Paleoenvironmental reconstruction using benthic foraminiferal assemblages across the Cretaceous/Palaeogene boundary in the Alborz basin, Northern Iran

Masoud Asgharian Rostami[1]*, Mohammad Vahidinia[1], Ebrahim Ghasemi-Nejad[2]

1-Faculty of Science, Department of Geology, Ferdowsi University of Mashhad, Mashhad, Iran
2-Faculty of Science, Department of Geology, University of Tehran, Iran
*Corresponding author: masoud.rostami@hotmail.com

Abstract: Benthic foraminiferal assemblages, in contrast to planktic foraminifera, generally did not suffer mass extinctions at the Cretaceous/Palaeogene boundary. High-resolution study of benthic foraminifera from the Galanderud section provides detailed data on palaeoenvironmental turnover across the K/Pg boundary. The Galanderud section records a dramatic change in the structure of benthic foraminiferal assemblages across the K/Pg boundary. Uppermost Maastrichtian assemblages are well preserved, highly diversified, and abundant. They consist of a mixture of epifaunal and infaunal morphogroups in which epifaunal morphogroups are less abundant. This indicates an optimum environment with mesotrophic to weakly eutrophic conditions during the latest Cretaceous. At the K/Pg boundary, benthic foraminifera indicate a major faunal turnover, a dramatic decrease in the percentage of both infaunal morphogroups and diversity that illustrate oligotrophic conditions. This extinction or temporary emigration of most infaunal morphogroups is interpreted to be the result of a sudden collapse of the food web. This sudden collapse in primary productivity may be the result of the extraterrestrial impact. Faunal recovery and restructuring is recognizable during the lowermost Danian reflecting a gradual recovery after the K/Pg boundary event.

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1. Introduction

The Cretaceous/Paleogene boundary marks one of the largest mass extinctions of the Phanerozoic. This event records a catastrophic crisis in the history of life on Earth and is one of the most investigated of all stratigraphic intervals (Alvarez et al., 1980). Although during the last three decades, it has been the subject of multiple high resolution analyses, there are still some unresolved aspects relating to the type and causes of the extinctions. The cause of this extinction has been attributed to meteorite impact, volcanism, climatic and sea level changes (Alvarez *et al.*, 1980; Courtillot *et al.*, 1988; Barrera, 1994; Barrera and Huber, 1990).

Benthic foraminifera constitute an important tool for reconstructing palaeoenvironmental changes at the Cretaceous–Paleogene boundary, because they are an important source of information about environmental conditions at the sea floor, such as ocean productivity and oxygenation (e.g., Van der Zwaan *et al.*, 1999). Many studies of benthic foraminifera at the K/Pg boundary clearly show that this group, in contrast to planktonic foraminifera and calcareous nannoplankton, did not suffer major extinction, but only temporary restructuring of various kinds followed by at least a partial recovery observed in different regions of the world and environmental settings (e,g., Keller, 1988; Widmark and Malmgren, 1992a; Coccioni *et al.*, 1993; Coccioni and Galeotti, 1994; Peryt *et al.*, 1997; Alegret and Thomas, 2001 ; Alegret *et al.*, 2003; Culver, 2003; Alegret and Thomas, 2004; Molina *et al.*, 2005). In this paper a paleoenvironmental reconstruction across the K/Pg boundary of the Galanderud section is presented to indicate what happened in this region.

2. Location

The Alborz mountain system extends in a sinuous manner for about 2000 km from the Lesser Caucasus of Armenia and Azerbaijan in the northwest corner of Iran to the Paropamisus mountains of northern Afghanistan in the east (Alavi, 1996). The Galanderud section is located in the Alborz mountains in the southwestern corner of Noor Province about 25 km south of the city of Royan in the proximity of some limestone and coal mines (Fig. 1). The Galanderud section spans the upper part of the Cenomanian into the Miocene (Yari-Nejad, 2004). Maastrichtian sediments in this section consist of gray to brown pelagic marls, interbedded with marly limestones. Marly sediments are rich in foraminifera and macrofossils including echinoids and inoceramids (Yari-Nejad, 2004). The K/Pg transition is well exposed, and can be easily sampled from a road. It is also characterized by a major lithological change. Brown to dark brown marls at the end of Maastrichtian are suddenly replaced by clay and then chalk layers at

base of Danian (Fig. 2). In the clay layers the CaCO3 content decreases to less than 13 % (Fig. 4).
This section has been chosen as it is complete, expanded and easy to reach and so it provides an excellent opportunity to study the K/Pg boundary. To our knowledge, no investigation has been conducted across the K/Pg boundary in this section to date.

