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INTEGRATED STRATIGRAPHY OF THE MONT-PANISEL BOREHOLE SECTION (151E340), YPRESIAN (EARLY EOCENE) OF THE MONS BASIN, SW BELGIUM

by

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ABSTRACT

An integrated stratigraphy is established for the middle Ypresian of the Mons Basin (southwest Belgium), based on evidence from lithofacies, heavy minerals, calcareous nannoplankton, microfaunas and macrofaunas in the Mont-Panisel borehole. The Mont-Panisel succession comprises representatives of the Mons-en-Pévèle Sand Formation (new status, formerly Member), overlain by the Hyon Sand Formation (new term). The latter is subdivided into a lower Bois-la-Haut Sand Member (new) and an upper Mont-Panisel Sand Member. A sequence-stratigraphic interpretation of the Mont-Panisel succession is attempted, and regional correlations are proposed with central and northwest Belgium and the Paris Basin.

KEY-WORDS

Mont-Panisel, integrated stratigraphy, new classification, correlations, middle Ypresian.

RESUME

Un modèle de stratigraphie intégrée est proposé pour l'Yprésien moyen du Bassin de Mons (Sud-Ouest de la Belgique). Il est établi d'après les données de lithofacies, des minéraux lourds, du nannoplancton calcaire, des micro- et macrofaunes d'un forage au Mont-Panisel. La succession comprend de bas en haut la Formation de Mons-en-Pévèle (nouveau rang, autrefois membre) et la Formation d'Hyon (nouveau terme). Cette dernière est formée par le Membre du Bois-la-Haut (nouveau) surmonté par le Membre du Mont-Panisel. Les formations sont interprétées en termes de stratigraphie séquentielle, et mises en corrélation avec les dépôts yprésiens de la Belgique septentrionale et centrale et du Bassin de Paris.

MOTS-CLES

Mont-Panisel, stratigraphie intégrée, classification nouvelle, corrélations, Yprésien moyen.

1. INTRODUCTION

Mont-Panisel, a hill within the Mons Basin, close to Mons (SW Belgium), is the type locality of the "Paniselien" stage of Dumont (1851), an obsolete term including sediments of middle Ypresian age. These sediments, of which the stratigraphic position has been contested for more than a century (*see* Dupuis *et al.*, 1988 for a chronologic overview) have recently been designated the Panisel Member of the Ieper Formation (Steurbaut & Nolf, 1986). This Member is now re-evaluated and incorporated, together with the underlying much coarser Bois-la-Haut Sand Member (new), in the here defined Hyon Sand Formation. This Formation is classified, together with the underlying Ypresian deposits, in the Ieper Group (new status, formerly Formation ; introduced in 1988 (p. 81) by Marechal and Laga in a provisional document compiled on behalf of the Belgian "Nationale Commissies voor Stratigrafie"). At its type locality the Hyon Sand Formation

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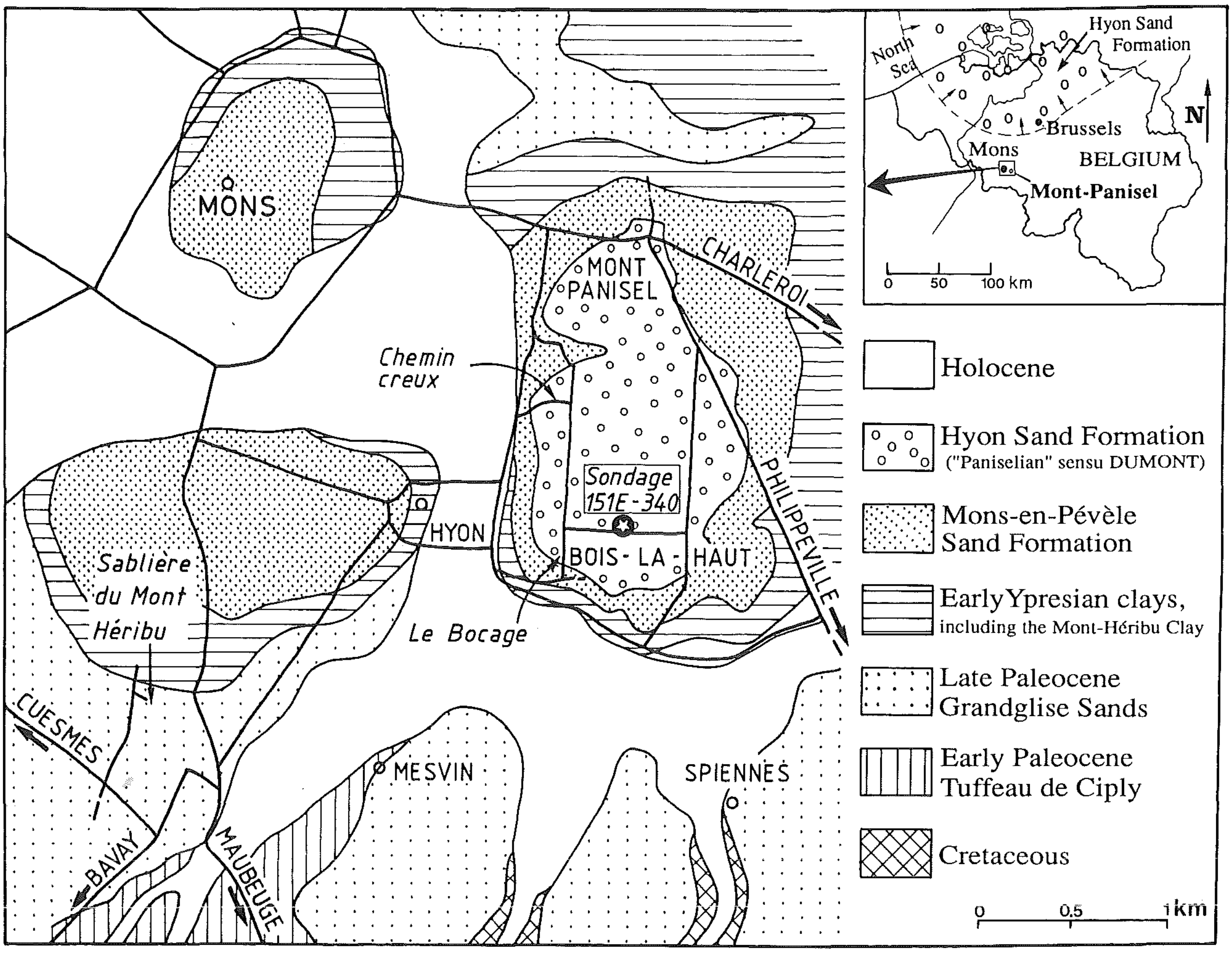

Figure 1. Geological map of he central part of the Mons Basin with location of the Mont-Panisel borehole (sondage 151E340) (after Dpuis *et al.*, 1988 ; modified) and main outcrop of the Hyon Sand Formation in northern Belgium (top right).

forms a small outlier, south of the main outcrop in the Belgian Basin (fig. 1).

The Hyon Sand Formation at Mont-Panisel overlies the Mons-en-Pévèle Sand Formation (= Mons-en-Pévèle Member sensu Steurbaut & Nolf, 1986). The upper part of the latter is poorly exposed on Mont-Panisel, but lower levels of the Ypresian, including the beds immediately below the Mons-en-Pévèle Sand Formation, are unexposed. The basal unit of the Ieper Group, the Mont-Héribu Clay Member, is outcropping at its type locality c. 2.5 km southwest of Mont-Panisel (De Coninck, Geets & Willems, 1983) (see also fig. 1).

The Mont-Panisel borehole (151E340) was drilled on behalf of the Geological Survey of Belgium in 1986 (map sheet Mons-Givry 45/7-8 ; x = 122.300, y = 125.375), to enable investigation of the biostratigraphy and the lithostratigraphy of the Ypresian succession in the southern part of the Belgian Basin. It was cored continuously from the surface to the final depth of 65.50 m. The Hyon Sand Formation was penetrated between the surface and 21.58 m (including the Mont-Panisel Sand Member between the surface and 17.70 m). The borehole terminated in clayey sands with thin clay layers, which were originally assigned to the Mont-Héribu Member.

A description of the drilling of the borehole, with preliminary stratigraphic results, was given by Dupuis *et al.* (1988). A symposium on the geological results of the borehole was held in December 1989 at the Faculté Polytechnique in Mons, and a series of papers on aspects of the sedimentology and palaeontology of the borehole, including studies of dinoflagellates, foraminiferids and ostracods, were published as a special issue of the Bulletin de la Société belge de Géologie (volume 99, parts 3 to 4) in 1992.

This paper presents the results of a detailed lithostratigraphic and biostratigraphic study of the Ypresian succession in the Mont-Panisel borehole, based on careful lithological logging and close spaced sampling of the core. It incorporates information on the calcareous nannofossils, "pseudarcellids" and allied taxa, molluscs and other miscellaneous fossil groups, and supplementary data on the foraminiferids and ostracods. An integrated stratigraphic and sedimentological interpretation is attempted, and regional correlations are proposed with Belgium and the Paris Basin.

2. LITHOLOGY AND LITHOSTRATIGRAPHIC CLASSIFICATION

2.1. General comments

The Ypresian in the Mont-Panisel borehole is represented by sandy facies, which can be grouped into two main units with fairly homogeneous lithological, mineralogical and sedimentological characteristics (fig. 2). The uppermost unit, the newly introduced Hyon Sand Formation (from 0 to 21.58 m depth), consists of poorly sorted, highly glauconitic fine sand (the glauconite is fine to medium grained) with numerous irregular siliceous sandstone concretions. It is decalcified, except in the nuclei of the siliceous concretions. The underlying Mons-en-Pévèle Sand Formation (from 21.58 m to ?, base probably not reached at the final depth of 65.50 m) is much more differentiated. As a whole it can be described as a poorly glauconitic (except for some discrete levels), very fine well-sorted sand, increasing in silt and clay content towards the base. Actually glauconite is present throughout, forming 1-3 % of the sand fraction, but is predominantly very fine grained. The Mons-en-Pévèle Sand Formation is partially decalcified, but well-preserved calcareous nannofloras and microfaunas are present in the interval between 34 and 61 m.

2.2. Hyon Sand Formation

Name : Hyon, small village 2 km southeast of Mons, on which the hills of Bois-la-Haut and Mont-Panisel are located (fig. 1).
Rank : new formation, introduced to include a lower Bois-la-Haut Sand Member (new) and an upper Mont-Panisel Sand Member.
Stratotype : the Mont-Panisel borehole, 151E340 ; map sheet Mons-Givry 45/7-8 ; x = 122.300, y = 125.375, z = 102 m T.A.W. (figs 1 & 2).
Depth level of unit : from 0 to 21.58 m below surface.
Thickness : 21.58 m.
Lithology : the entire unit is decalcified (except in the nuclei of the concretions), highly glauconitic (fine to medium grained and forming 10 to 15 % of the sand fraction) and contains numerous irregular siliceous sandstone concretions ; the upper 17.70 m consist of poorly sorted, clayey fine sand, which rests on a 3.58 m thick, somewhat better sorted, fine to medium sand (30 cm of core is missing at the contact of these units).
Heavy mineral distribution : homogeneous throughout the unit, dominated by tourmaline (more than 35 %) ; other characteristics are the frequency of zircon (19 to 24 %), and the extremely low numbers of garnet (around 1 %) and epidote (less than 1 %) (Geets, 1992, p. 319).
Overlying unit : the Hyon Sand Formation is the youngest Eocene unit preserved in the type locality ;
Underlying unit : glauconitic, very fine well-sorted sand of the Mons-en-Pévèle Sand Formation ; the junction is sharp, corresponding to a major hiatus.
Macrofossils : one level with *Nummulites planulatus* is mentioned by Dupuis *et al.* (1988, p. 42) at 14.10 m depth ; molluscs occur in the siliceous concretions.
Microfossils : not recorded, except for a few specimens of *Pterospermella* (phytoplankton, class of Prasinophyceae) at 9.75 and 18.10 m depth (De Coninck, 1992, p. 312).
Distribution : continuously recorded in outcrops and boreholes in the area between Gent-Brussel-Ronse (Renaix) ; known from small outliers in SW Belgium and NW France ; thickness highly variable, occasionally up to 20 m (Steurbaut, in prep.).
Junctions : junctions with overlying and underlying units are always sharp, and often erosional (contact with overlying unit not seen at the stratotype !).
Sequence stratigraphy : the Hyon Sand Formation represents one distinct third order depositional sequence (tentatively labeled sequence Y - X).
Biostratigraphy : rich calcareous microfaunas (King, unpublished) ; diversified calcareous nannoflora (Steurbaut & Nolf, 1986 ; Steurbaut, 1991), attributable to the uppermost part of Zone NP12 (Steurbaut's unit VIII).
Palaeontology : 50 mollusc species (represented by moulds and casts), among which 1 cephalopod, and several levels with *Nummulites planulatus* are recorded from the Mont-Panisel outcrop (see Cornet & Briart, 1874, p. 537-538 ; Houzeau de Lehaie, 1874, p. 556 ; Vandenbroeck, 1874, p. 559) ; rich, but only partially studied, mollusc associations are known from the area between Gent and Aalst.
Depositional environment : deposited in a fairly open marine shelf environment with normal salinities.
Correlation with other units : is overlain by the Merelbeke Clay Member and rests on the Egem Sand Member, or on older deposits towards the south (see below).
Age : the Hyon Sand Formation is of Middle Ypresian (Early Eocene) age.

2.2.1. Bois-la-Haut Sand Member

Name : Bois-la-Haut, a small hill on which borehole 151E340 was drilled, located near the village of Hyon, about 1 km south of its twin hill the Mont-Panisel (fig. 1).
Rank : new member.
Stratotype : the Mont-Panisel borehole, 151E340 ; map sheet Mons-Givry 45/7-8 ; x = 122.300, y = 125.375, z = 102 m T.A.W. (figs 1 & 2).

