II. — MICROFAUNA CLOSE TO THE EOCENE-OLIGOCENE BOUNDARY IN THE BORING AT KALLO, NEAR ANTWERP

BY

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ABSTRACT.

An interval of some 70 m. in the boring at Kallo (near Antwerp) corresponds to Eocene-Oligocene transitional strata in between the Upper Eocene Asse Clay and the Middle Oligocene Boom Clay. Some meters in this interval yielded a distinctly marine foraminiferal fauna. This association is unknown from other stratigraphic units in the North Sea basin, for which reason the placing of any Oligocene-Eocene boundary in this sequence on foraminiferal evidence has to remain arbitrary.

THE STRATIGRAPHIC PROBLEM.

Kallo is a village, some kilometres west of the town of Antwerp (fig. 1). A stratigraphic reconnaissance boring was carried out in 1964 on behalf of the Belgian Geological Survey. Because of its far northern location in the Belgian part of the North Sea basin it was thought that the core samples and their contents might give a better insight into some of the existing stratigraphic problems of the area (see GULINCK, 1968).

One of these problems concerns the position of the Eocene-Oligocene boundary for the international chronostratigraphic scale, for which a presumably continuous series of marine sediments was sought in this classical area of northern Belgium.

Although northern Belgium is classical for some stages of the Upper Eocene, such as the Ledian and the Wemmelian and the contemporaneous (?) Assian (= Bartonian according to many authors), and for the Tongrian and Rupelian Stages of the Oligocene, the Eocene-Oligocene boundary of the area could not be linked to any biostratigraphic zonation of more than local importance. This is due to the fact that exposures as well as subsurface samples at both sides of this boundary so far only have yielded scarce and insignificant faunas or no fauna at all.

Many rock units of local importance have been inserted between formations of distinct Upper Eocene (Asse Clay) and distinct Middle Oligocene (Boom Clay). From a microfaunistic point of view these stratigraphic units, Asse Clay and Boom Clay, contain fully marine and clearly different associations, which can be recognized over

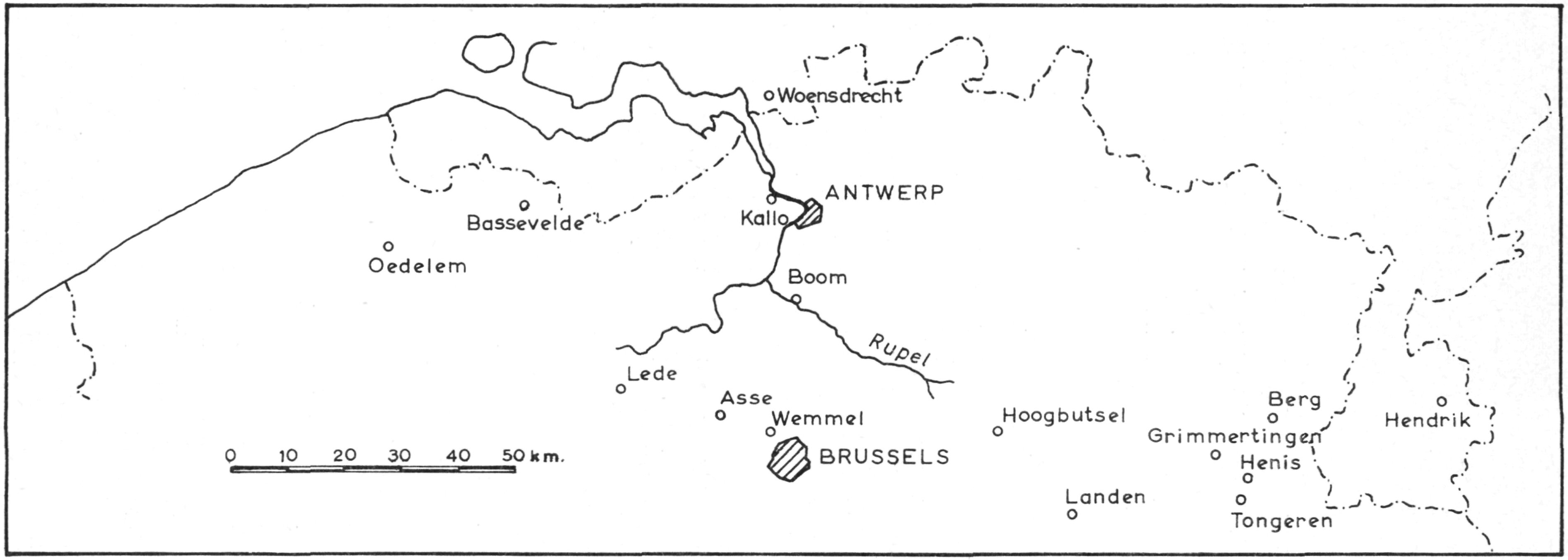

FIG. 1. — Map with localities that are mentioned in the text.

considerable distances, at least in the North Sea basin. Fairly complete faunal reviews have been given by BATJES (1958) of the Oligocene foraminifera, by KAASSCHIETER (1961) of the Eocene foraminifera, and by KEIJ (1957) of the ostracoda of both Eocene and Oligocene.

Rock units of the Oligocene, underlying the Boom Clay have been described mainly from northeastern Belgium, from the area of Tongeren (fig. 2). Overlying much older (mainly Paleocene) sediments the Tongeren Formation of this area contains the type deposits of the Tongrian Stage, which stage has frequently been considered the lowermost stage of the Oligocene. The formation consists of two parts, indicated as Lower and Upper Tongeren Formation by BATJES.

The Lower Tongeren Formation consists of two members, the Sands of Grimmertingen (or Sands of Vliermaal) below, the Sands of Neerrepen on top. The latter are devoid of fossils or nearly so. From the Sands of Grimmertingen molluscs (amongst others *Ostrea ventilabrum*, *Turritella crenulata*) and bryozoans have been reported. Possibly on account of decalcification microfaunas appeared to be very scarce in the few available outcrops.

The best microfauna of foraminifera and ostracoda of the Sands of Grimmertingen, not too far from the type area, was found by BATJES in the shaft Hendrik IV in nearby Southern Limburg (Netherlands). It has an Eocene aspect according to this author, amongst other things owing to the presence of *Nummulites germanicus* (=*N. orbignyi*) and *Asterigerina bartoniana*, the latter species known only from the Eocene. However, according to GRAMANN (1964), the *Asterigerina* species from Hendrik IV would be younger than the Eocene forms. We checked BATJES' material in the Utrecht collections and found GRAMANN's suggestion of the presence of *A. brandhorstiana* and *A. rotula haeringensis* to be correct. Both types are present, but variation of the entire group of individuals in size, relative proportions and thickness of the test is very wide, which variation resembles that found in recent and Neogene *Amphistegina lessonii* of different habitats. On the basis of GRAMANN'S differential diagnosis of these Eo-Oligocene species many of BATJES' forms have to remain unnamed. Finding GRAMANN's suggestion correct, it follows that the Sands of Grimmertingen of Dutch Southern Limburg would then be younger than the Upper Eocene Asse Clay of western Belgium, which idea, however, was advanced by BATJES as well. He rather placed these Sands of Grimmertingen parallel to the sterile Asse Sands, which overlie the Asse Clay of western Belgium (see below).

If not of fluviatile origin the members of the Upper Tongeren Formation, such as the Clay of Henis and the Sands and Marls of Oude Biezen (=Vieux-Joncs), clearly point to deposition in a brackish environment. Their poor microfaunas of low salinity type merge via various intermediate associations found in the Sands of Berg and the Clay of Kleine-Spouwen (=*Nucula* Clay of authors), into that of the Middle Oligocene Boom Clay of fully marine character. Both the Sands of Berg and the Clay of Kleine-Spouwen, defined again in the Tongeren area and underlying the Boom Clay, already belong to the Rupelian and are considered to be more near-shore equivalents of the lower part of the Boom Clay in its type area along the Rupel. A similar position, lateral of the Boom Clay, was advanced by BATJES for the units of the Upper Tongeren Formation. No trace of these brackish Upper Tongeren deposits has ever been found outside the Tongeren area.

