



Catastrophic mass extinction and assemblage evolution in planktic foraminifera across the Cretaceous/Paleogene (K/Pg) boundary at Bidart (SW France)

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ABSTRACT

A high-resolution biostratigraphic analysis of planktic foraminifers confirms that the Bidart section at the eastern margin of the Atlantic Ocean exhibits a continuous and complete Cretaceous/Paleogene (K/Pg) transition interval. The biozones and subzones recorded in this section are less expanded than their equivalent in Tunisian sections: El Kef (Global Stratotype Section and Point: GSSP for the K/Pg boundary) and Ellès (auxiliary section), but they are sufficiently thick to allow a detailed analysis of the evolution of the planktic foraminiferal assemblages across the K/Pg transition.

Throughout the uppermost 4 m Maastrichtian, the planktic foraminiferal assemblages are highly diversified, containing up to 72 species. These Maastrichtian assemblages are rich in cosmopolitan taxa (70%), dominated by small biserial morphotypes which belong mainly to the genus *Heterohelix* which coexist with less abundant but highly diverse tropical and subtropical species.

The extinction pattern at the Bidart section suggests a sudden catastrophic mass extinction at the K/Pg boundary which affected at least 53 out of 72 species. The species becoming extinct include globotruncanids (e.g. *Contusotruncana* spp., *Globotruncana* spp., *Globotruncanita* spp.) and complex heterohelids (e.g. *Racemiguembelina* spp., *Pseudotextularia* spp., *Gublerina* spp.). At the Bidart section, only *Archaeoglobigerina cretacea* disappears 2 m below the K/Pg boundary event. Specimens of 18 small and even tiny Maastrichtian species, are found at the lowermost Danian. Only a few of these species belonging to the genera of *Guembelina*, *Hedbergella* and *Heterohelix* are considered to be real “Cretaceous survivor species”, whereas the specimens belonging to the rest, are most probably reworked, because they differ in their preservation.

Throughout lowermost Danian, the planktic foraminiferal assemblages are dominated by “opportunistic” species of the genus *Guembelina*. These opportunists are associated to small and poorly diversified pioneer globigerinids (*Palaeoglobigerina* spp. and *Parvularugoglobigerina* spp.). These assemblages became progressively more diversified across the early Danian containing species with cancellate walls (*Eoglobigerina* spp., *Parasubbotina* spp., *Subbotina triloculinoides* and *Praemurica* spp.) and new taxa of biserial heterohelids (*Woodringina* spp. and *Chiloguembelina* spp.) suggesting a paleoenvironmental recovery.

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1. Introduction

The Cretaceous–Paleogene transition (K–Pg) is one of the best studied time intervals in the Earth's history due to the paleobiological crisis causing the extinction of numerous taxa, including the popular dinosaurs. It is ranking among the major extinction events of the Phanerozoic (Raupe and Sepkoski, 1986). Most authors (e.g. Alvarez et al., 1980; Smit and Hertogen, 1980; Hildebrand et al., 1991) now accept that the impact of a large 10 km-size meteorite at Chicxulub (Yucatan Peninsula, Mexico), caused the catastrophic mass extinction of the calcareous plankton (e.g. Luterbacher and Premoli-Silva, 1964;

Perch-Nielsen et al., 1982; Smit, 1990; Gartner, 1996; Molina et al., 1998). This meteorite impact induced an anomalous enrichment in Ir and other impact-derived materials, such as microtektites, shocked quartz grains and Ni-rich spinels, in the deposits recording the K/Pg boundary (e.g. Smit and Ten Kate, 1982; Sharpton et al., 1992; Rocchia et al., 1987; Peryt et al., 1993; Smit et al., 1996; Robin and Rocchia, 1998; Arenillas et al., 2006).

The extinction model of planktic calcareous groups (foraminifers and coccolithophorids) is yet under debate. Some authors consider that the lower Danian assemblages include reworked specimens of Maastrichtian taxa (Thierstein, 1981; Pospichal, 1994; Arenillas et al., 1998; Gardin and Monechi, 1998; Zaghib-Turki et al., 2000; Gardin, 2002), whereas others have suggested that at least a substantial part of the latest Maastrichtian species survived into the earliest Danian (Perch-Nielsen et al., 1982; Keller, 1988; Keller et al., 1995). Noncalcareous pelagic groups (e.g. dinoflagellates and radiolarian)

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were less affected by this crisis and crossed the K/Pg boundary with apparently no major changes in diversity and abundance (Elliot et al., 1994; Hollis, 1996). Also deep-water benthic foraminifers were less influenced by the K/Pg boundary event, but their diversity and abundance decreased temporarily (see e.g. Alegret et al., 2005).

In order to reconstitute the scenario of the K/Pg boundary event, many studies based on high-resolution sampling across the continuous K/Pg sections have been undertaken in Tethyan, Atlantic and Pacific faunal provinces. Some of the most significant K/Pg sections are located in Tunisia (e.g. El Kef, Ellès, Aïn Settara and El Melah, see Perch-Nielsen et al., 1982; Smit, 1982; Arenillas et al., 2000a,b; Zaghib-Turki et al., 2000; Dupuis et al., 2001; Karoui-Yaakoub et al., 2002) and in Spain (as Caravaca, Agost and Zumaya, see Canudo et al., 1991; Apellániz et al., 1997; Molina et al., 1998, 2005; Arenillas et al., 1998; Arz et al., 2000). These Tunisian and Spanish sections are among the best documented and most complete and continuous sections known to date. The principal features of the K/Pg event (Ir anomaly, spinels, etc.) and expanded lower Danian planktic foraminiferal zones and subzones are recorded in them. The Global Stratotype Section and Point (GSSP) for the base of the Danian (equivalent to the K/Pg boundary) was defined near El Kef, Tunisia (see Molina et al., 2006). The sections of Aïn Settara, Ellès (Tunisia), Caravaca and Zumaya (Spain), Bidart (France), Bochil and El Mulato (Mexico) in which the K/Pg boundary event is well recorded, have been proposed to be auxiliary sections for the definition of the K/Pg boundary (Molina et al., in press).

The Zumaya section (northern Spain) and the Bidart section (south-western France), are among the most complete European K/Pg boundary sections exposed in the Atlantic margin (Seyve, 1990; Haslett, 1994; Apellániz et al., 1997). Recently, the continuity of the Bidart section across the K/Pg boundary has been confirmed by studies of magnetostratigraphic and calcareous nannofossils (Galbrun and Gardin, 2004). The aim of this paper is to analyze the effects of the Chicxulub bolide impact on the whole planktic foraminiferal assemblages in this area and to check their extinction pattern. The Bidart section provides an excellent opportunity to study the K/Pg boundary event, based on quantitative analysis of the planktic foraminiferal extinction patterns and of their assemblages' evolution.

2. Materials and methods

The Bidart section is located in south-western France between Hendaye and Biarritz bordering the Bay of Biscay. It is easily accessible from the national highway R. N. 10, by the road which leads to the beach at about 2 km N of the village of Bidart. The upper Cretaceous to Paleogene succession of the Basque Pyrenean Basin is well exposed along the beach of Bidart. We have sampled and studied in detail the uppermost 4 m of the Maastrichtian and the lowermost 4 m of the Danian. The K/Pg boundary is located at 43° 27' N, and 1° 35' E (Fig. 1).

Many authors have analyzed different aspects of the Bidart section. Lezaud (1967) and Martini (1971) have been the first authors to study the calcareous nannofossils. Subsequent studies have dealt with ammonites and inoceramids (Ward, 1988; Ward and Kennedy, 1993; Haslett, 1994), planktic foraminifera (Haslett, 1994; Fondacave-Wallez et al., 1995; Apellániz et al., 1997), benthic foraminifera (Alegret et al., 2004) and calcareous nannofossils (Perch-Nielsen, 1979; Seyve, 1990; Burnett et al., 1992; Minoletti et al., 2004) or have covered aspects of sedimentology (Peybernès et al., 1997), magnetostratigraphy (Galbrun, 1997; Galbrun and Gardin, 2004), geochemistry (Renard et al., 1982; Bonté et al., 1984; Rocchia et al., 1987), mineralogy (Robin and Rocchia, 1998), and chronostratigraphy (Galbrun and Gardin, 2004). The composition of stable isotopes of several elements have been analyzed by Romein and Smit, (1981), Renard et al. (1982); Nelson et al. (1991), the iridium concentration by Smit and Ten Kate (1982), Bonté et al. (1984) and Delacotte (1982). According to Renard et al. (1982), the Maastrichtian sediments at Bidart have a Tethyan character, whereas the Paleocene was more influenced by the North Atlantic.

