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Calcareous benthic foraminifera across the Cretaceous/Tertiary boundary in the Geulhemmerberg (SE Netherlands)

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Abstract

Recently, a section comprising the Cretaceous/Tertiary boundary was discovered in an underground quarry at the Geulhemmerberg, South Limburg, the Netherlands. A series of samples collected from these strata were analysed for their calcareous benthic foraminiferal contents. Upper Maastrichtian and indifferent Upper Maastrichtian to Lower Paleocene species were found to be the most common elements throughout the sequence and no drastic faunal changes have been observed. Extremely rare inner-neritic Paleocene elements, however, enable a tentative identification of the position of the system boundary between samples G2A and G2B. Slightly higher in the section, an increase in palaeo-water-depth is inferred from the first occurrence of the mid-shelf species *Tappanina selmensis*.

Introduction

The stratigraphy of the Upper Maastrichtian and Lower Paleocene limestones of South Limburg is based primarily on a lithologic division into minor rock units (Jagt et al., this issue). For years, the foraminiferal contents of these rocks have been the subject of numerous studies, both in the Netherlands (Van Rijsinge 1932; Van Bellen 1946; Visser 1951; Bellier and Villain 1975; Villain 1977; Romein et al. 1977; Sprechmann 1978, 1981; Felder et al. 1985a, b; Herngreen et al. 1986) and in adjacent areas (e.g. Beissel 1891; Ebensberger 1962; Felder et al. 1985a, b; Bless et al. 1990a, b, 1993). Extremely productive was Jan Hofker, who, between 1926 and 1966 published over a 100 papers on foraminifera from the Cretaceous and Paleocene limestones in South Limburg. His efforts culminated in a zonation (Hofker 1966), based mainly on benthic foraminifera, which has since been the primary means of correlation in the area (Meessen 1977; Albers and Felder 1979; Robaszynski et al. 1985; Herngreen et al. 1986; Bless et al. 1993).

The present study forms part of the 'Deep Dark Hole Project' (see Brinkhuis and Smit, this issue) which aims to clarify the depositional history of the Netherlands around the time of the K/T boundary event. The study of calcareous benthic foraminifera was included in the project because it might supply additional biostratigraphic and/or palaeoecologic information.

Material and methods

The Geulhemmerberg samples used for this study can be divided into two groups. From samples from the clayey horizons in the upper part of the Meerssen Member, we received washed residues from which planktonic foraminifera had already been picked (Smit and Zachariasse, this issue). These are numbered G2D, G4A, G4G–G4I, G5A–G5D, G6, G7A and G7B. In addition, we received other, whole-rock samples which are numbered G1A–G1C, G2A, G2B and G4E (Figure 1; see also Brinkhuis and Smit, this issue). Approximately 100 g of each of these limestone samples was crushed and dried, after which the chips were soaked in a supersaturated Glauber's salt solution and placed in a freezer for a few days. Subsequently, the sample was disaggregated by thawing in a microwave oven and then washed under running water. Residues were dried prior to sieving, splitting and hand-picking. Representative fractions containing more than 200 specimens

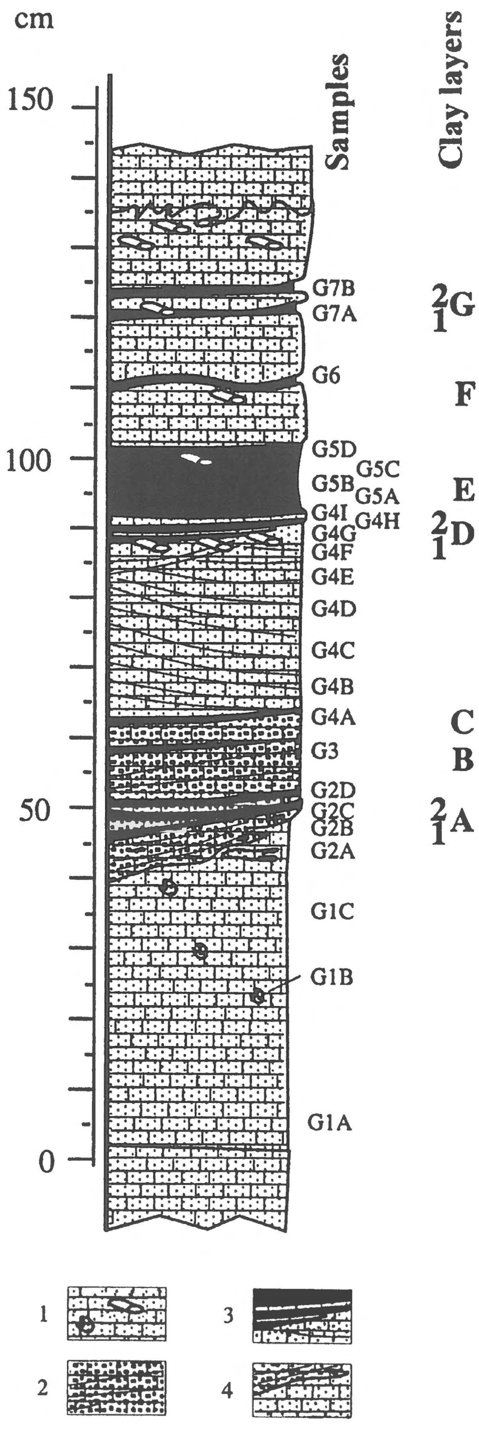

Figure 1. Lithologic column of the Geulhemmerberg K/T boundary section, 6 km ENE of Maastricht, showing the positions of the studied samples. For section location and stratigraphy see Brinkhuis and Smit (this issue). 1 = Calcarenites, fine to medium-grained, with burrows; 2 = calcarenites, coarse-grained; 3 (black) = clay layers and clayey intercalations; 4 = hardground.

in the size fraction exceeding 63 μm were analysed quantitatively for calcareous benthic foraminifera.