On field evidence it is quite reasonable to suppose that the lower and upper parts of the Tongeren Formation are separated by a considerable break in the sedimentation in the near-shore environment of the type region. Fossil soils at the top of the Neerrepen Member, and the vertebrate-bearing horizon of Hoogbutsel, point to an

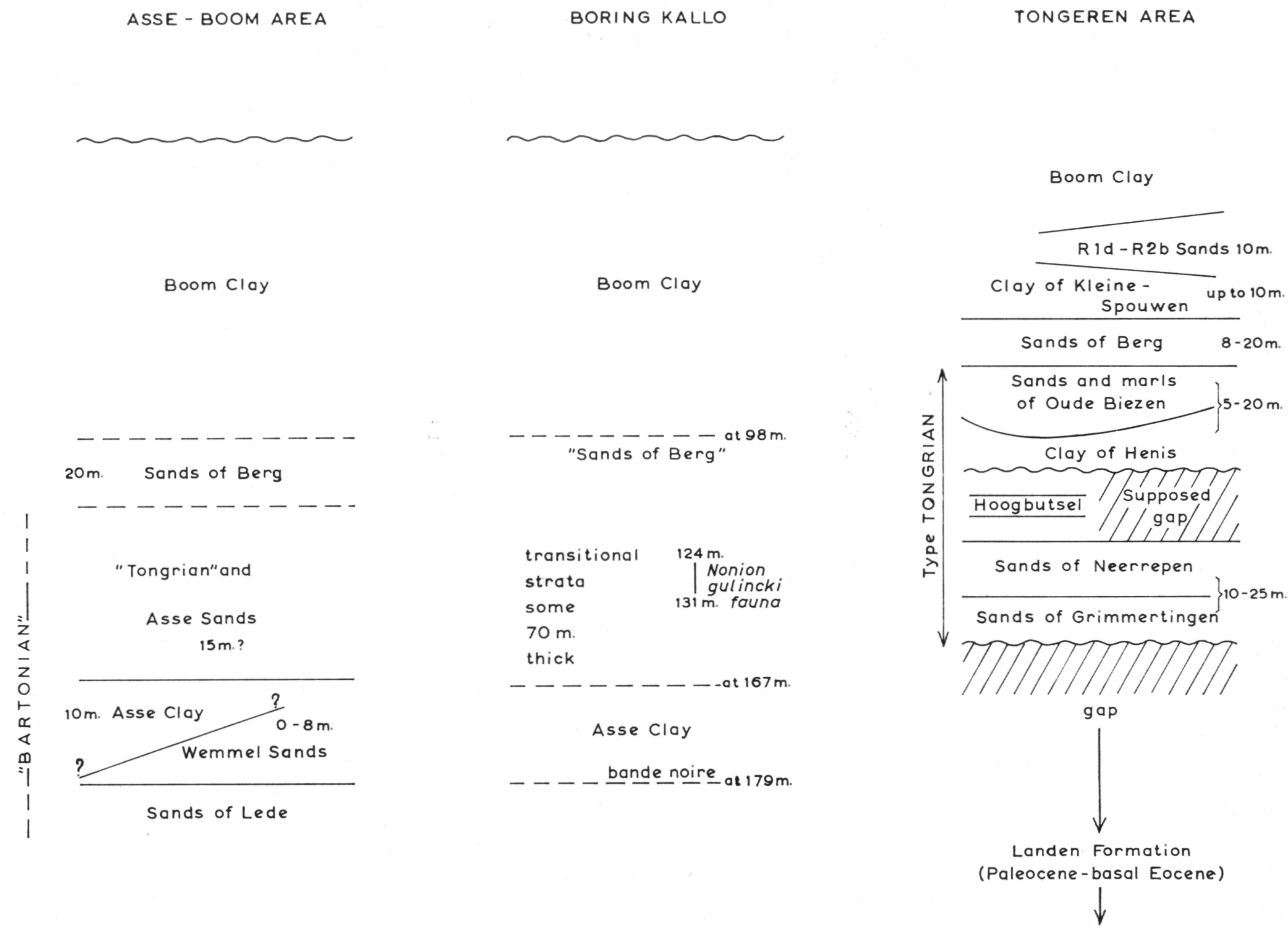

FIG. 2. — Tentative correlation of sediments in the Kallo boring with classical deposits in the Asse-Boom and Tongeren areas.

emersion gap between both parts of the Tongeren Formation. All these reasons together made BATJES (1958), KAASSCHIETER (1961) and DROOGER (1964) place the Eocene-Oligocene boundary at the middle of this type Tongrian.

In borings in north-western and north-central Belgium the Lower Tongeren Formation has sometimes been recorded because of the presence of oysters, determined as *Ostrea ventilabrum*, while the sand immediately underlying the Boom Clay of these areas is generally equated to the Sands of Berg. A distinct delimitation of the Tongeren Formation, and hence of the Tongrian, appeared imposible, however.

Instead, the borings frequently contain another rock unit overlying the Asse Clay, considered to belong te the Upper Eocene as well, the so-called Sands of Asse consisting of alternating sands and clays, from which no fauna, at least no microfauna, has been reported apart from some *Nummulites*. This absence of fauna is probably again due to decalcification. These sediments are generally considered to belong to the top of the Eocene. According to BATJES and others the Asse Sands might be contemporaneous with the Lower Tongeren Formation. Because of this there would be an overlap of the Oligocene Tongrian Stage and the Upper Eocene supposed to belong to the Bartonian Stage.

It is not surprizing that neither in the Asse-Boom area nor in that of Tongeren the Eocene-Oligocene boundary could find support in fossil evidence of any weight. The presence or absence of *Ostrea ventilabrum* is of dubious value, and the presence of either *Nummulites orbignyi-wemmelensis* (Eocene) or *N. germanicus* (Oligocene) is equally invalid as an argument, as long as these species cannot be differentiated by clear paleontological methods.

THE KALLO BORING.

If we want to find evidence from more marine, off-shore sediments in the Eocene-Oligocene transitional interval, we have to look well north of the line Tongeren-Asse. As such the situation of the Kallo boring could be favourable. A thick transitional suite of sediments has formerly been reported from the boring Woensdrecht, north of Antwerp. Some 60-70 m. were recorded between Boom Clay above and (nearly 60 m. of) Asse Clay below, but the interpretation, mainly on lithological data, was different from one author to the other (see amongst others TEN DAM and REINHOLD, 1942; TEN DAM, 1944; BATJES, 1958; KAASSCHIETER, 1961).

A suite of comparable thickness was met with in the Kallo boring. Between depths of roughly 30 and 90 m., the Boom Clay is present, and at 179 m. depth a glauconite-rich bed is equated to the « bande noire », basis of the Asse Clay (see lithologic description and stratigraphic interpretation given by GULINCK, 1968). In between, the series of alternating clays, silts and sands does not allow one to draw any limit that can be unambiguously correlated with lithostratigraphic boundaries near Tongeren or near Asse. We might expect at least some 10 m. of Asse Clay to be present above the « bande noire », and some 20 m. of Berg Sands at the top of the interval. Mica-rich fine sands at about 140 m. reminded GULINCK (preliminary unpublished column of the boring) of the Sands of Grimmertingen, but on lithologic data alone various interpretations are possible in subdividing the interval 179-90 m. Actually GULINCK's open nomenclature consisting of six alternating sandy (s_1, s_2, s_3) and clayey (a_1, a_2, a_3) deposits in his « complexe argilo-sableux de Kallo » is the most realistic one.

Starting from above with the study of the foraminiferal contents of the core samples our first task was to trace the typical Boom Clay association downwards.

Two samples, at 87 and at 92 m., taken from silty clay and clayey fine sand respectively, yielded good foraminiferal associations. The fauna compares well with those given as characteristic for the Belgian Boom Clay by BATJES. Some scattered faunal elements of little significance, but not necessarily different from the higher associations, were still found in the more silty-sandy sediments lower down, at 95.50 and at 98 m.

In the interval farther down to about 120 m. with predominantly sandy deposits, all available samples were checked and found to be barren. The wash residues contain much quartz and variable quantities of mica, glauconite and pyrite. No trace of calcareous particles was found.

From 120 to 130 m., one sample from green sand at 124 m., had immediately attracted attention because it contained numerous small *Nummulites*. Such rather flattened individuals occur at 127 m. as well. They appeared undeterminable because most of their test had been dissolved, leaving irregular frameworks with or without fragmentary pyrite molds (Pl. 5, fig. 6). The sample appeared to contain no other microfaunal elements. It is interesting to note that GULINCK (1968) correlates these s_3 sands with the « Sands of Bassevelde », which contain *Ostrea ventilabrum* in addition to flattened *Nummulites*.

However, samples from more clayey sands and silts at 125.10, 125.50 and 127 m. together yielded a rather varied but poor microfauna. Preservation is moderate, because many specimens have a corroded surface. Some additional individuals were still found at 131 m. This fauna from 124-131 m. forms the main subject of our investigation. At 122 and 129.50 m. samples were found to be devoid of fauna. In the lower one the wash residue consisted of over 90 % of glauconite.

Below 131 m. and down to 167 m., in alternating clayey and silty deposits all samples were inspected. They contain occasional benthonic foraminifera, but without value for stratigraphic interpretation. Apart from these few benthonic forms, there were some scattered Globigerinids. More frequent throughout this interval were Hystrichospherids and small egg-shaped whitish pellets of unknown systematic position, which elements occurred in the higher and deeper intervals as well. One gets the impression that the deposits are of marine origin but that decalcification might have destroyed the original faunas. However, the absence of arenaceous forms and possibly the frequent presence of plant remains in the wash residues show that the assumption of influence of restricted bottom conditions during sedimentation cannot be ruled out either.

At 178 m. there is again a varied fauna with many flat *Nummulites*, but all faunal elements are rather ill-preserved. Most of the specimens suffered from corrosion, and their surface is frequently strongly pitted, where adhering sediment particles had been removed by the washing. This fauna compares well with those of the Asse Clay, Wemmel Sands and Lede Sands, which is not surprizing since we are approximately one meter above the so-called « bande-noire », which is thought to mark the base of the Asse Clay in northwestern Belgium. Some foraminifera fitting in well with the known Upper Eocene assemblages were still found at 176, 168.50 and 167.50 m.

