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LITHOSTRATIGRAPHY AND BIOSTRATIGRAPHY BASED ON BENTHONIC FORAMINIFERA OF THE NEOGENE DEPOSITS OF NORTHERN BELGIUM

by F.J. DE MEUTER * and P.G. LAGA **

SUMMARY. - Recently the complete succession of the Neogene deposits of Belgium could be studied in temporary exposures around and north of the city of Antwerpen. The authors have established a new lithostratigraphy and biostratigraphy according to the recommendations of the International Subcommission on stratigraphic classification. In the Antwerpen area, the lithostratigraphical column consists of five different formations, partly subdivided into members and correlated with lateral equivalents in the Antwerpse and Limburgse Kempen. The biostratigraphy consists of six biozones (five assemblage-zones and one peak-zone) based on the benthonic Foraminifera. One new subspecies *Uvigerina hosiusi deurmensis* is described. All the boundaries between the biozones coincide with the lithologic boundaries. The biozonation allows interregional correlation of the Neogene marine deposits of northern Belgium.

RESUME. - Récemment la succession complète des dépôts Néogènes en Belgique a été étudiée dans les excavations temporaires situées en périphérie et au nord de la ville d'Antwerpen. Les auteurs ont établi une nouvelle lithostratigraphie et biostratigraphie suivant les recommandations de l'"International Subcommission on stratigraphical classification". Dans la région d'Antwerpen, la colonne stratigraphique comprend cinq formations différentes, subdivisées partiellement en membres et corrélées avec des équivalents latéraux dans l'Antwerpse et Limburgse Kempen (Campines Anversoise et Limbourgeoise). La biostratigraphie comprend six biozones (cinq cénozones et une épibole) basées sur l'étude des Foraminifères benthoniques. Une nouvelle sous-espèce *Uvigerina hosiusi deurmensis* a été décrite. Toutes les limites entre les biozones coïncident avec les limites lithologiques. La biozonation permet une corrélation interrégionale des dépôts Néogènes marins du nord de la Belgique.

INTRODUCTION

The present work is a summary of two doctorate theses, presented in the faculty of Sciences of the Katholieke Universiteit, Leuven. The first by P.G. LAGA (1972) deals with the Foraminifera of the Pliocene and Pleistocene marine deposits of Belgium. The second by F.J. DE MEUTER (1974) deals with the Foraminifera of the Miocene marine deposits of Belgium.

Important public works have been carried out around the city of Antwerpen, for the E3- Kleine Ring motorway and in the harbour area north of this city between 1965 and 1970. Temporary exposures have shown the complete succession of the Neogene deposits. Boreholes in the Kempen from the Belgian Geological Survey were also available.

* Laboratorium voor Paleontologie, Redingenstraat, 16 bis, 3000. Leuven.

** Belgische Geologische Dienst, Jennerstraat, 13, 1040. Brussel.

This abundant new material enabled the authors to study the microfauna of the Neogene deposits.

The present work deals with the lithostratigraphy and the biostratigraphy, drawn up according to the recommendations of the International Subcommission on stratigraphic classification (International Commission on Stratigraphy).

The lithostratigraphy of these Neogene deposits is based mainly on the extensive study of numerous temporary exposures and of some borings. It is also partly based on data of the literature. More extended data on these outcrops have been published in a Professional Paper of the Belgian Geological Survey (P.P. 1976 nr. 3 - DE MEUTER, WOUTERS & RINGELÉ).

The biostratigraphy consists of a biozonation based on the association of the benthonic Foraminifera. The study of the planktonic Foraminifera has been published by DE MEUTER & LAGA (1970) and extensively by HOOYBERGHS & DE MEUTER (1972).

The two subjects of the theses are separated by the Miocene-Pliocene boundary, as defined by the resolutions of the Gent Symposium in 1961 (published in 1963). The stratigraphical division in series, outlined in this Symposium, is followed in this paper. However, the upper boundary of the Pliocene admitted in this work is not in agreement with the quoted resolutions. In our opinion, all the marine deposits, from the Kattendijk Sands up to and including the Merksem Sands, belong to the Pliocene series. In fact, there is no important change in the foraminiferal association, which could indicate a Pliocene-Pleistocene boundary. VAN VOORTHUYSEN, TOERING & ZAGWIJN (1972) have stated a narrow Range Zone of the Foraminifer *Elphidium oregonense* CUSHMAN & GRANT, 1927. This Range Zone falls into the lower part of the first glacial stage of the Pleistocene, the Praetigian, as defined by means of pollen-analysis. This species has never been found in Belgium.

I. LITHOSTRATIGRAPHY (Table 1)

1. The Miocene

1.1. BERCHEM FORMATION (*New formation, new name*).

NAME : Berchem, southern suburb of Antwerpen City.

TYPE-LOCALITIES : Antwerpen, Berchem and Borgerhout.

TYPE-SECTIONS : temporary (1965-1970) exposures of the excavations for the "E3 - Kleine Ring" motorway around Antwerpen, from Antwerpen - Zuidstation to Borgerhout - Rivierenhof.

DIAGNOSTIC DESCRIPTION : green to blackish, fine to medium fine, often slightly clayey, very glauconiferous sand; rich in shells, dispersed in the sediment or concentrated in subhorizontal, sometimes massive layers; locally decalcified; basal gravel more or less developed, consisting mainly of dark rounded flint pebbles.

FORMER NAMES : "Sables inférieurs d'Anvers" (VANDEN BROECK, 1876); "Anversien" (COGELS *in* VAN ERTBORN, 1879).

DISTRIBUTION : Antwerpen province : subsurface exposures and borings to the north and east of Antwerpen.

SUBDIVISION :

1.1.1. EDEGEM SANDS (de HEINZELIN, 1955c, after NYST, 1861a)

NAME : Edegem, village 5 km south of Antwerpen city.

TYPE-LOCALITY : Edegem.

TYPE-SECTION : submerged brickyard near Fort VI (Wilrijk) (see NYST, 1861a).

DIAGNOSTIC DESCRIPTION : dark green, fine, clayey, very glauconiferous sand; very rich in molluscs, mostly dispersed in the sediment, very rarely more concentrated in nests; basal gravel, known as Burcht Gravel (DEWALQUE, 1876) fairly well developed with dark small rounded flint pebbles, reworked septaria from the underlying Boom Clay, concentrated shell fragments, small silicified shark's teeth and bone fragments.

FORMER NAMES : "Sables d'Edegem à *Panopaea Menardi*" (NYST, 1861a); "Sables à *Panopaea Menardi*" (VANDEN BROECK, 1876).

DISTRIBUTION : excavations and brickyards at the southern edge of the Antwerpen province; deep borings of more northern localities of the same province.

1.1.2. *KIEL SANDS* (New member, after VANDEN BROECK, 1876).

