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Planktic foraminifera in the Cretaceous/Tertiary boundary clays of the Geulhemmerberg (Netherlands)

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Abstract

In the Geulhemmerberg section across the Cretaceous/Tertiary (K/T) boundary, planktic foraminiferal assemblages were found only in the basal Paleocene clay layers. These layers are interpreted to correspond to the planktic foraminiferal P0 Zone because Paleocene planktic foraminifers do not occur yet, whilst Paleocene nannofossil and dinoflagellate assemblages are already present. This is consistent with the K/T boundary clays (P0 Zone) of El Kef in Tunisia and of Agost and Caravaca in Spain, in which Paleocene species are also absent. The planktic assemblages of the clay layers have a low diversity, comparable to P0 planktic assemblages from the Nye Kløv section in Denmark. *Heterohelix globulosa* (Ehrenberg) dominates the assemblages.

Excellent preservation of the planktic foraminifers, and anomalously high planktic foraminifer percentages (P/(P+B) = 53.3%) provide compelling arguments for survivorship of at least five generalist Cretaceous taxa into the basal Paleocene P0 Zone, as shown earlier at Caravaca, El Kef and Nye Kløv. However, due to the lack of planktic faunas in under- and overlying sediments, it is impossible to infer whether the planktic foraminiferal faunas in the P0 Zone clay-layers have changed, or are impoverished compared to Upper Maastrichtian faunas.

Introduction

Recently, the fate of the planktic foraminifers across the Cretaceous/Tertiary (K/T) boundary was hotly debated (Kerr, 1994). The main issues concern the proposed extinction patterns across this boundary. Smit (1977, 1982, 1990) defends the viewpoint that the planktic foraminifers, except for a few generalist surviving species, suddenly – catastrophically – disappear at the boundary without significant extinctions directly preceding the boundary. Keller (1988) defends a pattern of stepwise extinctions, including extinctions before, at, and after the boundary. Keller (1988, 1996) postulated an important step (14% species extinct) just below the boundary where large, tropical, ornamented forms disappear. The next extinction step would be at the boundary where the remaining large forms disappear. The largest extinction step would occur above the boundary where most non-specialized cosmopolitan forms disappear, suggesting that a large planktic population (26%) survived into the basal Paleocene P0 and *Globigerina eugubina* zones. The P0 Zone was first defined by Smit (1977), and defined as a zone between the mass extinction of most Cretaceous planktic foraminifers and the first appearance of the Paleocene planktic taxon *G. eugubina* Luterbacher & Premoli Silva.

Extinctions preceding the K/T boundary are clearly incompatible with impact-induced catastrophic extinctions, without special pleading. A 'blind test' excercise, under supervision of R. Ginsburg, has been designed to address these questions. Four micropaleontologists were invited to analyse the coded foraminiferal assemblages from three samples (75, 15 and 6 cm) below and three samples (7, 15, 85 cm) above the K/T boundary in the El Kef section. They failed to demonstrate significant pre-K/T boundary extinctions (Ginsburg et al., in preparation). Another issue is the question of survivorship of planktic species above the boundary. Significant survivorship of planktic taxa