Below and above the K/Pg boundary layer, the lithology contrasts sharply. The light gray marls of the upper Maastrichtian are overlain by the dark clays of the lowermost Danian. The K/Pg boundary is marked by 2 mm thick layer of “rusty” sediments characterized by an Ir anomaly (Smit and Ten Kate, 1982; Bonté et al., 1984; Rocchia et al., 1987) and the presence of Ni-rich Spinel (Robin and Rocchia, 1998). This thin “rusty” layer is overlain by 6 cm of dark clays (“boundary clay”). It is overlain by brownish clays, thin laminated dark grey marls and pink and white limestones. These limestones include mass flow

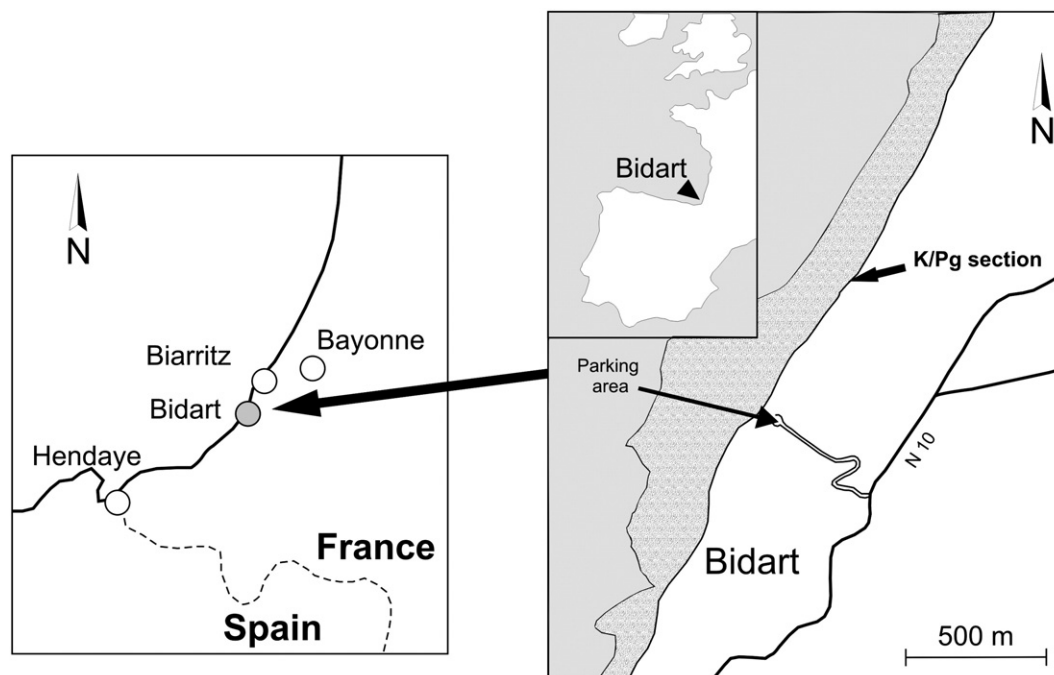


Fig. 1. Location map of the Bidart section in SW France, between Bidart and Biarritz [modified from Minoletti et al., 2004].

deposit with a clear erosive basal surface. A breccia occurs between 1.6 m and 2.10 m above the K/Pg boundary “rusty” layer (Fig. 2).

For this study, we collected a total of 19 samples in an interval including 4 m of the uppermost Maastrichtian immediately below the K/Pg boundary (samples B-400 cm to B-0–2 cm) and 3.60 m of the lowermost Danian overlying the K/Pg “rusty layer” (samples B 0–2 cm to B 360 cm). These samples are irregularly spaced. The upper Maastrichtian and lower Danian have been sampled at 50 cm to

100 cm intervals. Within the 50 cm embracing the rusty layer, the samples are spaced at 2 cm to 10 cm intervals. Below and above this “boundary interval”, the samples are generally taken at 20 cm to 50 cm intervals.

The soft clayey or marly samples were disaggregated in water with diluted H₂O₂, whereas the limestone samples were soaked in diluted (80%) acetic acid for 6 h. Then they were washed through a 63 µm sieve. All the samples were dried in an oven at 50 °C. Species richness

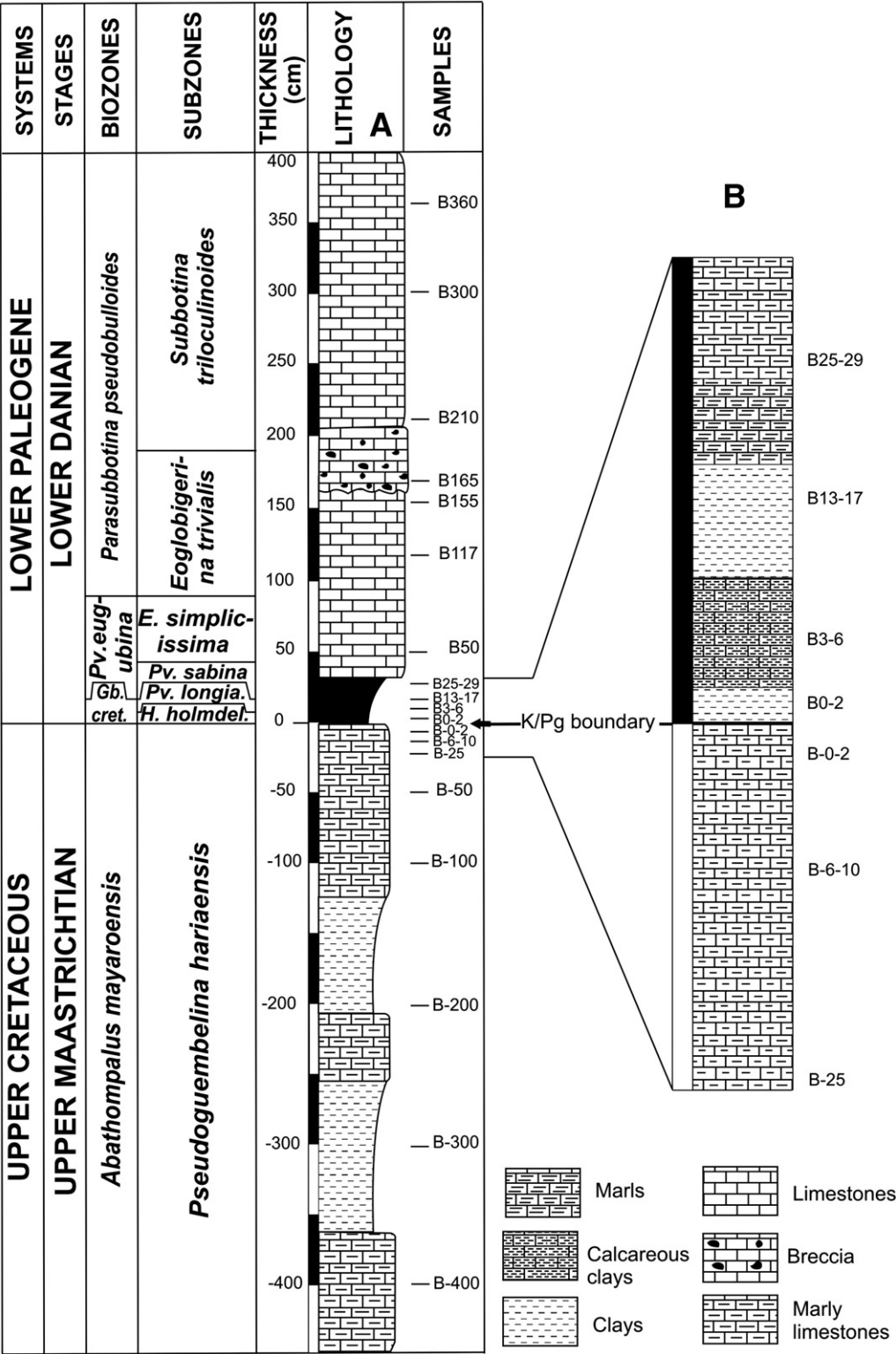


Fig. 2. (A) The Bidart section: lithology and samples location, (B): detail of the K/Pg boundary.

Table 1

Relative abundance data of the planktic foraminiferal species and genera across the Cretaceous–Paleogene transition at the Bidart section in the >63 µm size fraction.