Faunal composition

Preservation and composition of the recovered faunas differ significantly from those described from 'classical' sites in the area, such as the nearby Curfs quarry, Maurits III mine-shaft and Bunde 61F-312 borehole. Hofker (1966), Van Voorthuysen (1962) and Herngreen et al. (1986) gave faunal descriptions for these locations. Whether the poor preservation of the Geulhemmerberg samples results primarily from dissolution, recrystallisation or encrusting, or from a combination of these, could not be established.

Although very little variation in composition of benthic foraminiferal faunas was found in these samples, the sequence could be tentatively subdivided into three parts. The lower part (samples G1A–G1C) contains solely Upper Maastrichtian and indifferent Upper Maastrichtian to Paleocene forms. Faunas that characterise the middle part of the sequence (samples G2A and G2B) are, grosso modo, similar in composition but, in addition, some rare Paleocene elements appear. Faunas from the upper part (G2D–G7B) do, again, not differ substantially from those of the underlying layers, but can be distinguished by the presence of a well-preserved species characterising deeper water, *Tappanina selmensis* (Cushman 1933). The systematics of the fauna is dealt with in the Appendix.

Biostratigraphy

Unlike ostracods, which show a rather distinct faunal change at the K/T boundary in the South Limburg area (Bless 1988), the benthic foraminifera record a more gradual change. Hofker's (1966) foraminiferal zonation presumes different faunal associations on either side of the K/T boundary. It should be noted that Hofker (1962a) equates the type Danian (Faxe, Denmark) to the uppermost part of the type Maastrichtian (in the ENCI quarry near Maastricht). This seriously complicates correlation of the Maastrichtian/Danian boundary between South Limburg and other areas (Brinkhuis and Smit, this issue). The uppermost unit of the Maastricht Formation, the Meerssen Member, is identified by his 'Zones' L or M, and also, although of more dubious nature, N or O. The basal lithologic unit of the Houthem Formation, the Geulhem Member, can be equated with Hofker's Zone P, the age of which would be early Danian in current nomenclature. The benthic foraminifera present in the Geulhemmerberg samples do not unequivocally point to any of Hofker's zones.

Characteristic Upper Maastrichtian foraminifera were present in all samples studied. Forms that are generally considered to be excellent markers for the Cretaceous, such as *Siderolites calcitrapoides* Lamarck 1799 and *Tremastegina roestae* (Visser 1951), occur even in the uppermost sample (G7A). Therefore, considerable reworking is inferred, which seems to increase towards the upper part of the sequence. The presence of *Bolivinoides decoratus* (Jones 1886), an Upper Campanian marker, in sample G4A, shows that reworking was not restricted to Upper Maastrichtian layers. The bulk of the faunas, however, consists of specimens that are not indicative of either the Cretaceous or the Tertiary. This may be due to various reasons. A species' stratigraphic value may be limited as a result of its long range or confusing taxonomy. In other cases, poor preservation significantly hampers identification and thus reduces the value of potential markers.

A few unambiguous indicators for the Paleocene, however, are present. Well-preserved *Ceratobulimina tuberculata* Brotzen 1948 first appear in sample G2D. This first occurrence coincides with the first occurrence of other forms which, judging from their preservation, can be considered autochthonous: *Tappanina selmensis* (Cushman 1933) and *Reussella cimbrica* (Troelsen 1937). The latter two forms are, according to the literature, not exclusively Paleocene, and their first occurrence may be related to changes in environment, rather than have any time-stratigraphic significance. On the basis of the first appearance of *Ceratobulimina tuberculata* we would position the K/T boundary below sample G2D. First occurrences of *Rosalina brotzeni* Hofker 1961 in sample G2B, and of *Gyroidinoides subangulata* (Plummer 1926) and *Neoconorbina paleocenica* Hofker 1962 in sample G2A, force us to push it down another few centimetres.

Palaeoecology

The value of Upper Cretaceous and Paleocene benthic foraminifera as palaeoenvironmental indicators has improved significantly since the results from the Deep Sea Drilling Project cores have become available (Berggren 1972, 1974a, b; Berggren and Aubert 1975). Some authors (Jäger 1993) claim that environmental conditions prevailing during the deposition of the Meerssen Member and the Geulhem Member were quite similar. Others, e.g. Bless (1988), however, disagree and presume that dramatic changes in environment occurred during the time represented by the Vroenhoven Horizon. This apparent discrepancy was expressed particularly well in the following understatement by Bignot (1993) who used foraminiferal assemblages to reconstruct the Danian palaeogeography and concluded: 'The geological history of NW Europe across the K/T boundary is very complex and difficult to reconstruct'.

In an earlier paper, this same author (Bignot 1992) suggests that the Danian limestones of Bunde and Houthem were deposited in a fore-reef environment. This is only slightly deeper than time-equivalent rocks of the Mons Basin (Belgium) but significantly shallower than those at Faxe (Denmark). In the Geulhemmerberg samples, none of the benthic foraminiferal associations points conclusively to a specific depth range. Rather, the general picture indicates an association comprising elements from various depth zones. Using somewhat scattered data from published literature we attempted to group palaeoecologically the forms encountered most often. Environmentally induced faunal changes reflect palaeogeographic, palaeoceanographic or climatic changes and are interrelated with faunal migration patterns. In the oversimplified model used here, only depth preference is considered. The data used are from Pozaryska and Szczechura (1968), Berggren (1972, 1974a, b), Berggren and Aubert (1975), Villain (1977), Boersma (1978), Sprechmann (1978, 1981), Liebau (1978b, c, 1980), Bignot (1987, 1992), Keller (1988) and Murray et al. (1989).