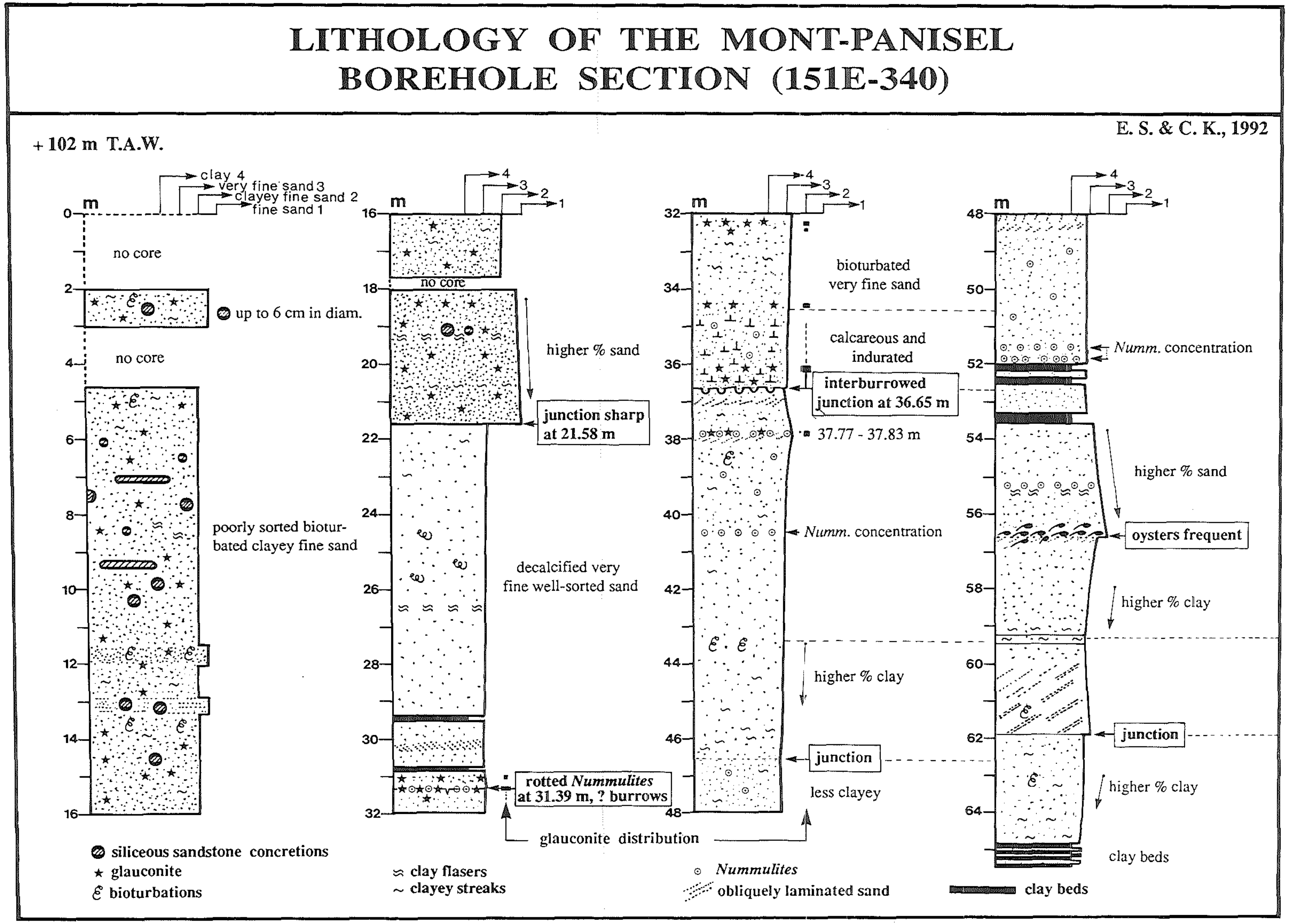

Figure 2. Lithology of the Mont-Panisel borehole section.

Depth level of unit : from 18.00 to 21.58 m below surface.
Thickness : about 3.58 m (30 cm core is missing at the contact with the overlying unit).
Lithology : highly glauconitic, highly bioturbated, rather well-sorted fine to medium sand, occasionally clay patches and some clay flasers (glauconite c. 10-15 %, as in overlying Mont-Panisel Mb.).
Heavy mineral distribution : most frequent minerals are tourmaline (48 %), zircon (19 %), kyanite (12 %), staurolite (8 %) and Ti-minerals (7 %) ; low numbers of garnet (1.3 %) and epidote (0.8 %).
Overlying unit : Mont-Panisel Sand Member ; contact missing due to core loss.
Underlying unit : sparsely glauconitic, very fine well-sorted sand of the Mons-en-Pévèle Sand Formation ; the junction is sharp, corresponding to a major hiatus.
Macrofossils : not observed.
Microfossils : not recorded, except for a few specimens of *Pterospermella* (phytoplankton, class of Prasinophyceae) at 18.10 m depth (De Coninck, 1992, p. 312).
Distribution : up to now only known from the following localities : the stratotype (see above), from boreholes in the area between Aalst and Brussels (highly glauconitic (medium grained) fine sand), and from the Ampe quarry at Egem, where the unit is cemented and represented by a fossiliferous glauconitic sandstone, tentatively named bed X (see below, heading : comparison with adjacent areas in Belgium). The Bois-la-Haut Member has not been identified in the outcrop "le Bocage" at Bois-la-Haut (see fig. 1 ; see addendum 2).
Junctions : the junction with underlying units is always sharp and corresponds to a hiatus ; the junction with overlying units has not yet been studied in detail (conctact not cored in the stratotype section).
Sequence stratigraphy : the Bois-la-Haut Sand Member represents the transgressive system tract of a third order depositional sequence (for explanation see below, heading sequence stratigraphy).
Biostratigraphy : biostratigraphical data are not yet available, except for the calcareous sandstone at Egem, which yields moderately diverse foraminiferid, ostracod and pteropod assemblages (King, 1990, p. 84) and a well diversified dinoflagellate association. The latter is substantially different from the Merelbeke Clay and the Pittem Clay dinoflagellate assemblages, because of the absence of the genera *Pulvinosphaeridium* and *Spinidinium* and the presence of very rare *Areosphaeridium diktyoplokus*, very rare *Pediastrum* and rare *Impletosphaeridium rugosum* (De Coninck, unpublished).
Palaeontology : see above.
Depositional environment : shallow marine deposit.
Correlation with other units : is overlain by the Mont-Panisel Sand Member. Rests on the Egem Sand Member in the north, on the Aalbeke Clay Member in the Aalst area and on the Mons-en-Pévèle Sand Formation at Mont-Panisel.
Age : Middle Ypresian, Early Eocene.

2.2.2. Mont-Panisel Sand Member

Name : Mont-Panisel, a small hill near the village of Hyon, type locality of the "Paniselian" (fig. 1).
Rank : member, may be considered equivalent of the term Panisel Member of Steurbaut & Nolf (1986, p. 127).
Stratotype : the Mont-Panisel borehole, 151E340 ; map sheet Mons-Givry 45/7-8 ; x = 122.300, y = 125.375, z = 102 m T.A.W. (figs 1 & 2).
Depth level of unit : from 0.00 to 17.70 m below surface.
Thickness : about 17.70 m (30 cm core is missing at the contact with the underlying unit).
Lithology : poorly sorted clayey fine sand, prominently glauconitic (fine to medium grained and forming 10-15 % of the sand fraction), highly bioturbated and decalcified ; several irregular siliceous sandstone concretions ; at some levels (11.50-12.00 and 12.90-13.32 m) somewhat coarser sand with traces of horizontal lamination.
Heavy mineral distribution : dominated by tourmaline (39 %), zircon (24 %), Ti-minerals (13 %), kyanite (9 %) and staurolite (8 %) ; low numbers of garnet (0.8 %) and epidote (0.8 %).
Overlying unit : the Mont-Panisel Mb. is the youngest Eocene unit preserved in the type locality.
Underlying unit : Bois-la-Haut Sand Member.
Macrofossils : one level with *Nummulites planulatus* is mentioned by Dupuis *et al.* (1988, p. 42) at 14.10 m depth.
Microfossils : not recorded, except for a few specimens of *Pterospermella* (phytoplankton, class of Prasinophyceae) at 9.75 m depth (De Coninck, 1992, p. 312).
Distribution : see above, data on the Hyon Sand Formation.
Junctions : the junction with underlying units is often erosional (contact not observed in the stratotype due to core loss) ; the junction with overlying units has not yet been studied in detail (contact missing in the stratotype).
Sequence stratigraphy : the Mont-Panisel Sand Member represents the highstand systems tract of a third order depositional sequence (for explanation see below, heading sequence stratigraphy).
Biostratigraphy and Palaeontology : see above, data on the Hyon Sand Formation.
Depositional environment : deposited in a fairly open marine shelf environment with normal salinities.
Correlation with other units : is mostly overlain by the Merelbeke Clay Member and rests on the Bois-la-Haut Sand Member, or on older deposits if the latter is missing.
Age : Middle Ypresian, Early Eocene.

2.3. Mons-en-Pévèle Sand Formation

The term Mons-en-Pévèle Sand Formation is used here to include all sediments previously incorporated in the Mons-en-Pévèle Sand Member of Steurbaut & Nolf (1986). A description of the stratotype was given by these authors (*op. cit.*, p. 124-125).

2.3.1. Lithofacies

The sediments of the Mons-en-Pévèle Sand Formation in the Mont-Panisel borehole can be grouped into four lithofacies (fig. 2) :

1. *Bioturbated clayey sand* : very fine sand, subangular, moderately well-sorted, glauconitic (1-3 %), thoroughly bioturbated, with diffuse clayey streaks and flasers. The glauconite is very fine grained. This facies occurs as four units, < 1 m to < 3 m thick (intervals from 32-34 m, 36.65-37.30 m, 45-46.63 m and 61.88-64.60 m).
2. *Bioturbated fine sand* : very fine to fine sand, silty, moderately well-sorted, glauconitic (1-3 %), intensely bioturbated, almost homogenised. The glauconite is very fine grained. This facies occurs as four units, c. 4 to c. 7 m thick (intervals from 22-29 m, 37.30-44 m, 46.63-51.60 m, and 53.60-58.90 m).
3. *Laminated/cross laminated sand* : very fine to fine sand, subangular, well-sorted, glauconitic, evenly laminated (laminae are emphasised by glauconite concentrations), with few discrete horizontal and vertical burrows. The laminae are horizontal or low-angle oblique ; horizontal sets tend to alternate with low-angle oblique sets. Occasional thin planar or lenticular beds of silty clay. This facies occurs as one unit c. 2 m thick (60-61.88 m) and other thinner units (31.16-31.39 m ; 36.95-37.00 m ; 37.74-38.00 m ; 48.00-48.75 m ; 52.05-52.94 m ; 56.87-57.00 m ; ....).
4. *Calcareous glauconitic sandstone* : this facies consists of carbonate-cemented very fine to fine sand. At its base the sand is coarser than in other facies. The glauconite is also coarser and more abundant (up to 14 %). This facies occurs as a single unit (34.55-36.65 m). It is exposed at "le Bocage" (see fig. 1).

2.3.2. Facies relationships

Based on relative degree of bioturbation and clay content, the three major facies can be ranked in order of increasing energy, from facies 1 through facies 2 to facies 3. Facies 1 is interpreted as shallow offshore sands because of its grain-size and degree of bioturbation, which reflect fairweather conditions. Facies 2 can be interpreted similarly, although its lower clay and silt content indicates deposition in a higher energy, probably slightly shallower environment. Facies 3 resembles shoreface sands, but, generally, there is no clear vertical trend from facies 1 to 2 to 3 (facies 3 is also not significantly coarser !). Most units of facies 3 occur as sharply bounded units between units of facies 2. They are therefore interpreted as deposited during storm-generated pulses of erosion and sediment transport, by reworking and sorting of the shallow offshore sands (winnowing out of fines). This is reflected in the occurrence of Nummulite-rich laminae (e.g. at 40.75 m, 51.79 m and 51.83 m), formed by winnowing and concentration from the nummulitic sands of facies 2. Some units of facies 3 (e.g. those at 37.74-38.00 m, 56.87-57.00 m and 60.00-61.88 m) are probably recognisable at other localities in Belgium (e.g. in the Kester borehole (101W79), 15 km southwest of Brussels ; King & Steurbaut, in prep.). These thick and widespread units are therefore considered to represent phases of shallowing.

The diverse benthic microfaunas of the Mons-en-Pévèle Sand Formation (see below) indicate a shallow marine, well-oxygenated environment of normal salinity. There is little evident difference between the microfaunas of lithofacies 1, 2 and 3.

Facies 4 differs from the other facies in the grain-size (the base is somewhat coarser), its higher carbonate content (up to 40 %, versus 5 % for the remainder of the formation), its higher heavy mineral content and presence of coarser-grained glauconite. These features suggest relatively slow sedimentation in a shallow marine well-oxygenated environment. The single unit of facies 4 grades up into sands of facies 1. There is a significant discontinuity at its base, marked by an interburrowed contact.

2.3.3. Omission surfaces, interpreted as minor hiatuses

Eight hiatuses are identified in the Mont-Panisel borehole section, marked by abrupt lithology changes, interburrowed contacts or glauconite-rich levels (fig. 3).

Surface 1 at 61.88 m - The junction at 61.88 m is sharp and marked by an abrupt change in composition, texture and structure of the beds. Very clayey bioturbated silty sand of facies 1 is overlain by a c. 2 m thick very fine obliquely laminated sand of facies 3. These sudden changes in depositional conditions probably reflect a minor sea-level fall.

