

Biostratigraphy and Mass Extinction Pattern across the Cretaceous/Paleogene Boundary, Northern Alborz, Iran

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ABSTRACT

High resolution sampling across the Cretaceous/Paleogene boundary (K/Pg) at the Galanderud section in northern Iran provides the most expanded and continuous section for us to consider biostratigraphy and the mass extinction pattern of Cretaceous planktic foraminifera. Based on planktic foraminifera, four biozones and five sub-biozones have been identified across the K/Pg boundary. These biozones include the *Abathomphalus mayaroensis* Biozone (*Plummerita hantkeninoides* subbiozone), the *Guembelitria cretacea* Biozone (including two sub-biozones: the *Hedbergella holmdelensis* and the *Parvularugoglobigerina longiapertura*), the *Parvularugoglobigerina eugubina* Biozone (including two subbiozones: the *Parvularugoglobigerina Sabina* and the *Eoglobigerina simplicissima*) and finely the *Parasubbotina pseudobulloides* Biozone. Planktic foraminiferal extinction occurred over a brief period, with 3% of the species disappearing in the late Maastrichtian, and 72% of the species becoming extinct at the K/Pg boundary. About 25% of the species are survived into the early Danian. Extinction of 73% of the species at the K/Pg boundary is very compatible with the effect of a large asteroid impact.

Keywords: Biostratigraphy; Mass Extinction Pattern; Cretaceous/Paleogene Boundary; Northern Alborz; Iran

1. Introduction

The Cretaceous-Paleogene boundary (K/Pg) is one of the major crises in the history of life on Earth. Planktonic foraminifera suffered the most dramatic extinctions among marine organisms across the Cretaceous-Paleogene boundary. The proposed causes of this mass extinction are widely considered as a combination of degassing of the Deccan Traps and a bolide impact in Chicxulub, Mexico [1]. Alvarez and his colleagues [2] suggested the bolide impact theory as the cause for the mass extinctions at Cretaceous-Paleogene boundary. This meteorite impact is evidenced by anomalous abundance of Ir, microtektites, shocked quartz and Ni-rich spinels in K/Pg boundary deposits. Also, Courtillot [3] and Keller *et al.*, 2011 pointing out the key role of volcanic eruptions in mass extinction at the end of the Cretaceous. The planktonic foraminifera mass extinction at the K-Pg boundary event has been pointed out by many specialists [4-6]. The aim of this paper is to determine the biostratigraphy and model the extinction pattern of planktonic foraminiferal species in the Galanderud section.

2. Location and Lithology

The Alborz Mountain system of northern Iran, extends in a sinuous manner for about 2000 km from the Lesser Caucasus of Armenia and Azerbaijan Republics of the former Soviet Union to the Paropamisus Mountains of northern Afghanistan in the northeastern corner of Iran east [7].

The section that was sampled is located next to a limestone mine, about 25 km south of the city of Royan and in the southwest corner of Noor province. An exposure of 7 m spanning the K/Pg boundary was sampled at 5 - 10 cm intervals, except for the boundary clay where samples were taken at 2 cm intervals. This study includes about 2 m of Maastrichtian and 5 m of Danian sediment. Sediments of the upper most Maastrichtian consist of brown to dark brown marls, The K/Pg transition is marked by a lithological change from brown marl at end of Maastrichtian to a clay layer preceding a chalk layer at base of Danian.

3. Materials and Methods

Samples were collected every 5 to 10 cm and every 2 cm at the critical K/Pg boundary interval. A total of 54 samples

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were analyzed for study. The samples were processed for foraminiferal analysis by standard micropaleontological techniques. They were disaggregated in tap water and washed through a 120 µm and 53 µm sieve and dried at 50°C. Preservation of the planktic Foraminifera were good to very good. In order to prevent the Signor and Lipps effect, a blind test at K/Pg boundary was used to precisely examine samples for rare species in several sieves [8].