Inner neritic (0–30 m). The upper parts of the Upper Maastrichtian with a depositional depth of 0 to 10 m are generally characterised by larger foraminifera: *Siderolites calcitrapoides, Orbitoides faujasi* (Defrance 1823) and *Nummofallotia cretacea* (Schlumberger 1899). In general, the characteristic elements for this depth range are reef dwellers (Berggren 1974b) or forms that are optimally equipped to resist wave action (Liebau 1978a). The internally reinforced rotaliids such as *Pararotalia tuberculifera* (Reuss 1862) and *Tremastegina roestae* that occurred during both the Late Maastrichtian and the Danian indicate a high-energy environment (Sprechmann 1981). Berggren (1974a) also considers the combination of *P. tuberculifera* and *Alabamina midwayensis* Brotzen 1948 characteristic of the shallow-water inner shelf, although the latter species is considered indicative of deeper water by others. The association of these two species with *Cibicidoides alleni* (Plummer 1926), *C. succedens* (Brotzen 1948) and *Gavelinella danica* (Brotzen 1940) was reported earlier from the Paleocene of Poland (Pozaryska and Szczechura 1968). The latter three species, however, are characteristic for the outer to middle shelf (30–200 m). On the basis of methods used for recent foraminifera by Murray (1973), Sprechmann (1981) attempted a morphological characterisation of the sublittoral Maastrichtian foraminifera from the ENCI and Curfs quarries in South Limburg. Unfortunately, no explicit palaeoenvironmental conclusions were presented.

Middle neritic (30–100 m). Worldwide, this palaeoenvironment is characterised by the so-called Midway-type fauna, which is dominated by species of *Cibicidoides, Anomalinoides* etc., indicating, approximately, mid-shelf depths (Berggren, 1974b). *Cibicidoides alleni* and *Anomalinoides acuta* (Plummer 1926) are two characteristic, worldwide 'Midway fauna' species that are also abundant in the Geulhemmerberg samples.

Outer neritic (100–200 m). Deeper-water (outer-shelf and beyond) species are rare and are completely lacking in the lowest four samples. Of the species considered in the literature to indicate deeper water, only one was found in abundance: *Tappanina selmensis*. It first appears in sample G2D, which was taken a few centimetres higher in the sequence than samples G2A and G2B, which yielded the first Paleocene elements. We suspect that *Reusella cimbrica* may point to similar environmental conditions as *Tappanina selmensis. Gavelinella danica*, also considered an outer-shelf species (Berggren and Aubert 1975; Boersma 1978), is present, but very rare.

Concluding remarks

Throughout the Geulhemmerberg section, Upper Maastrichtian and indifferent Upper Maastrichtian to Lower Paleocene foraminifera are abundant. Their state of preservation reflects variable, probably repeated, reworking and provides no clues for a possible position of the K/T boundary. However, after filtering out the effects of this reworking, we cautiously conclude that the K/T boundary may be situated just below sample G2B. Above it, a palaeoecological change, and increase in water depth, is evident of which the effects become apparent no earlier than in sample G2D.

Distinctive bioevents that can be recognised within the succession are:

- the first occurrences of *Gyroidinoides subangulata* and *Neoconorbina paleocenica*, probably both Paleocene markers, in sample G2A,
- the first occurrence of *Rosalina brotzeni*, a Paleocene marker, in sample G2B,
- the first occurrence of *Ceratobulimina tuberculata*, a Paleocene marker, in sample G2D,
- the first occurrence of well-preserved *Tappanina selmensis* in sample G2D, indicating deeper water,
- the first occurrence of well-preserved *Reussella cimbrica* in sample G2D, possibly indicating deeper water.

For regional reconstructions, the time represented by the Vroenhoven Horizon is a basic issue. Therefore, future foraminiferal research should aim at direct quantitative correlation of samples from the Geulhemmerberg with those from nearby sites that also contain the K/T boundary, such as the Curfs and Blom quarries, the Maurits III mine-shaft, several Bunde boreholes and the Albert Canal sections.

Appendix

Systematic descriptions

Significant species recovered from the 18 samples studied are reviewed below in alphabetical order. Reference is made only to papers that contribute to the understanding of the species within the present context, be it with respect to identification, biostratigraphy and/or palaeoecology. A taxonomic update of several of the species reported, which is no doubt necessary, is beyond the scope of the present paper. Over the years, a number of foraminiferal workers have noted inconsistencies in Hofker's (1966) identifications. Where superfluous, we refrained from including references to that publication. Species that are not discussed below are included in the distribution chart (Table 1).

Table 1. Distribution of calcareous benthic foraminifera in the Geulhemmerberg samples.