Surface 2 at c. 56.60 m - In the interval from 56.50 to 56.90 m occurs bioturbated homogeneous fine sand of facies 2, although somewhat less clayier than normally in facies 2 and with common small oysters (*Crassostrea* cf.. *multicostata*). This oyster-rich interval is known from various other outcrop and borehole sections in Belgium (e.g. in the Kester borehole). It al-

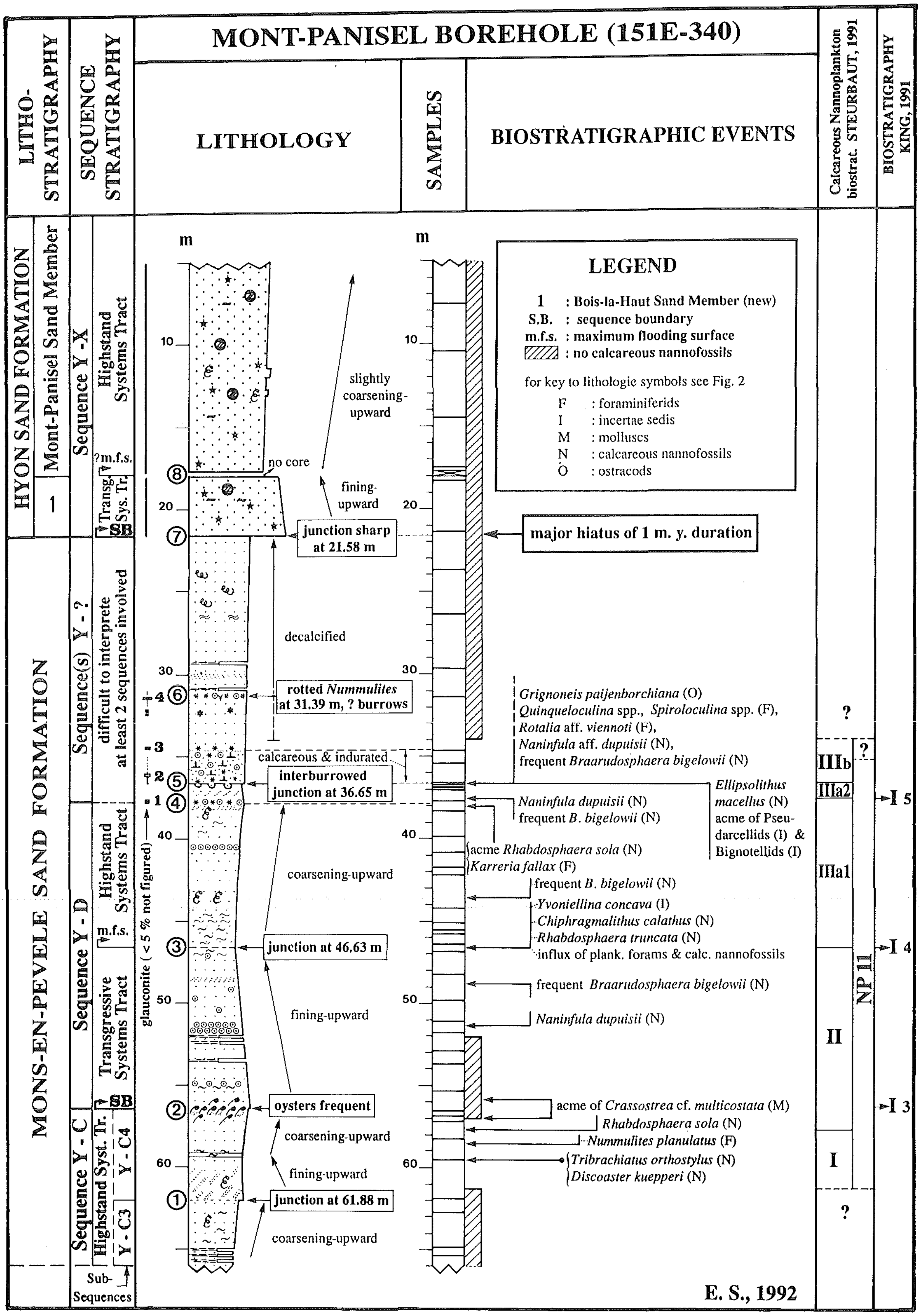

Figure 3. Integrated stratigraphy of the Mont-Panisel borehole section.

ways occurs at the transition of an underlying coarsening-upward sequence and an overlying fining-upward sequence. It might represent a phase of very slow sedimentation, or non deposition (resulting in an accumulation of oysters), or even submarine erosion (concentration of oysters through winnowing), due to a prominent eustatic sea-level fall, followed by a sea-level rise.

Surface 3 at 46.63 m - The junction at 46.63 m is sharp and separates silty bioturbated very fine sand of facies 2 from an overlying unit of very clayey sand of facies 1. The latter unit, which extends from 46.63 to c. 45.00 m, is the most prominent clayey unit of the entire section between the oyster-rich level at 56.70 m and the next break at 37.83 m. It reflects a substantial deepening of the depositional environment (see comments on calcareous nannofossils and planktonic foraminiferids below). Higher up, between c. 45 to 37.83 m the grain-size is slightly increasing.

Surface 4 at 37.83 m - A very fine sand packed with *Nummulites* and frequent dispersed medium grained glauconite is recorded between 37.77 and 37.83 m. It occurs between slightly inclined laminated sand of facies 3. The nummulite and glauconite concentrations indicate slow sedimentation or non deposition which might reflect the onset of a significant eustatic sea-level rise, after a period of relative shallowing.

Surface 5 at 36.65 m - The junction at 36.65 m is interburrowed. It forms the boundary between very fine bioturbated slightly clayey sand of facies 1 and the overlying calcareous glauconitic sandstone of facies 4. The base of the latter is the most coarse-grained unit of the Mons-en-Pévèle Sand Formation in the Mont-Panisel borehole, and contains common dispersed medium grained glauconite and scattered nummulites. Higher up its grain-size is slightly decreasing, and the sandstone passes through a ? sharp boundary at 34.55 m into very fine bioturbated clayey sand of facies 1. The sandstone seems to be deposited during a phase of deepening, after a period of substantial sea-level fall.

Surface 6 at 31.39 m - A c. 1 cm thick grained glauconite bed with rotted *Nummulites* is recognised at 31.39 m depth. This bed occurs at the base of a laminated fine sand with glauconite concentrations on bedding planes, which overlies a slightly clayey bioturbated silty fine sand of facies 1. The glauconite seems to be burrowed down to approximately 31.62 m depth. This prominent glauconite bed was also recorded at Bois-la-Haut ("le Bocage") at about 75 m above sea-level (see fig. 1), where it contained a rather rich shark teeth fauna (Houzeau de Lehaie, 1874, p. 555). The glauconite bed is interpreted as a condensed section and is believed to reflect the onset of a significant eustatic sea-level rise, after a period of substantial sea-level fall.

Surface 7 at 21.58 m - The contact at 21.58 m is sharp, separating highly glauconitic bioturbated fine sand of the Hyon Sand Formation from underlying very fine sand of facies 2 of the Mons-en-Pévèle Sand Formation. According to what is known from other localities in Belgium (the Kortrijk area and the Kester borehole ; for locations see addendum 2 at the end of the present paper) this junction represents a major hiatus of approximately 1 million year (interval from the upper middle part of chron C23R to the start of chron C22R ; palaeomagnetic data from Ali, unpublished).

Surface 8 around 17.80 m - There must have been an important change in sedimentation conditions between the deposition of the Bois-la-Haut Sand Member and the Mont-Panisel Sand Member. The sudden increase in clay content at 17.80 m (?) depth (difficult to pinpoint as there was no core recovery between 17.70 and 18.00 m) suggests a considerable deepening of the depositional environment.

2.3.4. Occurrence and significance of glauconite

The thin glauconitic beds within the clay facies of the middle of the Ieper Group, already recognised by Gulinck (1967) and emphasised by Steurbaut & Nolf (1986) were investigated in detail by King (1991a), who demonstrated that at least six of these beds could be identified and correlated regionally. The Mont-Panisel borehole and the Kester borehole have demonstrated that similar glauconite-rich beds are present within the middle of the Mons-en-Pévèle Sand Formation, implying the possibility of direct correlation. The glauconitic beds are interpreted as condensed deposits, formed in a shallow marine environment during phases of very slow sedimentation , due to clastic starvation in the transgressive phase of a sedimentary cycle (condensed section of Van Wagoner *et al.*, 1988).

Seven glauconite-rich beds have been identified in the Mons-en-Pévèle Sand Formation of the Mont-Panisel borehole, between 31.39 and 37.83 m. Some of these are rather diffuse, but four are believed to have regional correlation potential (figs 2 and 3). Glauconitic bed 1 at 37.77-37.83 m is characterised by frequent dispersed medium grained glauconite. It is correlated with a glauconitic bed in the clay facies of the Ieper Group, associated by King with event I5 (King, 1991a, p. 353-354). Bed 2, which corresponds to the lower part of the calcareous unit (from 36.16 to 36.65 m) contains common dispersed medium grained glauconite. Bed 3 at 34.46 m is represented by dispersed glauconite concentrations. Bed 4 at 31.39 m, of which the glauconite is burrowed down to about 31.62 m, is the most prominent glauconitic bed of the Mons-en-Pévèle Sand Formation. It was also recognised at Bois-la-Haut, "le Bocage" (Houzeau de Lehaie, 1874, p. 555).

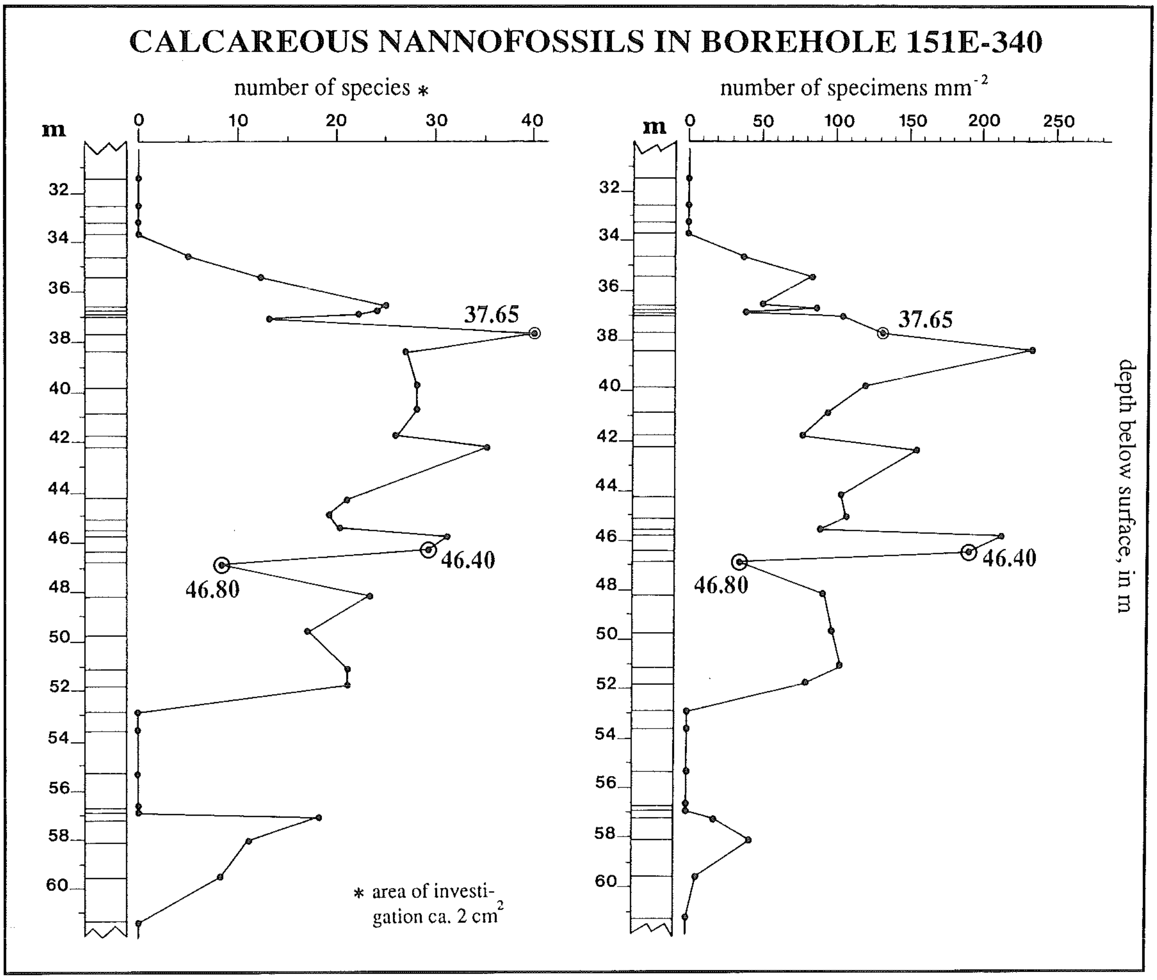

Figure 4. Quantitative distribution of calcareous nannofossils in the Mons-en-Pévèle Sand Formation of the Mont-Panisel borehole.

2.3.5. Heavy mineral distribution

The heavy mineral distribution in the Mons-en-Pévèle Sand Formation is significantly different from that in the overlying Hyon Sand Formation (see Geets, 1992, p. 319). Garnet and epidote, which are extremely rare in the Hyon Sand Formation (around 1 %), are well represented in the Mons-en-Pévèle Sand Formation (respectively up to 14 % and 5.5. % of the association), whereas tourmaline has decreased from more than 40 % to 9 %. These differences can only be explained by a change in source area, and not by differences in grain-size or by dissolution. This in turn can only be the result of substantial palaeogeographical changes which must have occurred in the time span between the deposition of the Mons-en-Pévèle Sand Formation and the Hyon Sand Formation. This strongly reinforces suggestions made by Steurbaut in 1989 at the occasion of the Symposium at Mons (see introduction) that the major hiatus, which also forms the boundary between the two above mentioned formations, lies at 21.58 m and not at 17.70 m depth as previously suggested by Dupuis *et al.* (1988, p. 37).

3. CALCAREOUS NANNOFOSSILS

3.1. Techniques

Thirty-five samples from the calcareous interval (31.39 m to 61.50 m) in the Mont-Panisel borehole have been processed. Preparation of smear-slides for light-microscopic examinations followed standard procedures. Each sample was also analysed on a semi-quantitative basis, using methods developed by Backman (Backman & Shackleton, 1984, p. 145). Abundances in calcareous nannofossils, expressed in number of specimens per square millimeter were given for each sample (fig. 4). These numbers can be used for inter-sample comparison, as they are only influenced by the grain distribution on the glass-slide, which according to Backman (op. cit.) remains surprisingly constant if the slides are made by a single experienced worker. Separate counts were made for a few stratigraphical or palaeogeographical important taxa (figs 5 & 6). All other species were quantitatively interpreted using the following abundance-classes : rare ($n \leq 1$; n = specimens/mm²), few ($1 < n \leq 20$), frequent ($20 < n < 50$) and abundant ($n \leq 50$) (see table 1).