Biozone	<i>Abathomphalus mayaroensis</i>								<i>Gt. cretacea</i>		<i>Pv. eugubina</i>			<i>Ps. pseudobulloides</i>					
Species	B-400	B-300	B-200	B-100	B-50	B-25	B-6–10	B-0–2	B+0+2	B+3+6	B+13+17	B+25+29	B+50	B+117	B+155	B+165	B+210	B+300	B+360
<i>Guembelitra cretacea</i>		0.5	0.5	0.8	0.5	0.8	0.5	0.6	5.8	24.1	18.3	2.8	0.7	4.8	14.4	17.5	11.6	1.7	2.7
<i>Guembelitra cf. trifolia danica</i>			0.5	0.8	0.5	0.2	0.5	0.9	5.8	21.5	16.1	2.4	1.5	3.4	13.7	16.8	7.4	1.7	2.7
<i>Guembelitra danica</i>										2.5	2.2	0.9	1.1	0.6	1.4	2	1.05	2.2	0.2
<i>Guembelitra irregularis</i>										2.5	1.4	1.9	0.7	1	2.8	2	1	0.5	0.1
<i>Guembelitra alabamensis</i>										1	2.9	0.9	1.1	2	1.4	1.3	2.1	0.5	0.2
<i>Guembelitra</i>		0.6	1.2	1.8	1.2	1.2	1.2	1.5	1.2	30.6	17	5.7	4.2	10.6	14.2	18.2	13.3	10	7.8
<i>Heterohelix planata</i>	4.1	6.1	4.6	5.1	6.3	5.4	7.8	5.6	5.8	3	2.9	0							
<i>Heterohelix pulchra</i>	8.4	8	6.9	7.4	9.2	6.8	6.9	6.4	8.7	1.5	2.1	2.3							
<i>Heterohelix punctulata</i>	4.5	5.8	4.6	4.5	4.1	3.2	6.9	5.9	5.8	0.5									
<i>Heterohelix carinata</i>	3	3.6	2.8	2.6	2.1	2.4	2.6	3.7											
<i>Heterohelix glabrans</i>	3	2.2	2.3	3.2	2.1	1.9	3.1	2.8	2.9	1									
<i>Heterohelix labellosa</i>	3	3.3	2.8	2.1	2.47	1.9	2.3	2.8	5.8	0.5									
<i>Heterohelix navarroensis</i>	2.4	1.6	1.7	3.2	4.9	3.8	2.3	2.1	8.8	1.1									
<i>Heterohelix globulosa</i>	9.3	6.9	7.8	5.8	3.4	6.4	5.5	7.4	5.8	2.5									
<i>Heterohelix postsemicostata</i>	7.5	5.5	6.3	8.2	6.5	8.9	8.1	8.4											
<i>Heterohelix dentata</i>	0.9	1.1	0.5	1	0.2	0.5	0.8	0.6											
<i>Heterohelix glabrans</i>	1.2	0.5	0.7	1	0.5	1	0.8	0.6											
<i>Heterohelix</i>	47.3	45.4	41.5	44.9	42.5	42.6	49.9	46.8	44.1	9.2	5.1	2.4							
<i>Pseudotextularia intermedia</i>	1.2	1.4	0.7	1	1.3	1	0.8	1.2											
<i>Pseudotextularia elegans</i>	1.2	1.4	1.54	1.34	1	1.9	2.3	0.6											
<i>Pseudotextularia nuttalli</i>	1.5	0.5	1.2	1	1.3	1	0.8	0.6											
<i>Pseudotextularia</i>	3.9	3.3	3.5	3.5	3.8	4.1	3.1	2.5											
<i>Gublerina acuta</i>	1.5	1.1	1.5	1	0.5	1	1.4	1.8											
<i>Gublerina cuvillieri</i>	1.5	1.1	2	1.6	1.3	0.8	1.7	0.6											
<i>Gublerina</i>	3	2.2	3.5	2.6	1.9	1.9	3.1	2.5											
<i>Pseudoguembelina excolata</i>	0.6	1.1	1.2	1	1.6	2.1	0.5	1.2											
<i>Pseudoguembelina hariaensis</i>	0.9	1.1	0.5	1.3	1	1.6	0.8	0.6											
<i>Pseudoguembelina palpebra</i>	1.5	0.5	1.2	1.6	1	2.1	0.5	0.9	2.9	1									
<i>Pseudoguembelina costulata</i>	0.9	0.5	1	1.3	1	0.5	1.1	0.9	2.9	1	2.2	0.9	0.3						
<i>Pseudoguembelina costellifera</i>	0.6	1.1	1.2	1	1.6	1	0.5	0.9											
<i>Pseudoguembelina kempensis</i>	0.6	1.6	1	0.5	1.8	1	0.5	1.2	2.9	1	0.7								
<i>Pseudoguembelina</i>	5.1	6.1	6.4	7	7.4	8.74.3	5.9	8.3	3	2.9	0.9	0.3							
<i>Planoglobulina acervulinoides</i>	0.9	1.1	2	2.4	3.2	3.5	1.4	1.8											
<i>Planoglobulina carseyae</i>	1.8	1.9	2	1	1.3	1.3	2.6	1.8											
<i>Planoglobulina multicamerata</i>	2.1	1.4	0.5	3.5	3.2	2.4	1.7	1.8											
<i>Planoglobulina riograndensis</i>	2.7	3.3	3.2	4.3	3.2	2.4	1.4	1.8											
<i>Planoglobulina manuelensis</i>	2.1	1.4	1.5	2.4	2.1	2.1	2	1.8											
<i>Planoglobulina</i>	9.7	9.2	9.5	13.4	13.4	10.6	9.3	7.8											
<i>Racemiguembelina powelli</i>	1.2	1.1	0.7	1.3	1.9	1	1.4	1.8											
<i>Racemiguembelina fructicosa</i>	0.6	1.9	1	1.3	1.9	1.6	1.1	1.5											
<i>Racemiguembelina</i>	1.8	3	1.7	2.6	3.8	2.7	2.6	3.4											
<i>Globigerinelloides volutes</i>	0.6	0.2	1	0.8	0.54	1	0.2	0.6											
<i>Globigerinelloides subcarinatus</i>	1.2	0.5	1.7	0.8	1.3	1	0.5	1.2											
<i>Globigerinelloides aspera</i>	0.6	1.1	0.5	0.8	0.2	0.5	0.8	1.2											
<i>Globigerinelloides yaucoensis</i>	0.6	0.2	0.2	1	0.5	0.5	1.1	0.6											
<i>Globigerinelloides</i>	3	2.2	3.5	3.5	2.7	3.2	2.9	3.7											

Table 2

Relative abundance data of the planktic foraminiferal species and genera across the Cretaceous–Paleogene transition at the Bidart section in the >63 µm size fraction.

Biozone	<i>Abathomphalus mayaroensis</i>								<i>Gt. cretacea</i>		<i>Pv. eugubina</i>			<i>Ps. pseudobulloides</i>					
Species	B-400	B-300	B-200	B-100	B-50	B-25	B-6–10	B-0–2	B+0+2	B+3+6	B+13+17	B+25+29	B+50	B+117	B+155	B+165	B+210	B+300	B+360
<i>Hedbergella holmdelensis</i>	0.3	0.5	0.2	0.8	0.5	1	0.5	0.9	5.8	7.6									
<i>Hedbergella monmouthensis</i>	0.6	0.3	0.7	1.1	0.5	0.3	0.3	0.6	2.8	7.1									
<i>Hedbergella</i>	0.9	0.8	1	1.8	1	1.3	0.8	1.5	8.8	14.8									
<i>Globotruncanella havanensis</i>	0.6	0.8	1	0.8	0.5	0.2	0.5	1.2											
<i>Globotruncanella petaloidea</i>	0.6	1.1	0.7	0.2	0.5	1	0.5	0.3											
<i>Globotruncanella minuta</i>	1.2	1.4	0.5	0.8	0.5	1	0.2	0.6											
<i>Globotruncanella pschadae</i>	0.6	1.4	0.7	1	0.5	1	1.4	0.6	2.94	0.5									
<i>Globotruncanella caravacaensis</i>	0.6	0.2	0.7	0.5	0.5	0.2	1.1	0.6											
<i>Globotruncanella</i>	3.6	5	3.8	3.5	2.7	3.8	4	3.4	2.9	0.5									
<i>Rugoglobigerina milamensis</i>	0.6	0.5	1	0.8	0.5	0.2	0.2	0.6											
<i>Rugoglobigerina reicheli</i>	0.9	0.5	0.2	0.5	0.8	2.4	3.4	2.5											
<i>Rugoglobigerina rotundata</i>	1.5	0.5	0.7	1	1.3	0.5	0.2	0.9											
<i>Rugoglobigerina rugosa</i>	0.9	1.9	3.5	0.5	0.8	2.4	3.4	3.1	2.9	1									
<i>Rugoglobigerina hexacamerata</i>	0.6	0.2	0.5	1.6	0.8	0.5	1.1	0.6											
<i>Rugoglobigerina scotti</i>	2.1	1.6	0.7	0.8	3.8	1	0.5	0.6											
<i>Rugoglobigerina pennyi</i>	0.6	0.2	0.7	0.3	0.2	0.1	0.1	0.2											
<i>Rugoglobigerina macrocephala</i>	1.21	1.6	0.5	0.1	0.1	0.2	0.1	0.2											
<i>Rugoglobigerina</i>	8.5	7.5	8.2	5.3	8.2	7.3	9.3	8.4	2.9	1									
<i>Schackoina multispinata</i>	0.3	0.2	0.5	0.2	0.2	0.5	0.2	0.3											
<i>Schackoina</i>	0.3	0.2	0.5	0.2	0.2	0.5	0.2	0.3											
<i>Archeoglobigerina blowi</i>	0.3	0.5	0.2	0.3	0.1	0.2	0.2	0.1											
<i>Archeoglobigerina cretacea</i>	0.6	0.2	0.2																
<i>Archeoglobigerina</i>	0.9	0.8	0.5	0.3	0.1	0.2	0.2	0.1											
<i>Globotruncana aegyptiaca</i>	0.6	0.8	1	0.5	1	1.3	0.5	1.8											
<i>Globotruncana insignis</i>	1.2	0.5	1	0.8	1.6	0.5	0.2	0.9	2.9	0.5									
<i>Globotruncana esnehensis</i>	0.9	1.4	0.5	1	0.8	0.5	1.1	0.9											
<i>Globotruncana falsostuarti</i>	0.6	0.8	1	0.2	0.8	1	0.5	0.9											
<i>Globotruncana rosetta</i>	0.6	0.8	1.5	1	0.5	0.2	0.8	0.6	5.8	0.5									
<i>Globotruncana orientalis</i>	0.6	0.8	0.5	0.8	0.1	0.2	0.1	0.1											
<i>Globotruncana arca</i>	0.6	0.8	0.2	0.1	0.1	0.2	0.2	0.1											
<i>Globotruncana</i>	5.1	6.1	5.9	4.5	4.9	3.8	3.4	5.3	8.8	1									
<i>Globotruncanita conica</i>	0.6	0.8	1	0.8	0.5	0.2	0.8	0.6											
<i>Globotruncanita stuarti</i>	0.3	0.5	0.7	1	0.5	0.2	0.5	31.2											
<i>Globotruncanita pettersi</i>	0.6	0.8	1	0.5	0.8	0.2	0.5	0.9											
<i>Globotruncanita elevata</i>	0.6	0.8	1	0.2	0.5	0.8	1.1	0.6											
<i>Globotruncanita angulata</i>	0.6	0.8	1	0.2	0.5	0.8	1.1	1.5											
<i>Globotruncanita stuartiformis</i>	0.6	0.2	0.7	0.5	0.1	0.2	0.1	0.1											
<i>Globotruncanita</i>	3.3	4.2	5.6	3.5	3	2.4	4.3	34.9											
<i>Abathomphalus mayaroensis</i>	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.3											
<i>Abathomphalus intermedius</i>	0.3	0.2	0.2	0.2	0.1	0.1	0.2	0.2											
<i>Abathom Phalus</i>	0.6	0.5	0.5	0.4	0.3	0.3	0.4	0.5											
<i>Parvularugoglobigerina longiapertura</i>										1.02	12.5	6.76	3.43						
<i>Parvularugoglobigerina eugubina</i>											7.1	11.9	12.1	1.1					
<i>Parvularugoglobigerina sabina</i>											4.14	7.48	8.35	5.79					
<i>Parvularugoglobigerina</i>										1.02	23.4	26.5	24	7					