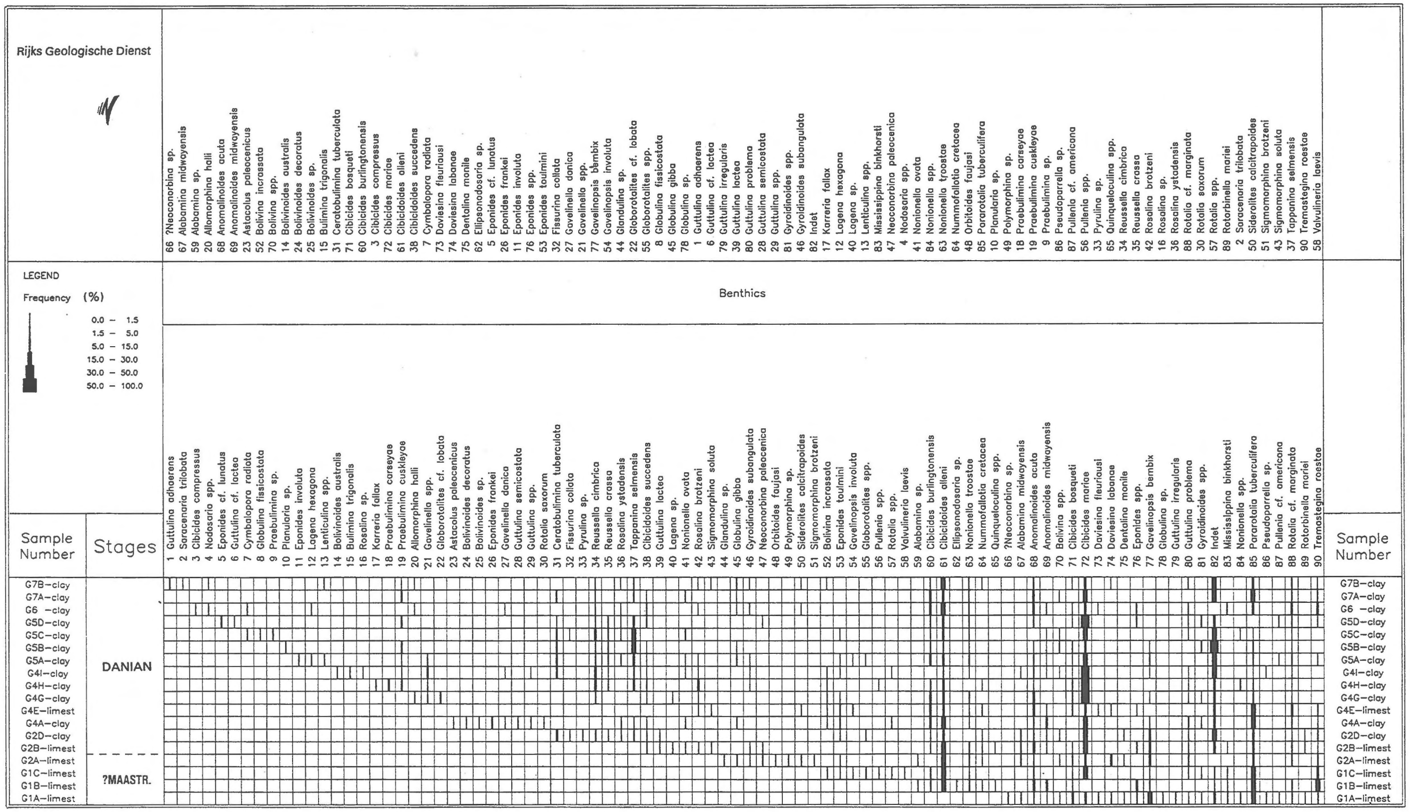

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Plate 1. Benthic foraminifera from the Geulhemmerberg. Magnification 89 ×, except Figures 8, 12, 13, 17, 18, 19, 21 (156 ×), Figures 4, 6, 11, (56 ×) and Figures 5 and 10 (28 ×). Figure 1. *Tremastegina roestae* (Visser, 1951), a. sample G2B, ventral view, b. same specimen, dorsal view. Figure 2. *Siderolites calcitrapoides* Lamarck, 1799, sample G2A. Figure 3. *Mississippina binkhorsti* (Reuss, 1862), sample G6, ventral view. Figure 4. *Cymbalopora radiata* Hagenow, 1851, sample G6, ventral view. Figure 5. *Orbitoides faujasi* (Defrance, 1823), sample G2A. Figure 6. *Nummofallotia cretacea* (Schlumberger, 1899), sample G2B. Figure 7. *Rotalia* sp. cf. *R. marginata* d'Orbigny, 1826, a. sample G1A, ventral view, b. same specimen, dorsal view. Figure 8. *Rosalina brotzeni* Hofker, 1961, a. sample G7B, ventral view, b. same specimen, dorsal view. Figure 9. *Pararotalia tuberculifera* (Reuss, 1862), a. sample G4A, ventral view, b. same specimen, dorsal view. Figure 10. *Sigmomorphina soluta* Brotzen, 1948, sample G7B, side view. Figure 11. *Allomorphina halli* Jennings, 1936, sample G7B, ventral view. Figure 12. *Rosalina ystadensis* Brotzen, 1948, a. sample G5C, ventral view, b. same specimen, dorsal view. Figure 13. *Neoconorbina paleocenica* Hofker, 1962, a. sample G5D, ventral view, b. same specimen, dorsal view. Figure 14. *Nonionella troostae* (Visser, 1950), sample G5D, side view. Figure 15. *Bolivinoides australis* Edgell, 1954, sample G4I, side view. Figure 16. *Bolivinoides decoratus* Jones, 1886, sample G4A. Figure 17, *Tappanina selmensis* (Cushman, 1933), sample G4I, side view. Figure 18. *Reussella cimbrica* (Troelsen, 1937), sample G5D, side view. Figure 19. *Ceratobulimina tuberculata* Brotzen 1948, a. sample G5C, ventral view, b. same specimen, dorsal view. Figure 20. *Alabamina midwayensis* Brotzen, 1948, sample G2A, ventral view. Figure 21. *Reussella crassa* (Brotzen, 1948), sample G5D, side view.

Alabamina midwayensis Brotzen, 1948

Plate 1, Figure 20

1948 *Alabamina midwayensis* nov. nom. –
Brotzen, p. 99, pl. 16, figs 1, 2, text fig. 26
1965 *Alabamina midwayensis* Brotzen, 1948 –
Pozaryska, p. 114, pl. 21, figs 3a–c
1974a *Alabamina midwayensis* Brotzen –
Berggren, p. 431, pl. 5, figs 15, 16
1975 *Alabamina midwayensis* Brotzen, 1948 –
Berggren & Aubert, p. 147, pl. 2, figs 14a–c, pl. 12, fig. 2
1983 *Alabamina midwayensis* Brotzen, 1948 –
Doppert & Neele, p. 9, pl. 23, figs 3a–c

Remarks: This species is common in Midway-type faunas, and considered to represent the inner shelf. Mostly recorded from the Paleocene, but in South Limburg also found in Upper Maastrichtian rocks (e.g. Romein et al. 1977).

Anomalinoides acuta (Plummer, 1926)

Plate 2, Figure 3

1948 *Anomalinoides acuta* Plummer –
Brotzen, p. 87, pl. 14, figs 2a–c
1965 *Anomalinoides praeacuta* Vasilenko, 1954 –
Pozaryska, p. 129, pl. 28, figs 2a–c
1975 *Anomalinoides acuta* (Plummer, 1926) – Berggren & Aubert,
p. 149, pl. 5, figs 4a–d, pl. 8, figs 3a, b pl. 9, fig. 1, pl. 12,
fig. 5, pl. 13, fig. 8, pl. 17, fig. 5, pl. 18, fig. 2, pl. 19, fig. 2
1983 *Anomalina acuta* (Plummer, 1926) –
Doppert & Neele, p. 6, pl. 10, figs 3a–c
?1988 *Anomalinoides acuta* (Plummer) –
Keller, p. 155, pl. 2, figs 9–16
1994 *Anomalinoides praeacutus* (Vasilenko) –
Speijer & Van der Zwaan, p. 60, pl. 8, figs 1a–c

Remarks: Considered a typical element of the Midway-type fauna by Berggren and Aubert (1975), representing the continental shelf with a depth of 20–100 m (Berggren 1974a). In the El Kef section (Keller 1988), this species is very abundant across the K/T boundary, and the dominant form in the lowermost Danian. Present in almost all Geulhemmerberg samples.