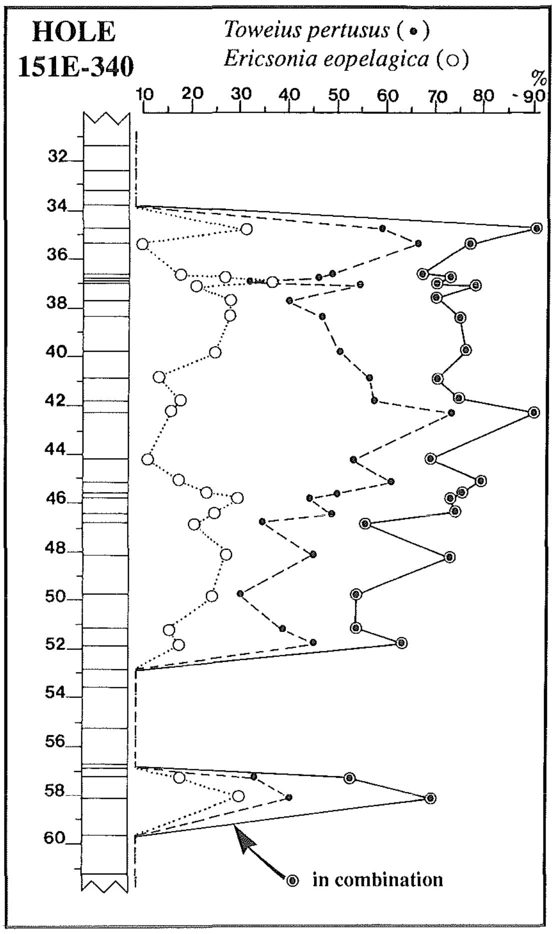

Figure 5. Abundance patterns of dominant nannofossil species in the Mons-en-Pévèle Sand Formation of the Mont-Panisel borehole.

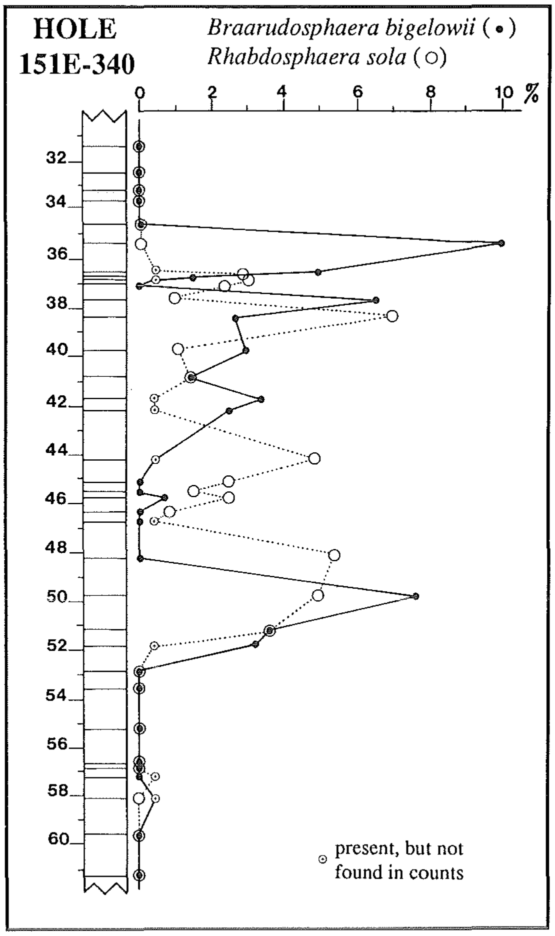

Figure 6. Abundance patterns of selected nannofossil species in the Mons-en-Pévèle Sand Formation of the Mont-Panisel borehole.

3.2. General comments

Calcareous nannofossils are preserved in the Mons-en-Pévèle Sand Formation between 34.00 m and 60.00 m, except in the interval 52 m-57 m (see figs 3 & 4). The preservation quality is rather low, and characterised by frequent etching and secondary overgrowth (especially at 57.20 m). Moderately high diversity assemblages are recorded from 46.40 m (29 species ; 190 specimens/mm^2) to 37.65 m (40 species ; 130 specimens/mm^2). Above and below this interval nannofossil associations are less rich and less diversified (in each sample less than 25 species and less than 100 specimens per mm^2). An extremely impoverished association was found at 59.55 m (5 specimens/mm^2).

The calcareous nannoflora of the Mons-en-Pévèle Sand Formation at Mont-Panisel contains fifty-six species (table 1). As most of these are figured in Steurbaut's detailed iconography of Ypresian calcareous nannofossils (Steurbaut, 1991), no additional illustrations are included here. In the following text species will be cited only by their species name, without mentioning author and date of publication. Such additional information is given in a special list at the end of the paper.

The nannoflora of the Mont-Panisel borehole section is dominated by only two species, *Toweius pertusus* and *Ericsonia eopelagica*, which together represent more than 70 % of the nannofossils in the association (fig. 5). Consequently, the nannofossil assemblages are very similar throughout the section, although some minor floral breaks can be identified (see table 1 ; and next chapter on biostratigraphy).

3.3. Distribution of selected taxa

Braarudosphaera bigelowii

This taxon has a worldwide distribution and is considered to range from the late Early Cretaceous to the present. Today it occurs in high concentrations in hyposaline coastal waters and is only rarely represented in open seas with normal salinities (Moshkovitz & Ehrlich, 1982, p. 44). However, salinity seems not to be the only determining parameter controlling the abundancy patterns of *B. bigelowii*, as this species is also common in shallow marine environments of normal salinity (e.g. those from the Mons-en-Pévèle Sand Formation at Mont-Panisel). By its heavy, tightly and solidly constructed cells, probably cysts, it appears

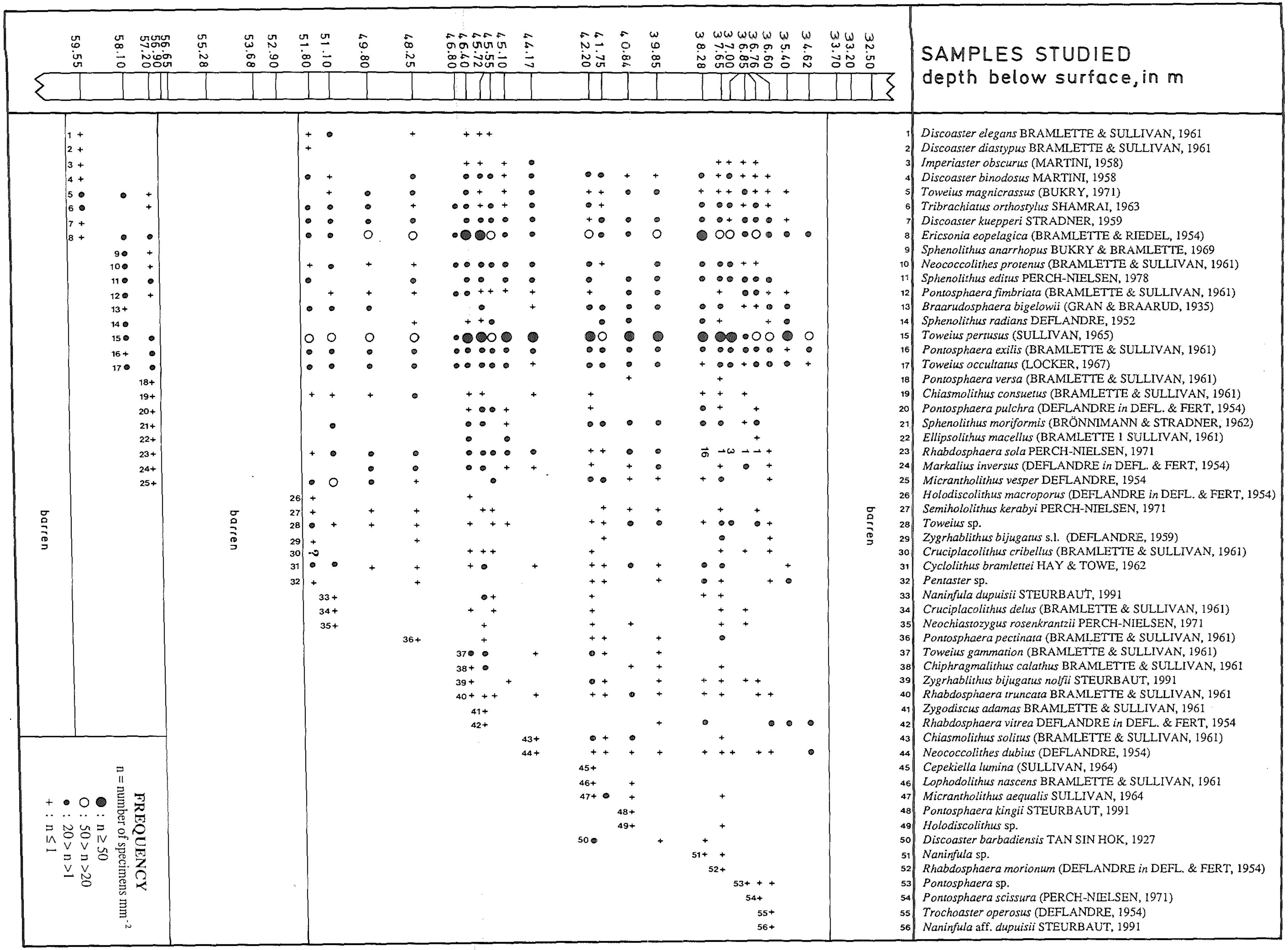

Table 1. Distribution of calcareous nannofossils in the Mons-en-Pévèle Sand Formation of the Mont-Panisel borehole.

to be extremely well adapted to very shallow highly turbulent and turbid coastal waters. Most of the fossil records of *B. bigelowii* probably have to be interpreted in this sense.

The distribution of *B. bigelowii* is shown on fig. 6. It is entirely absent in the interval 32.50 m-34.62 m, and virtually absent between 45.10 m and 48.25 m, and below 52.90 m. Its absence in the upper and lower part of the section is mainly due to decalcification. Its absence in the middle nannofossil-rich interval is facies controlled. This interval consists of very fine sands and clayey very fine sands of facies 1 and 2, and represents the deepest part within the sedimentary cycle, extending from 37.83 m to 56.60 m.

A few other trends in the distribution pattern of *B. bigelowii* can be recognised. There is a progressive increase in the abundance of this species, from less than 1 % of the association at 44.17 m to 6.5 % at 37.65 m, followed by an abrupt fall to less than 2 % in the interval 37.00 m-36.70 m. Its abundance increases again up to more than 10 % in the overlying "calcareous unit". These data suggests that there is a first order correlation between the abundance of *B. bigelowii* and the grain-size. Its abundance increases with grain-size, and, as a consequence, reflects the energy level and, to a certain degree, the water depth of the paleoenvironment.

Chiphragmalithus calathus

This species is restricted to the middle Ypresian. Its first occurrence seems to represent a synchronous datum in the North Sea Basin, and probably beyond. It has been used to define the base of Steurbaut's nannofossil-unit IIIa1, which is correlatable with the lower upper part of Zone NP 11. Its last occurrence is located in the lower part of NP 12. Early forms (NP 11) appear to be slightly more elliptical than those of NP 12 (Steurbaut, unpublished).

Discoaster kuepperi

The first occurrence of *D. kuepperi* has often been considered to very close to the first occurrence of *Discoaster lodoensis*, and consequently used to approximate the NP 11/NP 12 boundary in the North Sea Basin (for discussion see Aubry, 1983, p. 97). Recent work in this area (Steurbaut, 1991 and unpublished), and in the northern Atlantic (Muller, 1985) has shown that its first occurrence is much earlier, in the middle of NP 11. The presence of *D. kuepperi* in the lowermost nannofossil-bearing sample of the Mont-Panisel section (59.5 m) indicates that this part of the section is younger than the middle of NP 11.

Discoaster lodoensis

Discoaster lodoensis, whose first occurrence defines the base of Zone NP 12, has not been recorded in the Mont-Panisel borehole section. Its absence in the uppermost nannofossil-rich sample (35.40 m) suggests that this part of the section is still within Zone NP 11, although it must be emphasised that in the North Sea Basin *D. lodoensis* is extremely rare in the lower part of NP 12 (Muller, 1986, p. 143 ; Steurbaut, unpublished).

Backman (1986, p. 48 and 52) recorded the first marked increase in abundance of *D. lodoensis* immediately above magnetic anomaly 24 A (=chron C24 AN) in the tropical Pacific (DSDP Hole 577) and the mid-latitude Southern Atlantic (Hole 527). This led him to believe that the first increase of this species represents a synchronous datum, and not its absolutely lowermost occurrence. The first consistent occurrence of *D. lodoensis* seems to coincide with the end of chron C24 AN in the North Sea Basin (Steurbaut, unpublished ; paleomagnetic data from Ali, unpublished) which reinforces Backman's suggestions.

Ellipsolithus macellus

This species is rather long-ranging, from late Early Paleocene (base NP 4) to middle Early Eocene (top NP 11). Its last occurrence was believed to be very close to the first occurrence of *D. lodoensis*, and used to approximate the NP 11/NP 12 boundary (Steurbaut, 1991). Recent investigations in the Belgian Basin (Steurbaut, unpublished) have shown that the last occurrence of *E. macellus* is slightly prior to the first consistent occurrence of *D. lodoensis*. In the Mont-Panisel borehole section the topmost occurrence of *E. macellus* is at 36.76 m, immediately below discontinuity 5 at 36.65 m.

Naninfula dupuisii

This taxon is sporadically recorded in middle Ypresian sediments from the North Sea Basin (upper NP 11). Its first occurrence lies within Steurbaut's nannofossil-unit II, its last occurrence was used to define the top of unit IIIa1 (Steurbaut, 1991, p. 258).

Naninfula aff. *dupuisii*

This form is very similar and closely related to *N. dupuisii*. It differs from the latter by its slender outline. *N.* aff. *dupuisii* is known from a few outcrops and boreholes in the North Sea Basin (Belgium, Denmark, U.K.), and up to now has only been recorded in the lower part of NP 12. In the Mont-Panisel borehole it is recorded at the base of the calcareous unit (sample 36.60 m), suggesting that its first occurrence sometimes precedes the first consistent occurrence of *D. lodoensis*.

Rhabdosphaera sola

R. sola is known to range from the middle of NP 10 to the top of NP 12 (Müller, 1985, tab. 7 & 10). In the North Sea Basin its distribution is much more restricted, extending from the middle of NP 11 (base of Steurbaut's nannofossil unit II) to the top NP 12 (top of unit VIII). There is an abrupt and substantial decrease in abundance of this species close to the boundary of the nannofossil-units III a1 and III a2 (fig. 6). This event seems to be stratigraphically important, as it was recognised in several outcrops and boreholes in the North Sea Basin (Belgium, including the Mont-Panisel borehole ; Denmark and the U.K.).