4. Biostratigraphy

The Maastrichtian and Danian foraminiferal biozonation used in this paper is based upon studies conducted in middle and lower latitudes. The biozonation of Keller and colleagues [9] and Arenillas and colleagues [10,11] is used for this study with some changes (Figures 1 and 2). We have identified a high-resolution planktic foraminiferal zonation and have described four biozones and five subbiozones across the K/Pg boundary in this section. These biozones include: the *Abathomphalus mayaroensis* Biozone (*Plummerita hantkeninoides* subbiozone), the *Guembelitra cretacea* Biozone (including two sub-biozones: the *Hedbergella holmdelensis* and the *Parvularugoglobigerina longiapertura*), the *Parvularugoglobigerina eugubina* Biozone (including two sub-biozones: (the *Parvularugoglobigerina Sabina* and the *Eoglobigerina simplicissima*) and the *Parasubbotina*

pseudobulloides Biozone.

4.1. *Abathomphalus mayaroensis* Zone

This zone initially introduced by Bronnimann [12] was defined by great diversity of the nominate taxon. This species is rare or absent in shallow water and at high latitudes appeared in the Campanian, but disappears prior to the K/Pg boundary [8].

Based on Keller [9] the *A. mayaroensis* zone is subdivided into four subzones in stratigraphic order: the *Racemiguembelina fructicosa*, the *Pseudoguembelina hariensis*, the *P. palpebra* and the *Plummerita hantkeninoides* subzones. Also, Keller (1995) initially proposed the *Plummerita hantkeninoides* Zone for the uppermost Maastrichtian at El Kef, Tunisia and Agost, Spain. Keller defined this subzone as the total range of nominate taxon to determine the uppermost Maastrichtian. At the current section, *P. hantkeninoides* spans the top 2 m of the Maastrichtian.

4.2. *Guembelitra cretacea* Biozone

This biozone was first defined by Smit 1982 [13]. He introduced the *Guembelitra cretacea* Zone as the interval between the last occurrence of Cretaceous species at the Cretaceous-Paleogene boundary and the first occurrence of *Parvularugoglobigerina eugubina* Arenillas et

PERIODS	AGES	Events in the section studied	CRETACEOUS-PALEOCENE BOUNDARY PLANKTONIC FORAMINIFERA BIOZONATION							
			This paper	Arenillas et al. 2004	Keller, 1993 Keller et al. 1995	Ben Abdelkadar et al. 1992	Canudo et al. 1991	Smith, 1982 Smith et al. 1992	Berggren and Miller, 1988	
PALEOCENE	DANIAN	<i>G. Compressa</i>	Para. <i>Pseudobulloides</i> Not subzone	Para. <i>Pseudobulloides</i>	S. <i>triloculinoides</i>	P1b	Para. <i>Pseudobulloides</i>	Para. <i>Pseudobulloides</i>	P1b E. <i>taurica</i>	P1a&P1b
		<i>Pv. eugubina</i> Para. <i>Pseudobulloides</i>								
PALEOCENE	DANIAN	<i>E. simplicissima</i>	Pv. <i>eugubina</i>	E. <i>simplicissima</i>	E. <i>simplicissima</i>	P1a	Pv. <i>eugubina</i>	Pv. <i>Longiapertura</i>	P1a Pv. <i>eugubina</i>	P _a
		<i>P. taurica</i>								
PALEOCENE	DANIAN	<i>G. daubjergensis</i>	G. <i>cretacea</i>	G. <i>cretacea</i>	Pv. <i>longiapertura</i>	P0 G. <i>cretacea</i>	P0 G. <i>cretacea</i>	G. <i>cretacea</i>	P0 G. <i>cretacea</i>	P _a
		<i>Pv. eugubina</i>								
PALEOCENE	DANIAN	<i>W. homerstownensis</i>	G. <i>cretacea</i>	G. <i>cretacea</i>	Pv. <i>longiapertura</i>	P0 G. <i>cretacea</i>	P0 G. <i>cretacea</i>	G. <i>cretacea</i>	P0 G. <i>cretacea</i>	P _a
		<i>E. eobuloides</i>								
PALEOCENE	DANIAN	<i>E. fringa</i>	G. <i>cretacea</i>	G. <i>cretacea</i>	Pv. <i>longiapertura</i>	P0 G. <i>cretacea</i>	P0 G. <i>cretacea</i>	G. <i>cretacea</i>	P0 G. <i>cretacea</i>	P _a
		<i>R. edita</i>								
PALEOCENE	DANIAN	<i>Pv. longiapertura</i>	G. <i>cretacea</i>	G. <i>cretacea</i>	Pv. <i>longiapertura</i>	P0 G. <i>cretacea</i>	P0 G. <i>cretacea</i>	G. <i>cretacea</i>	P0 G. <i>cretacea</i>	P _a
		<i>H. holmdelensis</i>								
CRETACEOUS	MAASTRICHTIAN	<i>Plum. hantkeninoides</i>	Abathomphalus <i>mayaroensis</i>	Plum. <i>hantkeninoides</i>	Abathomphalus <i>mayaroensis</i>	Plum. <i>hantkeninoides</i>	Plum. <i>Hantkeninoides</i>	P. <i>deformis</i>	Abathomphalus <i>mayaroensis</i>	Abathomphalus <i>mayaroensis</i>
		<i>A. mayaroensis</i>								
CRETACEOUS	MAASTRICHTIAN	<i>Plummerita hantkeninoides</i>	Abathomphalus <i>mayaroensis</i>	Plum. <i>hantkeninoides</i>	Abathomphalus <i>mayaroensis</i>	Plum. <i>hantkeninoides</i>	Plum. <i>Hantkeninoides</i>	P. <i>deformis</i>	Abathomphalus <i>mayaroensis</i>	Abathomphalus <i>mayaroensis</i>
		<i>Plummerita hantkeninoides</i>								