NAME : Kiel, southern quarter of Antwerpen city.

TYPE-LOCALITY : Antwerpen - Kiel.

TYPE-SECTION : excavations for the chain of fortresses around Antwerpen (see VANDEN BROECK, 1876); now replaced by the "E3 - Kleine Ring" motorway.

DIAGNOSTIC DESCRIPTION : grey-green, medium fine to coarse, loose, very glauconiferous sand; without fossils; typical fine whitish tracks, sometimes concentrated in bands; locally dark brown oxidation bands and dark green glauconite concentration, rare clay streaks and sandstone, locally thin layer of coarse sand grains at the base.

FORMER NAME : "Partie supérieure altérée des sables à Panopées du Kiel" (VANDEN BROECK, 1876).

DISTRIBUTION : restricted to the central and southern part of Antwerpen city, becoming fossiliferous to the north and east where it is indistinguishable from the underlying Antwerpen Sands.

1.1.3. *ANTWERPEN SANDS* (de HEINZELIN, 1955c, after NYST, 1845).

NAME : Antwerpen city.

TYPE-LOCALITY : Antwerpen city centre.

TYPE-SECTION : excavations for the "Fort et canal de Hérenthals à Anvers" (see NYST, 1845); since filled up and now centre of the city park.

DIAGNOSTIC DESCRIPTION : dark green, medium fine, slightly clayey, very glauconitic sand; typical variable shell layers with numerous specimens of the mollusc "*Pectunculus pilosus*" (= *Glycymeris lunulata baldii*) (GLIBERT & VAN DE POEL, 1965); levels with phosphatic concretions, bones and shark's teeth; concentration of friable sandstones towards the base; no clear basal gravel except local concentration of coarse sand grains.

FORMER NAMES : "Sable noir du fort Hérenthals" (NYST, 1845); "Crag noir ou inférieur" (LYELL, 1852); "Sables à *Pectunculus pilosus*" (VANDEN BROECK, 1876).

DISTRIBUTION : Excavations and borings in and around Antwerpen city.

1.1.4. *ZONDERSCHOT SANDS* (New member, new name).

NAME : Zonderschot, hamlet of Heist-op-den-Berg, village 30 km south-east of Antwerpen city.

TYPE-LOCALITY : Heist-op-den-Berg, Zonderschot.

TYPE-SECTION : temporary (1972) excavation for a new pipe line (1).

DIAGNOSTIC DESCRIPTION : dark green, fairly fine, clayey, very glauconiferous sand; very rich in shells, homogeneously dispersed in the sediment; micaceous, concentrations of very coarse glauconite grains, slightly ligniferous.

DISTRIBUTION : very restricted to scarce excavations and borings in the neighbourhood of the type-locality.

1.2. *BOLDERBERG FORMATION* (New formation, after DUMONT, 1850).

NAME : Bolderberg, hamlet of Zolder, locality 10 km north of Hasselt, Limburg province.

TYPE-LOCALITY : Zolder, Bolderberg.

TYPE-SECTION : outcrops of the road cuttings on the Bolderberg hill.

DIAGNOSTIC DESCRIPTION : lateral succession from marine to continental sandy deposits; dark green, medium fine, slightly clayey, often very micaceous, very slightly ligniferous, glauconiferous sand, fossiliferous in the lower part, passing into white, fairly coarse sand with lignite layers and glassy quartzite banks; basal gravel well developed with dark rounded flint pebbles and shark's teeth (= Elsloo Gravel; see HALET, 1920).

FORMER NAME : "Boldérien" (DUMONT, 1850); "Houthaléen" (HINSCH, 1952); "Houthalenien-Boldérien" (GULINCK, 1963).

(1) We thank Dr. J. VANDENBERGHE for informing the authors of this exposure.

DISTRIBUTION : exposures and deepborings of the western edge of the Limburg province: exposures on the hills around and to the south of Diest, Brabant province.

SUBDIVISION :

1.2.1. *HOUTHALEN SANDS* (TAVERNIER & de HEINZELIN, 1963, after GLIBERT, 1945, 1952).

NAME : Houthalen, village 12 km north of Hasselt, Limburg province.

TYPE-LOCALITY : Houthalen.

TYPE-SECTION : mine shaft "Puits n°1, Charbonnage de Houthaelen" (GLIBERT, 1945).

DIAGNOSTIC DESCRIPTION : dark green, medium fine, micaceous, very slightly ligniferous, glauconiferous sand; molluscs dispersed, or concentrated in shell layers in the lower part; locally becoming white yellowish, badly preserved or reworked molluscan fauna in the basal gravel of the upperlying Diest Formation (= "Faune du Bolderberg", see VANDEN BROECK, 1880).

FORMER NAMES : "Boldérien, étage marin" (DUMONT, 1850); "Horizon de Houthaelen" (GLIBERT, 1945 & 1952).

DISTRIBUTION : deep borings in the neighbourhood of the type-locality; exposures on the hills of Bolderberg and Waanrode - Loksbergen, south of Diest.

1.2.2. *GENK SANDS* (de HEINZELIN & GLIBERT, 1957, after MOURLON, 1898).

NAME : Genk, village 13 km east of Hasselt, Limburg province.

TYPE-LOCALITY : Genk.

TYPE-SECTION : "Coupe et sondage de la sablière près de la station de Genck" (MOURLON, 1898).

DIAGNOSTIC DESCRIPTION : whitish, fine to fairly coarse and gravelled sand, locally with lignite layers and glassy quartzite banks (also called the Mechelen-aan-de-Maas or Opgrimbie Sands).

FORMER NAMES : "Sables et graviers de Genck" (MOURLON, 1898); "Boldérien, étage fluviatile" (DUMONT, 1850).

DISTRIBUTION : central and eastern part of Limburg province, exposures and deep borings.

NOTE : *HEIZEL SANDS* (= "Sables chamois LE HON, 1862).

Fine micaceous, yellow-brown sand, without fossils; basal gravel (= Heizel Gravel; see GULINCK, 1956) with flint pebbles and reworked shark's teeth, indicating a Miocene age (LERICHE, 1934). Restricted to the western hills of Brussel; lithostratigraphically isolated but resembling the continental facies of the Bolderberg Formation (see GULINCK, 1959).

1.3. *DIEST FORMATION* (New formation, after DUMONT, 1839)

NAME : Diest, town of the northeastern part of Brabant province.

TYPE-LOCALITY : Diest.

TYPE-SECTION : exposures at the former town fortresses.

DIAGNOSTIC DESCRIPTION : grey-green to brownish, at most coarse, locally clayey, glauconiferous sand often with sandstone layers; mainly without fossils, except the very local Deurne and Dessel Sands Members (see below); well developed basal gravel with small rounded flint pebbles and locally with bone fragments and shark's teeth.