Rhabdosphaera truncata

This species was considered to be restricted to zone NP 12 (Aubry, 1983, p. 99). Subsequent investigation by one of us (E.S.) has demonstrated that its first occurrence is much earlier, close to the first occurrence of *C. calathus*, which was used to mark the base of unit III a1 (the upper part of NP 11). In the North Sea Basin its last occurrence is believed to fall within unit IIIb. At Mont-Panisel it is sporadically present in the interval 36.60-46.40 m.

Toweius pertusus

This species is the most abundantly occurring nannofossil in the Mons-en-Pévèle Sand Formation. Its percentage lies within 30 % to 74 %, with a mean value of 49 % (fig. 5). It is known to have a worldwide distribution, ranging from early Late Paleocene to middle Early Eocene. Its last occurrence marks the top of Steurbaut's nannofossil unit V, which correlates with the lower middle part of Zone NP 12.

Tribrachiatus orthostylus

According to Backman (1986, p. 48) the first increase in abundance of *T. orthostylus*, which virtually coincides with the initial rise in abundance of *Sphenolithus radians*, can be used for an approximate alternative identification of the NP 10/NP 11 boundary. Both nannofossil-events are very close to the start of chron C24 BN, and are considered to represent reliable nannofossil datums. The common occurrence of *T. orthostylus* and *S. radians* in the lowermost nannofossil-bearing samples of the Mont-Panisel borehole indicates assignment to NP 11.

3.4. Biostratigraphy

Calcareous nannofossils have proved to be extremely useful for subdividing and correlating Ypresian sediments in the North Sea Basin (Steurbaut, 1988, 1991). Martini's (1971) standard Paleogene calcareous nannoplankton zones NP 11, NP 12 and NP 13 have currently been identified in onshore and offshore sequences. These standard zones have been subdivided by one of the authors (E.S.) on the basis of additional calcareous nannoplankton events (first or last occurrences), of which the majority is believed to represent synchronous datums, at least in the North Sea Basin. Zone NP 11 was subdivided in units I, II and IIIa ; zone NP12 in units IIIb, IV, V, VI, VII, VIII and zone NP 13 in units IX and X.

Since the early seventies many datings, based on Martini's standard calcareous nannoplankton zonation have been produced. For a non-specialist it is likely to believe that the first or last occurrences, which define the zonal boundaries in the zonation, are easily, permanently recognisable events, which can be used as time lines over wide geographic areas. However, the truth is that this is an over-simplification, and that the identification of such events is not so straightforward. The vertical distribution pattern of many marker species is characterised by a stepwise increase in abundance (Backman, 1986 ; Steurbaut, in prep.). In general, species are only discontinuously and rarely represented in the lowermost part of their range (e.g. *Discoaster multiradius*, *D. lodoensis*, *Micrantholithus mirabilis*, etc.). Absolute lowermost occurrences are often very difficult to pin-point, and, therefore, less useful for biostratigraphy. The first rise in abundance is much more significant, as it is nearly always recognisable (except in some extremely poor assemblages) and in many cases represents a synchronous datum. Higher up in the range of many species occurs a sharp prominent increase in abundance (base of the acme or peak abundance). Recent work in the North Sea Basin (E.S.) has shown that the base of such intervals of high or peak abundance may provide synchronous datums. Disappearances can also be sharp (e.g. *Tribachiatus orthostylus*) or stepwise.

The calcareous nannoflora of the Mons-en-Pévèle Sand Formation in the Mont-Panisel borehole is similar throughout the section, because of the dominance of *Toweius pertusus* and *Ericsonia eopelagica*, which represent more than 70 % of the associations (fig. 5). No major floral breaks are recognised, as the species appear and disappear rather gradually. However, some minor breaks, characterised by the joint appearance or disappearance of at least three species, are recorded, e.g. at 57.20 m, 51.10 m, 46.40 m, 42.20 m, 36.76 m, 36.60 m and 35.40 m (see table 1). Most of these breaks have only local significance, reflecting minor changes in depositional environment, differences in preservation, partial selective decalcification, etc. Only the floral changes between samples 46.80 m-46.40 m, and 36.76 m-36.60 m seem to have a substantial, basin-wide biostratigraphical significance.

The association at 46.40 m is characterised by the entry of several species, among which are the markers *Chiphragmalithus calathus* and *Rhabdosphaera truncata*, which have not been recorded from underlying strata, and by a sharp rise in nannofossil abundance (see fig. 4, a jump from 35 to 190 specimens/mm²). This drastic change reflects the injection of plankton-rich ocean waters into lower shelf areas, probably due to a substantial flooding event.

The break at 36.65 m is marked by the disappearance of *Ellipsolithus macellus* and *Zygrhablithus bijugatus nolfii*, by the first occurrence of *Naninfula* aff. *dupuisii* and the recurrence of common *Braarudosphaera bigelowii*. These events, together with the major changes in carbonate and glauconite content across surface 5 at 36.65 m can only be due to the entry of probably warmer, carbonate-rich waters.

Some individual species, and special events in their abundance patterns, have also proved to be biostratigraphically useful over wide geographic distances (e.g. the first occurrence and the top of the peak abundance of *Rhabdosphaera sola*).

Detailed comparison of the calcareous nannoflora of he Mons-en-Pévèle Sand Formation in the Mont-Panisel borehole with the nannofossil events elsewhere in the North Sea Basin leads to the following conclusions (see fig. 3) :

1. The entire nannofossil-rich part of the section (from 61 m to 35.00 m) is attributable to standard nannoplankton zone NP 11, because of the absence of *Discoaster lodoensis*.
2. Steurbaut's calcareous nannoplankton events and subdivisions I, II, III a1, III a2 and IIIb, which were defined in the clay facies of the Ieper Group and the distal facies of the Mons-en-Pévèle Sand Formation, are also recognisable in the more proximal facies of this formation.
3. The majority of Steurbaut's events coincide with major hiatuses and are correlatable to King's biostratigraphic events (I-events) : the boundary between units II and III a1 coincides with omission surface 3 and event I4 ; the boundary between units III a1 and III a2 is very close to surface 4 and event I5 ; the boundary between III a2 and IIIb coincides with surface 5 and event I6 (note that event I6 has not been identified in the Mont-Panisel borehole ; the correlations are based on data from other localities).
4. The co-occurrence of common *Tribrachiatus orthostylus* and *Discoaster kuepperi* in the lowermost nannofossil-bearing sample indicates that this part of the section is younger than middle NP 11.
5. The first occurrence of *Nummulites planulatus* is prior to the first occurrence of *Rhabdosphaera sola*, and thus falls within nannofossil unit I.
6. The oyster-rich level which has been associated with event I3 lies just above the first occurrence of *Rhabdosphaera sola*, and, hence, is to be located in the lower part of unit II.

4. CALCAREOUS MICROFOSSILS AND MACROFOSSILS

4.1. Techniques

Samples of c. 200-400 grams of sediment were collected from the borehole cores at appproximately 1 metre intervals. The samples were processed for microfaunal analysis by soaking in a 10 % solution of calcium hexametaphosphate ("Calgon") for one hour, followed by wet-sieveing through a 120 micron sieve.

The microfaunas were analysed on a semi-quantitative basis, with benthonic foraminiferids, ostracods and calcareous problematica recorded as rare, common or abundant (see figs 8 & 9). These ratios reflect relative rather than absolute abundance. Calcareous algae, bryozoa and molluscs were also studied.

4.2. General comments

The Mons-en-Pévèle Sand Formation in the Mont-Panisel borehole has been partly decalcified (Dupuis *et al.*, 1988, fig. 6), presumably by percolating acidic groundwaters. Calcareous fossils are preserved only in the interval between 34.80 m and 60.60 m (also at 31.39 m, where only corroded *Nummulites* are present) (see fig. 7). There is partial solution of the calcareous microfossils at the base of this interval, in samples at 60.6 m and 59.7 m, and also at 56.7 m and 55.3 m, where only very corroded specimens were recovered. Some reprecipitation of calcite on the surface of calcitic microfossil tests is evident in these intervals. The calcitic fossils are otherwise well-preserved. Most samples through the middle of the Mons-en-Pévèle Sand Formation are very rich in calcitic microfossils, with more than 10.000 foraminiferids per 100 grams of sediment.

Aragonitic shells of molluscs are common at several levels, but are partially decalcified and very "chalky", so that few survived the processing of the samples.

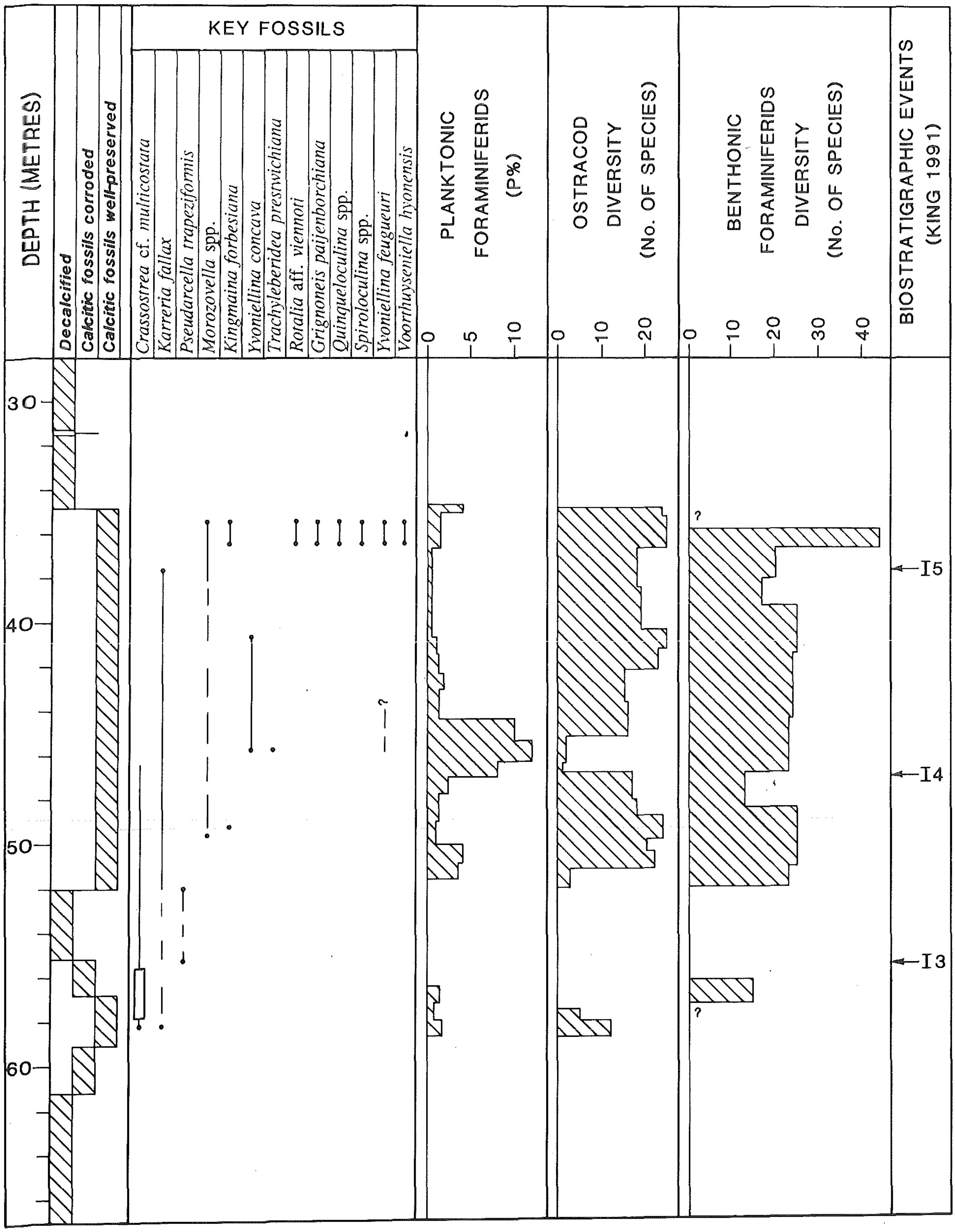

Figure 7. Faunal biostratigraphy and biofacies in the Mons-en-Pévèle Sand Formation of the Mont-Panisel borehole.

Above 34.8 m, and below 60.6 m, no microfauna or macrofauna was recovered from the samples processed, apart from teleost fish scales and bones.

Species are mentioned only by their species name in this chapter. Further taxonomic information (author and date of publication) is given in a special list at the end of the paper.

4.3. Benthonic Foraminiferids

A comprehensive quantitative analysis of the benthonic foraminiferids in the Mons-en-Pévèle Sand Formation of the Mont-Panisel borehole, with SEM photographs of many taxa, was carried out by Hooyberghs (1992), who recorded 49 taxa. The present study gave very similar results, and therefore no distribution charts are presented here. Some additional taxa have been recorded :

1. *Asterigerina bartoniana kaasschiteri* is one of the most common taxa throughout the interval 34.8 m-60.6 m, although not recorded by Hooyberghs (1992), presumably due to an oversight.
2. *Karreria fallax* is recorded between 37.6 m and 58.3 m, and is common between 38.3 m and 47.2 m. It may have been recorded as *Cibicides carinatus* by Hooyberghs (1992).
3. *Rotalia* aff. *viennoti*, as interpreted by Le Calvez (1970), was recovered at 35.2 m and 36.4 m.

The foraminiferid associations are dominated by cibicidids, anomalinids, *Asterigerina* and *Discorbis*, and are generally similar throughout the section, with no major faunal breaks (see Hooyberghs, 1992, table 2). The only significant faunal change identified is between the samples at 36.4 m and 36.9 m. This corresponds to the base of the "calcareous unit" (see above), and is marked by the appearance of a moderately diverse assemblage of miliolids (9 taxa, including representatives of *Quinqueloculina, Spiroloculina* and *Triloculina*), which occur commonly in the samples between 34.8 m and 36.4 m. They comprise up to 3 % of the foraminiferids in this interval, but are almost entirely absent at lower levels. *Rotalia* aff. *viennoti* is also recorded only from this interval, but is represented by very few specimens.

The outcrop at Bois-la-Haut (Dupuis & Robaszynski, 1986, fig. 8), which is in the "calcareous unit", and temporary sections on Mont-Panisel, have yielded very similar assemblages (Kaasschieter, 1961 ; King, unpublished data). An important additional record from Bois-la-Haut is of poorly preserved *Alveolina* sp. This foraminiferid has not been previously recorded from the Early Eocene of Belgium, although common in the Paris Basin.