As a result there is an indeterminate interval between 98 m. with the deepest faint indications of the Middle Oligocene Boom Clay fauna, and about 167 m. with elements of distinct Upper Eocene associations. It might be assumed that the Asse Clay ranges higher up, though the maximal thickness estimate of KAASSCHIETER is some 10 m. In the remaining interval of some 70 m. we may expect to find sediments lateral to all stratigraphic units from Asse Sands below to Berg Sands at the top. The only possibility for placing an Eocene-Oligocene boundary in this sequence may result from the determination of the fauna between 124 and 131 m.

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PLANKTONIC FORAMINIFERA.

Planktonic foraminifera are extremely scarce in the samples throughout our investigated interval. The majority cannot be determined with any certainty.

Three occurrences seem to allow for a more reliable specific determination. One concerns an individual of *Cassigerinella chipolensis* (CUSHMAN and PONTON) with indistinct, filled aperture at 131 m. (Pl. 1, fig. 3). Next there is a well preserved specimen of *Pseudohastigerina* (Pl. 1, fig. 2) from the Asse Clay at 178 m., which because of size of the test and curvature of the sutures better resembles *P. wilcoxensis* (CUSHMAN and PONTON) than *P. micra* (COLE). Finally at 167.50 m., still in the sediments considered to belong to the Asse Clay, a slightly damaged individual (Pl. 1, fig. 1) may be determined (?) as *Globorotalia cerro-azulensis* (COLE).

In addition to these three species, each one based on but a single (!) individual, the samples from 178 to 87 m. contain several scattered Globigerinids. If an experienced specialist had to determine these individuals of greatly differing size and with variable features, without knowing where they came from, the total stratigraphic conclusion would be one of gross contamination, possible only in the dustbin of a laboratory for routine determinations of planktonics. Another solution might be that our knowledge of Nordic Paleogene planktonics is as yet too scanty.

At the crucial level of 125.50 m. a number of specimens found may belong to *Globigerina praebulloides praebulloides* BLOW and to its variant *G. praebulloides leroyi* BLOW and BANNER, neither of which is of exact stratigraphic value. We will refrain from listing other specific names on the basis of dubious material so that the reader is not tempted to draw stratigraphic conclusions.

THE BOOM CLAY ASSOCIATION.

For determination the author closely followed the work of BATJES (1958). Amongst some 30 determined foraminiferal taxa in the samples at 87 and 92 m., the most common forms are :

Spiroplectammina carinata (D'ORBIGNY) with only a few small individuals of *S. deperdita* (D'ORBIGNY).

Karreriella siphonella (REUSS). In addition to typical forms also the variants *chilostoma* (REUSS) and *asiphonia* (ANDREAE) are present.

Nonion affine (REUSS).

Cassidulina carapitana HEDBERG.

Ceratobulimina contraria (REUSS).

Gyroidina soldanii D'ORBIGNY with its variants *girardana* (REUSS) and *mamillata* (ANDREAE).

Cibicides dutemplei (d'ORBIGNY) and *C. praecinctus* (KARRER).

Other, less frequent to rare, but more or less characteristic constituents of the fauna are :

Haplophragmoides latidorsatus (BORNEMANN).

Turrilina alsatica ANDREAE.

Angulogerina gracilis (REUSS), mainly the *oligocaenica* (ANDREAE) variant, but also *tenuistriata* (REUSS).

Sphaeroidina bulloides D'ORBIGNY.

Pullenia bulloides (D'ORBIGNY).

Pullenia quinqueloba REUSS.

Svratkina perlata (ANDREAE).

Hoeglundina elegans (D'ORBIGNY).

Cibicides tenellus (REUSS) and occasional Lagenids of the genera *Guttulina*, *Globulina*, *Fissurina*, *Lenticulina* and *Lagena*.

All this certainly best fits in with BATJES' Boom Clay associations. There are some unknown, rare elements, such as *Karreriella* cf. *bradyi* (CUSHMAN) and *Rotalia propingua* REUSS. There are also distinctly derived elements, either from sedimentary reworking of older deposits such as *Rugoglobigerina* sp. at 95.50 m., or from higher deposits, probably due to caving in the borehole, such as *Pseudoeponides pseudotepidus* (VAN VOORTHUYSEN) and possibly *Hanzawaia boueana* (D'ORBIGNY) known from Pliocene and Miocene-Upper Oligocene deposits of the area, respectively.

At 95.50 m. the meagre association found is still of Boom Clay character, at 98 m. it is already so poor as to be indefinite.

THE ASSE CLAY ASSOCIATION.

The association at 178 m., which should belong to the Asse Clay because of the presence of the « bande noire » immediately underneath, is of poor preservation. The small *Nummulites* may be determined as *N. orbignyi*, but separation of this species from *N. variolarius* on the one hand from *N. germanicus* on the other, is considered dubious with our present imperfect knowledge of Nordic *Nummulites*.

Following KAASSCHIETER's review of the Belgian Eocene faunas (1961) nearly the entire assemblage from 178 m. can be determined. Representatives of the Anomalinidae are rather frequent, but by no means predominant. The most frequent taxa are *Planulina burlingtonensis* (JENNINGS), *Cibicides proprius acutimargo* TEN DAM, *Loxostomum teretum* CUSHMAN (or rather *Bolivina nobilis* HANTKEN), *Spiroplectammina deperdita* D'ORBIGNY, *Textularia agglutinans* (D'ORBIGNY) and *Asterigerina bartoniana* TEN DAM (Pl. 3, fig. 1). Furthermore we may cite the presence of *Bolivina cookei* CUSHMAN, *Nonionella wemmelensis* KAASSCHIETER, *Cancris primitivus* CUSHMAN and TODD and *Bifarina selseyensis* (HERON-ALLEN and EARLAND).

Impoverished remnants of this association with some additional species were encountered in samples from 176, 168.50 and 167.50 m. Altogether 32 species were determined, which had been reported from the Eocene-Oligocene of the area by KAASSCHIETER and BATJES. Most of them are known from the Upper Eocene formations : Sands of Lede (27), Sands of Wemmel (28) and Asse Clay (24). Because of the lower total number of taxa known from the latter unit our association has proportionately somewhat more affinity with that from the Asse Clay : 25 % against some 20 % for Lede and Wemmel. Only 14 taxa are known from the Oligocene, amongst which only one (*Cassidulina subglobosa* var. BATJES) had not been reported from the Upper Eocene before.

As a whole we are dealing with a distinct Belgian Upper Eocene assemblage.

THE ASSOCIATION BETWEEN 124 AND 131 M.

Although the foraminiferal fauna is fairly rich in species, the number of individuals of most of the species is small, which renders a good analysis of the morphological features and of their variation impossible. As a consequence, determination is dubious if the specimens did not well fit in with the material described earlier. Open nomenclature had to be used for about one third of the taxa. Because of the scarce material we refrained in most cases from establishing new taxonomic units. Only one species has been described as new.

As primary reference for our determinations we used the collections of KAASSCHIETER and BATJES, stored in the Utrecht Geological Institute. In the systematic description only remarks will be given, unless the species has not been reported before from the Belgian Older Tertiary by one of the authors mentioned above.

Apart from the foraminifera some individuals of a small number of ostracod species were encountered. In addition to immature, undeterminable specimens, individuals were found to fit in best with the following of KEIJ's species (1957). *Cyamocytheridea heizelensis* (KEIJ), *Krithe* cf. *bartonensis* (JONES), *Pterygocythereis tuberosa* KEIJ, *Trachyleberis horrescens* (BOSQUET), *Leguminocythereis striatopunctata* (ROEMER) and *Cytheretta gracilicosta* REUSS. The generic names were kindly made up to date by Dr. KEIJ.

From the environmental point of view it is clear that we are dealing with fully marine faunas between 124 and 131 m. Comparison with recent ecological data is hardly possible. If we compare our frequent *Nonion gulincki* via *N. boueanum* with the recent *Nonionella atlantica*, this would indicate a marine pelitic environment of rather shallow depth, of for instance less than 75 m. The other faunal elements do not seem to be in contradiction with such an assumption.

There may have been some shallowing with (or) increased transport during deposition of the 131-124 m. interval. At the bottom the small association resembles that of the clayey Middle Oligocene Boom Clay better than that of 125-127 m. Higher up the *Nonion gulincki* fauna is followed at 124 m. by sands with numerous *Nummulites* only.

If we now try to weigh the total stratigraphic evidence from the assemblage 124-131 m. no clear conclusions can be drawn. The fauna is different from all other associations described earlier. The stratigraphic question, whether we have to place the Eocene-Oligocene boundary above, at, or below this interval cannot be solved with certainty.

The foraminiferal association is neither that from the Upper Eocene Asse Clay or Wemmel Sands, nor that of the Boom Clay. The bulk of the species, including the *Nummulites*, must be considered neutral to the question. Because of the presence of *Asterigerina* and *Alabamina wolterstorffi* also the fauna from the Lower Tongeren Formation of Hendrik IV, is different. Although the assemblage shows a mixture of Eocene and Oligocene elements, it has a character of its own, such as the relative abundance of *Nonion gulincki*.