Anomalinoides midwayensis (Plummer, 1926)

Plate 2, Figure 9

1946 *Anomalina bundensis* nov. sp. –
Van Bellen, p. 73, pl. 11, figs 1–3
1948 *Anomalinoides midwayensis* (Plummer) –
Brotzen, p. 88, pl. 14, figs 3a–c
1948 *Anomalinoides aspera* n.sp. –
Brotzen, p. 88, pl. 15, figs 4a–c
1948 *Cibicides umbilicata* n.sp. –
Brotzen, p. 84, pl. 13, figs 6a–c
1975 *Anomalinoides midwayensis* (Plummer) –
Berggren & Aubert, p. 149, pl. 6, figs 1a–f, pl. 9, fig. 3,
pl. 10, fig. 8, pl. 11, fig. 3, pl. 12, fig. 3, pl. 16, fig. 2
1987 *Hanzawaia midwayensis* (Plummer, 1926) –
Bignot, p. 155

Remarks: Berggren (1974a) estimates that the palaeodepth of this species ranges from 20 to 100 m.

Plate 1

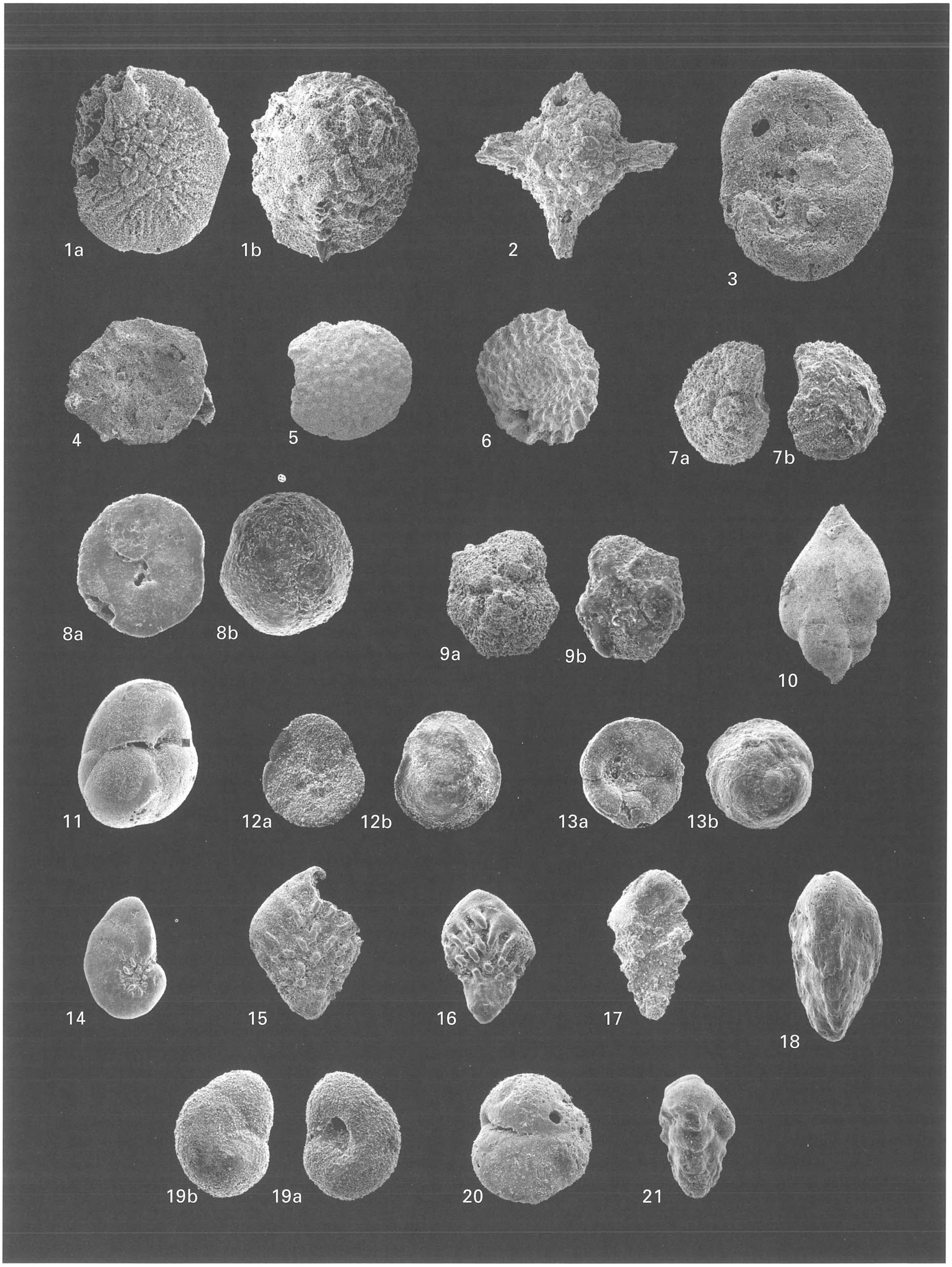
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Plate 2. Benthic foraminifera from the Geulhemmerberg. Magnification 89 ×, except Figures 3, 4, 7 (56 ×) and Figure 8 (28 ×). Figure 1. *Cibicides bosqueti* (Reuss, 1862), a. sample G2B, ventral view, b. same specimen, apertural view, c. same specimen, dorsal view. Figure 2. *Cibicides mariae* (Jones, 1852), a. sample G2B, dorsal view, b. same specimen, apertural view, c. same specimen, ventral view. Figure 3. *Anomalinoides acuta* (Plummer, 1926), a. sample G2B, dorsal view, b. same specimen, apertural view, c. same specimen, ventral view. Figure 4. *Gyroidinoides subangulata* (Plummer, 1926), a. sample G7B, ventral view, b. same specimen, dorsal view. Figure 5. *Gavelinella danica* Brotzen, 1940, a. sample G6, dorsal view, b. same specimen, ventral view. Figure 6. *Gavelinopsis bembix* (Marsson, 1878), a. sample G4A, ventral view, b. same specimen, apertural view, c. same specimen, dorsal view. Figure 7. *Cibicidoides succedens* (Brotzen, 1948), a. sample G2B, dorsal view, b. same specimen, apertural view, c. same specimen, ventral view. Figure 8. *Cibicidoides alleni* (Plummer, 1926), a. sample G7B, dorsal view, b. same specimen, apertural view, c. same specimen, ventral view. Figure 9. *Anomalinoides midwayensis* (Plummer, 1926), a. sample G4I, ventral view, b. same specimen, dorsal view.