Figure 1. Correlation between the upper Maastrichtian and lower Danian planktic foraminiferal biozonations.

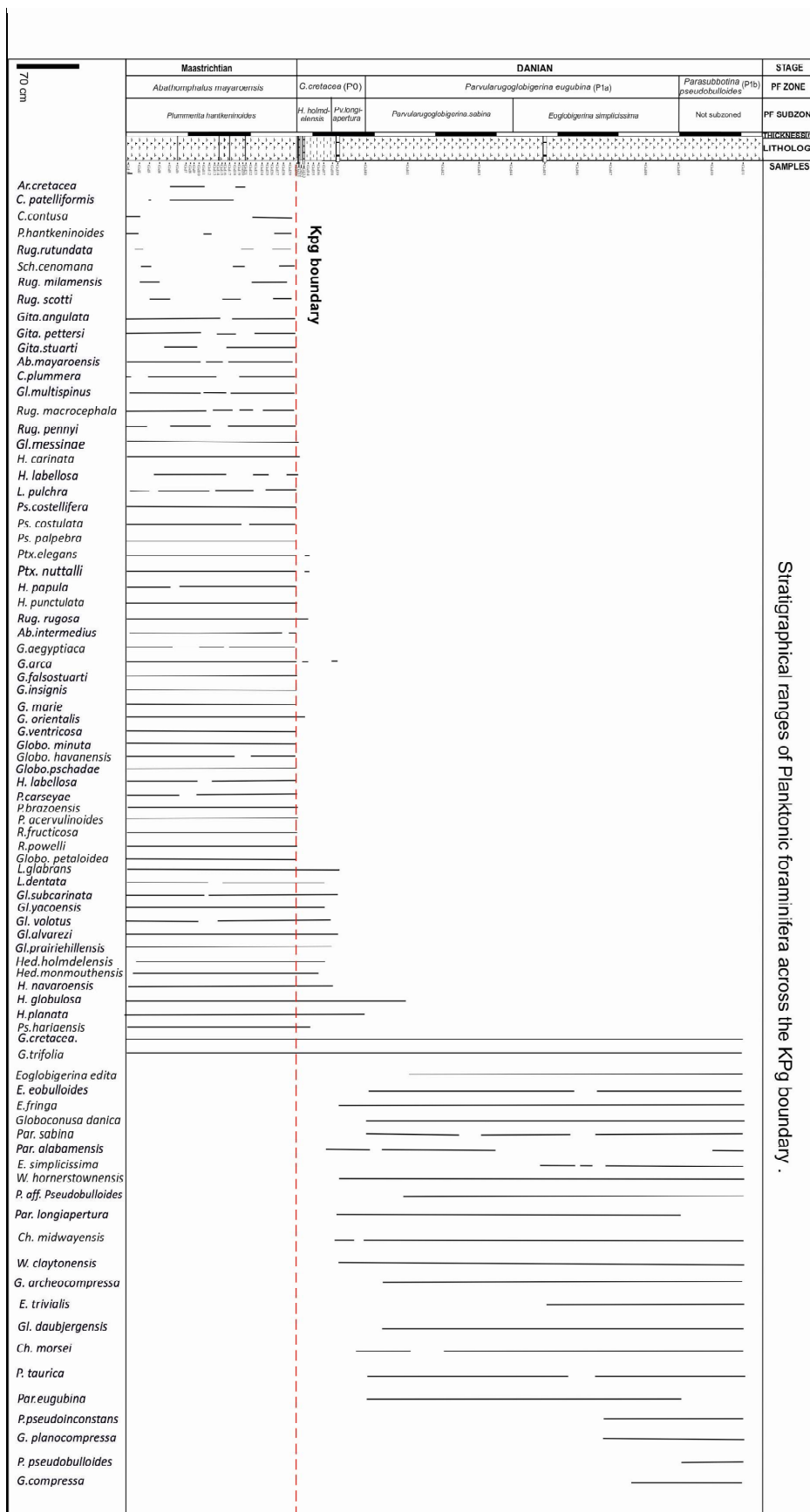


Figure 2. Planktonic foraminifera species ranges during the uppermost Maastrichtian and earliest Danian at Galanderud section. Note the sudden disappearances of species across the K/Pg boundary.

al., 2004 and *Parvularugoglobigerina extensa* [14]. The Zone is subdivided into two Sub-biozones that include: the *Hedbergella holmdelensis* and the *Parvularugoglobigerina longiapertura* Arenillas et al., 2004. The *Hedbergella holmdelensis* is defined by last occurrence of Cretaceous planktonic foraminifera specially the Globotruncanids, *Abathomphalus* and *Plummerita*, to the first occurrence of *Parvularugoglobigerina longiapertura*. It is equivalent to the P0 Zone of [13,15]. The second sub-biozone in the *Guembelitra cretacea* was defined by first occurrences of *Pv. longiapertura* and *Pv. Eugubina* [14]. In the Galanderud section, the *Guembelitra cretacea* Zone is characterized by high relative abundance of *Guembelitra* spp. It is ~60 cm thick.

4.3. *Parvularugoglobigerina eugubina* Biozone