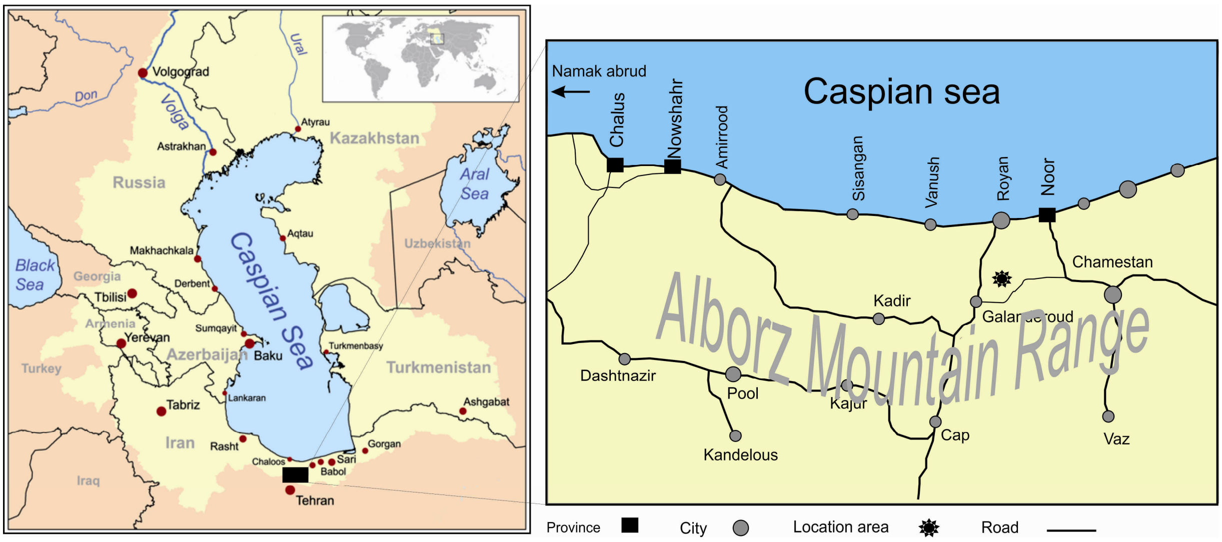

Figure 1. Location of the Galanderud section.

2. Materials and methods

The Galanderud section is one of the most expanded K/Pg sequences in existence. A preliminary study was performed for locating the K/Pg boundary, and then sampling was restricted to a 9m-interval ranging from upper Maastrichtian to lower Danian levels. A total of 54 samples were collected at ~15 cm intervals, on average, except for the boundary clay where samples were taken at higher resolution (~2 cm intervals). The samples were processed for foraminiferal analysis using standard micropaleontological techniques. Samples were disaggregated in tap water and washed through a 120µm and then a 53µm sieve and then dried at 50°C. A total of 54 samples were used for quantitative analyses of benthic foraminifera. Benthic foraminiferal identification in this analysis is largely based on Loeblich and Tappan (1987), Bolli *et al.*, (1994), Alegret and Thomas (2001), and Kaminski and Gradstein (2005).

3. Paleoenvironment reconstruction

Recent communities of benthic foraminifera are used as a modern analogue of past foraminiferal communities. We are then able to infer past microhabitat preferences and environmental parameters such as nutrient supply to the sea floor and sea water oxygenation (Corliss and Chen, 1988; Jorissen *et al.*, 1995). We allocated all foraminiferal taxa to morphogroups following Corliss (1985), Corliss and Chen (1988) and Alegeret *et al.*, (2003). In general, benthic foraminifera with plano-convex, biconvex and rounded trochospiral tests, tubular and coiled flattened and palmate tests are inferred to have had an epifaunal mode of life, living at the sediment surface or in its upper few centimeters. Benthic foraminifera with cylindrical or flattened tapered, spherical, rounded planispiral, flattened ovoid, globular unilocular or elongate multilocular tests are inferred to have had an infaunal foraminifera life in deeper layers of the sediment from 4-10 cm depth (Corliss, 1991).

Based on Corliss (1985) and Corliss and Chen (1988) the epifaunal morphogroup are considered as living in oligotrophic conditions with low productivity, whereas the infaunal morphogroup indicates eutrophic conditions and high productivity. Using modern analogue morphotypes and different tests of benthic foraminifera, three assemblages were recognized that could be related to changes in the relative abundance of epifaunal and infaunal species and to Agglutinate to Hyaline tests (Fig. 4).

Assemblage 1

(*Plummerita hantkeninoides* Subzone)

This assemblage is highly diverse and composed of a mixture of epifaunal and infaunal morphogroups though epifaunal are less abundant (Fig. 3, & 4). Within the epifaunal morphogroup, the genera Cibicidoides, Lenticulina, Gyroidinoides and Anomalinoides are common. The infaunal morphogroup is dominated by the genera *Laevidentalina*, *Bolivinoides*, *Gaudryina* and *Pseudouvigerina*. Agglutinated genera form 40–60% of the assemblage, and are represented by *Marsonella*, *Dorothia, Tritaxia* and *Gaudryina* (Figs. 3, & 4). This assemblage is characteristic of conditions of moderate to high primary productivity and a flux of organic detritus that is sufficient to sustain the infaunal norphogroup.