Table 3

Relative abundance data of the planktic foraminiferal species and genera across the Cretaceous–Paleogene transition at the Bidart section in the >63 µm size fraction.

Biozone	<i>Abathomphalus mayaroensis</i>								<i>Gt. cretacea</i>		<i>Pv. eugubina</i>			<i>Ps. pseudobulloides</i>					
Species	B-400	B-300	B-200	B-100	B-50	B-25	B-6–10	B-0–2	B+0+2	B+3+6	B+13+17	B+25+29	B+50	B+117	B+155	B+165	B+210	B+300	B+360
<i>Contusotruncana contusa</i>	0.6	0.2	0.7	0.5	1.3	2.1	0.2	0.6											
<i>Contusotruncana patelliformis</i>	0.6	0.2	1.2	0.5	1	2.4	0.2	0.6											
<i>Contusotruncana walfischensis</i>	0.6	0.5	0.2	0.2	0.1	0.2	0.2	0.1											
<i>Contusotruncana plicata</i>	0.6	0.8	0.2	0.1	0.1	0.2	0.1	0.1											
<i>Contusotruncana</i>	2.4	1.9	2.5	1.3	1.6	4.8	0.7	1.4											
<i>Palaeoglobigerina alticonusa</i>									3.5	4.4	3.4	5.7	3.3						
<i>Palaeoglobigerina fodina</i>									1.3	5.4	3.4	4	2.1						
<i>Palaeoglobigerina luterbacheri</i>									4.2	5.1	7.3	5.3	6.1						
<i>Palaeoglobigerina minutula</i>										5.2	3.1	6.2	4						
<i>Palaeoglobigerina</i>									9	20.1	17.2	21.2	15.5						
<i>Globoconusa daubjergensis</i>														0.6	0.7	1.3	1	0.5	1.3
<i>Globoconusa</i>														0.6	0.7	1.3	1	0.5	1.3
<i>Eoglobigerina eobulloides</i>													4.5	3.8	4.3	2	1	2.9	2.5
<i>Eoglobigerina simplicissima</i>													3.2	1	1.4	2.7	0.9	2.1	6.3
<i>Eoglobigerina trivialis</i>														1.7	1.4	0.6	0.5	1.1	1.3
<i>Eoglobigerina edita</i>														1.2	2.3	1.2	1.1	0.6	0.4
<i>Eoglobigerina microcellulose</i>														1.3	0.7	1.6	1.4	1.8	2.3
<i>Eoglobigerina</i>												7.7	9	10.1	8.1	4.9	8.5	12.8	
<i>Parasubbotina moskvini</i>												2.2	0.3	1.2	0.4	0.7	1.2	1.1	
<i>Parasubbotina pseudobulloides</i>													2.4	1.4	0.6	0.5	1.1	1.3	
<i>Parasubbotina varianta</i>													0.3	1.2	0.5	3.7	4.5	2.7	
<i>Parasubbotina</i>												2.2	3.1	3.8	1.5	4.9	6.8	5.1	
<i>Subbotina triloculinoides</i>																	6.8	4.1	4
<i>Subbotina</i>																	6.8	4.1	4
<i>Globanomalina archeocompressa</i>												3.1	3.2	2.1	2.9	1.2	0.5	1.3	
<i>Globanomalina planocompressa</i>														2.1	3.1	1.3	1.1	1.5	2.3
<i>Globanomalina imitata</i>													5.3	5.1	2.2	2.4	2.3	1.3	2.7
<i>Globanomalina</i>													8.4	10.4	7.4	6.6	4.6	3.3	6.3
<i>Praemurica taurica</i>												0.38	1	1.4	4.7	3.1	1.1	1.3	
<i>Praemurica inconstans</i>														0.5	0.7	5.4	3.1	2.2	1.4
<i>Praemurica pseudoinconstans</i>														2	5	4	4.2	0.5	1.1
<i>Praemurica</i>												0.38	3.5	7.2	14.1	10.5	4	3.8	
<i>Woodringina hornerstownensis</i>									2.5	3.6	7.23	7.63	13.7	19.4	18.8	21.5	20.5	9.5	
<i>Woodringina claytonensis</i>									2	0.7	4.83	4.58	6.2	2.8	1.3	6.3	8	2.7	
<i>Woodringina</i>									4.6	4.3	12.06	12.21	19.9	22.2	20.1	27.8	28.5	12.2	
<i>Chioguembelina taurica</i>											2.2	5.79	6.87	7.6	3.6	1.3	5.2	7.4	1.3
<i>Chioguembelina midwayensis</i>												6.28	6.1	7.2	2.8	2	6.8	6.2	2.7
<i>Chiloguembelina</i>											2.2	12.07	12.97	14.8	6.4	3.3	12	13.6	4
Total number counted	356	373	403	352	378	343	357	309	43	187	127	219	273	264	129	162	197	194	83

calculation and quantitative data were based on representative splits (using an Otto micro-splitter) containing between 300 and 400 specimens of planktic foraminifers larger than 63 μm .

The preservation of the planktic foraminifers is generally good. Faunal counts for >63 μm size fraction are listed in Tables 1–3.

3. Biostratigraphy

The Maastrichtian and Danian foraminiferal biozonation used in this paper is based on the studies in middle and lower latitudes (Fig. 3) published by Zaghbib-Turki et al. (2000), Arz and Molina (2002) and Arenillas et al. (2004). For the uppermost Maastrichtian and the lower Danian we used standard planktic foraminiferal zones:

3.1. *Abathomphalus mayaroensis* Zone

As defined by Bolli (1966), this zone corresponds to the total range interval of the nominate species (Fig. 3). At Bidart, *A. mayaroensis* is scarce in the uppermost Maastrichtian interval (Fig. 4), but it is present up to the K/Pg boundary. Although the Bidart section exhibits no hiatus, *Plummerita hantkeninoides* has not been found. This uppermost Maastrichtian index fossil seems to be absent in the sections of the Bay of Biscay area (Apellániz et al., 1997), and the Pyrenees (Arz and Molina, 2002). Keller (1993) has not found it in higher latitudes of the Atlantic and Antarctic oceans (DSDP sites 738C, 752B and 690C). It is possible, that this species is restricted to the deeper water of the tropical and subtropical realms. At the Bidart section, the most reliable index species of the uppermost Maastrichtian is *Psg. hariaensis*.

3.2. *Guembelitra cretacea* Zone

This zone was initially defined by Smit (1982) as the interval between the last occurrence datum (LOD) of typical Cretaceous taxa (*Abathomphalus*, *Globotruncana*, *Pseudoguembelina*, among others) at the K/Pg boundary and the first occurrence datum (FOD) of *Globigerina minutula* (= *Palaeoglobigerina alticonusa* in this paper).

Smit (1982) named it P0 Biozone. Its magnetostratigraphic position is in Chron C29r. The taxonomic concept of this zone is similar to that of the *Globocanusa conusa* Zone by Zaghbib-Turki et al. (2000), since the concept of *Gc. conusa* by these authors is the same as that of *G. minutula* by Smit (1982) and *Palg. alticonusa* in this paper. Bolli (1966) and Toumarkine and Luterbacher (1985) did not define any zone for this lowermost Danian interval. They placed the base of their *Globigerina eugubina* Zone at the FOD of *Parvularugoglobigerina eugubina*, which does not coincide with the K/Pg boundary as it is known today. Nevertheless, many others followed the original definition of the *Pv. eugubina* Zone by Luterbacher and Premoli-Silva (1964), and emended the P0 Biozone by Smit (1982) as the biostratigraphic interval between the LOD of *A. mayaroensis* with the other globotruncanids and the FOD of *Pv. eugubina* (e.g. Berggren and Miller, 1988; Smit, 1982; Berggren et al., 1995; Molina et al., 1996; Arenillas et al., 2004; Berggren and Pearson, 2005).