Luterbacher and PremoliSilva (1964) firstly introduced this biozone and it was defined as total range of the nominate taxon. This biozone was divided in two Subzones by Arenillas et al., (2004) that include of *Parvularugoglobigerina sabina* Subzone, which is the interval ranging from the first occurrence of *Parvularugoglobigerina eugubina* to the first occurrence of *Eoglobigerina simplicissima*; and *Eoglobigerina simplicissima* Subzone, which is the interval between the first occurrence of the nominal taxon and the first occurrence of *Parasubbotina pseudobulloides*.

The first subzone is ~170 cm thick and the second subzone is ~190 cm thick.

4.4. *Parasubbotina pseudobulloides* Zone

This zone was initially described by [16]. Arenillas (2004) subdivided the *Ps. pseudobulloides* Zone into the *Eoglobigerina trivialis* and *S. triloculinoidea* Subzones.

The *Eoglobigerina trivialis* Subzone includes the bio-

stratigraphical interval from the first occurrence of *Parasubbotina pseudobulloides* to first occurrence of *Subbotina triloculinoidea*; and the *Subbotina triloculinoidea* Subzone, which is the interval from the first occurrence of the *S. triloculinoidea* to the first occurrence of *Globanomalina compressa*. In this section, we could not determine a subzone.

This zone is ~70 cm thick.