There is a slight predominance of Upper Eocene elements, such as *Bolivina cookei*, *Uvigerina spinicostata*, *Globulina gibba punctata*, *Anomalina grosserugosa* and frequent *Spiroplectammina deperdita*. On the other hand, Oligocene elements, apart from *Bolivina fastigia* and some forms at 131 m. could not be determined with certainty. The single *Cassigerinella chipolensis* points to the Oligocene side of the balance. However, the small assemblage of ostracoda again fits in better with the Eocene faunas of KEIJ, not with the Oligocene ones.

This overall conclusion of a mixed fauna of rather Eocene aspect is the same as that drawn by BATJES and KEIJ for the association from shaft Hendrik IV, taken from the Lower Tongeren Formation. If of equal age, environmental influences might have been responsible for the differences in the associations. In this respect it is worth mentioning that the more Oligocene aspect of the small assemblage at 131 m. with *Bulimina* cf. *alsatica*, *Angulogerina gracilis tenuistriata*, *Spiroplectammina carinata*, *Cassidulina subglobosa* var., *Sphaeroidina bulloides* and *Cassigerinella chipolensis*, probably relates to environment, reflected in the more clayey sediment.

CORRELATIONS AND THE EOCENE-OLIGOCENE BOUNDARY.

If we neglect the evidence from the single *Cassigerinella* specimen and the associated elements at 131 m., we are tempted to place the major faunal break, that should correspond according to the ideas of classical stratigraphy to the Eocene-Oligocene boundary, above 124 m. in the Kallo boring. This leaves some 20-25 m. of sandy deposits below the Boom Clay which might be equated with the Sands of Berg. This thickness compares well with that of the Berg Sands east and west of Antwerp. Below these « Sands of Berg », we might conceive the « Lower Tongrian » overlying « Asse Sands », which in turn would merge into uncharacteristic « Asse Clay » at for instance 150 m. depth. Such a solution might somehow meet our ideas about the classical stratigraphy of the area, it is hardly more than wishful thinking.

During the recently held « Colloque sur l'Éocène » in Paris (1968) it has been proposed to place the Eocene-Oligocene boundary below the Sands of Grimmertingen and its equivalents, because in Germany the nannofossil *Ellipsolithus subdisthicus* had been found in sediments correlated with the type Lattorfian. If we take for granted these correlations of various « sandy » deposits below the Boom Clay and the German Septaria Clay, it follows that the Eocene-Oligocene boundary should preferably be placed below 131 m. in the Kallo boring, somewhere in the barren sandy and clayey sediments underneath. In itself, there is nothing against this solution, because such a boundary would not be worse for wider recognition than the previous one.

However, completely new problems seem to arise. Several papers of French origin (e.g. P. BRONNIMANN *et al.*, C. CAVALIER, C. POMEROL, all three 1968) suggest that not only should the Sands of Lede be placed in the Lutetian — the classical Middle Eocene stage — but also the Sands of Wemmel. Planktonic foraminifera and nannofossils would support such a correlation. Consequently, we might wonder whether the Asse Clay can be maintained outside this Lutetian.

Although the Wemmel Sands commonly underlie the Asse Clay in their type area, they wedge out in northwestern, supposedly offshore, direction between the Sands of Lede and the Asse Clay. This Wemmel unit is hard to imagine without contemporaneous offshore sediments in the north. Its open marine microfauna seems to contradict a position lateral of the Lede Sands with their typical shallow water, miliolid associations. The distribution of *Nummulites orbignyi* formerly favoured the idea that Wemmel Sands and Asse Clay are more likely to belong together. Because both units are in contact with the underlying Lede Sands (see KAASSCHIETER, maps 17, 18) and because the lower part of the Asse Clay contains a nearly identical, though somewhat impoverished microfauna, also KAASSCHIETER (1961) supported the opinion of many Belgian authors that Asse Clay and Wemmel Sands are roughly synchronous units. Suggestions, not only of successive units, but even separation by a considerable gap in the record (C. CAVALIER, 1968, p. 523) certainly is a novel idea.

If we are no longer certain that at the lower end, Wemmel Sands and Asse Clay can be kept outside the expanding Lutetian, and if at the top the Sands of Grimmertingen are placed back into the Lower Oligocene, nothing but some uncharacteristic upper Asse Clay and dubious Asse Sands would represent the Belgian Upper Eocene. This is probably exaggerated, but we have to consider seriously the presence either of one or more major breaks in the sedimentation more important than suspected so far, or rather of a strongly condensed sequence corresponding to the Upper Eocene. Is this the reason that practically everywhere the sediments that seem to straddle the Eocene-Oligocene boundary suffered from intense decalcification ?

As a final result we may assume that it becomes more and more unlikely that we will ever be able to give, on foraminiferal evidence, a biostratigraphic background to the Eocene-Oligocene boundary in the Belgian part of the North Sea basin that would stand outside this limited area. We might just as well look for an agreement on successions in more favourable sediments farther south, for instance on those of the type Priabonian and overlying strata in Italy. Because it seems unlikely that the type region of the Oligocene and of some of the « Upper Eocene » stages would ever be able to contradict a boundary defined elsewhere, at least not on the basis of foraminifera.

SYSTEMATIC DESCRIPTION OF THE FORAMINIFERA

No references are given for species recorded by BATJES (1958) and/or KAASSCHIETER (1961) from the Belgian Oligocene and Eocene. The reader is referred to their papers for the literature and more details. All other consulted literature on Nordic Eocene and Oligocene foraminifera appeared to give very few additional data for determining forms that could not be found clearly in the above two references.

Spiroplectammina carinata (D'ORBIGNY).

At 131 m. two well-preserved specimens were found, which are easily separable from those of the next species. The presence of *S. carinata* at this level and not in the higher samples from 124-127 m. may relate to the more clayey character of the sediment at 131 m.

Spiroplectammina deperdita (D'ORBIGNY).

(Pl. 1, fig. 4.)

Five individuals from 125.50 m., and more than 10 from 127 m. clearly belong to this species, although variation seems to include types approaching *S. adamsi* LALICKER.

The relative frequency of both our *Spiroplectammina* species is reported to differ in the Belgian Eocene and Oligocene. KAASSCHIETER found *S. deperdita* to outnumber *S. carinata* in the entire Upper Eocene (Lede-Asse) with the exception of a few samples in the Asse Clay. Predominance of *S. carinata* and intergradation into *S. deperdita* were reported by BATJES to be usual for the Oligocene deposits. As a consequence the relation found in our samples seems to favour an Eocene age.

Textularia sp.

(Pl. 1, fig. 5.)

Two individuals (127 m.), broken at the apertural end, show strongly inflated chambers and a rather truncated periphery. Similar forms were not found in the Belgian Eocene-Oligocene collections stored in Utrecht.

Karreriella sp.

(Pl. 1, fig. 6.)

A single small specimen from 131 m. possibly represents an immature individual of the Upper Eocene-Oligocene *K. siphonella* (REUSS), somewhat resembling the *globulifera* variant, as figured by ANDREAE (1884, pl. 7, fig. 9).

Lenticulina spp.

(Pl. 1, figs. 7 and 8.)

Eight individuals from 125.50 m. and ten others from 127 m. show a wide variation in size. Some somewhat resemble KAASSCHIETER's *L.* cf. *L. jugosa* (CUSHMAN and THOMAS) and *L.* cf. *L. costata* (D'ORBIGNY) from the Asse Clay of Oedelem. The majority agrees fairly well with BATJES' collection of *Lenticulina* spp. from the Lower Tongeren Formation of shaft Hendrik IV in Dutch Limburg.

Dentalina ludwigi (REUSS).

(Pl. 1, fig. 9.)

Two completely costate specimens (125.50 m.) well agree with the Eocene and Oligocene forms of this species in the Utrecht collections. The species occurs in the Upper Eocene (Wemmel, Asse) and Oligocene (Boom).

Dentalina cf. **intermittens** (ROEMER).

(Pl. 1, fig. 10.)

One fragment (127 m.) with striae over the depressed sutures which do not continue on the inflated part of the chambers.

Guttulina irregularis (D'ORBIGNY).

(Pl. 1, fig. 11.)

Two distinct individuals (127 m.) which may represent young stages of the next species.

Guttulina problema (D'ORBIGNY).

Another two individuals from 127 m. which agree fairly well with the figures of this species.

Guttulina lactea (WALKER and JACOB).

Some four individuals (127 m.), which are not well separable from those of *G. problema.*

Globulina gibba (D'ORBIGNY).

(Pl. 1, fig. 12.)

Many specimens were found which distinctly belong to this species : 125.10 m. (2), 125.50 m. (8), 127 m. (10).

Globulina gibba (D'ORBIGNY) var. **punctata** D'ORBIGNY.

(Pl. 1, fig. 13.)

Some distinct specimens were found at 125.10 m. (1) and 127 m. (2). KAASSCHIETER recorded this variant from the Belgian Eocene up to the Asse Clay.

Glandulina laevigata (D'ORBIGNY).

(Pl. 2, fig. 1.)

One individual from 127 m. is thought to belong to this species.

Nonion gulincki n.sp.

(Pl. 2, figs. 2-4.)

Etymology: Named in honour of Ir. M. GULINCK of the Geological Survey of Belgium, Brussels.