4.4. Planktonic Foraminiferids

Hooyberghs (1992) carried out a very comprehensive study of the planktonic foraminiferids in the Mons-en-Pévèle Sand Formation of the Mont-Panisel borehole, identifying 25 taxa. For the present study, only a generalised taxonomic assessment was made, but the percentage of planktonic foraminiferids in the total foraminiferid assemblage (**P** % of King, 1991a) was calculated for each sample.

Planktonic foraminiferids are recorded from all samples analysed (except the samples with very corroded microfaunas in the lower part of the section), but generally in low abundance. **P** lies within the range 0.1 % to 12 % (fig. 7). The highest proportions of planktonic foraminiferids (8 %-12 %) are recorded in the interval 46.8 m-44.6 m, falling abruptly to 1 % at 43.6 m.

The assemblages are dominated by *Acarinina* and *Muricoglobigerina*. *Subbotina* is present throughout, but is relatively uncommon. "Keeled" planktonics (*Morozovella* spp.) are recorded by Hooyberghs (1992, p. 277) and one of the present authors (C.K.) from the interval 49.8 m-35.3 m. They are represented by rare and mostly juvenile specimens (< 250 microns diameter) of *M. aequa* and *M. lensiformis*. They appear to be absent below 49.8 m.

4.5. Ostracods

Guernet (1992) studied 20 samples from the Mont-Panisel borehole, from the interval 52 m to 34 m. He identified 30 taxa, partly illustrated by SEM illustrations. In the present study, utilising a larger number of samples, 36 taxa were recovered (fig. 8).

Ostracods are common throughout the interval 58.3 m-34.8 m. The ostracod associations are similar throughout this interval, dominated by *Cyamocytheridea, Leguminocythereis, Schizocythere* and *Thracella*. The following features can ben noted :

58.3 m - 57.8 m : assemblage of low diversity.
56.7 m - 55.3 m : specimens too corroded to be identified.
51.99 m : a poorly preserved assemblage of low diversity.
51.1 m - 47.2 m : a major influx of ostracods at 51.1 m ; diverse and abundant ostracods are present in this interval.
46.8 m - 45.8 m : ostracods very rare, but including *Trachyleberidea prestwichiana* (recorded in the Mont-Panisel borehole only at 45.8 m). This species has previously been recorded in Belgium from the Morlanwelz Member of Gouy-les-Pieton (King, unpublished),

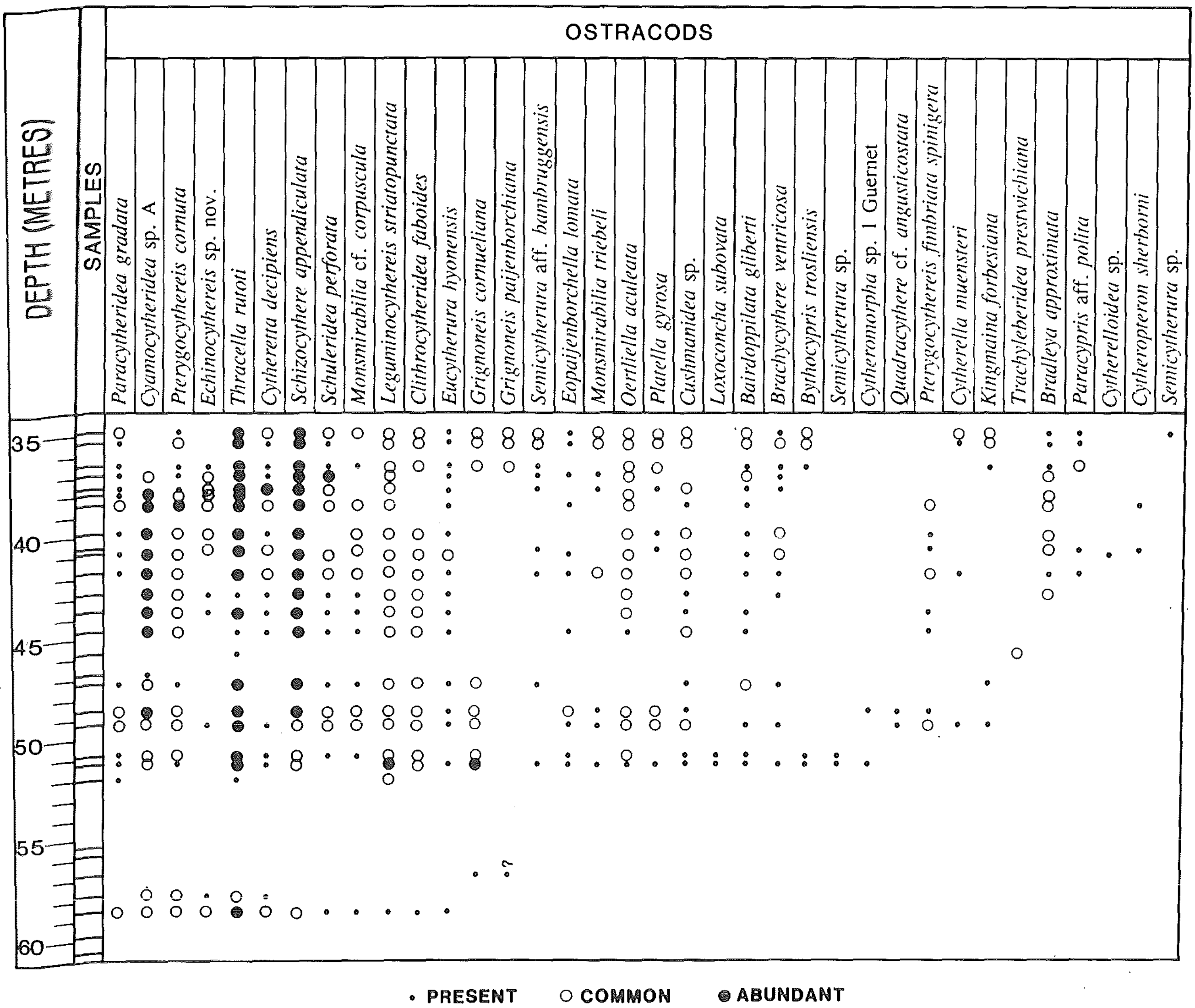

Figure 8. Distribution of ostracods in the Mons-en-Pévèle Sand Formation of the Mont-Panisel borehole.

and Godarville (in silty clays), from the Mons-en-Pévèle Sand Formation at Maulde near Tournai (in glauconite-rich nummulitic sandstone) (Keij, 1957, p. 109) and widely in the clay facies of the Ypresian.
44.6 m - 36.9 m : diverse and abundant ostracods ; a similar assemblage to the interval at 51.1 m - 47.2 m.
36.4 m - 34.8 m ("calcareous unit") : similar assemblages to those below, but differentiated by the appearance of *Grignoneis paijenborchiana*, and the common occurrence of *Kingmaina forbesiana*, *Semicytherura bambruggensis* and *Cytherella münsteri*, all of which are rare or absent at lower levels. A similar assemblage is recorded by Keij (1957) and the present author (C.K.) form the "calcareous unit" at the outcrop on Bois-la-Haut.

Somme comments can be made on individual taxa :

1. *Echinocythereis* sp. nov. This taxon is relatively common in the Mons-en-Pévèle Sand Formation at Mont-Panisel. It was recorded by Guernet (1992, pl. 2, fig. 7-9) as *E. reticulatissima* Eagar. It is present in the "Cuisian" of the Paris Basin, recorded as *E.* cf. *reticulatissima* by Ducasse *et al.* (1985, pl. 80, fig. 4), and has been recorded in the Mons-en-Pévèle Sand Formation at several other localities in Belgium. It was mistakenly identified as *Echinocythereis* sp.A by King (1991a) on the basis of few rather poorly preserved specimens. The well-preserved material now available demonstrates that it is morphologically distinct from other *Echinocythereis* taxa, characterised by its coarse pustular sculpture and a general absence of reticulation. It is characteristic of the fine glauconitic sand facies of the middle Ypresian. *E.* sp.A of King (1991b, Ph D thesis, pl. 21, fig. 2) has smaller pustules, and occurs in finer-grained facies (the London Clay Formation and clay facies of the middle Ieper Group). It is therefore possible that the differences between these taxa could reflect ecological rather than taxonomic significance, but their stratigraphic distribution is significantly different.

2. *Cyamocytheridea* sp. A of King (1991b). This undescribed taxon is very common in the London Clay and at some levels in the clay facies of the middle Ieper Group. It is differentiated from other taxa of *Cyamocytheridea* by its very weak pitting (see King, op. cit., pl. 17, fig. 9-12). It was recorded as *C.* cf. *heizelensis* by Guernet (1992, pl. 1, fig. 7).

4.6. Calcareous "problematica"

A rather diverse fauna of calcareous "problematica" is known from the middle Ieper Group, mainly from the clay facies (Willems, 1972). *Pseudarcella rhumbleri, Voorthuyseniella hyonensis* and *Yvoniellina feugueuri* are recorded from the Mons-en-Pévèle Sand Formation at Hyon (Mont-Panisel) by Keij (1970). These are probably from the "calcareous unit".

Pseudarcellids and bignotellids (Bignot, 1989) occur abundantly in the Mont-Panisel borehole in most samples through the interval 58.3 m-36.9 m, but are very rare in the "calcareous unit" (fig. 9). Six taxa have been identified. *P. rhumbleri, Bignotella polygona* and *Y. campanula* occur throughout the interval cited. *Pseudarcella trapeziformis* is recorded only at 51.99 m and 55.3 m. *Yvoniellina concava* occurs between 45.8 m and 40.57 m.

Voorthuyseniella gracilis occurs consistently between 36.9 m and 50.7 m. This species is widely distributed in Ypresian sediments in Belgium and southern England.

The specimens referred to *Voorthuyseniella gracilis* by Keij (1970, pl. 2) appear to display a wide range of morphological variation. Study of the *Voorthuyseniella* in the Mont-Panisel borehole and in the middle Ypresian at Marke (Kortrijk) suggests that several morphologically distinct forms can be differentiated ; the most common of these corresponds to the specimens figured in pl. 2, fig. 8 of Keij (the "spindle-shaped" form of Keij), with a long narrow slit ("porta" of Keij). The second form corresponds to the specimen illustrated in pl. 2, fig. 7 of Keij (his "ovoid" form), with a wider slit. This form is present in the London Clay Formation (King, 1991b). A third form, which may be a different species, is short and inflated, with a short oval slit. It is here referred to "*V.* sp. nov." (fig. 9). Further studies on these forms are planned.

Voorthuyseniella hyonensis occurs only in the "calcareous unit". Its holotype is probably also from this unit.

Rare specimens of *Claretinella helenae* were obtained from two adjacent samples, at 44.6 m and 45.8 m. This taxon has previously been recorded only from Spain and from the Mons-en-Pévèle Sand Formation at Mont-Saint-Aubert (Szczechura, 1979 : described under the non-valid name *Aubertianella keji*, see Bignot, 1989, p. 215 for taxonomic remarks), but also occurs in the upper part of the Roubaix Clay (Bailleul Member sensu King, 1991a) at Kortrijk (King, unpublished).

4.7. Serpulids

Rare specimens of *Ditrupa* sp. were recorded. *Rotularia* sp. was encountered at 43.6 m. This genus occurs rarely elsewhere in the Mons-en-Pévèle Sand Formation (e.g. at Vorst-Forest).

4.8. Bryozoa

Dittosaria wetherellii, a common London Clay species, was recorded from a number of samples. *Lunulites* sp. and *Nellia* sp. were also recorded at several levels.

4.9. Molluscs

Aragonitic molluscs, including venerids and *Venericardia* sp., are frequent at several levels, but are partially decalcified, and mostly too friable to survive the sample processing in identifiable condition. The characteristic "Cuisian" species *Phacoides squamulus* was recorded at 37.6 m.

Calcitic molluscs are less common, but well-preserved. The ostreid *Crassostrea* cf. *multicostata* is frequent between c. 55.7 m and c. 57.8 m, and occurs more rarely up to 46.8 m. Pectinid fragments, referable to *Pseudamusium* sp. of King (1991a), occur consistently between 37.6 m and 48.6 m. *Anomia* spp., and shell fragments probably referable to *Crenella* sp., are recorded in a number of samples.

4.10. Calcareous algae

Rare fragments of *Neomeris* sp. are recorded from two samples (37.6 m and 51.1 m). These appear to be the first records of calcareous algae from the Mons-en-Pévèle Sand Formation.

4.11. Brachiopods

Rare fragments of *Lingula* sp. occur in the lower part of the section (see fig. 9).

4.12. Echinoderms

Echinoid spines are common to abundant throughout the section. Fragments of echinoid tests were observed in the "calcareous unit" (at 34.8 m and 35.3 m).