FORMER NAMES : "Diestien" (partim) (DUMONT, 1839); "Deurnien" (de HEINZELIN & GLIBERT, 1957).

DISTRIBUTION : exposures on the hill tops of northeastern Brabant, southwestern Antwerpen and western Limburg provinces; deep borings of the more northern parts of Antwerpen and Limburg provinces.

SUBDIVISION :

1.3.1. *DEURNE SANDS* (GLIBERT & de HEINZELIN, 1955, after NYST, 1861b).

NAME : Deurne, eastern suburb of Antwerpen city.

TYPE-LOCALITY : Deurne.

TYPE-SECTION : temporary exposures of shallow excavations at Deurne.

DIAGNOSTIC DESCRIPTION : grey-green medium fine, very slightly clayey, glauconiferous sand; locally very rich in nests of *Bryozoa*, *Brachiopoda* and "*Ditrupa*" (Annelida); typical whitish tracks with dark glauconite coating, layers of sandy concretions; basal gravel with small rounded flint pebbles, bone fragments and shark's teeth.

FORMER NAME : "Couche à *Terebratula perforans*" (NYST, 1861b).

DISTRIBUTION : surroundings of the type-locality.

1.3.2. DESSEL SANDS (LAGA & DE MEUTER, 1973).

NAME : Dessel, village of the eastern part of the Antwerpen province.

TYPE-LOCALITY : Dessel.

TYPE-SECTION : Dessel, deep boring Belchim (31 W n° 221).

DIAGNOSTIC DESCRIPTION : grey-green, very fine, micaceous, glauconiferous sand; rich in Foraminifera; well developed basal gravel (= basal gravel of the Diest Formation).

FORMER NAME : "Sables fins du Diestien" (GULINCK, 1963).

DISTRIBUTION : deep boring of the Antwerpse Kempen.

2. The Pliocene

2.1. KATTENDIJK FORMATION (New formation, after de HEINZELIN, 1955c).

NAME : Kattendijk, locality north of Antwerpen city centre, disappeared at the time of the construction of the dock and the sluice Kattendijk.

TYPE-LOCALITY : de HEINZELIN & GLIBERT (1957) mention the surroundings of the Kattendijkdok, Amerikadok and Lefèbvredok in the southern part of the Antwerpen harbour.

TYPE-SECTION : the outcrop of the Verbindingsdok, described in detail by COGELS (1874), between - 4.80 and 1.00 m.

DIAGNOSTIC DESCRIPTION : dark grey to green-grey fine to medium fine glauconitic sand, slightly clayey; sometimes mottled by tracks, locally with an important amount of *Ditrupa*; shells dispersed in the sand and concentrated in one or more layers; basal gravel of rounded quartz and flints, together with shark's teeth, phosphatic nodules and rounded bones.

FORMER NAMES : "Sable à *Isocardia cor* (sable gris)" (COGELS, 1874); "Sable à *Isocardia cor*" et "*Terebratula perforata*" (HALET, 1931); "Sable du Kattendijk" (de HEINZELIN, 1955c).

DISTRIBUTION : region of Antwerpen, the northern part of the Antwerpse Kempen and very probably the "Land van Waas".

2.2. KASTERLEE FORMATION (New formation, after DUMONT, 1882).

NAME : village in the Antwerpen province, between Turnhout and Geel, north of the "Kleine Nete" river (former spelling : CASTERLEE).

TYPE-LOCALITY : Kasterlee.

TYPE-SECTION : outcrops on the hills at the right of the "Kleine Nete" valley.

DIAGNOSTIC DESCRIPTION : gray fine micaceous sand, without fossils slightly glauconiferous, with lenses of micaceous clay; at the base micaceous fine sand, often very glauconitic, burrowed and mottled; at some places, a basal gravel of flints and rare silicified fossils; often hardly distinguishable from the underlying Diest Formation; the upper limit is also hardly distinguishable from the Møl Formation.

FORMER NAME : "Assise moyenne fluvio-marine - Diestien Moyen" (HALET, 1935a).

DISTRIBUTION : southern part of the Antwerpse Kempen and the Limbурse Kempen; gradual transition to the Kattendijk Formation to the north.

2.3. LILLO FORMATION (New formation, new name).

NAME : former village, north of Antwerpen, disappeared with the digging of the Kanaaldok between the Churchilldok and the Zandvlietssluis.

TYPE-LOCALITY : Antwerpen, district Lillo.

TYPE-SECTION : outcrop of the Tijsmanstunnel under the Kanaaldok between 3.00 and 23.50 m under the natural land surface.

DIAGNOSTIC DESCRIPTION : grey, grey-brown and light grey-brown shelly sand, clayey in the lower part and with several shell layers; in the upper part gradual decrease of the clay content and the thick shell layers; in the uppermost part, gradual disappearance of the shells.

FORMER NAMES : "Scaldisien" (DUMONT, 1850); "Scaldisien supérieur" (COGELS, 1874); "Scaldisien" & "Poederlien" (VINCENT, 1889); "Scaldisien" & "Merxemien" (de HEINZELIN, 1955c) (partim).

DISTRIBUTION : harbour district of Antwerpen and the northern part of the Antwerpse Kempen; to the south of the Kempen gradual transition in the Poederlee Formation.

SUBDIVISION : This formation is subdivided in four different members, from below upwards : Luchtbal Sands, Oorderen Sands, Kruisschans Sands and Merksem Sands. Only the lowermost member has distinct boundaries; there is a gradual change between the other members, which represent different facies; often the Kruisschans Sands are missing in their typical facies.

2.3.1. THE LUCHTBAL SANDS (de HEINZELIN, 1955c, after LERICHE, 1912).

NAME : quarter of Antwerpen.

TYPE-LOCALITY : Antwerpen, Luchtbal quarter, situated north of the city centre and east of the harbour.

TYPE-SECTION : Second and Third Harbour dock, situated west of the Luchtbal quarter; between 10 m and 8 m below the natural land surface; thickness variable between 2 and 0 m. In the type-section of the Lillo Formation (the Tijsmanstunnel), the member outcropped from 21.20 to 23.50 m.

DIAGNOSTIC DESCRIPTION : light brown-grey to whitish very shelly glauconiferous sand; mainly shells notably well-preserved; rich in *Pseudamussium gerardi*, often with *Bryozoa*, *Ditrupea* and some Echinoderm spines.

FORMER NAMES : "Sables gris blanchâtres à la base du Scaldisien" (LERICHE, 1912); "Faluns blanchâtres" (LERICHE, 1927); "Zone à *Pecten gerardi*" (de HEINZELIN, 1952); "Zone à *Modiolus*" (de HEINZELIN, 1955a), "Horizon du Luchtbal" (de HEINZELIN, 1955c); "Sables et Faluns du Luchtbal" (de HEINZELIN, 1963).