Holotype: Pl. 2, fig. 2, Coll. no. S.26886, Utrecht.

Paratypes: Some 20 individuals.

Type locality: Boring at Kallo, near Antwerp, Belgium.

Type level: Eocene-Oligocene transitional strata in the Kallo boring, at a depth of 127 m.; lower s_3 in subdivision of GULINCK, 1968.

Diagnosis: A species of the *Nonion scaphum* group, characterized by the thick test and the broad, subtriangular apertural face of all encountered individuals of the assemblage.

Description: Test of considerable size, thick, planispiral, involute, with chambers rapidly increasing in length; some 8-11 chambers in the final whorl, commonly 9 or 10; chambers slightly inflated especially so in the later part of the test, sutures correspondingly depressed, curved; chambers broadening towards their base, bulging over the umbilical area; umbilicus commonly small with more or less distinct granules; wall smooth; periphery narrowly rounded; apertural face subtriangular, broadening towards the base; aperture a low, basal, median slit. Length range from 360 to 650 μ.

Remarks: According to some authors the generic name *Florilus* had better be applied to the new species. The rather big individuals differ from *N. scaphum* (FICHTEL and MOLL) or its near-relative *N. boueanum* (D'ORBIGNY) by their greater thickness caused by strong broadening of the basal part of the chambers. The apertural face thus obtains a subtriangular outline. Similar forms occur as variants at Oedelem in the Asse Clay and in shaft Hendrik IV in the Lower Tongeren Formation, but in these collections of KAASSCHIETER and BATJES they are outnumbered by the much flatter usual type of *N. scaphum* and *N. boueanum* respectively.

Distribution: In addition to five specimens at 125.50 m this form is common at 127 m. Whether this predominance of thick individuals in the Kallo boring reflects some environmental influence or is of local stratigraphic value cannot yet be evaluated.

Nonion graniferum (TERQUEM).

(Pl. 2, fig. 5.)

Two individuals (127 m.) closely resemble KAASSCHIETER' s Eocene *N. graniferum*. Possibly BATJES' *N. granosum* (D'ORBIGNY) from the Lower Tongeren Beds of Hendrik IV shaft had better be placed in this species as well.

Nonion affine (REUSS).

(Pl. 2, fig. 6.)

A few individuals were found (125.50 and 127 m.) of rather different size, which caused no determination difficulties. Reported from Early Eocene te Miocene.

Turrilina cf. **alsatica** ANDREAE.

(Pl. 2, figs. 7 and 8.)

There are five specimens at 125.50 m. variable in size and relative length. The biggest and proportionately longest individual agrees best with the Oligocene *T. alsa-*

tica. Because this individual was broken during preparation for drawing, a similar specimen from the Boom Clay at 87 m. was taken instead (fig. 7). The smaller individuals are shorter and they would be closer to the Eocene *T. brevispira* TEN DAM. Comparison with the suites of specimens of both species in the Belgian material of BATJES and KAASSCHIETER shows that the specific boundary on the basis of relative length of the test is rather vague. In both suites there is considerable variation, showing wide overlap, and the tendency to increase the relative length with increasing size. Big individuals of *T. alsatica* are relatively longest, but the Oligocene material reaches bigger size.

The small and short individuals in our material (fig. 8) are *Caucasina*-like, but the same is true in the stored Belgian material of both *Turrilina* species, in which more buliminoid apertures occur as well. These individuals seem to be different from *C. coprolithoides* (ANDREAE) and *T. carteri* (BHATIA), mainly in the shape and position of the aperture.

Bulimina cf. **alsatica** (CUSHMAN and PARKER).

(Pl. 2, fig. 9.)

Our single individual (131 m.) differs from *B. alsatica* by possessing blunt spines rather than short costae at the initial end of the test. The general shape better resembles ANDREAE's figure (*B. inflata*) than that of BATJES . There is some resemblance with the Pliocene *B. echinata* D'ORBIGNY (CUSHMAN and PARKER, 1947, *U. S. Geol. Survey*, Prof. Paper 210-D, p. 115, pl. 26, fig. 23, 24) which is more elongate.

Reussella limbata (TERQUEM).

(Pl. 2, fig. 10.)

A single, not well-preserved individual from 125.50 m., which amongst the four Eocene *Reussella* species of KAASSCHIETER, best resembles his *R. limbata*.

Uvigerina spinicostata CUSHMAN and JARVIS.

(Pl. 2, fig. 11.)

Three well-developed individuals (125.10 m.) are closest to the individuals of this species reported by KAASSCHIETER from the Asse Clay. Comparison with the material from Oedelem shows that our specimens are somewhat stouter, less tending to a biserial arrangement of the later chambers, and have slightly fainter costae.

Angulogerina gracilis (REUSS) var. **tenuistriata** (REUSS).

(Pl. 3, fig. 2.)

A single individual from 131 m. seems to be closest to the *tenuistriata* variant of this Oligocene species. It is less angular than the individual figured by BATJES.

Bolivina cookei CUSHMAN.

(Pl. 3, fig. 3.)

Two different, but closely adjoining types of ornamentation were found amongst our *Bolivina* individuals. There is no clear intergradation. The majority (some 10 individuals), found at 125.50 m. have numerous fine costae, best resembling KAASSCHIETER's *B. cookei* (Pl. 8, fig. 26). This type is also most numerous in KAASSCHIETER's collection from the Asse Clay of Oedelem. These forms also resemble *B. striatella jacksonensis* CUSHMAN and APPLIN from the North American Upper Eocene.

Bolivina fastigia CUSHMAN.

(Pl. 3, fig. 4.)

The second *Bolivina* type, found at 125.50 and 127 m., has more undulating sutures and fewer costae, of less regular course with commonly a stronger median one. This form is closer to *B. fastigia*, commonly reported from the Nordic Oligocene. Our individuals better resemble those figured by BHATIA (1955, pl. 66, fig. 15, textf. 5) from the Hamstead *Corbula* beds than those from BATJES' North Sea Upper Oligocene.

Cassidulina subglobosa BRADY var. BATJES.

(Pl. 3, fig. 5.)

A single individual from 131 m. closely resembles BATJES' unnamed, compressed variant from the Oligocene. *Cassidulina* species were not reported by KAASSCHIETER from the Belgian Eocene, but a very similar individual was found at 167.50 m. in the Asse Clay interval of the Kallo boring.

Cassidulina sp.

(Pl. 3, fig. 6.)

A single, small, lenticular individual of the *laevigata*-type was encountered at 131 m.

Sphaeroidina bulloides D'ORBIGNY.

(Pl. 3, fig. 7.)

One ill-preserved specimen of this species, reported to be frequent in the Belgian Oligocene and seemingly absent from the Eocene, was found in the clay at 131 m.

Discorbis cf. **limbata** (TERQUEM).

A single very small individual that might belong to this species, found at 131 m.

Cancris subconicus (TERQUEM).

(Pl. 3, fig. 8.)

Single individuals of this Eocene-Oligocene species were found at 125.50 m. and 127 m.

Valvulineria cf. **petrolei** (ANDREAE).

(Pl. 3, fig. 9.)

Some ten individuals (125.50 m.) of wide size range are hard to place generically. Big individuals (fig. 9) are thicker and dorsally more involute than the Oligocene *V. petrolei* and they lack the distinct apertural flap . The majority of our individuals are smaller forms, which are less thick and flatter and more evolute dorsally, and therefore resemble *V. petrolei* better. Their somewhat depressed dorsal spiral suture resembles that of *Gyroidina* species.

Gyroidina cf. **octocamerata** CUSHMAN and HANNA.

(Pl. 4, fig. 1.)

Four individuals of different size were found at 127 m. The smaller ones resemble *G. octocamerata* fairly well, the bigger ones are closer to *G. soldanii* as figured by BATJES (pl. 7, fig. 13, 14) and to KAASSCHIETER's *G.* cf. *soldanii* from the Asse Clay.

Anomalina grosserugosa (GÜMBEL).

(Pl. 4, fig. 2.)

A single distinct individual was found at 127 m. This species has been reported from the Belgian Eocene.

Cibicides dutemplei (D'ORBIGNY).

(Pl. 4, figs. 3 and 4.)

Representatives of *Cibicides* form the most common group in our samples. Some 45 specimens were found at 125.50 m. and some 30 at 127 m. Although clusters might correspond to different species of the literature, it appeared impossible to place all individuals, especially so the smaller ones. Intermediates between the three main groups seem to be present in both samples. The relative proportion of the groups is not identical in both samples.

The central group can best be identified with the long ranging Tertiary *C. dutemplei*, with indistinct delimitation to both sides. It is the most frequent group at 127 m., but not at 125.50 m.

Cibicides lobatulus (WALKER and JACOB).

(Pl. 5, fig. 1.)

This is the most common group with some 30 individuals at 125.50 m. Most of the specimens are small, some with a distinct glassy umbilical knob. Resemblance with KAASSCHIETER's *C.* cf. *tenellus* (REUSS) and his *C. westi* HOWE is occasionally present. In this sample, but also at 127 m., thick variants best resemble BATJES' *C. lobatulus* var. from the Lower Tongeren Formation of shaft Hendrik IV.

Cibicides pygmaeus (HANTKEN).