Ceratobulimina tuberculata Brotzen, 1948

Plate 1, Figure 19

1948 *Ceratobulimina tuberculata* n.sp. – Brotzen, p. 124, pl. 19, figs 2, 3
1961 *Ceratobulimina tuberculata* Brotzen – Brotzen & Pozaryska, p. 157
1965 *Ceratobulimina tuberculata* Brotzen, 1948 – Pozaryska, p. 117, pl. 20, figs 4a, b, 6a–c
1968 *Ceratobulimina tuberculata* Brotzen, 1948 – Pozaryska & Sczcechura, p. 93

Remarks: Although present in small numbers only, this species is one of the few unambiguous markers for the Paleocene. It was mentioned once before from South Limburg (Lower Paleocene: Hofker 1962b). This species may be conspecific with *Ceratobulimina bundensis* Van Bellen, 1946 which has been reported frequently from the Thanetian of NW Europe (Bignot 1990).

Cibicides bosqueti (Reuss, 1862)

Plate 2, Figure 1

1951 *Gavelinella bosqueti* (Reuss) – Visser, p. 266, pl. 5, figs 8a–c
1977 *Cibicides bosqueti* (Reuss, 1862) – Villain, p. 62, pl. 10, figs 7–9
1981 *Cibicides bosqueti* (Reuss, 1862) – Sprechmann, p. 215, figs 14/7–14/10

Remarks: This species is considered a facultative epizoid by Sprechmann (1981). Since the species may live both unattached or fixed to a substrate, its morphology is highly variable. As a consequence we have employed a wide species concept, following Villain (1977) and others.

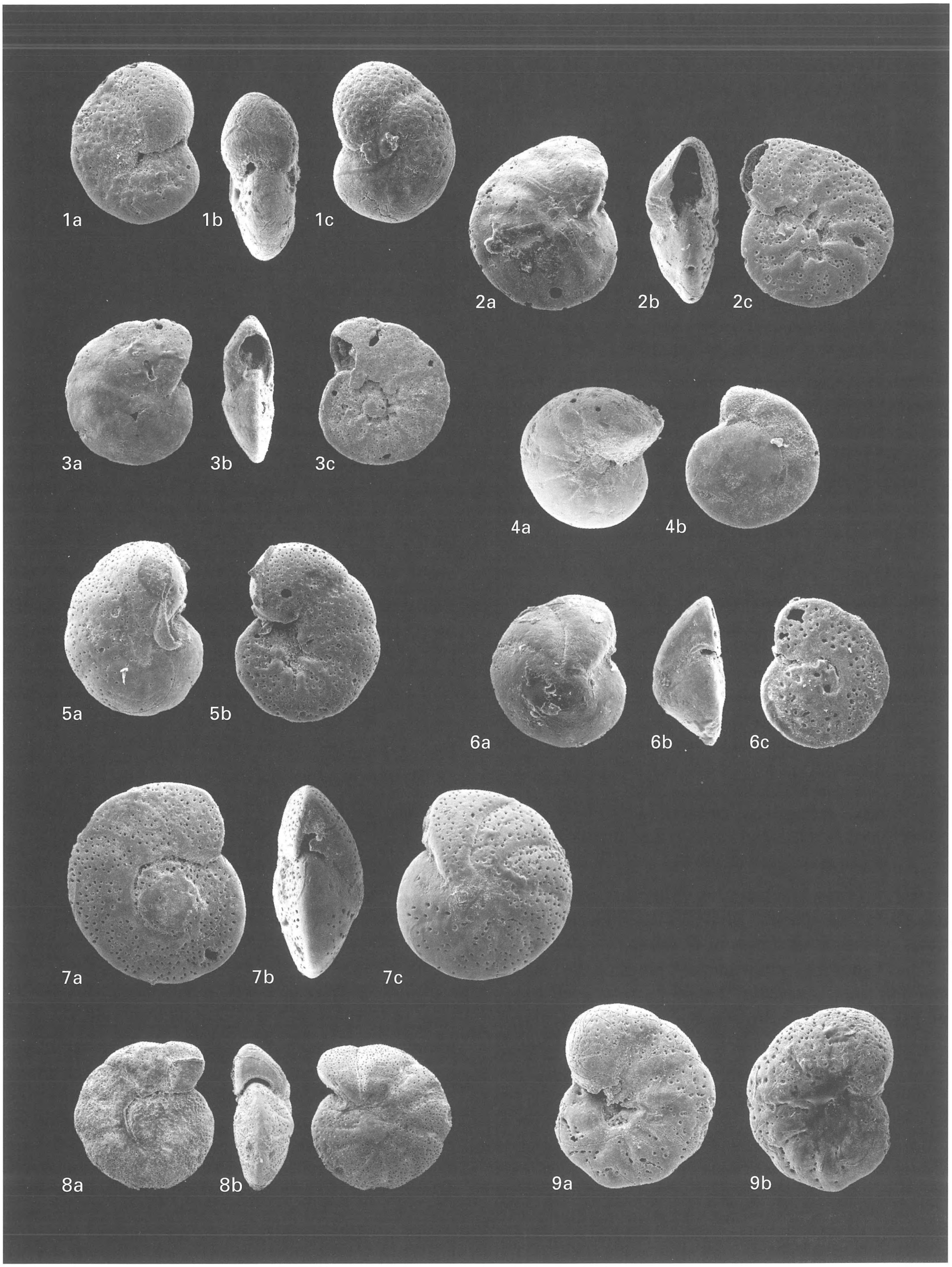
Cibicides mariae (Jones, 1852)