The *Gt. cretacea* Zone was subdivided into the *Hedbergella holmdelensis* and *Parvularugoglobigerina longiapertura* Subzones by Arenillas et al. (2004), because *Pv. longiapertura* is a distinct species and not a senior synonym of *Pv. eugubina*. At Bidart, the FODs of *Pv. longiapertura* and *Pv. eugubina* occur respectively at ~4 cm and ~15 cm above the K/Pg boundary.

SYSTEMS	STAGES	Index-species (This study)	BIOZONATIONS						
			Arenillas et al. (2004), Arz and Molina (2002)		Zaghib-Turki et al. (2000)	Berggren et al. (1995), Berggren and Pearson (2005)	Keller et al. (1995)	Smit (1982)	
LOWER PALEOGENE	LOWER DANIAN	<i>S. triloculinoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1b <i>S. triloculinoides</i> <i>G. compressa</i>	P1c <i>Pr. inconstans</i> +	P1c(2)	P1b
		<i>Pv. eugubina</i> L							
		<i>Ps. pseudobulloidis</i> L	<i>Eoglobigerina trivialis</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1(c1)		
		<i>Pv. longiapertura</i> L							
UPPER CRETACEOUS	UPPER MAASTRICHTIAN	<i>E. simplicissima</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1b	P1a
		<i>Pv. eugubina</i> L							
		<i>Pv. longiapertura</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(2)	
		<i>Gt. cretacea</i> L							
UPPER CRETACEOUS	UPPER MAASTRICHTIAN	<i>Ab. mayaroensis</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	P1a
		<i>Psg. hariaensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
UPPER CRETACEOUS	UPPER MAASTRICHTIAN	<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	P1a
		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
UPPER CRETACEOUS	UPPER MAASTRICHTIAN	<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	P1a
		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
UPPER CRETACEOUS	UPPER MAASTRICHTIAN	<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	P1a
		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
UPPER CRETACEOUS	UPPER MAASTRICHTIAN	<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	P1a
		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
UPPER CRETACEOUS	UPPER MAASTRICHTIAN	<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	P1a
		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
UPPER CRETACEOUS	UPPER MAASTRICHTIAN	<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	P1a
		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
UPPER CRETACEOUS	UPPER MAASTRICHTIAN	<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	P1a
		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
UPPER CRETACEOUS	UPPER MAASTRICHTIAN	<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	P1a
		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
UPPER CRETACEOUS	UPPER MAASTRICHTIAN	<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	P1a
		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
UPPER CRETACEOUS	UPPER MAASTRICHTIAN	<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	P1a
		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
UPPER CRETACEOUS	UPPER MAASTRICHTIAN	<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	P1a
		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
UPPER CRETACEOUS	UPPER MAASTRICHTIAN	<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	P1a
		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
UPPER CRETACEOUS	UPPER MAASTRICHTIAN	<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	P1a
		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
UPPER CRETACEOUS	UPPER MAASTRICHTIAN	<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	P1a
		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
UPPER CRETACEOUS	UPPER MAASTRICHTIAN	<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	P1a
		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
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		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
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		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
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		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
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		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
UPPER CRETACEOUS	UPPER MAASTRICHTIAN	<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	P1a
		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
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		<i>Abathomphalus mayaroensis</i> L							
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		<i>Abathomphalus mayaroensis</i> L							
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		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
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		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
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		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
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		<i>Abathomphalus mayaroensis</i> L							
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		<i>Abathomphalus mayaroensis</i> L							
		<i>Plummerita hantkeninoides</i> L	<i>Parasubbotina pseudobulloidis</i>	<i>Subbotina triloculinoides</i>	<i>Parasubbotina pseudobulloidis</i>	P1a <i>Pv. eugubina-Subbotina triloculinoides</i>	<i>P. varianta</i> +	P1a(1)	
		<i>Abathomphalus mayaroensis</i> L							
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		<i>Abathomphalus mayaroensis</i> L							
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		<i>Abathomphalus mayaroensis</i> L							
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		<i>Abathomphalus mayaroensis</i> L							
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		<i>Abathomphalus mayaroensis</i> L							
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		<i>Abathomphalus mayaroensis</i> L							
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		<i>Abathomphalus mayaroensis</i> L							
UPPER CRETACEOUS									

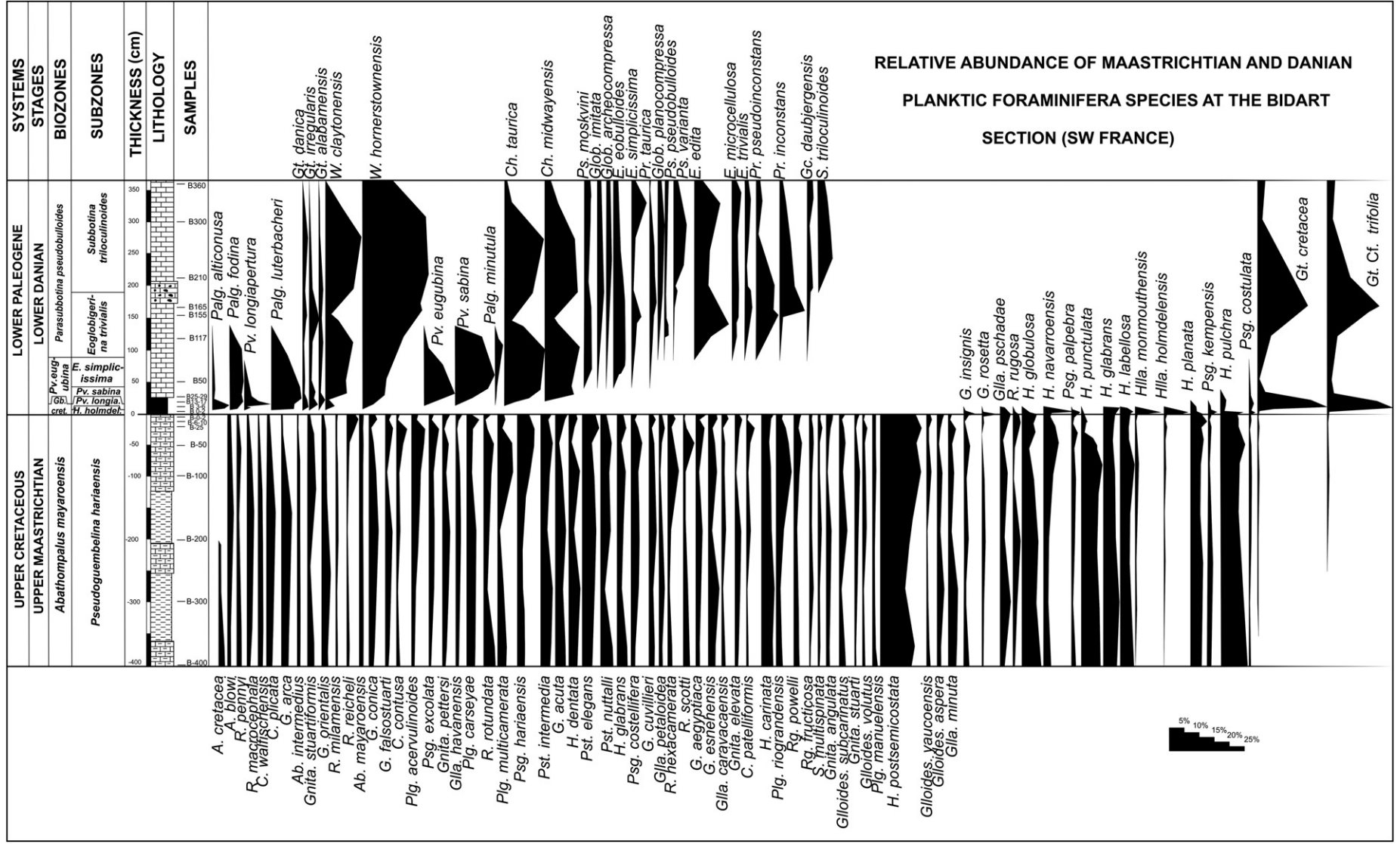


Fig. 4. Relative abundances of the Maastrichtian and Danian planktic foraminiferal species at the Bidart section. Genera abbreviations mentioned in this figure and text: A: *Archaeoglobigerina*, Ab: *Abathomphalus*, C: *Contusotruncana*, Ch: *Chiloguembelina*, E: *Eoglobigerina*, G: *Globotruncana*, Gnita: *Globotruncanita*, Glla: *Globotruncanella*, Glloides: *Globigerinelloides*, Glob: *Globanomalina*, Gt: *Guembelitra*, Gc: *Globoconusa*, H: *Heterohelix*, Hlla: *Hedbergella*, Plg: *Planoglobulina*, Psg: *Pseudoguembelina*, Pst: *Pseudotextularia*, Palg: *Palaeoglobigerina*, Pv: *Parvularugoglobigerina*, Ps: *Parasubbotina*, Pr: *Praemurica*, R: *Rugoglobigerina*, Rg: *Racemiguembelina*, S: *Schackoina*, S: *Subbotina*, W: *Woodringina*.