(Pl. 5, fig. 2.)

This name stands for the least distinct group and in our interpretation the most variable one, such as in the number of chambers in the final convolution. Especially at 127 m. the specimens with relatively few chambers in the final coil are close to KAASSCHIETER's concept of *C. pygmaeus* (HANTKEN). Other individuals seem to be closer to *C. sulzensis* (HERMANN). There is never a glassy filling in the umbilicus. All individuals share the strongly evolute character of the dorsal side.

Cribrononion subnodosum (ROEMER).

(Pl. 5, figs. 3 and 4.)

This species (*sensu latu*) occurs at 125.50 m. (4 individuals) and at 127 m. with nine. Our specimens never show a well separated keel as in BATJES' forms from the Upper Oligocene, but the periphery is narrowly rounded. The sutures are often hardly depressed, if at all. At 125.50 m. they show distinct open fissures frequently subdivided, in the other sample the sutures are rather closed. The number of chambers in the final whorl varies from 11 to 15, usually it is 12. Some individuals somewhat resemble *Elphidium laeve* (D'ORBIGNY) of KAASSCHIETER'S collections (p. 239, pl. 16, fig. 17, 18) which has a more distinct depression around the umbilical mass.

Nummulites sp.

(Pl. 5, figs. 5 and 6.)

In addition to the numerous fragments at 124 m., some others were found at 125.50 and 127 m. All show but few of the features of the individuals. Evidently we are dealing with a rather flat species, thickest in the central part with distinctly recurving sutures. These *Nummulites* have no stratigraphic value, greater than the other foraminifera, because, for a specific determination, it is impossible to choose between *N. orbignyi-wemmelensis* and *N. germanicus*, thought to be characteristic for the Upper Eocene and the Lower Oligocene of the North Sea Basin respectively. If we determine the specimens from the Asse Clay at 178 m. (fig. 5) as *N. orbignyi* (GALEOTTI), there is no reason to give another name to those from 127-124 m. (fig. 6).

ACKNOWLEDGEMENTS.

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PLATE 1

EXPLANATION OF PLATE 1.

FIG. 1. — *Globorotalia cerro-azulensis* (COLE). a. dorsal view, b. apertural view, c. ventral view. Kallo 167.50 m. Asse Clay, ×75.

FIG. 2. — *Pseudohastigerina wilcoxensis* (CUSHMAN & PONTON). a. side view, b. apertural view. Kallo 178 m. Asse Clay, ×95.

FIG. 3. — *Cassigerinella chipolensis* (CUSHMAN & PONTON), side view. Kallo 131 m., ×115.

FIG. 4. — *Spiroplectammina deperdita* (D'ORBIGNY), side view. Kallo 127 m., ×45.

FIG. 5. — *Textularia* sp., side view. Kallo 127 m., ×45.

FIG. 6. — *Karreriella* sp., side view. Kallo 131 m., ×85.

FIG. 7, 8. — *Lenticulina* sp., side view. Kallo 125.50., ×30.

FIG. 9. — *Dentalina ludwigi* (REUSS). Kallo 125 50 m., ×30.

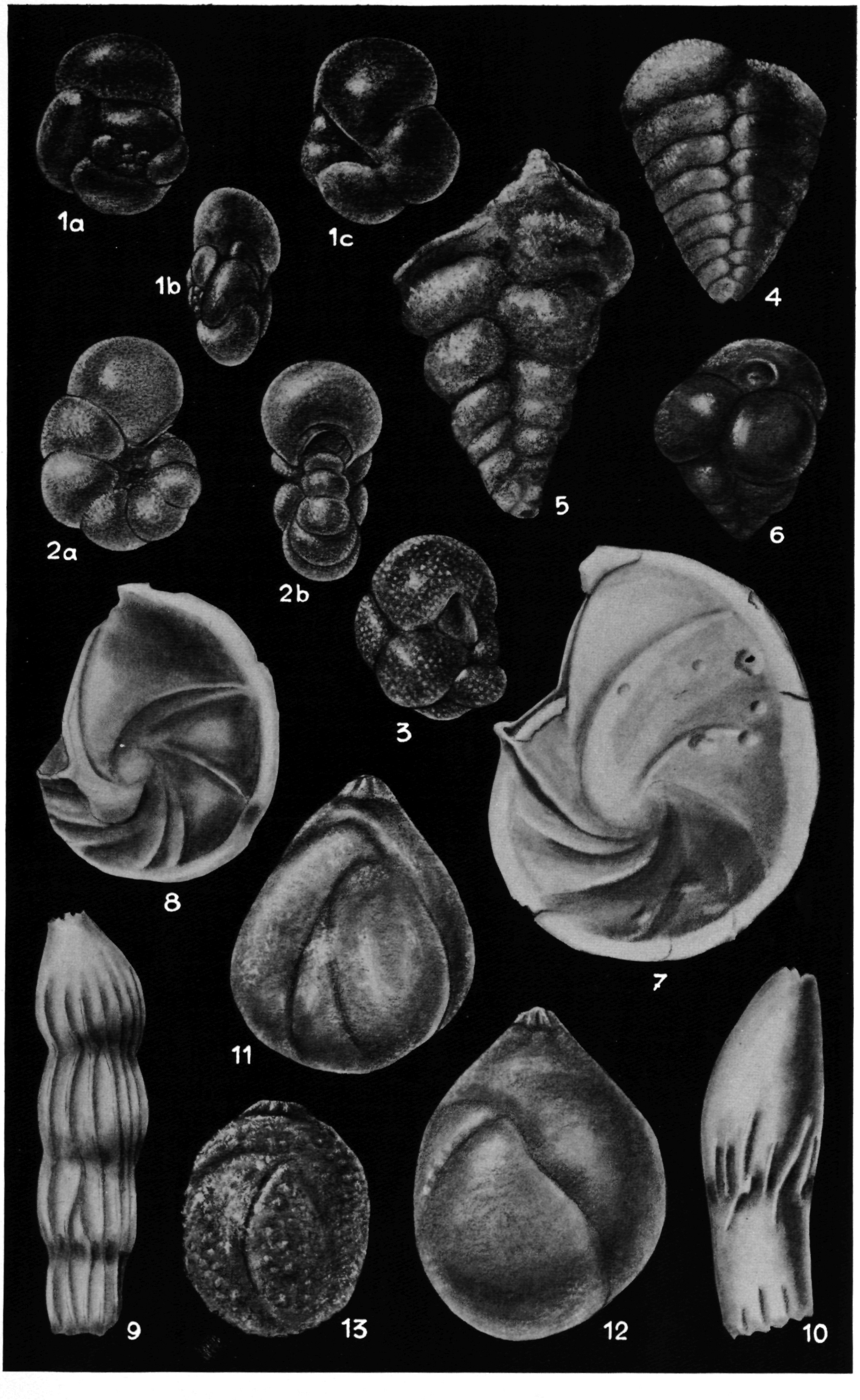
FIG. 10. — *Dentalina* cf. *intermittens* (ROEMER). Kallo 127 m., ×30.

FIG. 11. — *Guttulina irregularis* (D'ORBIGNY). Kallo 127 m., ×60.

FIG. 12. — *Globulina gibba* (D'ORBIGNY). Kallo 127 m., ×60.

FIG. 13. — *Globulina gibba* (D'ORBIGNY) var. *punctata* d'ORBIGNY. Kallo 127 m., ×60

PLATE 1



C. W. DROOGER. — Microfauna close to the Eocene-Oligocene boundary in the boring at Kallo, near Antwerp.

PLATE 2

EXPLANATION OF PLATE 2.

FIG. 1. — *Glandulina laevigata* (D'ORBIGNY). Kallo 127 m., ×60

FIG. 2-4. — *Nonion gulincki* n.sp. 2. holotype, 3, 4. paratypes. 2 a. oblique side view; 3, 4 a. side views; 2 b, 4 b. apertural views. Kallo 127 m., lower S_3 member, Eocene-Oligocene transitional strata, ×45.

FIG. 5. — *Nonion graniferum* (TERQUEM). a. side view, b. apertural view. Kallo 127 m., ×45.

FIG. 6. — *Nonion affine* (REUSS). a. side view, b. apertural view. Kallo 127 m., ×45

FIG. 7. — *Turrilina alsatica* ANDREAE, side view. Kallo 87 m., Boom Clay, Oligocene, ×75.