NOTE : In several excavations in the Antwerpen harbour, the member outcropped (Van Cauwelaertsluis, Petroleumhaven) but it was wrongly stratigraphically interpreted as "the Kattendijk Sands" by several authors (VAN STRAELEN, HASSE, TAVERNIER & GULINCK, VAN VOORTHUYSEN & PANNEKOEK, de HEINZELIN, LAGAAIJ) in all their papers between 1923 and 1957. This wrong interpretation has been corrected by GLIBERT, 1957. VAN VOORTHUYSEN (1958) however maintained the former interpretation.

DISTRIBUTION : rather patchy in the Antwerpen harbour region; known in borings in the northern Kempen, about 10 m thick.

2.3.2. THE OORDEREN SANDS (New name).

NAME : former village in the harbour region, situated north of the Churchill-dok.

TYPE-LOCALITY : Antwerpen - Oorderen.

TYPE-SECTION : Boudewijns-luis, between - 13.50 m and - 10.50 m O.D.; in the type-section of the Lillo Formation between 15 and 21 m depth.

DIAGNOSTIC DESCRIPTION : fine glauconiferous shelly sand, mainly with three important thick compact shell layers; lowest shell layer with gravel and rounded bones; lower part of the unit grey-brown, homogeneous; upper part darker grey, clayey to very clayey; characteristic molluscs : *Neptunea contraria*, *Angulus benedeni*, *Pinna pectinata*, *Scaphella lamberti*.

FORMER NAMES : "Sables à *Trophon antiquum*" (COGELS, 1874); "Sables à *Fusus contrarius*" (MOURLON, 1880); "Sables à *Neptunea contraria*" (HALET, 1935b); "Sables de Kallo" (de HEINZELIN, 1955c and de HEINZELIN & GLIBERT, 1957).

DISTRIBUTION : well known in the Antwerpen harbour region, and in the northern part of the Kempen; in borings however, the distinction from the upperlying members of the same Formation is difficult.

REMARKS : The new name "Oorderen Sands" is proposed here to replace the term "Kallo Sands" (sensu de HEINZELIN, 1955c) which is ambiguous; in the type section of the Kallo Sands (= "Sable de Callo", DUMONT, 1839), a sand pit at Kallo, was not the described member exposed, but a stratigraphic higher member, according to the geometrical position, the mollusc content (1) and the lithological characteristics. Consequently, this term has been used to define two different lithological units, and is thus ambiguous.

2.3.3. THE KRUISSCHANS SANDS (de HEINZELIN, 1955c).

NAME : former fort "Kruisschans", situated on the right bank of the river Scheldt, in the former municipality of Oorderen.

TYPE-LOCALITY : Antwerpen - Kruisschans.

TYPE-SECTION : Boudewijnsluis, between - 7.50 and - 5.50 m O.D.; in the type-section of the Lillo Formation, between 15 and 12 m depth.

DIAGNOSTIC DESCRIPTION : grey-green fine to medium fine, but locally even coarse glauconiferous sand with fine shell remains and many small shells, many lenses and layers of pure dark grey clay, mainly 1 to 1.5 cm thick, but locally up to 10 - 15 cm; no distinct boundary with the Oorderen Sands below: going down, the sediment is more and more burrowed and clay and sand are mixed to give the clayey sand of the Oorderen Sands; above, no distinct boundary with the Merksem Sands, the clay layers becoming more and more rare; very locally, at the base of the member gravel was found in the harbour region.

FORMER NAME : "Sables à *Laevicardium parkinsoni*" (de HEINZELIN, 1955a).

DISTRIBUTION : patchy distribution in the Antwerpen harbour region, only identifiable in outcrops.

2.3.4. MERKSEM SANDS (de HEINZELIN, 1950 a & b, after VANDEN BROECK & COGELS, 1877).

NAME : Merksem suburb, situated north-east of Antwerpen.

TYPE-LOCALITY : Merksem.

TYPE-SECTION : excavation of the Fort of Merksem at 4.40 m depth; in the type-section of the Lillo Formation, between 12 to 3 m depth.

DIAGNOSTIC DESCRIPTION : grey-yellow fine (sometimes coarse) loose glauconiferous sand, fairly homogeneous, fossiliferous; frequent molluscs : *Corbula gibba* and *Lyropecten opercularis*; lower part : sets of cross bedding and thin clay layers; upper part : rare clay layers, and a fairly horizontal stratification; locally, sandstone concretions and sideritic concretions (see VAN TASSEL, 1965).

FORMER NAMES : "Sables à *Corbula striata* de Merxem" (VANDEN BROECK & COGELS, 1877); "Sables à *Corbulomya complanata*" (VINCENT, 1889); "Sables gris à *Aloides gibba*" (de HEINZELIN, 1955a, b, c).

DISTRIBUTION : known from digging works in the whole Antwerpen harbour region; to the south distinction between the Oorderen Sands and Merksem Sands is difficult owing to the small thickness of the latter.

2.3.5. ZANDVLIET SANDS (New name, after GULINCK, unpublished).

NAME : Zandvliet, district near the border of Holland, north of Antwerpen.

TYPE-LOCALITY : Zandvliet.

TYPE-SECTION : outcrop exposed during the digging works for the Zandvliet-sluis.

DIAGNOSTIC DESCRIPTION : generally fine glauconiferous sand, horizontal stratification burrowed, sideritic sandstone layers and very little clay, no chalk or shells; going down, these sands change gradually into the Merksem Sands, due to the increasing chalk content and the appearance of shells.

DISTRIBUTION : known in the harbour digging works, at Berendrecht and Zandvliet.

NOTE : The placing of the sands in the Lillo Formation is somewhat in contradiction to the definition of the Lillo Formation which contains shells

(1) According to GLIBERT (1958), *Spisula inaequilatera* (NYST) is only present in the upperlying members Kruisschans and Merksem Sands. The type-locality of the holotype of this species is the sandpit of Kallo.