Plate 2, Figure 2

1946 *Cibicides choctawensis* Cushman & Mc Glamery, var. *ornata* – Van Bellen, p. 79, pl. 12, figs 7–9
1948 *Cibicides ekblomi* n.sp. – Brotzen, p. 82, pl. 13, figs 2a–c
1965 *Cibicides ornatus* Van Bellen, 1946, emend. Pozaryska, 1965 – Pozaryska, p. 133, pl. 25, figs 1a–c
1965 *Anomalina ekblomi* (Brotzen, 1948) – Pozaryska, p. 127, pl. 27, figs 6a–c
1975 *Cibicicidina mariae* (Jones), 1852 – Berggren & Aubert, p. 146
1989 *Cibicides (Cibidina) mariae* (Jones) – Murray et al., p. 516, pl. 10.4, figs 17–19
1990 *Gavelinella ekblomi* (Brotzen, 1948) – Schönfeld, p. 109, pl. 6, figs 1–3
1994 *Anomalinoides ekblomi* (Brotzen) – Speijer & Van der Zwaan, p. 58, pl. 8, fig. 2

Remarks: Worldwide species, characteristic of the Late Cretaceous–Paleocene inner-shelf environment and very abundant in parts of the Midway Formation (Kellough 1959). It has been reported under several names, of which *Gavelinella ekblomi* has been used most frequently in NW Europe. Distinctive for this species are the subtrapezoid shape in side view and the curved sutures. These features are shared with *Cibicides choctawensis* Cushman & Mc Glamery, var. *ornata* (= *Cibicides ornatus* Van Bellen of Pozaryska 1965), which differs only in minor details and therefore seems to fall within the range of variation of the species. For this reason we consider *C. ornatus* conspecific with *C. mariae*.

Plate 2



Cibicidoides alleni (Plummer, 1926)

Plate 2, Figure 8

1948 *Cibicidiodes proprius n.sp.* –
Brotzen, p. 78, pl. 12, figs 3, 4
1965 *Cibicides propius* (Brotzen, 1948) –
Pozaryska, p. 134, pl. 27, figs 1a–c, 5a–c
1975 *Cibicidoides alleni* (Plummer, 1926) – Berggren & Aubert, p. 151, pl. 5, figs 1a–d, pl. 7, figs 1a–d, pl. 9, fig. 5, pl. 10, fig. 1, pl. 11, fig. 2, pl. 12, fig. 11, pl. 14, fig. 2, pl. 15, fig. 11, pl. 18, fig. 1, pl. 19, fig. 5
1983 *Cibicides propius* (Brotzen, 1948) –
Doppert & Neele, p. 6, pl. 11, figs 2a–c
1989 *Cibicidoides alleni* (Plummer) –
Murray et al., p. 518, pl. 10.5, figs 13–15

Remarks: Cosmopolitan species, which has been reported from many areas under various names. Ecology brackish to normal marine, estimated water depth 20–100 m (Berggren 1974a), substrate variable (Murray et al. 1989).

Cibicidoides succedens (Brotzen, 1948)

Plate 2, Figure 7

1948 *Cibicides succedens* n.sp. –
Brotzen, p. 80, pl. 12, figs 1a–c
1965 *Cibicides succedens* Brotzen, 1948 –
Pozaryska, p. 136, pl. 28, figs 1a–c, figs 5a–c
1972 *Cibicidoides hercegovinensis* (De Witt Puyt) –
Berggren, pl. 6, figs 12–14
1975 *Cibicidoides succedens* Brotzen, 1948 –
Berggren & Aubert, p. 154, pl. 14, fig. 5
1976 *Cibicidoides succedens* (Brotzen, 1948) –
Aubert & Berggren, p. 432, pl. 11, figs 1a–c
1989 *Cibicides (Cibicidina) succedens* Brotzen, 1948 –
Murray et al., p. 518, pl. 10.5, figs 1–3

Remarks: Considerable confusion appears to exist with respect to this species. Brotzen (1948) clearly illustrates two different forms of *C. succedens*: his plate 12, fig. 1 shows a form with small plugs on the umbilical and spiral sides, fig. 2 shows a form with large plugs. According to Brotzen, the specimen illustrated in plate 12, fig. 1, the form with the small plugs, should be considered the Holotype. Quite correctly, Berggren & Aubert (1975) do not include the specimen figured by Brotzen as plate 12, fig. 2 in their synonymy list.

Surprisingly, Pozaryska (1965) explicitly excludes the first form of Brotzen (plate 12, fig. 1) from her synonymy list; her plate, however, shows considerable variation in the size of the plugs and the height of the specimens. We think those illustrated on her plate 28, figs 1a–c probably belong to the closely related *C. alleni*, to which transitional forms apparently exist (Berggren and Aubert 1975).

Gyroidinoides subangulata (Plummer, 1926)

Plate 2, Figure 4

1926 *Rotalia soldanii* (d'Orbigny) var. *subangulata* n. var. –
Plummer, p. 154, pl. 12, figs 1a–c
1965 *Gyroidinoides subangulata* (Plummer, 1926) –
Pozaryska, p. 108, pl. 18, figs 1a–c
1975 *Gyroidinoides subangulata* (Plummer, 1926) –
Berggren & Aubert, p. 148, pl. 3, figs 2a–c, pl. 10, fig. 3, pl. 13, fig. 3, pl. 15, fig. 12
1976 *Gyroidinoides subangulata* (Plummer, 1926) –
Aubert & Berggren, p. 429, pl. 8, figs 6a–c
1987 *Gyroidinoides subangulata* (Plummer, 1926) –
Bignot, p. 155, pl. 5, figs 3, 4
1988 *Gyroidinoides subangulata* – Keller, p. 162, pl. 2, figs 1–4

Remarks: Generally considered a typical Paleocene form, although Keller (1988) reports it from either side of the K/T boundary in the El Kef section.