5. The Mass Extinction Pattern

Smit 1982 indicated that dominated species of the upper Maastrichtian planktic foraminifera have been recorded in the lower most Danian all are considered to be reworked, except for one species *Guembelitra cretacea*. Olsson and colleagues (1999) considered *Hedbergella holmdelensis*, *H. monmouthensis* and *G. cretacea*, to be survivors into the lower Danian. Based on these papers, this extinction was a catastrophic mass extinction and resulting from an extraterrestrial impact. On the other hand, Gerta Keller and colleagues (1989) presented different data. At these data, they showed gradual pattern across the boundary and they indicate Cretaceous species survive many thousands in Paleocene.

In order to describe the mass extinction pattern the Galanderud section was chosen. Species ranges and extinction patterns are illustrated in across the K/Pg transition, at Galanderud section in (Figures 2 and 3). Based on detail study, we identified 61 Cretaceous species. Based on our data gain following data:

The upper Maastrichtian, planktonic foraminifera are dominated by small biserial species (heterohelicids and pseudoguembelinids), triserial species and small morphology trochospiral (hedbergellids) are rare in this section. Also, globigerinelloid and globotruncanellid species are also common. Rugoso trochospiral species, complex biserial and multiserial (rugoglobigerinids, pseudotextularids

Sections and Authors Age	Keller 1988 (EI Kef)	Keller et al 1995 (EI Lef)	Molina et al 1998 (Agost)	Arz et al 1999 (Zumaya)	Arz et al 2000 (Caravaca)	Arenillas et al 2000a (Ain settara)	Zaghib-Turki et al 2000 (Elles)	Luciani 2002 (Ain settara)	Gallala et al 2009 (Bidart)	This section (Galanderud)
Danian Extinct percent	10(18%)	24(19%)	16(24%)	15(24%)	17(25%)	18(28%)	13(23%)	33(57%)	4(5.5%)	16(26.22%)
Kpg Extinct percent	31(58%)	7(12%)	47(70%)	44(71%)	49(71%)	44(65%)	36(63%)	13(22%)	53(73%)	43(70.49%)
Maastrichtian Extinct percent	12(24%)	24(69%)	4(6%)	3(5%)	3(4%)	5(7%)	8(14%)	12(21%)	1(1.38%)	2(3.27%)

Figure 3. Comparative number and percent of extinct species across the K/Pg boundary and the Cretaceous survivors at the lower Danian interval.

planoglobulinds and racemiguembelinids) are common.

At the K/Pg boundary, many Cretaceous species suddenly disappear, and only some genera such as Guembilitria, Heterohelix, Globigerinelloides and Hedbergella are common in the clay layer. Based on this study, *A. cretacea* and *Contusotruncana patelliformis* (3.27%) are the only species that disappeared between 2 m below and the K/Pg boundary, 44 species (72.13%) became extinct at the K/Pg boundary (**Plate 1**). The remaining 15 species (about 24.59%) represent the Cretaceous survivors in the Early Danian sediments, but disappear by 1 m above the K/Pg boundary in Zones P0 (**Plate 1**). This pattern supports the sudden catastrophic pattern of species extinctions across the K/Pg boundary elsewhere.

Comparison with Other Section

There is still the debate regarding the planktic foraminiferal extinction model at the K/Pg boundary. Differences are the result of various selection the methodologies, differences in obtaining the data, and diverse interpretations of the data (**Figure 3**).

The mass extinction pattern at the K/Pg boundary of the Galanderud section indicates that (44: 72%) species became extinct. This extinction at K/Pg boundary is similar to many sections around the world. For example: In Spanish sections (Agost: 46 extinct species (70%), at Caravaca: 46 extinct species (71%)) [17].