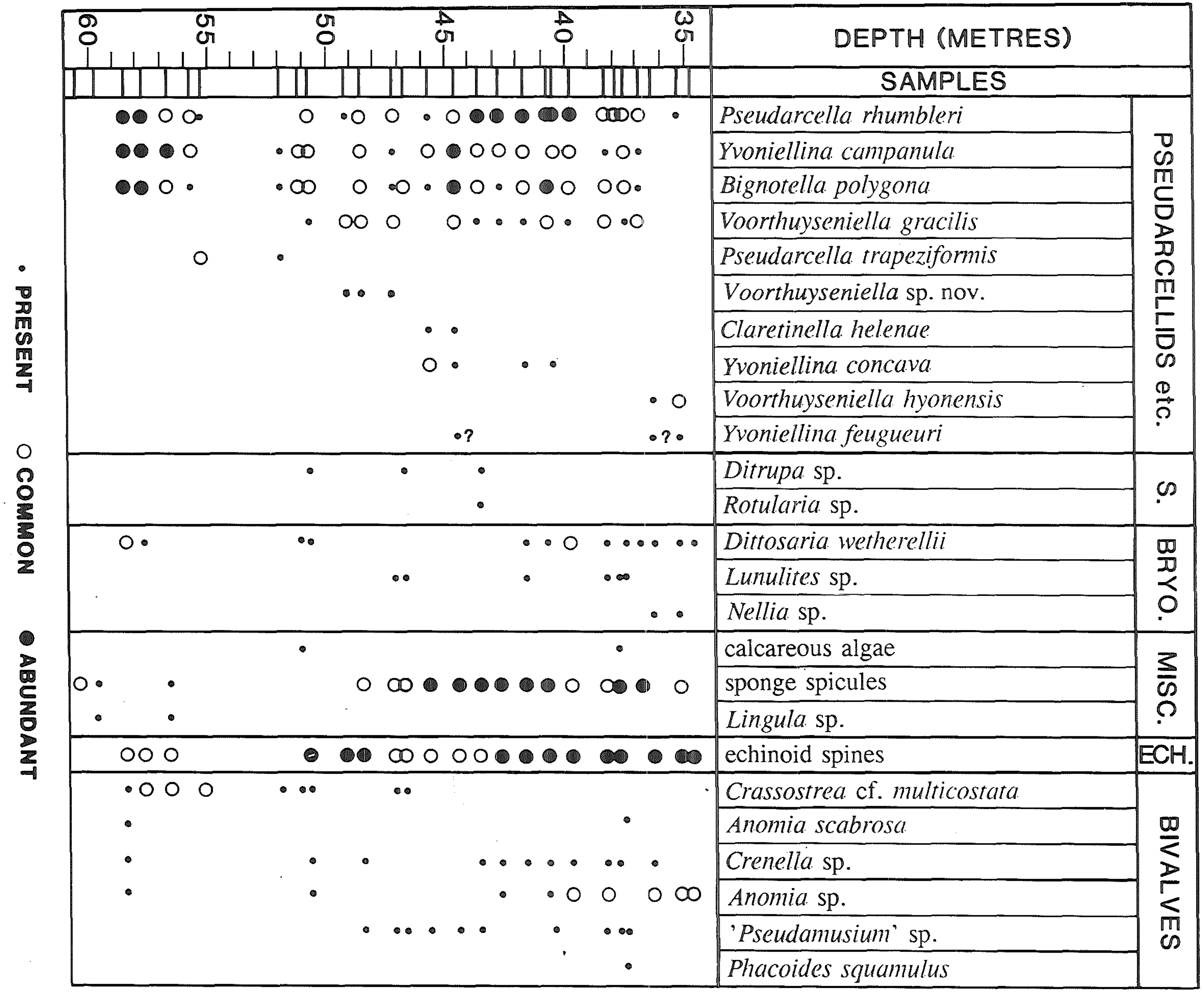

Figure 9. Distribution of selected microfossils in the Mons-en-Pévèle Sand Formation of the Mont-Panisel borehole.

4.13. Sponges

Siliceous sponge spicules are common to very common through the interval 35.2 m to 48.6 m. It is possible that these could be reworked from the Late Cretaceous, but there is no evidence to contradict the interpretation that they are indigenous.

4.14. Biostratigraphy

Biostratigraphic subdivisions and correlations within the middle of the Ieper Goup in southwestern Belgium have recently been proposed by King (1991a), based on the calcareous microfaunas and macrofaunas. Seven biostratigraphic events, I (for Ieper) 1 to I7, were identified. These have been integrated with lithostratigraphic correlations, based partly on correlation of thin glauconitic units. These correlations are elaborated by King & Steurbaut (in prep.).

These studies have been carried out mainly within the clay facies of the lower part of the Ieper Group and the distal (very fine grained) facies of the Mons-en-Pévèle Sand Formation. The lithologies and microfaunas of the Mons-en-Pévèle Sand Formation in the Mont-Panisel borehole indicate a more proximal (shallower) marine environment. There are major differences between the benthonic microfaunas of this facies and those of e.g. the Kortrijk area. Biostratigraphic correlations are therefore imperfect and subject to caution in interpretation.

Correlation with the succession in the Kortrijk area can be summarised as follows :

1. The occurrence of planktonic foraminiferids throughout the section indicate that the lowest sample of the Mons-en-Pévèle Sand Formation with calcareous fossils (at 60.6 m) lies above microfaunal event I1.

2. Microfaunal events I2 and I3 cannot be directly identified, as *Textularia smithvillensis*, whose entry and exit defines these events, has not been recorded here. However, the occurrence of common oysters (*Crassostrea* cf. *multicostata*) between 55.7 m and 57.8 m strongly suggests correlation with the interval between events I2 and I3. *Crassostrea multicostata* is common in the upper part of this interval over a wide area in southwestern Belgium, both in clay facies and in the distal facies of the Mons-en-Pévèle Sand Formation (as at Montroeul-au-Bois, King, 1991a). Event I3 is tentatively correlated here with the top of the oyster-rich interval (55.7 m).

3. The influx of planktonic foraminiferids at 46.8 m can be correlated with the planktonic foraminiferid influx designated event I4.

4. Event I5 (*Asterigerina bartoniana kaasschiteri* influx) cannot readily be identified. This taxon is clearly strongly facies-controlled, as it is common to abundant throughout the section in the Mont-Panisel borehole (and also the Kester borehole), but has a more stratigraphically restricted distribution in the distal facies of the Mons-en-Pévèle Sand Formation and in the clay facies of the lower Ieper Group. However, large and strongly "frilled" specimens of *A. b. kaasschiteri*, comparable morphologically to those at event I5, occur most commonly at c. 37.6 m-39.8 m, suggesting correlation of I5 with this level. *Karreria fallax* is present in the clay facies mainly between I4 and I5. In the Mont-Panisel borehole, this species is common between 38.3 m and 47.2 m, and is not recorded above 37.6 m, confirming this correlation.

5. The presence of planktonic foraminiferids in the highest sample with calcareous microfossils (34.8 m) indicates that this sample lies below event I7.

5. SEQUENCE-STRATIGRAPHIC INTERPRETATION

The sequence-stratigraphic interpretation of the Ypresian deposits in the Mont-Panisel borehole forms part of a continuing programme of research on the Belgian Palaeogene carried out by Vandenberghe, Steurbaut *et al.* Although many additional outcrop and borehole data have been taken in account, the interpretation of the Mont-Panisel borehole deposits is still tentative. It is based on detailed analyses of lithofacies, including grain-size, heavy minerals, carbonate and glauconite content, in combination with an allround micropaleontological investigation. The sequence-stratigraphic concepts and terminologies used here have been thoroughly discussed by Van Wagoner *et al.* (1988), and will therefore not be commented on.

The lowermost part of the Mons-en-Pévèle Sand Formation (from 65.50 m to 56.60 m) shows a general coarsening-upward trend (figs 2 & 3). It is considered to represent the highstand systems tract (or part of it) of a third order depositional sequence, labeled sequence Y - C (Y = Ypresian ; C = believed to be the third "third order" Ypresian sequence). The increase in grain-size is not regular within the coarsening-upward unit, but presents some minor oscillations. The junction at 61.88 m is considered to be the boundary between 2 sub-sequences (term used sensu Whittaker *et al.*, 1991, p. 819), labeled Y - C3 and Y - C4. Only the highstand part of sub-sequence Y - C3 was penetrated. Sub-sequence Y - C4 is represented by a lower fining-upward set and an overlying coarsening-upward set.

The coarser-grained oyster-rich level at 56.60 m is interpreted as a type 2 sequence boundary of the next sequence Y - D. Grain-size decreases upwards, from the base of this level to a minimum value at about 46.60 m, and then, increases again up to 37.80 m. The lower unit with fining-upward lithology represents the transgressive systems tract, and the overlying coarsening-upward unit the highstand systems tract of sequence Y - D. The fine-grained interval between 46.60 m and 45 m, which immediately occurs above a short break in sedimentation at 46.63 m (labeled surface 3), is marked by a substantial influx of planktonic foraminiferids and calcareous nannofossils. This surface is believed to represent the maximum flooding surface of sequence Y - D.

The upper part of the Mons-en-Pévèle Sand Formation is less easily interpretable in terms of sequence stratigraphy, as no distinct trends in lithology are recorded. However, the presence of 3 supplementary discontinuities at 37.83 m, 36.65 m and 31.39 m, which coincide with major changes in microfaunas and nannofloras (these changes have not been recorded at 31.39 m because of decalcification, but they are known to occur at this level in other boreholes), indicates that important environmental changes must have occurred during this interval. These discontinuities are believed to be linked to eustatic sea-level changes. From what is known from the Kortrijk area (King & Steurbaut, in prep.), they all might represent sequence boundaries.

The overlying Hyon Sand Formation represents the next third order depositional sequence, tentatively labeled sequence Y-X. The lower Bois-la-Haut Sand Member represents its transgressive system tract, the overlying Panisel Sand Member its highstand systems tract. Between the Hyon Sand Formation and the underlying Mons-en-Pévèle Sand Formation lies a major hiatus of c. 1 million year, encompassing several sequences (Steurbaut, work in progress).

6. COMPARISON WITH ADJACENT AREAS IN BELGIUM

Correlation of the "Paniselian" strata at Mont-Panisel, redefined here as the Hyon Sand Formation, with deposits in northwest Belgium has not been well understood until now. This is due to the scarcity of detailed and well interpretable data (only very few outcrops, inaccurate borehole data), the poor quality of the Mont-Panisel outcrops (strongly leached, decalcified and oxidised) and the complexity of middle and late Ypresian stratigraphy in northwest Belgium. High resolution stratigraphy of recently drilled boreholes (e.g. at Mont-Panisel, and Kester) an re-interpretation of some key-sections have now led to the identification of the Hyon Sand Formation, in northwest Belgium. This newly acquired information is mainly based on lithologic, geometric and depositional criteria, supported by some macrofaunal evidence.

The Egem (Ampe) sand quarry - The Egem quarry is the type locality of the Egem Sand Member (Steurbaut & Nolf, 1986, p. 127). This member mainly consists of glauconitic (fine grained), fossiliferous very fine sands, often very rich in *Nummulites planulatus* (with *N.* cf. *aquitanicus* in the top of the member) (King, 1981, p. 133). It is overlain by a 40 cm thick glauconitic calcareous sandstone (between 3.80 m to 4.20 m below surface = between c. 39.40 m and 39.80 m T.A.W.), rich in molluscs and *Nummulites planulatus*, containing shark teeth at the base. The glauconite is coarse grained, with irregular lumps up to 5 mm in diameter. The base and top of this bed are marked by omission surfaces.

This sandstone, which is tentatively named bed X, was up to now erroneously incorporated in the Pittem Clay Member. Its integration in this member, as suggested by De Coninck & Nolf (1979, p. 171) cannot be upheld anymore because of differences in lithology, and because its dinoflagellate association is substantially different from those of the Merelbeke Clay and Pittem Clay Members (presence in bed X of very rare *Areosphaeridium diktyoplokus*, very rare *Pediastrum* and rare *Impletosphaeridium rugosum*, and total absence of any representative of the genera *Pulvinosphaeridium* and *Spinidinium*) (De Coninck, unpublished).

Correlation of bed X with the Bois-la-Haut Sand Member at Mont-Panisel is based on the similarity in lithofacies (occurrence of fine grained, slightly clayey sand, although cemented at Egem ; presence of coarse grained glauconite) and in depositional characteristics (both units are transgressive), on geometric deductions and on macrofaunal evidence (*Nummulites planulatus* which is common in bed X is also recorded from the Panisel Sand Member at Mont-Panisel, but does not occur in the Merelbeke Clay Member and in overlying strata ; the mollusc taxa *Orthocardium, Pinna, Venericardia* and nautilids are known from bed X and from the Panisel Sand Member at Mont-Panisel). From what is known from the former Ring-kanaal exposures at Merelbeke (near Gent), it is likely that the entire Hyon Sand Formation was deposited at Egem, but subsequently eroded, down to the top of the sandstone bed (Steurbaut, work in progress).

The Kortrijk area and the Kester borehole (see addendum 2) - The microfaunal, macrofaunal and nannofossil data indicate that, although the lithofacies are quite distinct, reliable detailed biostratigraphic correlation can be established between the proximal facies of the Mons-en-Pévèle Sand Formation and the clay facies of the Ieper Group. These correlations can only be applied within the calcareous part of the Mons-en-Pévèle Sand Formation (King & Steurbaut, in prep.), but further conclusions can be made :

1. Stratigraphic comparisons with the Kortrijk area indicate that the basal interval of the Mont-Panisel borehole, below 58.3 m, is likely to be much younger than the Mont-Héribu Clay Member. This is confirmed by the absence of the characteristic microfauna of the Mont-Héribu Clay, and by the dinflagellate assemblage at 65.3 m (De Coninck, 1992, p. 313).

2. Biostratigraphic correlation with the Kester borehole (unpublished data) indicates that a similar thickness of the upper part of the Mons-en-Pévèle Sand Formation is present in both boreholes. This suggests that there is probably no significant localised truncation of the Mons-en-Pévèle Sand Formation at Mont-Panisel, as in the Kester borehole it is overlain conformably by the Aalbeke Clay Member. Thus the preserved thickness at Mont-Panisel is probably close to the originally deposited thickness.

3. At Mont-Panisel there is a major hiatus of approximately 1 million year between the Mons-en-Pévèle Sand Formation and the overlying Hyon Sand Formation (see heading "omission surfaces"). This hiatus is slightly greater in the outcrop, because of the absence of the Bois-la-Haut Sand Member. The contact between these formations in the outcrop is marked by a highly glauconitic clayey bed, deeply burrowed down into the Mons-en-Pévèle Sand Formation. The major hiatus decreases progressively towards the north and northwest, the gap being gradually filled in with sediment, passing into an almost conformable succession in the extreme northwest of Belgium (Steurbaut, work in progress).

7. COMPARISON WITH THE SUCCESSION IN THE PARIS BASIN

The benthonic microfauna of the Mons-en-Pévèle Sand Formation in the Mont-Panisel borehole is similar to that recorded from the Mons-en-Pévèle Sand Formation at Forest (Kaasschieter, 1961 ; Keij, 1957 ; King, 1991a) and in the Kester borehole (hole 101W79, see addendum 2, unpublished data). As noted by King (1991a) these microfaunas differ significantly from those in the more "distal" facies of the Mons-en-Pévèle Sand Formation (including the stratotype section) and the clay facies of the Ieper Group, but are very similar to the "Cuisian" microfaunas of the Paris Basin. Among the foraminiferids, the miliolids, polymorphinids, *Bolivina carinata, Trifarina muralis, Discorbis* spp., *Eponides toulmini, Cibicides tenellus, C. westi, Pararotalia armata* and *Elphidium laeve* are characteristic "Cuisian" species (Le Calvez, 1970), which are very rare or absent in the more distal facies. Of approximately 30 taxa of ostracods described from the "Cuisian" (Keij, 1957 ; Ducasse *et al.*, 1985), at least 19 are also recorded from the Mont-Panisel borehole.