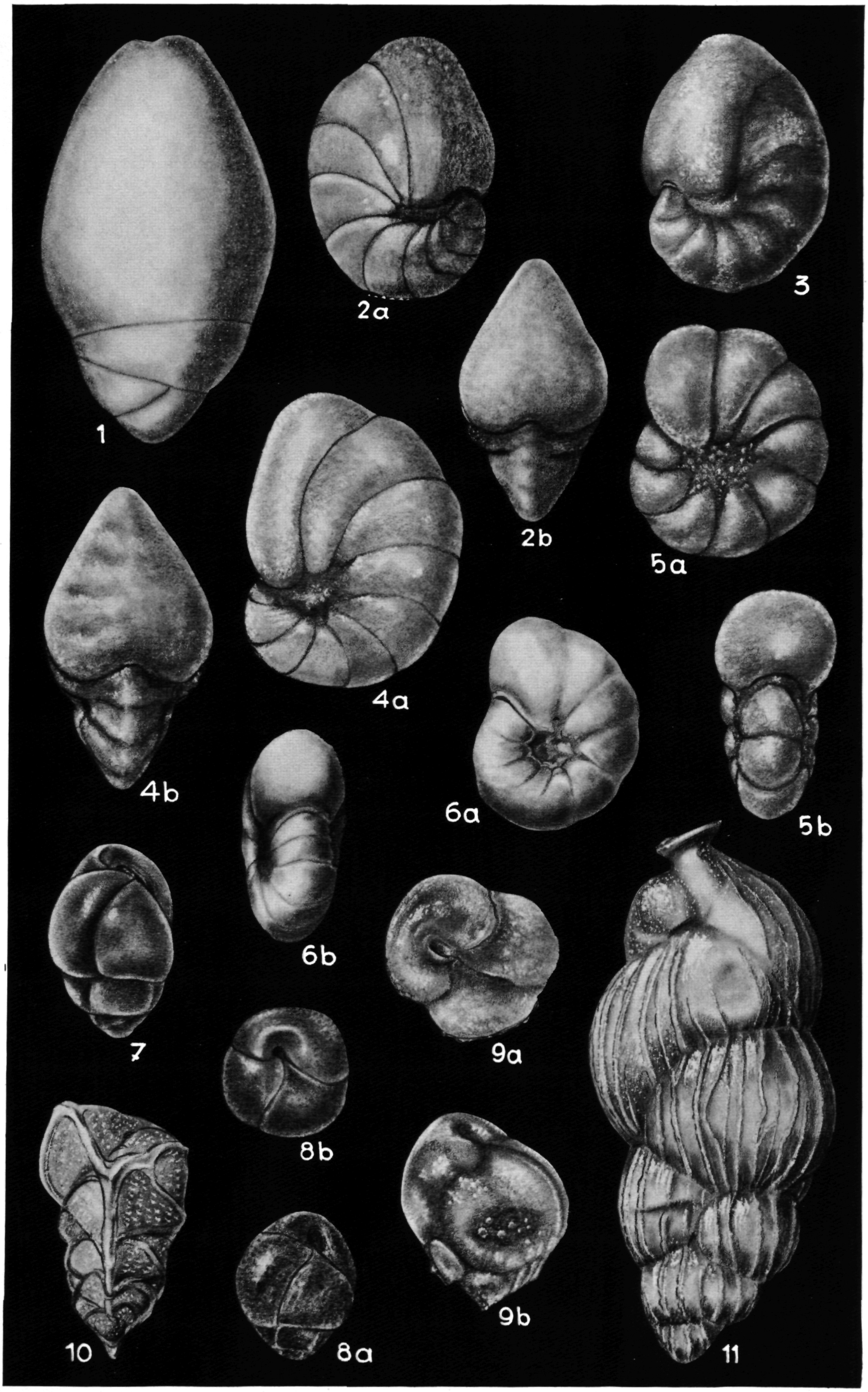
FIG. 8. — *Turrilina* cf. *alsatica* ANDREAE. a. side view, b. apertural view. Kallo 125.50 m., ×100.

FIG. 9. — *Bulimina* cf. *alsatica* (CUSHMAN & PARKER). a. side view, b. apertural view. Kallo 131 m., ×110.

FIG. 10. — *Reussella limbata* (TERQUEM). Kallo 125.50 m., ×80.

FIG. 11. — *Uvigerina spinicostata* CUSHMAN & JARVIS. Kallo 125.10 m., ×95.

PLATE 2



C. W. DROOGER. — Microfauna close to the Eocene-Oligocene boundary in the boring at Kallo, near Antwerp.

PLATE 3

EXPLANATION OF PLATE 3.

FIG. 1. — *Asterigerina bartoniana* TEN DAM. a. dorsal view, b. peripheral view, c. ventral view. Kallo 178 m., Asse Clay, ×35.

FIG. 2. — *Angulogerina gracilis* (REUSS) var. *tenuistriata* (REUSS), side view. Kallo 131 m., ×95.

FIG. 3. — *Bolivina cookei* CUSHMAN, side view. Kallo 125.50 m., ×95.

FIG. 4. — *Bolivina fastigia* CUSHMAN, side view. Kallo 127 m., ×95.

FIG. 5. — *Cassidulina subglobosa* BRADY var. BATJES, oblique side view. Kallo 131 m., ×115.

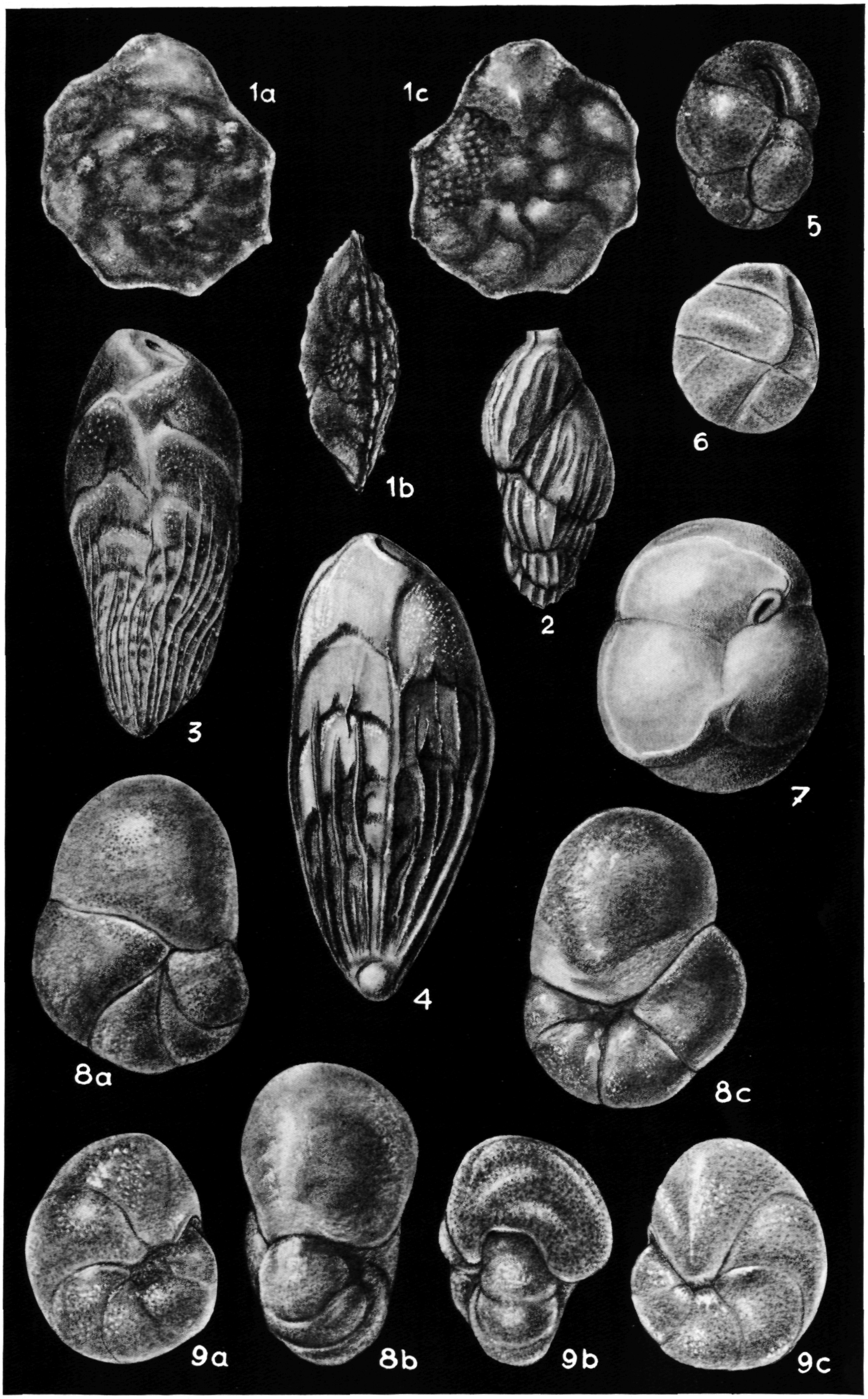
FIG. 6. — *Cassidulina* sp., side view. Kallo 131 m., ×80.

FIG. 7. — *Sphaeroidina bulloides* D'ORBIGNY. Kallo 131 m., ×85.

FIG. 8. — *Cancris subconicus* (TERQUEM). a. dorsal view, b. apertural view, c. ventral view. Kallo 125.50 m., ×60.

FIG. 9. — *Valvulineria* cf. *petrolei* (ANDREAE). a. dorsal view, b. apertural view, c. ventral view. Kallo 125.50 m., ×85.