The lower subzone of the *Gt. cretacea* Zone is the stratigraphic interval between the LOD of *A. mayaroensis* together with many other globotruncanids and *P. hariaensis* to the FOD of *Pv. longiapertura*. It is equivalent to the P0 Zone of Smit (1982), Keller (1993), Berggren et al. (1995), Zaghbib-Turki et al. (2000) and Berggren and Pearson (2005). The overlying subzone is the interval from the FOD of *Pv. longiapertura* to the FOD of *Pv. eugubina*. Since Berggren et al. (1995) considered *Pv. longiapertura* to be a senior synonym of *Pv. eugubina*, they included the interval corresponding to the *Pv. longiapertura* Subzone in their P α Zone. This interval, with an estimated duration of 18–21 ky (Arenillas et al., 2004), is in the upper part of basal Danian Chron C29r (Berggren and Pearson, 2005).

At the Bidart section, the *Gt. cretacea* Zone is characterized by high relative abundance of *Guembelitra*. It is ~15 cm thick. The samples from this zone are very poor in fauna; planktic foraminifers are scarce and dominated by small sized heterohelicids such as *Heterohelix globulosa*, *Heterohelix planata*, *Heterohelix navarroensis*, *Guembelitra* and tiny hedbergellids.

3.3. *Parvularugoglobigerina eugubina* Zone

This zone was defined by Luterbacher and Premoli-Silva (1964) as the biostratigraphical interval characterized by the total range of the nominate taxon (Fig. 3). The P α by This definition was used for the P1a Biozone by Keller (1988), and Keller et al. (1995), and Zaghbib-Turki et al. (2000), and for the P α Biozone by Berggren et al. (1995) and Berggren and Pearson (2005). Keller et al. (1995) used the *Parasubbotina pseudobulloides* FOD to subdivide this biozone into P1a (1) and P1a (2). The biozone was emended by Bolli (1966), Blow (1979) and Toumarkine and Luterbacher (1985), by placing the top of the biozone at the FOD of *Ps. pseudobulloides* (Fig. 3). The emended definition was followed by Molina et al. (1996) and Arenillas et al. (2004). Their *Pv. eugubina* Zone is not exactly equivalent to the P1a by Zaghbib-Turki et al. (2000) or to the P α by Berggren and Pearson (2005). Nevertheless, many authors working on other complete K–Pg transition sections (e.g. El Kef, Ellès, Agost, Caravaca, Zumaya, Ain Settara) have noted that the FOD of *Ps. pseudobulloides* and LOD of *Pv. eugubina* are very close (Toumarkine and Luterbacher, 1985; Keller, 1993; Haslett, 1994; Molina et al., 1998; Arenillas et al., 2000a,b; Molina et al., 2006). Also in Bidart, the two biohorizons are very close; the FOD of *Ps. pseudobulloides* is at ~100 cm above the K/Pg boundary, and the LOD of *Pv. eugubina* is at ~125 cm. Applying the biozonation by Zaghbib-Turki et al. (2000), the thickness of the *Pv. eugubina* Zone at the Bidart section is ~100 cm.

The *Pv. eugubina* Zone was subdivided by Arenillas et al. (2004) into the *Parvularugoglobigerina sabina* and *Eoglobigerina simplicissima* Subzones. The boundary between these two subzones is the FOD of *E. simplicissima*, i.e., the first occurrence of species with pitted or weakly cancellate surface wall as typical of eoglobigerinids in the Cenozoic. At the Bidart section, the FOD of *E. simplicissima* is observed at ~50 cm above the K/Pg boundary.

3.4. *Parasubbotina pseudobulloides* Zone

This zone was introduced by Leonov and Alimarina (1961) as *Globigerina pseudobulloides*–*Globigerina daubjergensis* Zone. Bolli (1966) shortened the name to *G. pseudobulloides*. It was defined as the interval between the LOD of *Pv. eugubina* and the FOD of *Acarinina trinidadensis* (Toumarkine and Luterbacher, 1985; Zaghbib-Turki et al., 2000). In our opinion, the *Ps. pseudobulloides* Zone includes approximately the P1b, P1c subzones of Keller et al. (1995). Berggren et al. (1995) and Berggren and Pearson (2005) redefined it as the interval between the FOD of *Ps. pseudobulloides* and the FOD of *Acarinina uncinata*, and named it Biozone P1. They divided it into three subzones: P1a, P1b and P1c, using the FODs of *Subbotina triloculinoides* and *Globanomalina compressa* as markers of the boundaries between

the subzones. Molina et al. (1996) also emended the definition of the top of the biozone and redefined it as the interval between the FOD of *Ps. pseudobulloides* and the FOD of *Gl. compressa*. Later, Arenillas et al. (2004) subdivided the *Ps. pseudobulloides* Zone into the *Eoglobigerina trivialis* and *S. triloculinoides* Subzones (Fig. 3). Only its lower part is studied in this paper. At the Bidart section, the FOD of *S. triloculinoides* characterizing the boundary between both subzones occurs at ~175 cm above the K/Pg boundary.

4. Turnover of the planktic foraminiferal assemblages

The qualitative and quantitative analysis across the K/Pg boundary in Bidart indicates that the uppermost Cretaceous planktic foraminiferal assemblages were much diversified, in contrast to the lowermost Paleocene ones, which were less diversified (Figs. 4 and 5).

Those of the Upper Maastrichtian are composed of 72 species. They are dominated by biserial, multiserial and spiral morphotypes belonging mainly to *Heterohelix*, *Planoglobulina* and *Rugoglobigerina* (Fig. 5). These cosmopolitan species represent about 70% of the assemblages (in the fraction larger than 63 μ m). The relative abundances of *Heterohelix* species (including *H. planata*, *H. pulchra*, *H. navarroensis*, *H. labellosa* and *H. glabrans*) exceed 50%. In contrast to other Pyrenean sections (Arz and Arenillas, 1998), representatives of the genus *Gublerina* are also frequent in Bidart. *Rugoglobigerina* species (e.g. *R. milamensis*, *R. reicheli*, *R. scotti*) are frequent, whereas planispiral (*Globigerinelloides*) and other low trochospiral (*Hedbergella*, *Globotruncanella*) species are common.

The high species richness (Fig. 5) of the Maastrichtian assemblages is mainly due to larger and more complex species belonging to globotruncanids with ornate and keeled trochospiral tests (e.g. *Globotruncana*, *Globotruncanita*, *Abathomphalus*) and large biserial and multiserial heterohelicids (e.g. *Pseudotextularia*, *Racemiguembelina*, *Planoglobulina*). These species are considered as dwelling in a deep habitat, and are more diversified (with 46 species) but less abundant (~30%) than the cosmopolitan species (30 species and ~70%) (Fig. 5).

Only very slight changes in the composition of planktic foraminiferal assemblages are observed within the upper part of the Psg. *hariaensis* Subzone, below the K/Pg boundary. As also observed by Arenillas et al. (2006) at the El Kef section, *A. cretacea* is the only species having its LOD slightly below the K/Pg boundary.

In Bidart, the LODs of 53 species coincide with the K/Pg boundary, meaning that at least 73.6% of the uppermost Maastrichtian species suddenly became extinct. The extinct taxa are mainly globotruncanids and heterohelicids with large and ornate tests, belonging to the genera *Contusotruncana*, *Globotruncana*, *Globotruncanita*, *Abathomphalus*, *Rugoglobigerina*, *Gublerina*, *Racemiguembelina*, *Planoglobulina* and *Pseudotextularia*. These taxa are considered to be inhabitants of deeper and intermediate water depths of the tropical to subtropical latitudes (Hart, 1980; Zaghbib-Turki et al., 2000). This extinction of 73.6% of the planktic foraminiferal species at the same level in Bidart corroborates the pattern of a catastrophic mass extinction coinciding with the K/Pg boundary.