The overall aspect of the microfaunas in the lower and middle part of the fossiliferous interval at Mont-Panisel borehole is similar to that of the upper part of the Aizy sands in the Paris Basin (Le Calvez, 1970 ; Murray & Wright, 1976 ; King, unpublished data). *Asterigerina* and *Cancris subconicus* are common and characteristic of this interval in the northern Paris Basin. This is reinforced by the occurrence of *Crassostrea* cf. *multicostata*, whose abundant occurrence characterises the upper Aizy sands (King, unpublished data). The faunal change at the base of the calcareous indurated unit at Mont-Panisel, marked by the appearance of miliolids and the entry of *Alveolina* sp. (only known from the outcrop), is comparable to that seem at the base of the overlying Pierrefonds sands in the Paris Basin. These correlations are supported by the lithology and calcareous nannofossil data.

The changes in nannoflora between the upper Aizy sands and the Pierrefonds sands are comparable to those observed at the base of the calcareous sandstone at Mont-Panisel (disappearance of *Ellipsolithus macellus* and of abundant *Rhabdosphaera sola*, recurrence of common *Braarudosphaera bigelowii* and *Rhabdosphaera vitrea* at the base of the Pierrefonds sands). The lower part of the Pierrefonds sands, well-exposed at the village of Pierrefonds, is prior to the first consistent occurrence of *Discoaster lodoensis*. The upper part, outcroppoing at Aizy-Jouy, contains very rare *D. lodoensis* and therefore has to be attributed to zone NP 12 (see also Steurbaut, 1988, p. 107).

One single calcareous sandstone band is recorded within the whole of the Mons-en-Pévèle Sand Formation at Mont-Panisel and in the "Cuisian" succession in the Cuise-la-Motte outcrop and borehole. There is good biostratigraphic evidence that the greenish calcareous sandstone which occurs at the base of the Pierrefonds sands (see Bignot *et al.*, 1980, B 12, p. 8), correlates with the glauconitic sandstone band at Mont-Panisel.

These comparison strongly reinforce previous suggestions (e.g. Steurbaut, 1988, p. 110 ; King, 1991a) that the Mons-en-Pévèle Sand Formation is the distal continuation of the largely coastal to shallow marine "Cuisian" sand facies of the northern Paris Basin. This throws into doubt the existence of the "Artois axis" as a structural barrier between these areas at this time (cf. Megnien, 1980, p. 451), as already concluded by Mercier-Castiaux *et al.* (1988, p. 147) on the basis of clay mineral distributions.

8. CONCLUSIONS

1. The Ypresian succession in the Mont-Panisel borehole comprises representatives of the Mons-en-Pévèle Sand Formation (new status, formerly Member), overlain by the Hyon Sand Formation (new term). The borehole terminated within the lowest part of the Mons-en-Pévèle Sand Formation. The underlying Ypresian deposits, including the basal Mont-Héribu Clay Member, which outcrops nearby, were not penetrated.

2. The Mons-en-Pévèle Sand Formation and Hyon Sand Formation are separated by a hiatus of approximately 1 m.y. duration. The heavy mineral composition of these formations is significantly different, suggesting that major palaeogeographic changes took place in the intervening period.

3. The Mons-en-Pévèle Sand Formation comprises very fine to fine glauconitic sands, within which four lithofacies can be differentiated. Deposition of bioturbated sand facies took place in well-oxygenated shallow marine environments. Beds of laminated sand with nummulite concentrations were deposited as storm-generated beds, or reflect shallowing to shoreface environments during episodes of relative sea-level fall.

4. Six minor stratigraphic breaks or condensed sections have been identified within the Mons-en-Pévèle Sand Formation, marked by discontinuities or glauconite-rich units. These are interpreted as reponses to relative sea-level rise of fall, and some are believed to represent third-order sequence boundaries (Ypresian sequences Y - C to Y - ?).

5. The Mons-en-Pévèle Sand Formation is partially decalcified. Calcareous nannofloras, microfaunas and macrofaunas are present within the interval 34.6 m - 61 m. The entire interval falls within calcareous nannofossil zone NP 11. The nannofossil biostratigraphic units I to IIIb of Steurbaut (1988) have been identified. The microfaunal biostratigraphic events I3 to I5 of King (1991a) are identified or inferred. These permit correlation with the distal facies of the Mons-en-Pévèle Sand Formation, and the laterally equivalent clay facies of the Ieper Group (formerly Formation). They confirm previous correlations by Steurbaut & Nolf (1986) and King (1991a).

6. The integration of biostratigraphic and lithostratigraphic data permits evaluation of the relationship between microfaunal and nannofossil events in the Mons-en-Pévèle Sand Formation. It is noticeable that many correspond to the stratigraphic breaks noted above. The abundance of planktonic foraminiferids and calcareous nannofossils displays vertical changes interpreted as due to relative sea-level fluctuation.

7. The microfauna and nannoflora of the Mons-en-Pévèle Sand Formation show marked similarities to those of the Early Eocene "Cuisian" sands of the Paris Basin. Those below 36.65 m can probably be correlated with the upper Aizy Sands. There is a marked biostratigraphic and lithostratigraphic break at 36.65 m. The overlying glauconitic calcareous sandstone unit can probably be correlated biostratigraphically with the lower part of the Pierrefonds sands of the Paris Basin. These comparisons reinforce previous suggestions (Steurbaut, 1988 ; King, 1991a) that the Mons-en-Pévèle Sand Formation is a lateral continuation of the "Cuisian" sands, and indicate that there was continuity of sedimentation between the two areas. This indicates that the Artois "Axis" had little or no influence on sedimentation during the middle Ypresian.

8. The Hyon Sand Formation comprises highly glauconitic bioturbated sands with siliceous sandstone concretions. It is subdivided into a lower Bois-la-Haut Sand Member (new) and an upper Mont-Panisel Sand Member. These units are characterised by a much higher and coarser glauconite content than the Mons-en-Pévèle Sand Formation, and a distinctive heavy mineral assemblage. The basal contact on the Mons-en-Pévèle Sand Formation is sharp. The contact between the two members is not seen due to core loss, but is inferred also to be sharp.

9. The Hyon Sand Formation is decalcified, and no significant new biostratigraphic data have been obtained. The Bois-la-Haut Sand Member is interpreted as the transgressive systems tract of Ypresian sequence Y - X. The Mont-Panisel Sand Member represents the highstand systems tract of sequence Y - X. The Bois-la-Haut Member is correlated with the calcareous sandstone of the Egem (Ampe) quarry, tentatively named bed X, which was previously assigned to the lower part of the Pittem Clay Member (middle Ypresian) (Steurbaut, work in progress).

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ADDENDUM 1 : TAXONOMIC DETAILS OF SPECIES CITED

Calcareous nannofossils

Braarudosphaera bigelowii (GRAN & BRAARUD, 1935)
Cepekiella lumina (SULLIVAN, 1964)
Chiasmolithus consuetus (BRAMLETTE & SULLIVAN, 1961)
C. solitus (BRAMLETTE & SULLIVAN, 1961)
Chiphragmalithus calathus BRAMLETTE & SULLIVAN, 1961
Cruciplacolithus cribellus (BRAMLETTE & SULLIVAN, 1961)
C. delus (BRAMLETTE & SULLIVAN, 1961)
Cyclolithus bramlettei HAY & TOWE, 1962
Discoaster barbadiensis TAN SIN HOK, 1927
D. binodosus MARTINI, 1958
D. diastypus BRAMLETTE & SULLIVAN, 1961
D. elegans BRAMLETTE & SULLIVAN, 1961
D. kuepperi STRADNER, 1959
D. lodoensis BRAMLETTE & RIEDEL, 1954
D. multiradiatus BRAMLETTE & RIEDEL, 1954
Ellipsolithus macellus (BRAMLETTE & SULLIVAN, 1961)
Ericsonia eoplegica (BRAMLETTE & RIEDEL, 1954)
Holodiscolithus macroporus (DEFLANDE *in* DEFLANDRE & FERT, 1954)
Imperiaster obscurus (MARTINI, 1958)
Lophodolithus nascens BRAMLETTE & SULLIVAN, 1961
Markalius inversus (DEFLANDRE *in* DEFLANDRE & FERT, 1954)
Micrantholithus aequalis SULLIVAN, 1964
M. mirabilis LOCKER, 1965
M. vesper DEFLANDRE, 1954
Naninfula dupuisii STEURBAUT, 1991
Neochiastozygus rosenkrantzii PERCH-NIELSEN, 1971
Neoccolithes dubius (DEFLANDRE, 1954)
N. protenus (BRAMLETTE & SULLIVAN, 1961)
Pontosphaera exilis (BRAMLETTE & SULLIVAN, 1961)
P. fimbriata (BRAMLETTE & SULLIVAN, 1961)
P. kingii STEURBAUT, 1991
P. pectinata (BRAMLETTE & SULLIVAN, 1961)
P. pulchra (DEFLANDE *in* DELFANDRE & FERT, 1954)
P. scissura (PERCH-NIELSEN, 1971)
P. versa (BRAMLETTE & SULLIVAN, 1961)
Rhabdosphaera morionum (DEFLANDRE *in* DEFLANDRE & FERT, 1954)
R. sola PERCH-NIELSEN, 1971
R. truncata BRAMLETTE & SULLIVAN, 1961
R. vitrae DEFLANDRE *in* DEFLANDRE & FERT, 1954
Semihololithus kerabyi PERCH-NIELSEN, 1971
Sphenolithus anarrhopus BUKRY & BRAMLETTE, 1969
S. editus PERCH-NIELSEN, 1978
S. moriformis (BRÖNNIMANN & STRADNER, 1962)
S. radians DEFLANDRE, 1952
Toweius gammation (BRAMLETTE & SULLIVAN, 1961)
T. magnicrassus (BUKRY, 1971)
T. occultatus (LOCKER, 1967)
T. pertusus (SULLIVAN, 1965)
Tribrachiatus orthostylus SHAMRAI, 1963
Trochoaster operosus (DEFLANDRE, 1954)
Zygodiscus adamas BRAMLETTE & SULLIVAN, 1961
Zygrhablithus bijugatus s.l. (DEFLANDRE, 1959)
Z. bijugatus nolfii STEURBAUT, 1991

Calcareous "problematica"

Bignotella polygona WILLEMS, 1975
Claretinella helenae KEIJ, 1974
Pseudarcella rhumbleri SPANDEL, 1909
P. trapeziformis WILLEMS, 1972
Voorthuyseniella gracilis KEIJ, 1970
V. hyonensis KEIJ, 1970
Yvoniellina campanula (LE CALVEZ, 1959)
Y. concava WILLEMS, 1972
Y. feugueuri (LE CALVEZ, 1959)

Dinoflagellates

Areosphaeridium diktyoplokus (KLUMPP, 1953)
Impletosphaeridium rugosum MORGENROTH, 1966

Foraminiferids

Asterigerina bartoniana kaaschiteri ZANEVA, 1972
Bolivina carinata TERQUEM, 1882
Cancris subconicus (TERQUEM, 1882)
Cibicides tenellus (REUSS, 1865)
C. westi HOWE, 1939
Elphidium laeve (d'ORBIGNY, 1865)
Eponides toulmini BROTZEN, 1948
Karreria fallax RZEHAK, 1891
Morozovella aequa CUSHMAN & RENZ, 1942
M. lensiformis SUBBOTINA, 1953
Nummulites cf. *aquitanicus* BENOIST, 1889
N. planulatus (LAMARCK, 1804)
Pararotalia armata (d'ORBIGNY, 1826)
Rotalia aff. *viennoti* GRIEG, 1935
Textularia smithvillensis (CUSHMAN & ELLISOR, 1933)
Trifarina muralis (TERQUEM, 1882)

Bryozoa

Dittosaria wetherellii (BUSK, 1866)

Molluscs

Crassostrea cf. *multicostata* (DESHAYES, 1824)
Phacoides squamulus (DESHAYES, 1866)

Ostracods

Bairdoppilata gliberti KEIJ, 1957
Brachycythere ventricosa (BOSQUET, 1852)
Bradleya approximata (BOSQUET, 1852)
Bythocypris trosliensis (APOSTOLESCU, 1956)
Clithrocytheridea faboises (BOSQUET, 1838)
Cyamocytheridea sp. A sensu KING, unpublished
Cytherella münsteri (ROEMER, 1838)
Cytheretta decipiens KEIJ, 1957
Cytheromorpha sp. 1 sensu GUERNET, 1985

Cytheropteron sherborni BOWEN, 1953
Echinocythereis reticulatissima EAGAR, 1965
Eopaijenborchella lomata (TRIEBEL, 1949)
Eucytherura hyonensis KEIJ, 1957
Grignoneis cornueliana (BOSQUET, 1852)
G. paijenborchiana (KEIJ, 1957)
Kingmaina forbesiana (BOSQUET, 1852)
Leguminocythereis striatopunctata (ROEMER, 1838)
Monsmirabilia corpuscula (HASKINS, 1968)
M. triebeli (KEIJ, 1957)
Oertliella aculeata (BOSQUET, 1852)
Paracypris polita (SARS, 1866)
Paracytheridae gradata (BOSQUET, 1852)
Platella gyrosa (ROEMER, 1838)
Pterygocythereis cornuta (ROEMER, 1838)
P. fimbriata spinigera KEIJ, 1957
Quadracythere angusticostata (BOSQUET, 1852)
Schizocythere appendiculata TRIEBEL, 1950
Schuleridea perforata (ROEMER, 1838)
Semicytherura bambruggensis (KEIJ, 1957)
Thracella rutoti (KEIJ, 1957)
Trachyleberidea prestwichiana (JONES & SHERBORN, 1887)

ADDENDUM 2 : DETAILS ON OUTCROPS AND BOREHOLES DISCUSSED IN TEXT

"le Bocage" : several small outcrops along footpath on the Bois-la-Haut Hill (see fig. 1 of the present paper). Map sheet 45/7-8 ; coordinates : x = 121.950, y = 125.200.

Egem (Ampe) sand quarry : large quarry, 2 km west of the village of Egem. Map sheet 21/1 ; coordinates : x = 70.105, y = 190.150.

Kester borehole (101W79) : drilled for the Geological Survey of Belgium in 1988, 15 km southwest of Brussels. The Ieper Group was penetrated between 16.40 m and 111.82 m. Map sheet 31/5-6 ; coordinates : x =131.309, y = 162.736.

Marke clay quarry : quarry in the clay facies of the Ieper Group, 5 km southeast of Kortrijk. Map sheet 29/5 ; coordinates : x = 69.000, y = 166.800.