LITHOSTRATIGRAPHIC DIVISION of the NEOGENE DEPOSITS of NORTHERN

Table 1

Currently used older names	LEGEND Geological Map (1896) "Stages"		LEGEND Geological Map (1929) "Stages"		STRATIGRAPHICAL TABLE DE HEINZELIN, 1955 SYMPOSIUM on northern Neogene, 1961		
'Argile grise et noire de la Campine' 'Sable de Mol'	PLEISTOCENE	Campinien	UPPER	Amstetien	LOWER PLEISTOCENE	— Amstetien	Argiles de la Campine Sables de Mol
'Sables à <i>Corbula gibba</i> ' 'Sables à <i>Fusus (Chryso-domus) contrarius</i> (or <i>Neptunea c.</i>)' 'Falun blanchâtre'	PLIOCENE	Poedertien Scaldisien	MIDDLE	Scaldisien	LOWER PLEISTOCENE	Merksemien	Sables de Merksem, Kruisschans et Austruweel <small>(graver du Bassin America)</small>
'Sable gris glauconifère à <i>Isocardia cor</i> (<i>I. humana</i>)' or 'Sable à <i>Ditrupa</i> '			LOWER	Diestien	UPPER	Scaldisien	Sables de Kullo Faluns du Luchtbal
'Sable et grès de Diest à <i>Terebratula perforata</i> ' or 'Sable à Hétérocètes'		Diestien				Deurnien (=Diestien)	Sables de Diest Sables de Deurne
'Sable noir d'Anvers à <i>Pectunculus pilosus</i> ' 'Sable argileux d'Edeghem à <i>Panopea menardi</i> '	UPPER MIOCENE	Bolderien	UPPER MIOCENE	Anversien (=Antwerpiaan)	MIDDLE MIOCENE	Anversien	Sables d'Anvers Sables d'Edeghem
'Sable blanc du Bolderberg'			MIDDLE MIOCENE	Bolderien	LOWER MIOCENE	Houthalenien	Sables d'Houthalen
— 'Argile de Boom à <i>Leda deshayesiana</i> '	MIDDLE OLIGOCENE	Rupelien	UPPER OLIGOCENE	Chattien	OLIGOCENE	Chattien	Sables de Voort
			MIDDLE OLIGOCENE	Rupelien		Rupelien	

BELGIUM and CORRELATION with the previous stratigraphic divisions

LITHOSTRATIGRAPHY			SERIES
Antwerpen	N Antwerpse Kempen _S	Limburgse Kempen	
—	Kempen Formation <small>(Complex of sands + clays)</small> Merksplas Formation	Brasschaat Formation	Pleistocene
Lillo Formation Zandvliet Sands Merksem Sands Kruisschans Sands Oorderen Sands Luchtbal Sands	Lillo Formation Luchtbal Sands	Poederlee or Mol Formation	Upper Pliocene
Kattendijk Formation	Kattendijk Formation	Kasterlee Formation	Lower
Diest Formation Deurne Sands	Diest Formation Dessel Sands	Diest Formation	Upper Miocene
Berchem Formation Antwerpen Sands	Berchem Formation Zonderschot Sands Antwerpen Sands	Bolderberg Formation Genk Sands Houthalen Sands <small>(Elsloo gravel)</small>	Middle Miocene Lower Miocene
?	Voort Formation	Voort Formation	Oligocene
Rupel Formation Boom Clay	Rupel Formation	Rupel Formation	

but the same lithologic feature and the gradual change of chalk content allow this grouping.

2.4. *POEDERLEE FORMATION* (New formation, after VINCENT, 1889).

NAME : village, about 30 km east of Antwerpen.

TYPE-LOCALITY : Poederlee.

TYPE-SECTION : tops of the hills, north of Poederlee : iron sandstone layers.

DIAGNOSTIC DESCRIPTION : fine slightly glauconiferous sand, with small lenses of clay in the lower part; base with gravel of rounded quartz and flint, silicified carbonates (also called the Hukkelberg Gravel); upper part much oxidized in the type region, sometimes limonitic sandstones with moulds of shells.

FORMER NAME : in borings, north of Poederlee, fossiliferous sand "La roche de Poederlé" (COGELS & VAN ERTBORN, 1881).

DISTRIBUTION : southern part of the Antwerpse Kempen.

2.5. *MOL FORMATION* (New formation, after MOURLON, 1896).

NAME : Mol, village about 50 km east of Antwerpen.

TYPE-LOCALITY : Mol.

TYPE-SECTION : sandpits for the exploitation of glass sands.

DIAGNOSTIC DESCRIPTION : white pure, coarse and medium fine sand, sometimes lignitic and with some lenses of a micaceous clay; in the type region, lower part very slightly glauconiferous.

FORMER NAME : "Sables de Moll" (MOURLON, 1896).

DISTRIBUTION : whole north-east of the Kempen.

II. BIOSTRATIGRAPHY (Tables 2 and 3)

1. *Trifarina gracilis rugulosa* - *Elphidium ungeri* Assemblage-zone.

1.1. NAME : The biozone is characterized by the frequent occurrence of the subspecies *Trifarina gracilis rugulosa* and by the rare but restricted findings of the species *Elphidium ungeri*.

1.2. TYPE-LOCALITIES AND TYPE-SECTIONS : Antwerpen - Zuidstation (Edegem Sands) and deep boring Wijshagen (Houthalen Sands).

1.3. DESCRIPTION : The base of the biozone is defined by the first appearance of the chronostratigraphical important subspecies *Trifarina gracilis rugulosa*. It resembles the *tenuistriata* "variety" (sensu BATJES, 1958) defined within the heterogeneous species *Trifarina gracilis* (REUSS, 1851) from the underlying Oligocene deposits.

The *rugulosa* subspecies extends into the upperlying biozone but the top of the described biozone is clearly delimited by the first appearance of representatives of the genus *Uvigerina*.

Elphidium ungeri is restricted to this biozone and in the upper part is associated with *Elphidium inflatum* which is typical of the younger biozone. Several well-represented species and subspecies start at the base of the biozone but range up to the top of the younger one. *Asterigerina guerichi staeschei* is considered to be a chronostratigraphical subspecies, *Asterigerina guerichi guerichi* (FRANKE, 1912) being typical of Oligocene deposits.

Heterolepa dutemplei peelenensis can be distinguished from *Heterolepa dutemplei dutemplei* found in the upperlying *Uvigerina hosiui deurnensis* - *Elphidium antoninum* biozone. Following taxa also are restricted to the first two Miocene biozones : *Bulimina dingdenensis*, *Cribronion heteroporum*, *Virgulinea pertusa pertusa*, *Loxostomum sinuosum*, *Melonis pompilioides*, *Ceratocancri hauerii*.

1.4. DISTRIBUTION : The associations of this biozone are found in the fossiliferous levels of the lithostratigraphical members Edegem Sands and Houthalen Sands.

2. *Uvigerina tenuipustulata* - *Elphidium inflatum* Assemblage-Zone.

2.1. NAME : The biozone is characterized by the association of the species *Uvigerina tenuipustulata* and *Elphidium inflatum*.

2.2. TYPE-LOCALITY AND TYPE-SECTION : Borgerhout - Rivierenhof (Antwerpen Sands).

2.3. DESCRIPTION : The base of the biozone is delimited by the first appearance of the species *Uvigerina tenuipustulata*. It is accompanied by the species *Elphidium inflatum*, ranging from the upper part of the underlying biozone. As noted above, *Trifarina gracilis rugulosa* extends into the studied biozone but with a decreasing frequency.