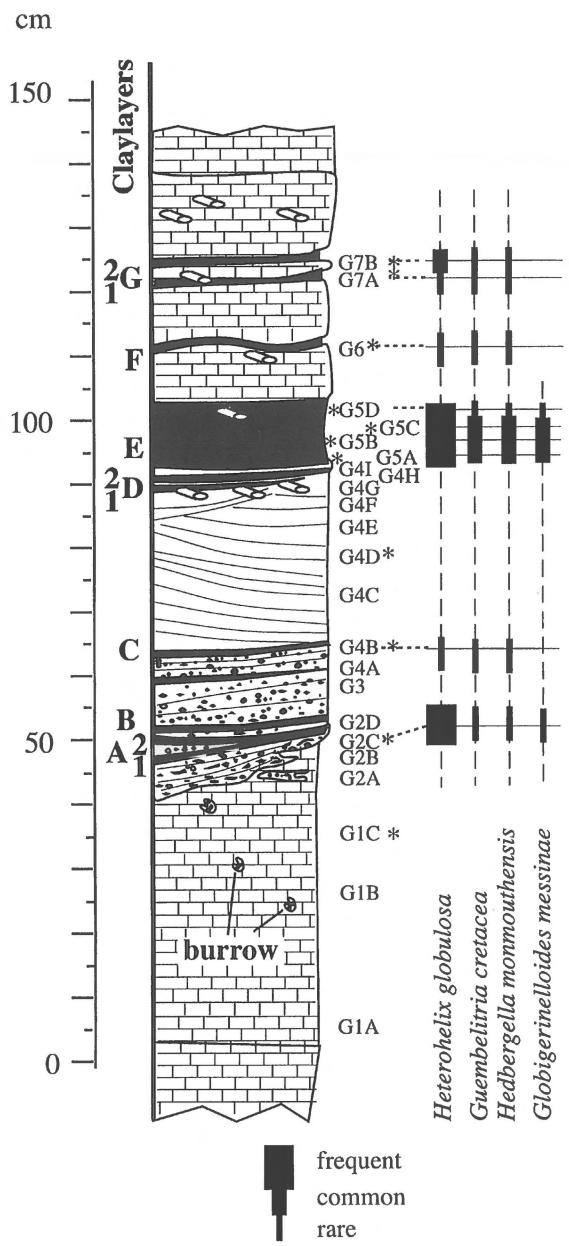

Figure 1. Stratigraphic distribution of the four most common planktic foraminiferal species in the Geulhemmerberg section. For location and legend see figures 1 and 4 of Brinkhuis and Smit (this issue). Asterisks * indicate samples investigated.

may not falsify an impact-induced extinction model, but may raise the question whether the extinctions were indeed catastrophic. The samples from the Geulhemmerberg section in the Maastrichtian type area were analysed on foraminiferal content, with the above problems in mind.

Samples and methods

Washed residues (> 63 μm mesh) were prepared from samples of the K/T reference section at Geulhemmerberg (Figure 1, see also Brinkhuis and Smit, this issue). Only the clay layers A, C, D (1, 2), E, F and G (1, 2) contain a well-preserved planktic fauna. In particular the D and E clay layers contain air-filled specimens. A few samples of the Upper Maastrichtian bioclastic grainstones of units IVf-6 and IVf-7 of the Meerssen Member were disaggregated, but yielded only a few, badly preserved specimens of planktic foraminifers (*Heterohelix* aff. *globulosa*), among abundant small benthic foraminifers. A large sample from the E clay (G5) was thoroughly cleaned from adhering coarse bioclasts, and the few conspicuous coarse burrow-fills were removed. Just 0.24 g of the > 63 μm residue remained of the 615 g dry bulk sample. Over 200 planktic specimens were randomly selected, identified and counted.

SEM-graphs were prepared of all the species encountered in the E clay (Figure 2).

From sample G5, Vonhof and Smit (this issue) obtained a basal Danian seawater $^{87}Sr/^{86}Sr$ ratio from well-preserved *H. globulosa*.

Results

The planktic foraminiferal assemblages show two types of preservation. The majority of the specimens is well-preserved, not corroded and air-filled. A small fraction is corroded and stained yellow. A list of species, mainly from the E clay (G5), is provided in Table 1. The quantitative results are presented in Table 2 and well-preserved species found in the E clay are shown in Figure 2.

Four species, *Heterohelix globulosa* (Ehrenberg), *Guembelitria cretacea* Cushman, *Hedbergella monmouthensis* (Olsson) and *Globigerinelloides messinae* (Brönnimann), occur consistently in all the clay layers (Figure 1), although *G. messinae* is extremely rare in the F and G clay layers. These species are all known from the Upper Maastrichtian *Abathomphalus mayaroensis* Zone, and the assemblage is comparable to assemblages in the K/T boundary section of Nye Kløv in Denmark (Keller et al., 1993).