In the lowermost Danian (e.i. *Gt. cretacea* Zone), the planktic foraminiferal assemblages are poor and little diversified. They are dominated by small species mainly belonging to the genus *Guembelitra* which we consider to be “generalistic” or “opportunistic” Cretaceous “survivors”. In addition to these Cretaceous “survivors”, the lowermost Danian contains representatives of the genera *Palaeoglobigerina* (*Palg. alticonusa*, *Palg. fodina*) and *Parvularugoglobigerina* (*Pv. longiapertura*). Initially, these Danian “pioneers” are very rare (Fig. 4). The basal Danian also contains specimens of other Cretaceous species (e.g. *Globotruncana insignis*, *G. rosetta*, *Globotruncanella pschadae*, *H. globulosa*, *H. navarroensis*, *H. punctulata*, *H. glabrans*, *H. labellosa*, *H. planata*, *H. pulchra*, *Rugoglobigerina rugosa*, *Pseudoguembelina palpebra*, *Psg. kempensis* and *Psg. costulata*). These have poorly preserved (probably dissolved) wall structures and their colour, altered by ferruginization, differs from that

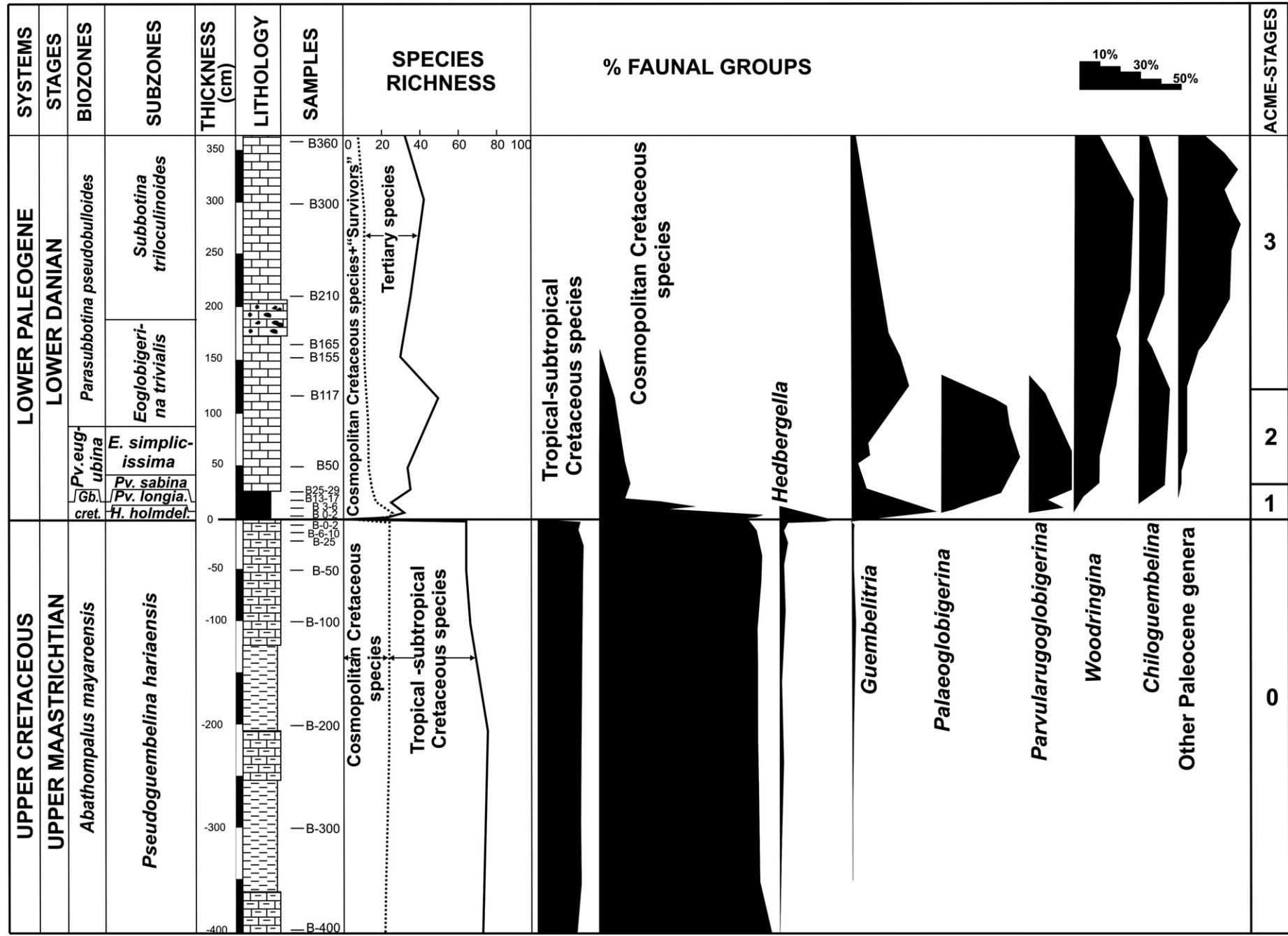


Fig. 5. Relative abundances of tropical–subtropical and cosmopolitan cretaceous species, quantitative Acme-stages and species diversity at the Bidart section in the >63 µm size fraction.

of the autochthonous Danian species. In addition, the size of these specimens is distinctly smaller than that of the representatives of the same species in the Maastrichtian, thus suggesting reworking and grain size selection. The extinction rate at the K/Pg boundary is even higher than 73.6%, if these representatives of Cretaceous species are considered to be allochthonous. Elsewhere at Caravaca and other sections, the isotopic data supported that representatives of the same species found in the lowermost Danian are reworked (Kaiho and Lamolda, 1999; Macleod et al., 2001).

Within the *Pv. eugubina* Zone, some Danian species reached a larger size (>150 µm). Species with smooth wall texture (e.g., *Gl. planocompressa*, *Gl. imitata* and *Gl. archeocompressa*) have their FODs in the middle and upper part of this zone. The lower Danian assemblages became largely dominated by *Palaeoglobigerina* (*Palg. luterbacheri*, *Palg. minutula*) and *Parvularugoglobigerina* (*Pv. eugubina*, *Pv. sabina*). Moreover, eleven (11) planktic foraminiferal species appear gradually. In the upper part of the same zone, the LODs of seven species belonging to *Parvularugoglobigerina* and *Palaeoglobigerina* that have a smooth wall surface are observed (i.e. *Pv. longiapertura*, *Pv. eugubina*, *Pv. sabina*, *Palg. alticonusa*, *Palg. fodina*, *Palg. luterbacheri*, *Palg. minutula*). Many species originated in the *Gt. cretacea* zone and the *Pv. eugubina* zone have short stratigraphical ranges.

Within the *Ps. pseudobulloides* Zone, the FODs of ten (10) species are progressively recorded. Nine (9) of them appeared in the lower part of the zone (sample B117): *Gl. planocompressa*, *Ps. pseudobulloides*, *Ps. varianta*, *E. edita*, *E. microcellulosa*, *E. trivialis*, *Praemurica pseudoinconspans*, *Pr. inconspans*, *Gc. daubjergensis*; whereas *S. triloculinoides* have their FODs in the middle part of the biozone. General trends in the evolution of the planktic foraminiferal assemblages within the *Ps. pseudobulloides* Zone include the increase in size, the diversification of the wall structure, and the increase of the species diversity.

The changes in the species relative abundance, observed in the successive planktic foraminiferal assemblages at Bidart section, make it possible to recognize four Acme-stages across the K/Pg transition (see also Arenillas et al., 2000a,b; Fig. 5).

4.1. Acme-stage 0

This Acme-stage is typical of the upper Maastrichtian interval. It is characterized by the highest species richness (72 species) within the entire studied interval. This Acme-stage is dominated by cosmopolitan species dwelling at near-surface and intermediate water depths (~80%), among which species belonging to the genus *Heterohelix* reach more than 50% of the assemblages. The heterohelids are associated with many less abundant (~20% in total) tropical and subtropical species, which are considered to live in deeper water. The high diversity of the generic and specific composition of the assemblages in this Acme-stage indicates optimal mesotrophic and oxygenated tropical to subtropical marine conditions.

4.2. Acme-stage 1

This Acme-stage is typical of the *Gt. cretacea* Zone at Bidart, and in particular of the *Hlla. holmdelensis* Subzone. It is characterized by a low abundance, low species richness, and small sized species. The assemblages are dominated by species belonging to *Guembelitra*, which are “opportunists” and constitute the bulk of the “Cretaceous survivors” of the K/Pg boundary event. The Danian “pioneer species” (e.g., *Palg. alticonusa*, *Palg. fodina*, *Pv. longiapertura*) are less abundant (<10%) and always smaller than 150 µm.

4.3. Acme-stage 2

This Acme-stage corresponds to the *Pv. eugubina* Zone. At the Bidart section, the assemblages characterizing this stage are dominated mainly by specimens belonging to *Palaeoglobigerina* and *Parvularugoglobigerina*, which together reached 55%. Representatives of the genera *Chiloguembelina* (10–15%) and *Woodringina* (15–20%) show a rather unequal distribution.

4.4. Acme-stage 3

This Acme-stage characterizes mainly the *Ps. pseudobulloides* Zone. Its assemblages are dominated by biserial species belonging to *Chiloguembelina* (about 15%) and *Woodringina* (about 30%). *Guembelitra* is frequent (~18%) in the lower part of this Acme-stage (approximately in the *E. trivialis* Subzone). Within the middle and upper part of Acme-stage 3, species of *Praemurica* become more common, while those having cancellate spinose and non spinose wall (*Subbotina*, *Parasubbotina* and *Praemurica*) are less abundant. They are considered to have lived near the sea surface.

The succession of distinct Acme-stages characterized by the predominance of one or several taxa within the Cretaceous–Paleogene transition of the Bidart section is comparable with that recognized at Spanish (e.g. Zumaya, San Sebastian, Osinaga, Músqiz) and Tunisian sections (e.g. El Kef, Ellès and Ain Settara) by Arenillas et al. (1998, 2000a). The planktic foraminiferal assemblages of the Bidart section are close to those of the neighbouring Zumaya section in both the uppermost Maastrichtian and the lowermost Paleogene.