The top of the biozone is characterized by the complete disappearance of both *Uvigerina tenuipustulata* and *Elphidium inflatum* together with the first appearance of several well-represented taxa typical of the younger biozone. On the other hand, there is a close resemblance with the associations of the underlying biozone. In fact, few representatives of the genus *Uvigerina* are restricted to the here considered biozone : *Uvigerina hosiuseri hosiuseri* and *Uvigerina graciliformis*.

2.4. DISTRIBUTION : The associations of this biozone are found in the members Antwerpen Sands and Zonderschot Sands.

3. *Uvigerina hosiuseri deurnensis* - *Elphidium antoninum* Assemblage-Zone.

3.1. NAME : The biozone is characterized by the frequent occurrence of *Uvigerina hosiuseri deurnensis* nov. subsp. and the very rare but restricted findings of the species *Elphidium antoninum*.

3.2. TYPE-LOCALITY AND TYPE-SECTION : Borgerhout - Rivierenhof (Deurne Sands).

3.3. DESCRIPTION : The base is clearly delimited by the first appearance of the chronostratigraphical subspecies *Uvigerina hosiuseri deurnensis* nov. subsp. distinguishable from *Uvigerina hosiuseri hosiuseri* found in the underlying biozone. Moreover, very rare specimens of *Elphidium antoninum* are found only in the described biozone.

The top is defined by the nearly complete disappearance of *Uvigerina hosiuseri deurnensis* and the first appearance of *Monspeliensina pseudotepida* associated with other taxa typical of the upperlying deposits.

The biozone is characterized by the following well-represented species and subspecies : *Siphotextularia sculpturata*, *Bulimina elongata aculeata*, *Uvigerina pygmaea*, *Trifarina angulosa*, *Cassidulina laevigata* and *Heterolepa dutemplei*. Most of them range into the upperlying biozone.

Finally, there is a remarkable abundance of *Bolboforma metzmacheri*. This calcareous microfossil undoubtedly does not belong to the Foraminifera, but is restricted to the uppermost Miocene deposits of the North Sea basin (see LANGER, 1969 and WILLEMS, 1976).

3.4. DISTRIBUTION : The associations of this biozone are found in the members Deurne Sands and Dessel Sands.

4. *Monspeliensina pseudotepida* - *Florilus boueanus* Assemblage-Zone.

4.1. NAME : The biozone is characterized by the frequent occurrence of the species *Florilus boueanus* and the appearance and frequent occurrence of *Monspeliensina pseudotepida*.

4.3. DESCRIPTION : The base of this biozone is characterized by the appearance of several species : *M. pseudotepida*, *Buccella frigida* occurring frequently; *Bulimina pseudoplicata*, *Cribrononion incertum*, *Discorbitura cushmani* and *Rosalina williamsoni* occurring rarely and *Textularia decrescens*, *Heronallenia lingulata*, *Alliatina excentrica*, *Elphidium crispum* and *Cribrononion haagense* occurring very rarely.

The base of this biozone is also defined by the disappearance of four species: *Elphidium antoninum*, *Uvigerina pygmaea*, *Heterolepa dutemplei dutemplei* and *Bolboforma metzmacheri*.

Three species, appearing at the base of the preceding biozone are restricted to these two biozones, namely : *Uvigerina hosiuseri deurnensis*, *Globobulimina auriculata* and *Siphotextularia sculpturata*.

The top of this biozone is also defined by the appearance of four species in the upperlying biozone.

The biozone is also characterized by the presence of a problematic microfossil, apparently *Bolboforma*-like, undoubtedly different from the underlying *B. metzmacheri*. This form is described as "Lagena" Y (LAGA, 1972), and corresponds probably with the species *Lagena costairregularis* TOERING & VAN VOORTHUYSEN, 1972. Finally, the biozone is characterized by a number of species, ranging from the base of the preceding biozone, up to the uppermost biozone. The species are : *Bulimina elongata aculeata*, *Cassidulina laevigata*, *Planorbulina mediterraneensis*, *Textularia truncata* and *Trifarina angulosa*.

- 4.4. DISTRIBUTION : This biozone is restricted to the Kattendijk Formation.
5. *Cibicides lobatulus* Peak-Zone.
- 5.1. NAME : The biozone is characterized by a high number of *Cibicides lobatulus* specimens (50 to 60%).
- 5.2. TYPE-LOCALITY AND TYPE-SECTION : Antwerpen - Lillo, excavation of the Tijsmanstunnel, between 21 and 23.50 m depth.
- 5.3. DESCRIPTION : The base of the biozone is delimited by the first appearance of the rare species *Pararotalia serrata* and the very rare species *Cribrononion excavatum*, *Planularia pannekoeki* and *Faujasina subrotunda*. This base is also delimited by the disappearance of *Uvigerina hosiusi deurmensis*, *Globobulimina auriculata* and *Siphotextularia sculpturata*. The top of the biozone is defined by the appearance of *Elphidiella hannai*, and the disappearance of *Textularia deerescens*. All the other species, occurring from the base of the two preceding biozones and the present biozone, range up into the succeeding biozone. The biozone is furthermore characterized by the rare occurrence of *Buccella frigida* and *Cribrononion haagensis* and the quite frequent occurrence, at least in some parts in the biozone, of *Trifarina angulosa* and *Quinqueloculina seminula*.
- 5.4. DISTRIBUTION : This Peak-Zone is found in the Luchtbal Sands Member (part of the Lillo Formation).
6. *Elphidiella hannai* - *Cribrononion excavatum* Assemblage-Zone.
- 6.1. NAME : The biozone is characterized by the appearance of *Elphidiella hannai* and the frequent occurrence of *Cribrononion excavatum*.
- 6.2. TYPE-LOCALITY AND TYPE-SECTION : Antwerpen - Lillo, excavation of the Tijsmanstunnel, between 1 and 21 m depth.
- 6.3. DESCRIPTION : The base of the biozone is defined by the appearance of *E. hannai*. The upper part of this biozone is characterized by the gradual disappearance of several species, namely : *Pararotalia serrata*, *Heronallenia lingulata*, *Bolivina pseudoplicata* and of several species of the families *Miliolidae* and *Cassidulinidae*. The species *Elphidiella hannai*, *Cribrononion excavatum* and *Ammonia beccarii* become relatively more important.
- 6.4. DISTRIBUTION : The biozone is restricted to the members Oorderen Sands, Kruisshans Sands and Merksem Sands (part of the Lillo Formation).

III. SYSTEMATICS

Uvigerina hosiusi deurmensis nov. subsp.

(Pl. 1, fig. 7-8)

SYNONYMY :

1962 *Uvigerina* sp. - INDANS, p. 60; pl. 9, fig. 4-5.

1969 *Uvigerina* sp. - LANGER, p. 49; pl. 3, fig. 28.