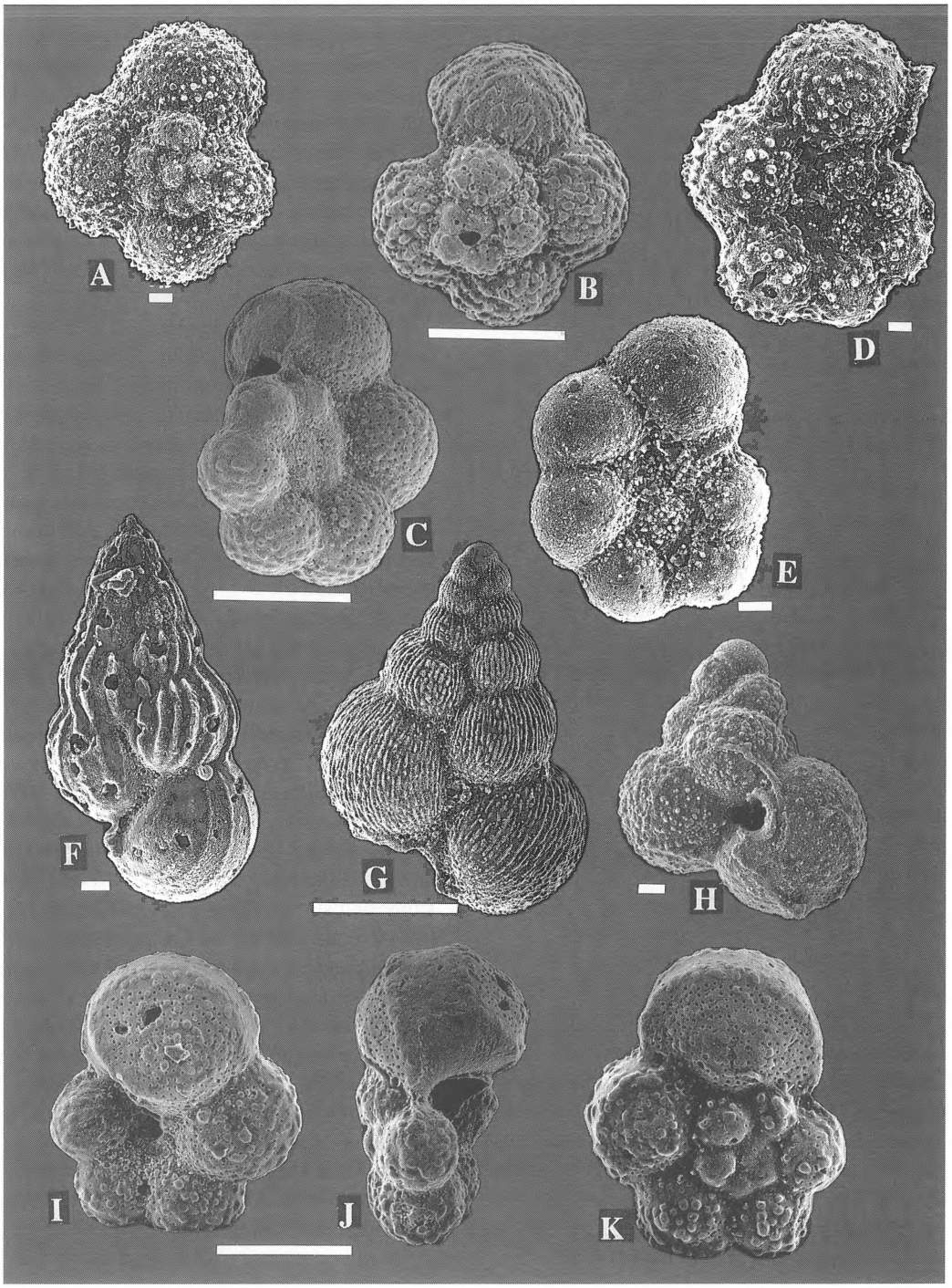

Figure 2. Scanning electron micrographs of well-preserved specimens of planktic foraminifers of the Geulhemmerberg section. All specimens are from sample G5B (E clay). A) *Hedbergella monmouthensis*. B, C) *Rugoglobigerina rugosa*. D) *Globigerinelloides messinae*. E) *Globigerinelloides asperus*. F) *Pseudoguembelina costata*. G) *Heterohelix globulosa*. H) *Guembelitria cretacea*. I–K) *Rugotruncana* aff. *circumnodifer*. Scale bars: B, C, G, I–K = 100 μm; A, D–F, H = 10 μm.

Table 1. List of species of planktic foraminifers from the A to G clay layers of the Geulhemmerberg K/T section.

Species	Abundance
Heterohelix globulosa (Ehrenberg)	abundant
Hedbergella monmouthensis (Olsson)	few
Globigerinelloides messinae (Brönnimann)	few
Globigerinelloides asperus (Ehrenberg)	few
Rugoglobigerina aff.*rugosa* (Plummer)	1 ex.
Rugotrucana aff. *circumnodifer* (Finlay)	extr. rare
Pseudoguembelina costulata (Cushman)	1 ex.
Guembelitria cretacea Cushman	common
Globutruncana aff. *arca* (Cushman)	1 ex.

Table 2. Quantitative analysis of a random split of the washed residue of clay E.

	Counts	% of all groups	% of total planktics
Heterohelix globulosa	200	44.15	95.24
Globigerinelloides messinae	3	0.66	1.43
Globigerinelloides asperus	3	0.66	1.43
Hedbergella monmouthensis	2	0.44	0.95
Guembelitria cretacea	2	0.44	0.95
Hyaline benthics	142	31.35	
Agglutinated benthics	42	9.27	
Ostracods	36	7.95	
Sponge spicules	23	5.08	
Total counted	453		
Total planktics	210		
% planktics = P/(P+B)	53.30%		

Lowermost Paleocene taxa, such as *Eoglobigerina minutula* (Luterbacher & Premoli Silva) (= *Globoconusa conusa* (Khalilov) sensu Keller 1988), *Eoglobigerina fringa* (Morozova) or *Globigerina eugubina* have not been found. Interestingly, the planktic percentage in the E clay sample is high: P/(P+B) = 53.3% (Table 2). Usually, but not here, as discussed further on, one would interpret this rather high percentage as indication for a waterdepth greater than 100 m.