PLATE 3



C. W. DROOGER. — Microfauna close to the Eocene-Oligocene boundary in the boring at Kallo, near Antwerp.

PLATE 4

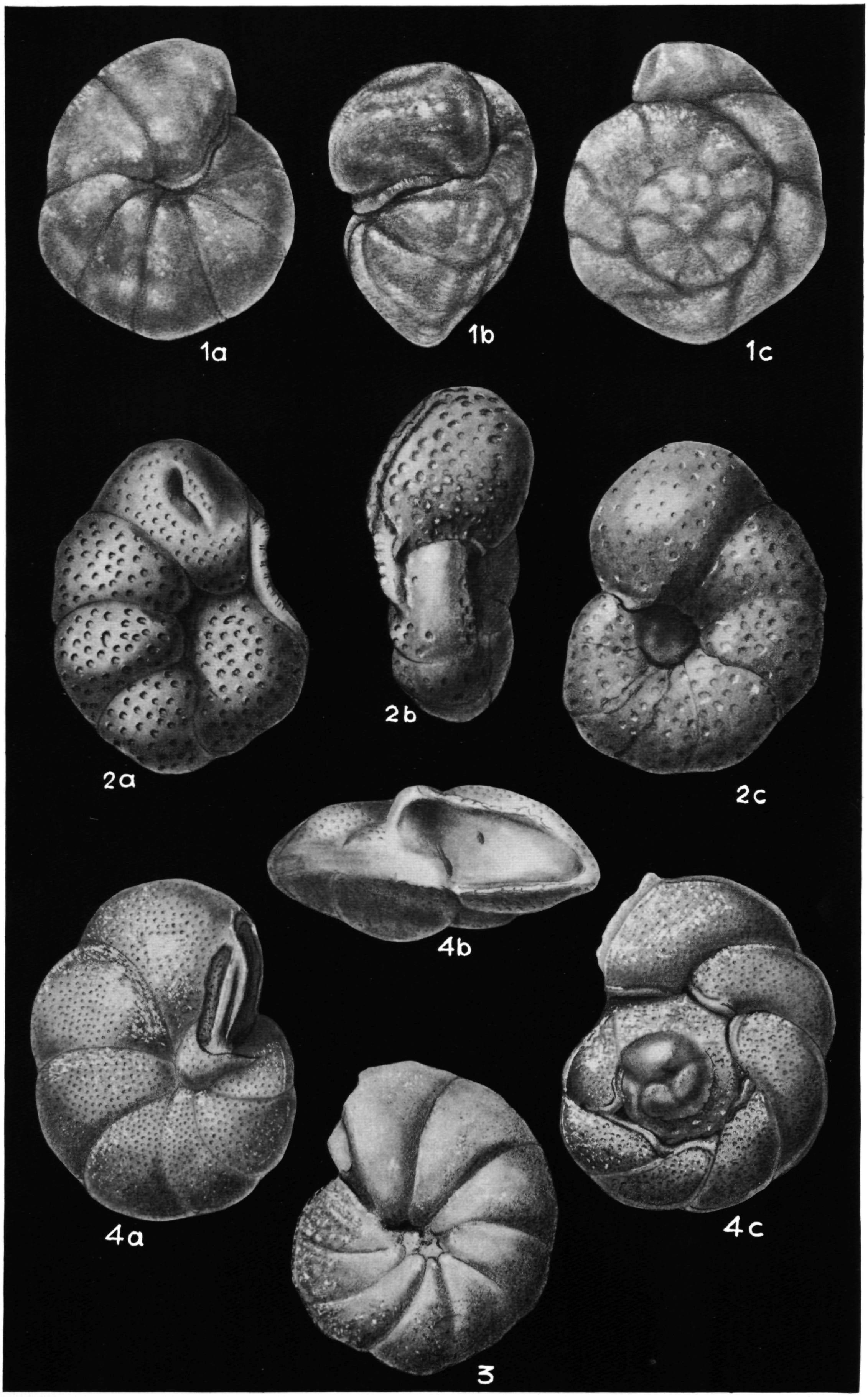
EXPLANATION OF PLATE 4.

FIG. 1. — *Gyroidina* cf. *octocamerata* CUSHMAN & HANNA. a. ventral view, b. apertural view, c. dorsal view. Kallo 127 m., ×50.

FIG. 2. — *Anomalina grosserugosa* (GÜMBEL). a, c. side views, b. apertural view. Kallo 127 m., ×60.

FIG. 3, 4. — *Cibicides dutemplei* (D'ORBIGNY). 3, 4 a. ventral views, 4 b. apertural view, 4 c. dorsal view. Kallo 125.50 (fig. 4) and 127 m. (fig. 3), ×60.

PLATE 4



C. W. DROOGER. — Microfauna close to the Eocene-Oligocene boundary in the boring at Kallo, near Antwerp.

PLATE 5

EXPLANATION OF PLATE 5.

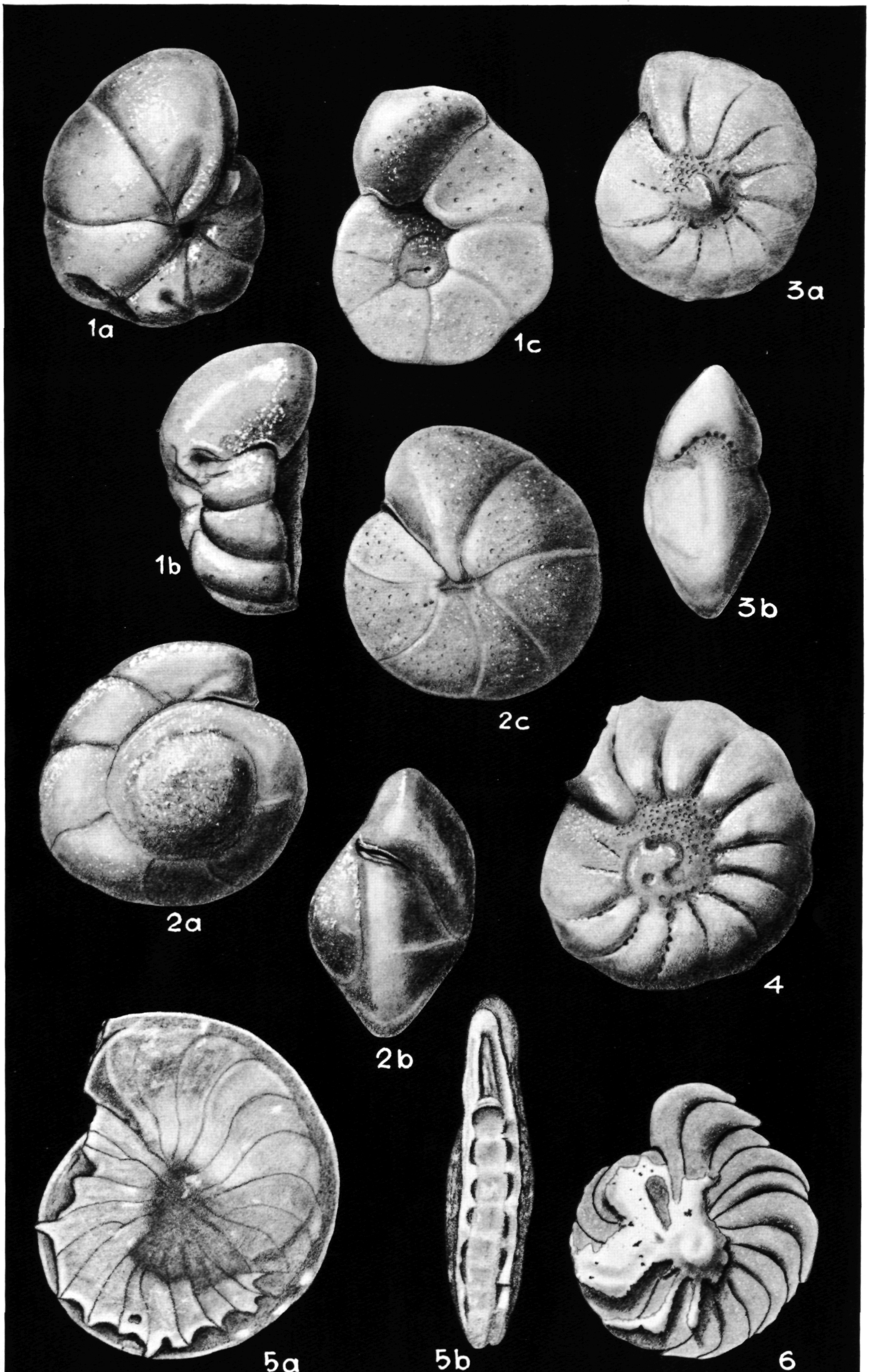
FIG. 1. — *Cibicides lobatulus* (WALKER & JACOB). a. ventral view, b. apertural view, c. dorsal view. Kallo 127 m., ×60.

FIG. 2. — *Cibicides pygmaeus* (HANTKEN). a. dorsal view, b. apertural view, c. ventral view. Kallo 127 m., ×60.

FIG. 3, 4. — *Cribrononion subnodosum* (ROEMER). 3 a, 4. side views, 3 b. apertural view. Kallo 125.50 (fig. 4) and 127 m. (fig. 3), ×45.

FIG. 5, 6. — *Nummulites* sp. 5 a, 6. side views, 5 b. peripheral view. Kallo 178 m., Asse Clay (fig. 5), and 127 m. (fig. 6), ×15.

PLATE 5



C. W. DROOGER. — Microfauna close to the Eocene-Oligocene boundary in the boring at Kallo, near Antwerp.