1973 *Uvigerina* sp. LANGER, 1969 - LAGA & DE MEUTER, p. 216.

DESCRIPTION : Test elongate, two to four times as long as broad; three to five triserial coils. About ten to fifteen inflated chambers, slowly increasing in size as added. Sutures not limbate, slightly depressed at the distal end. Wall calcareous, ornamented throughout (including the last-formed chamber) with longitudinal costae without connections between the costae of successive chambers. Aperture terminal, on a neck with lip.

Dimensions : length 0.43 - 0.88 mm
breadth 0.28 - 0.40 mm.

REMARKS : Undoubtedly, the general shape of the test resembles *Uvigerina hosiusi* as described by TEN DAM & REINHOLD (1941). However the latter has a more inflated test, less pronounced longitudinal costae, mostly lacking on the last-formed chamber. We consider two chronostratigraphical subspecies in the Miocene of the North Sea basin : the *deurmensis* subspecies occurring in the upper Miocene while the *hosiusi* subspecies occurring in the underlying middle Miocene deposits.

SERIES	LITHOSTRATIGRAPHY		BIOZONATION based on BENTHONIC FORAMINIFERA	
	formations	members		
Pleistocene				
Pliocene	Upper	Lillo	<i>Elphidiella hannaï</i> <i>Cribrononion excavatum</i> assemblage zone	
		Formation		
	Lower	Kattendijk Formation	<i>Florilus boueanus</i> <i>Monspeliensina pseudotepida</i> ass zone	
Miocene	Upper	Diest Formation	Deurne Sands Dessel	<i>Uvigerina hosiï deurnensis</i> <i>Elphidium antoninum</i> ass zone
	Middle	Berchem Formation	Zonderschot Sands Antwerpen Sands	<i>Uvigerina tenuipustulata</i> <i>Elphidium inflatum</i> ass zone
		Bolderberg Formation	Houthalen Sands	<i>Tritarina gracilis rugulosa</i>
	Lower	Berchem Formation	Edegem Sands	<i>Elphidium ungeri</i> ass zone

BIOZONATION based on BENTHONIC FORAMINIFERA of the marine Neogene deposits of Belgium and the corresponding lithostratigraphic deposits.

Table 3

DERIVATIO-NOMINIS: The name is taken from the Deurne Sands Member where the specimens belonging to this subspecies were found in frequent numbers.

TYPE-LEVEL : Upper Miocene, Deurne Sands Member, Diest Formation.

TYPE-LOCALITY : Borgerhout near Antwerpen - Rivierenhof section (VII B.R.5-13).

TYPE-SPECIMEN : The holo- and paratypes are stored in the collections of the "Laboratorium voor Paleontologie, K.U.-Leuven".

Holotype : Coll. F 5961.

Paratype : Coll. F 5962.

DISTRIBUTION : The subspecies is reported from the "Upper Miocene" deposits of NW Germany (INDANS, 1962) and from the "Upper Miocene, Gram Stufe", of N Germany and Denmark (LANGER, 1969). LAGA & DE MEUTER (1973) have mentioned this subspecies in the Dessel Sands and Deurne Sands Members, Diest Formation, upper Miocene of Belgium.

CONCLUSIONS.

1. The boundaries of the proposed biozones coincide completely with those of the lithological units (formations or members). We must accept that there are more or less important gaps between these lithological units. This agrees with the general situation of the area at the southern edge of the North Sea Basin during the Neogene and confirms the suggestions of HOOYBERGHS & DE MEUTER (1972) based on their study of the planktonic Foraminifera.
2. The Houthalen Sands of the Limburgse Kempen must be placed chronologically between the Edegem and Antwerpen Sands, both members of the Berchem Formation in the Antwerpen area where they are separated by the unfossiliferous Kiel Sands.
3. The foraminiferal assemblages of the Deurne Sands, known from outcrops in the Antwerpen area, and those of the Dessel Sands from boreholes in the Antwerpse Kempen, seem to be perfectly comparable. However, the chronostratigraphical attribution of the main bulk of the unfossiliferous Diest Formation, in which the named members are grouped, is still hypothetical.
4. In the first two biozones, the assemblage is relatively constant. The first striking fauna break occurs between the *Uvigerina tenuipustulata*-*Elphidium inflatum* and *Uvigerina hosiï deurnensis* - *Elphidium antoninum* biozones. A similar fauna break is observed between the last named biozone and the upperlying *Monspeliensina pseudotepida* - *Florilus boueanus* biozone. This second break corresponds with the generally accepted Mio-Pliocene boundary. From the Pliocene on, the foraminiferal fauna gradually changes, related to an ecological trend rather than to a purely chronological one.

LITHOLOGIC UNITS		BIOZONES	SPECIES & SUBSPECIES
Horzsem Sands Kruisachans Sands Corderen Sands	<i>Ephidietia hanna?</i> <i>Cribrononion erocavatum</i> assemblage zone		(1) <i>Ephidium ungeri</i> (REUSS, 1860) (2) <i>Trifarina gracilis rugulosa</i> (REUSS, 1863) (3) <i>Siphonotularia labiata</i> (REUSS, 1861) (4) <i>Bulinina dingdenensis</i> BATJES, 1958 (5) <i>Bulinina elongata elongata</i> D'ORBIGNY, 1846 (6) <i>Asterigerina guerichi staeschei</i> T.D. & R., 1941 (7) <i>Cribrononion heteroporum</i> (EGGER, 1857) (8) <i>Cibicides ungerianus</i> (D'ORBIGNY, 1846) (9) <i>Virgulinello pertusa pertusa</i> (REUSS, 1861) (10) <i>Loxostomum sinuatum</i> CUSHMAN, 1936 (11) <i>Melonis pompilioides</i> (FICHEL & MOLL, 1798) (12) <i>Ceratocanaris hauerii</i> (D'ORBIGNY, 1846) (13) <i>Bolivina imporcata</i> CUSHMAN & RENE, 1944 (14) <i>Globocassidulina oblonga</i> (REUSS, 1861) (15) <i>Melonis affinis</i> (REUSS, 1851) (16) <i>Dentalina konincki</i> REUSS, 1861 (17) <i>Heterolepa dutemplei peelenensis</i> T.D. & R., 1942 (18) <i>Martinottiella communis</i> (D'ORBIGNY, 1846) (19) <i>Epistominella oveyi</i> BHATTA, 1955
Luichtbal Sands	<i>Cibicides lobatulus</i> peak zone		
Kattendijk Formation	<i>Florentia beccanue</i> <i>Morpeisirensis pseudolepida</i> assemblage zone		
Deurne & Dessel Sands	<i>Uvigerina hoetsni</i> daurmenesi <i>Ephidium orientinum</i> assemblage zone		
Zonderschot Sands Aalveerpen Sands	<i>Uvigerina tenuispinulata</i> <i>Ephidium trifidum</i> assemblage zone		
Houtshalen Sands Reeger Sands	<i>Trifarina gracilis rugulosa</i> <i>Ephidium ungeri</i> assemblage zone		