Among the keeled morphotypes, we have only identified extremely rare, juvenile double-keeled forms tentatively ascribed to *Rugotruncana circumnodifer* (Finlay), a form known thus far only from the Upper Maastrichtian of the southern oceans (Huber, 1991), and one specimen of *Globotruncana arca* (Cushman).

Discussion

Foraminifera from the E clay are either extremely well-preserved or corroded. The well-preserved fauna presumably occurs *in situ*, because it would be difficult, if not impossible, to selectively rework planktic foraminifers from the underlying Upper Maastrichtian bioclastic grainstones, which are rich in smaller benthic foraminifers. On the other hand, air-filled specimens of Cretaceous planktic foraminifers are known to occur in Pleistocene loess-deposits in England (M. Hart, personal communication).

An iridium anomaly has not yet been found in the Geulhemmerberg section. For this reason, one of the best tools to position the K/T boundary fails here (Smith and Rocchia, this issue). Paleocene taxa do not occur in the clay layers, although a basal Paleocene age is suggested by the benthics (Kuhnt; Witte and Schuurman, this issue), calcareous and organic-walled dinocysts (Brinkhuis and Schiøler; Willems, this issue) and nannofossils (Romein et al., this issue), and the overall lithological succession (Roep and Smit, this issue). This indirectly assigns the Geulhemmerberg clay layers to the planktic foraminiferal P0 Zone, correlative to the clay layers of P0 Zone age elsewhere, e.g. Stevns Klint in Denmark, El Kef in Tunisia and Caravaca in Spain. Therefore, these layers postdate the Ir-rich fallout layer, and the K/T boundary.

The good preservation and the high P/(P+B) ratio at Geulhemmerberg provide an argument for survivorship of several Upper Maastrichtian planktic taxa, at least into the basal Paleocene P0 Zone. Smit (1977) suggested survivorship of a few Cretaceous taxa into the P0 Zone clay of the Caravaca section because of the high relative abundance of *Guembelitria, Globigerinelloides, Hedbergella* and possibly some heterohelicids in this clay compared to their abundance in the same size fraction in the Upper Maastrichtian. Later, Keller (1988) and Keller and Lindinger (1989) suggested survivorship for the same species, and a few additional biserial species in the El Kef and Brazos River (Texas) sections. A low (Danian) $\delta^{13}C$ value of *H. globulosa* in P0 Zone sediments of these sections supported that suggestion.

Vonhof and Smit (this issue) found a $^{87}Sr/^{86}Sr$ ratio of 0.707923 in well-preserved *H. globulosa* tests, compatible with a lower Danian seawater ratio, supporting survivorship of *H. globulosa*. Although a direct comparison with Upper Cretaceous assemblages cannot be made in the Geulhemmerberg section, the low specimen yield of even a large (615 g) sample of the E

clay suggests that the planktic populations at P0 Zone time were probably reduced compared to Upper Maastrichtian populations, as at El Kef and Caravaca. Therefore, although some species clearly survive, we see no evidence here for 'thriving surviving Cretaceous planktic populations' as suggested by Keller et al. (1993).

The high P/(P+B) ratio (53.3%) in the E clay is peculiar. We reject a sudden deepening of the basin, because of the sedimentary evidence for a shallow waterdepth (20–40 m) above, between, and below the clay layers (Roep and Smit, this issue). Rather, the high P/(P+B) ratio seems a direct result of the K/T event itself. Apparently, both benthic and planktic foraminifers have suffered from the K/T extinction event, but in this area the benthics seem to have suffered even more than the planktic foraminifers.

Conclusions

1. Planktic foraminifers provide no reliable means to define the K/T boundary in the Geulhemmerberg section.
2. Planktic taxa characteristic for the Paleocene do not occur in the clay layers, although a Paleocene age is suggested by the benthics, calcareous and organic-walled dinocysts and nannofossils, and the overall lithological succession. This indirectly assigns the Geulhemmerberg clay layers to the planktic foraminiferal P0 Zone.
3. At least five taxa have probably survived the K/T impact event into the P0 Zone, but it could not be established whether these represent a mere remnant of the Upper Maastrichtian populations in the area.
4. The high P/(P+B) ratio in the E clay suggests a relatively high mortality among the benthic foraminifers as a consequence of the K/T event.

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