5. The extinction pattern at the K/Pg boundary

The debate on the planktic foraminiferal extinction model at the K/Pg boundary is still controversial mainly because it reflects differences in the methodologies used to obtain the data and different interpretations of these data (Molina et al., 1996, 1998, 2006; Arenillas et al., 2000b). The biostratigraphic and quantitative analyses, indicates that sedimentation at the Bidart section across the K/Pg transition is continuous, i.e., without any relevant hiatus.

Authors and studied sections Age	Keller (1988) El Kef	Keller et al. (1995) El Kef	Zaghbi-Turki et al. (2000) Ellès	Arenillas et al. (2000 a) Ain Settara	Arz et al. (2000) Caravaca	Molina et al. (1998) Agost	Arz et al. (1999) Zumaya	Arenillas et al. (2000 b) El Kef	(This paper) Bidart
DANIAN (Cretaceous survivors) ↓	10 (18%)	24 (19%)	13 (23%)	18 (28%)	17 (25%)	16 (24%)	15 (24%)	15 (22.5%)	4 (5.5%)
K/Pg: (Extinct species)	31 (58%)	7 (12%)	36 (63%)	44 (65%)	49 (71%)	47 (70%)	44 (71%)	46 (68.6%)	53 (73%)
MAASTRICHTIAN (Extinct species) ↓	12 (24%)	24 (69%)	8 (14%)	5 (7%)	3 (4%)	4 (6%)	3 (5%)	6 (8.9%)	1 (1.38%)

Fig. 6. Comparative number and frequencies of extinct species below and at the K/Pg boundary and the Cretaceous survivors at the lower Danian interval.

As in Zumaya (Molina et al., 1998; Arz et al., 1999), *P. hantkeninoides* was absent in Bidart and *A. cretacea* disappears a few meters below the K/Pg boundary. Lamolda (1990) indicated that *A. mayaroensis* is absent in the uppermost Maastrichtian of the Zumaya section; but Molina et al. (1998) have found this species in the uppermost Maastrichtian sample. In our high-resolution sampling and the intensive search for this species in the 25 cm below the K/Pg boundary at the Bidart section (from sample B-25 to sample B-2-0) we have however found very scarce specimens of *A. mayaroensis* in all Maastrichtian samples.

In Bidart, the mass extinction pattern at the K/Pg (53 species becoming extinct at the same level) is similar to that recognized at Spanish sections (Agost – 46 extinct species, Caravaca – 46 extinct species, Zumaya – 44 extinct species and San Sebastián – 44 extinct species; see Molina et al., 1996, 1998; Arz et al., 1999, 2000) and Tunisian sections (El Kef – 46 extinct species, Ellès – 36 or 45 extinct species, El Melah – 35 extinct species; see Arenillas et al., 2000b; Zaghib-Turki et al., 2001; Karoui-Yaakoub et al., 2002 and Ain Settara – 44 extinct species; see Arenillas et al., 2000a). There are only minor differences in the number of species and the morphotypes affected by the catastrophic event at the K/Pg boundary (Fig. 6).

Keller (1988) and Keller et al. (1995) suggested that the planktic foraminiferal extinction pattern across the K/Pg boundary at El Kef section is gradual and compatible with multiple extinction causes, including an increase of volcanic intensity and a drop in sea level. In their papers, these authors indicate extinction ratios which differ significantly from those that we and others have found. Keller (1988) estimated 24% of the upper Maastrichtian species disappeared prior to the K/Pg boundary, 58% of extinct species at the K/Pg boundary and 18% of “Cretaceous survivors”. Later, Keller et al. (1995) changed these percentages to 69% extinct species prior to the K/Pg boundary, 12% at the K/Pg boundary and 19% “survivors”. A test of the planktic foraminiferal distribution across the K/Pg boundary at El Kef section by Arenillas et al. (2000b) concluded that only 8.9% of the upper Maastrichtian species (representing 6 species: *A. cretacea*, *A. blowi*, *C. patelliformis*, *C. plicata*, *Abathomphalus intermedius* and *Gublerina acuta*) disappeared below the boundary, 68.6% of species became extinct at the K/Pg boundary and 22.5% probably survived into the lower Danian.

If the probably reworked specimens are confused with “survivors”, the extinction rate at the K/Pg boundary could be as high as ~95% of the planktic foraminiferal species, whereas the “Cretaceous survivors” persisting along the Danian is restricted to very few “opportunistic” species as *Gt. cretacea* and *G. cf. trifolia*, and may be some “generalist” species of *Hedbergella* and *Heterohelix*.

The small (<100 µm) *Guembelitra* species are rare (<2.5%) during the uppermost Maastrichtian (Acme-stage 0). During the lowermost Danian, the *Guembelitra* species with “opportunist” behavior, became more abundant (40%). In shallow marine environments (e.g. at Stevns Klint and Selja sections), the relative abundance of *Guembelitra* species also rises, but does not exceed 10–20% (Keller, 1993; Keller et al., 2002), but in deeper environments (e.g. El Kef, Ellès, El Melah, Ain Settara and Zumaya), the relative abundance of *Guembelitra* species can reach 80% (Arz et al., 1999; Arenillas et al., 2000a, Zaghib-Turki et al., 2000, 2001; Karoui-Yaakoub et al., 2002). This indicates that they are real “survivors”, which adapted to environmental stress conditions better than other species (Zaghib-Turki et al., 2000, 2001). The status as “survivors” of other short-ranging species (e.g., *H. labellosa*, *R. rugosa*, or *G. pschadae*) which progressively became extinct in Acme-stage 1 is more doubtful. The hedbergellids as *Hlla. monmouthensis* and *Hlla. holmdelensis* are less frequent than the guembelitrids in Acme-stage 1, but their relative abundance increases in the lower part of the *Gt. cretacea* Zone of the Bidart section. Like the guembelitrids and perhaps a few heterohelids and hedbergellids, these two species could be possible “survivors” (Olsson et al., 1999; Arenillas et al., 2000a,b).

The species of *Guembelitra* are the only “Cretaceous survivors” which lived for a long-time in the Danian and probably play a significant role in the phylogeny of the Danian “pioneer” taxa (Olsson and Liu, 1993; Smit and Nederbragt, 1997; Berggren and Norris, 1997; Molina et al., 1998; Arenillas et al., 1998, 2000a,b). The “Cretaceous survivor” species coexist with tiny globigerinids (e.g., *Palg. alticonusa*, *Palg. fodina*, *Palg. minutula*, *Palg. luterbacheri*, *Pv. longiapertura*, *Pv. sabina*, *Pv. eugubina*) and new taxa of heterohelids (e.g., *Woodringina claytonensis*, *W. hornerstownensis*, *Chiloguembelina taurica*, *Ch. midwayensis*), which first occur in the basal Danian (Acme-stage 1). Subsequently, in the Acme-stages 2 and 3, globigerinids became more and more diversified.

6. Conclusion

Our high-resolution biostratigraphical analysis confirms that the Bidart section (SW France) is complete and continuous across the K–Pg transition. We could not recognize any stratigraphic hiatus. All the planktic foraminiferal zones and subzones characterizing the uppermost Maastrichtian–lower Danian interval are present and easily recognized by their well preserved index species (Upper Maastrichtian: *A. mayaroensis* Zone with the *P. hariaensis* Subzone, lowermost Danian: *Gt. cretacea* Zone, *Pv. eugubina* Zone and *Ps. pseudobulloides* Zone).

At the Bidart section, the catastrophic mass extinction at the K/Pg boundary is recorded at the base of a 2 mm thick “rusty layer” as it is at the El Kef section (GSSP for the K/Pg boundary) and at most of the other complete sections (e.g., Ellès, Ain Settara, Zumaya, Agost, Caravaca). This catastrophic extinction affected the representatives of the genera *Abathomphalus*, *Rugoglobigerina*, *Pseudotextularia*, *Contusotruncana*, *Globotruncana*, *Globotruncanita*, *Racemigubelina*, i.e. the tropical to subtropical deep-water dwellers. Moreover, a sharp decrease in the abundance and the species richness of the planktic foraminifera is recorded just above the “rusty layer”. Only *Gt. cretacea* and *Gt. cf. trifolia* are the most probable true “Cretaceous survivors”, whereas species of *Hedbergella* (*Hlla. holmdelensis* and *H. monmouthensis*) and *Heterohelix* (e.g., *H. globulosa* and *H. navarroensis*) are somewhat more doubtful candidates.

The progressive early Danian turnover of planktic foraminiferal assemblages starts with the K/Pg boundary. At the Bidart section, this turnover occurs in three stages recorded as planktic foraminiferal Acme-stages 1 to 3. Acme-stage 1 is characterized by a predominance of *Guembelitra* species, a few other probable Cretaceous “survivor” species and a few Danian “pioneer” species. These “pioneers” have their first occurrences in the upper part of the *Gt. cretacea* Zone. These latter belonging to the genera *Palaeoglobigerina* and *Parvularugoglobigerina*, are predominant at Acme-stage 2 which mainly corresponds to the *Pv. eugubina* Zone. Finally, Acme-stage 3 in the *Ps. pseudobulloides* Zone is characterized by the predominance of new biserial taxa: *Woodringina* and *Chiloguembelina*, and the first record of larger and phylogenetically more evolved species of the genera *Eoglobigerina*, *Parasubbotina*, *Subbotina*, *Globoconusa*, *Globanomalina* and *Praemurica* with a cancellate wall.

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