OCCURENCE OF THE STRATIGRAPHICALLY MORE IMPORTANT BENTHONIC

(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(9)
(10)
(11)
(12)
(13)
(14)
(15)
(16)
(17)
(18)
(19)

PLATE 1

- Fig. 1 : *Cribrononion excavatum* (TERQUEM, 1875),
 a) side view, x 75
 b) apertural view, x 80
 Kruisschans Sands, (TK 160).
- Fig. 2 : *Elphidiella hanna* (CUSHMAN & GRANT, 1927),
 a) side view, x 65
 b) apertural view, x 45
 Merksem Sands, (TK 190).
- Fig. 3 : *Cibicides lobatulus* (WALKER & JACOB, 1798),
 umbilical side, x 40
 Luchtbal Sands, (III 00-Lu).
- Fig. 4 : *Pararotalia serrata* (TEN DAM & REINHOLD, 1941),
 a) umbilical side with broken last chamber, x 55
 b) spiral side, x 55
 Luchtbal Sands, (III 00-Lu).
- Fig. 5 : *Monspeliensina pseudotepida* (VAN VOORTHUYSEN, 1950),
 a) side view, x 50
 b) apertural view of dissected last chamber, x 45
 Kattendijk Sands, (KP5).
- Fig. 6 : *Florilus boueanus* (D'ORBIGNY, 1846),
 a) forma *janiformis* (JONES, 1897), side view, x 20
 b) apertural view, x 20
 Kattendijk Sands, (III 00-1).
- Fig. 7 : *Uvigerina hosiusi deurmensis* nov. subsp.,
 lateral view, x 35
 Deurne Sands, (VII B.R. 8).
- Fig. 8 : *Idem*, x 35.
 Deurne Sands, (VII B.R. 8).
- Fig. 9 : *Elphidium antoninum* (D'ORBIGNY, 1846),
 a) side view, x 35
 b) apertural view, x 35
 Deurne Sands, (VII B.P. 8).
- Fig. 10 : *Uvigerina tenuipustulata* VAN VOORTHUYSEN, 1950 ,
 lateral view, x 35
 Antwerpen Sands, (VI B.R. 3).
- Fig. 11 : *Uvigerina hosiusi hosiusi* TEN DAM & REINHOLD, 1941 ,
 lateral view, x 35
 Antwerpen Sands, (XI B.R. 14).
- Fig. 12 : *Elphidium inflatum* (REUSS, 1861),
 a) side view, x 35
 b) apertural view, x 35
 Antwerpen Sands, (XI B.R. 7).
- Fig. 13 : *Trifarina gracilis rugulosa* (REUSS, 1863),
 lateral view, x 35
 Edegem Sands, (P.A.R.Z. (0,0)).
- Fig. 14 : *Idem*, x 35
 Edegem Sands, (P.A.R.Z. (0,0)).
- Fig. 15 : *Elphidium unoeri* (REUSS, 1850),
 a) side view, x 35
 b) apertural view, x 35
 Edegem Sands, (T.R. 2).

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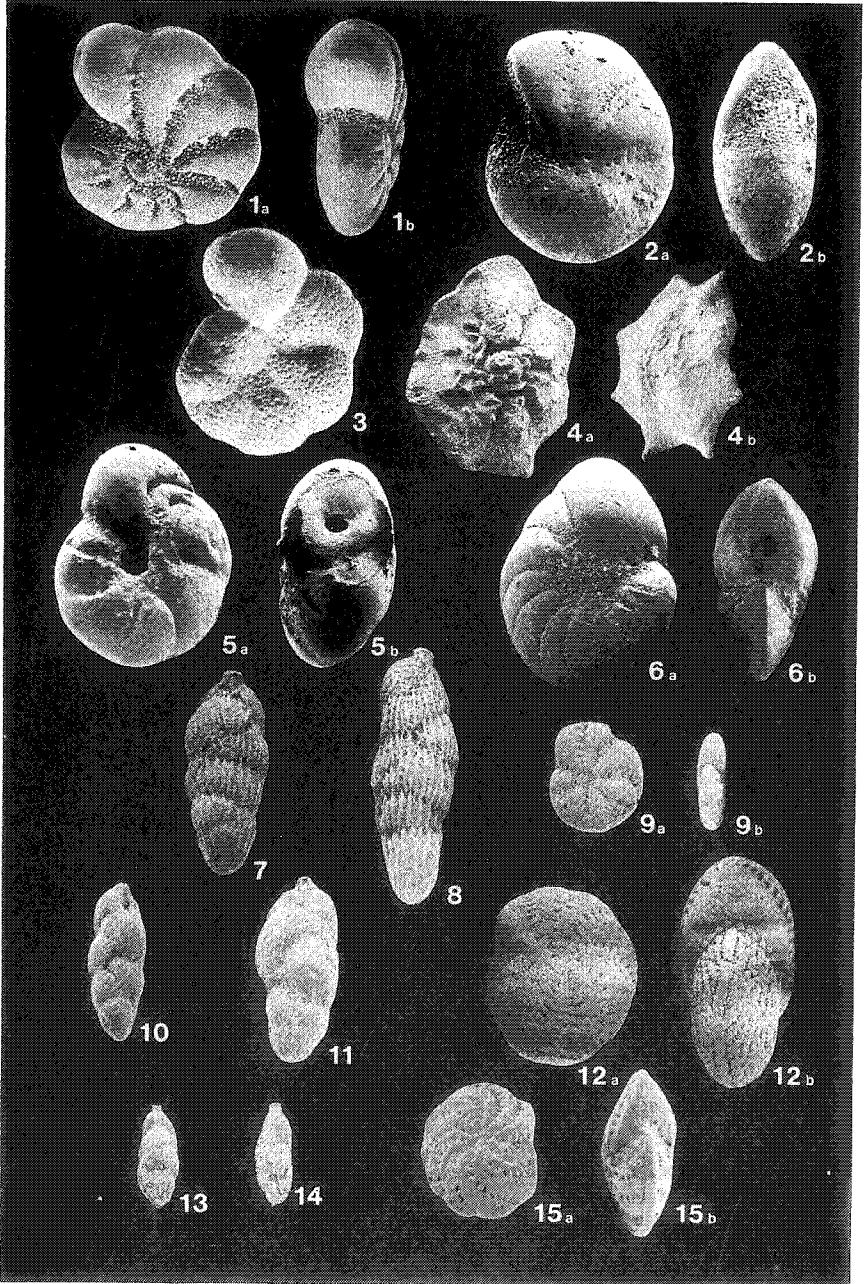
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PLATE 1

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