Pararotalia tuberculifera (Reuss, 1862)

Plate 1, Figure 9

1951 *Pararotalia tuberculifera* (Reuss) –
Visser, p. 274, pl. 5, fig. 14, pl. 10, figs 9, 10
1966 *Pararotalia tuberculifera* (Reuss) –
Hofker, p. 262, pl. 56, figs 113–116
1977 *Pararotalia tuberculifera* (Reuss) –
Villain, p. 66, pl. 6, figs 7–9
1981 *Pararotalia tuberculifera* (Reuss, 1862) –
Sprechmann, p. 207, fig. 11/3
1983 *Pararotalia tuberculifera* (Reuss, 1862) –
Doppert & Neele, p. 9, pl. 28, figs 2a–2c

Remarks: This species is common for the Upper Maastrichtian up to the uppermost Danian in western Europe and indicates an inner sublittoral depositional environment. The reinforcement of the test by internal pillars reflects its habitat: sandy surfaces with high wave action (Sprechmann 1981).

Reussella cimbrica (Troelsen, 1937)

Plate 1, Figure 18

1945 *Pseudouvigerina cimbrica* Troelsen – Brotzen, p. 47, pl. 1, figs 8, 9
1951 *Reussella cushmani* Brotzen – Visser, p. 261, pl. 8, fig. 9
1957 *Reussella cimbrica* (Troelsen) – Hofker, p. 219, figs 271a–271k
1962 *Reussella cimbrica* (Troelsen, 1937) – Hiltermann & Koch, p. 318, pl. 47, fig. 7, tbl. 19

Remarks: Very small, but characteristic species with a range from Upper Maastrichtian to Danian. In our material its lowest occurrence is in sample G2D; in higher samples it is relatively abundant. Although no support was found in the literature, its co-occurrence with *Tappanina selmensis* could indicate similar palaeoenvironmental requirements.

Reusella crassa (Brotzen, 1948)

Plate 1, Figure 21

1948 *Pyramidina crassa* n.sp. – Brotzen, p. 63, pl. 6, fig. 8
1966 *Reussella crassa* (Brotzen) – Hofker, p. 223, pl. 42, fig. 63, pl. 45, fig. 132, pl. 81, figs 157, 158

Remarks: Although only limited data are available on the occurrence of this species it is most probably restricted to the Lower Paleocene. In our samples it first occurs, together with other Paleocene markers, in sample G2D.

Rosalina brotzeni Hofker, 1961

Plate 1, Figure 8

1948 *Gavelinella* (?) sp. – Brotzen, p. 76, pl. 9, fig. 10
1961 *Rosalina brotzeni* nov. spec. – Hofker, p. 63, figs 3a–3c
1966 *Rosalina brotzeni* Hofker – Hofker, p. 225, pl. 46, fig. 138

Remarks: Hofker (1961) described this species from burrows through the Vroenhoven hardground penetrating the 'Maastrichtian' in the Curfs quarry. We found its lowest occurrence in sample G2B, which is interpreted as Danian.

Rotalia sp. cf. *R. marginata* d'Orbigny, 1826

Plate 1, Figure 7

1946 *Rotalia ? marginata* d'Orbigny – Van Bellen, p. 63, pl. 8, figs 8–10

Remarks: Numerous small specimens, in most cases heavily recrystallised, are tentatively referred to *Rotalia marginata*. They show some similarity to *Rotalia saxorum* but are considerably smaller. Moreover, the central knob on the umbilical side is less pronounced.

Tappanina selmensis (Cushman, 1933)

Plate 1, Figure 17

1948 *Bolvinita selmensis* Cushman – Brotzen, p. 56, pl. 9, fig. 7, Text fig. 16
1975 *Tappanina selmensis* (Cushman) – Berggren & Aubert, p. 87, pl. 2, fig. 8, pl. 13, fig. 9
1976 *Tappanina selmensis* (Cushman) – Aubert & Berggren, p. 420, pl. 4, figs 13a, 13b
1977 *Tappanina selmensis* (Cushman, 1933) – Koch, p. 64, pl. 17, figs 8, 9
1988 *Tappanina selmensis* (Cushman) – Keller, p. 156, pl. 2, fig. 8, tbl. 1
1989 *Tappanina selmensis* (Cushman) – Murray et al., p. 528, pl. 10.9, figs 14, 15
1994 *Tappanina selmensis* (Cushman) – Speijer & van der Zwaan, p. 46, pl. 7, fig. 2

Remarks: This characteristic foraminifer has a worldwide distribution and is considered indicative of deep water (Van Morkhoven et al. 1986). It ranges from Late Maastrichtian to Paleocene. This species is very abundant in some of our samples; its lowest occurrence is in sample G2D.

Tremastegina roestae (Visser, 1951)

Plate 1, Figure 1

1951 *Cibicides roestae* sp. n. – Visser, p. 291, pl. 6, fig. 9
1966 *Tremastegina roestae* (Visser) – Hofker, p. 190, pl. 36, fig. 30, pl. 39, fig. 46, pl. 63, fig. 105
1977 *Tremastegina roestae* (Visser, 1951) – Villain, p. 67
1981 *Pararotalia roestae* (Visser, 1951) – Sprechmann, p. 207, figs 11/4. 11/5
1993 *Praestorrsella roestae* (Visser) – Hottinger & Caus, 213, Text figs 1a–d, pl. 1, figs 1–19, pl. 2, fig. 1–9

Remarks: Probably restricted to the Upper Maastrichtian where it is indicative of high-energy, shallow sublittoral environments (Sprechmann 1981).

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