And in Tunisian sections (El Kef: 46 extinct species

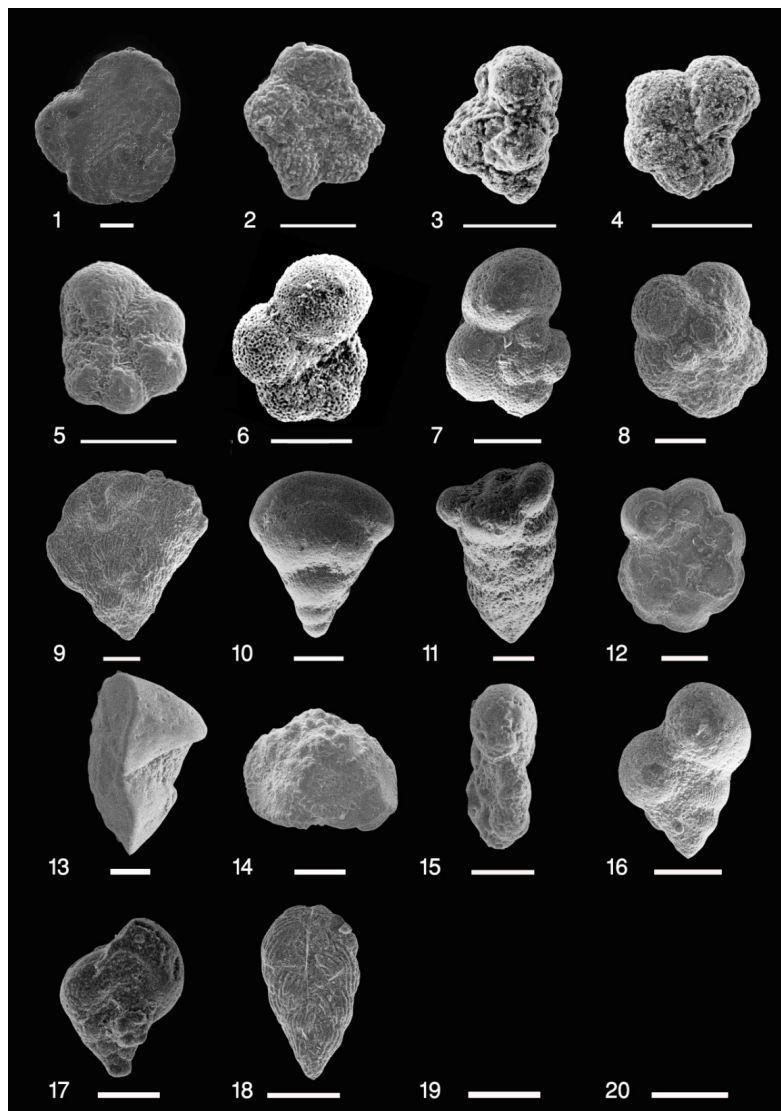


Plate 1: Scalebar = 50 micron; 1. *Abathomaphalus mayaroensis*; 2. *Plummerita hantkeninoides*; 3. *Guembilitria* sp.; 4. *Parvularugoglobigerina eugubina*; 5. *Parvularugoglobigerina longiapertura*; 6. *Eoglobigerina simplicicima*; 7. *Parasubbotina pseudobulloides*; 8. *Rugoglobigerina rugosa*; 9. *Planoglobulina* sp.; 10. *Pseudotextularia nuttalli*; 11. *Racemiguembelina powelli*; 12. *Globotruncana arca*; 13. *Globotruncanita stuartiformis*; 14. *Contusotruncana* spp.; 15. *Globigerinelloides* sp.; 16. *Heterohelix globulosa*; 17. *Laeviheterohelix dentata*; 18. *Pseudoguembelina costulata*.

(58%), at Elles: 36 or 45 extinct species (37%), species and at Ain Settara: 44 extinct species (65%) [10,18] and in a French section (Bidart 53 species (73%) became extinct [19].

6. Conclusion

Planktic foraminifera were very abundant and diversified during the late Cretaceous at the Galanderud section. Based on the planktic foraminifera data four biozones and five sub-biozones have been identified across the K/Pg boundary. Late Maastrichtian planktic foraminifera were much diversified and some species reached a very large size. These assemblages, that constituted about 73% of the species present, suddenly became extinct at the K/Pg boundary. This pattern of catastrophic mass extinction constitutes the largest and most dramatic extinction event in the history of planktic foraminifera. This data from this extinction event are very compatible with the catastrophic effects that might have been caused by the impact of a large extraterrestrial body.

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