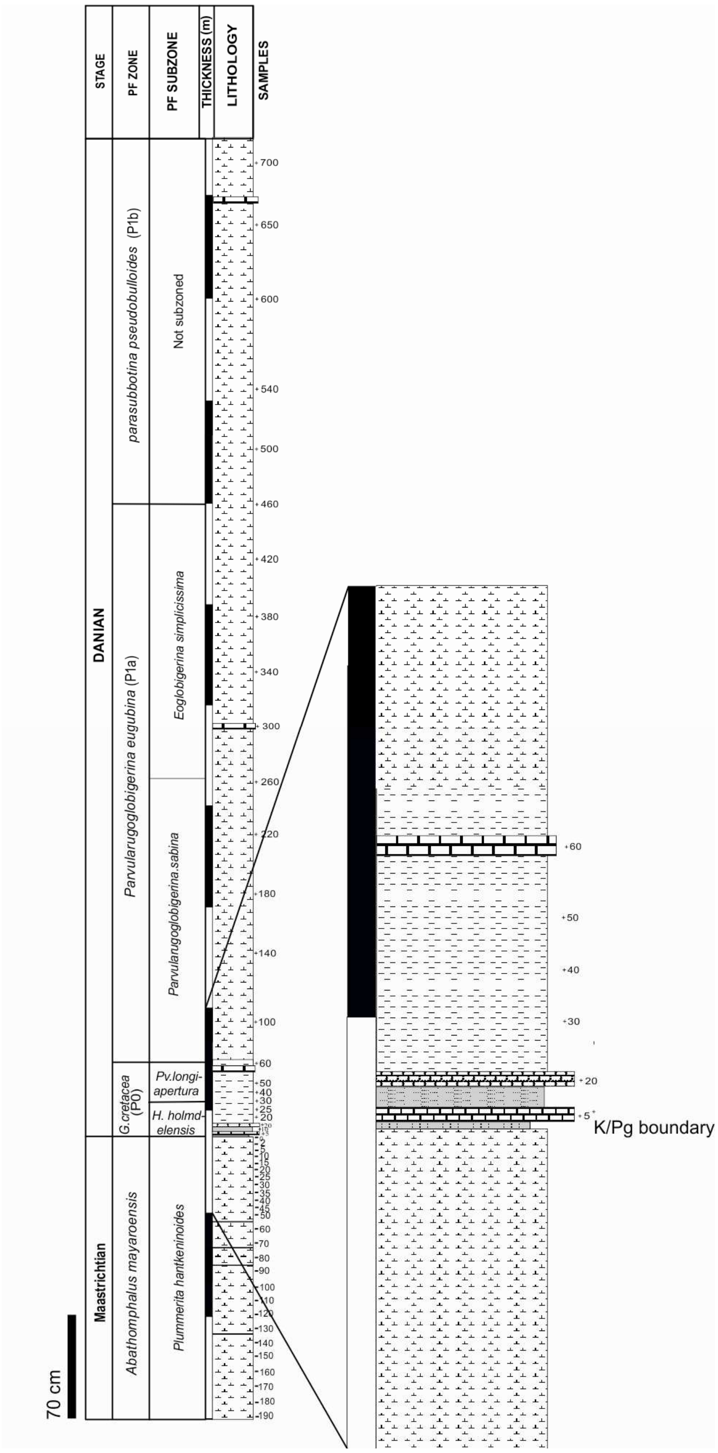

Figure 2. Detailed lithology changes at the K/Pg boundary in the Galanderud section.

Assemblage 2

(*Guembelitria cretacea* and the Lower part of *Parvularugoglobigerina eugubina* Zone)

The dramatic change in the structure of these benthic foraminiferal assemblages corresponds to K/Pg boundary and *G. cretacea* Zone (Figs. 2, & 3). At this point, several genera disappear, e.g. *Bolivinoides, Clavulinoides, Eouvigerina, Gaudryina, Neoflabellina, Dorothia, Ammodiscus, Ramulina, Reophax*, and *Saccamina*. Some of these became extinct, such as *Bolivinoides* and *Eouvigerina* , whereas others reappear again in the lower Danian, *e.g.*, *Lazarus* taxa. This assemblage contains little diversity in benthic foraminifera (mainly *Cibicidoides* and *Anoamlinoides* are present), and it is composed almost entirely of epifaunal species (80– 90% of the assemblage). Agglutinated forms are rare in this interval (Figs. 3, & 4). Assemblage 2 reflects a dramatic collapse in food supply on the seafloor, with assemblages dominated by epifaunal suspension feeders. Genera that prefer a high nutrient supply such as *Bolivinoides*, Euvigerina and *Marsonella* disappeared at this point. The severe shortage of food may have resulted in complete oxidation, collapse of primary productivity, and acidification of the seafloor.

Assemblage 3

(*Parvularugoglobigerina eugubina* and the Lower part of *Parasubbotina pseudobulloides* Zone)

This assemblage is characterized by high diversity, slight dominance of benthic genera, and a trend toward a decreasing relative abundance of epifaunal morphogroups (especially Cibicidoides) (Fig. 4). In this Assemblage, Lazarus taxa return (Fig. 3) and agglutinated foraminifer tests gradually increased in relative abundance (Fig. 3). These faunal changes indicate a gradual increase in the food supply and a decrease in acidification. This assemblage indicates a return to the pre-K/P boundary mesotrophic to oligotrophic conditions. However, there is not a complete return to prior conditions.

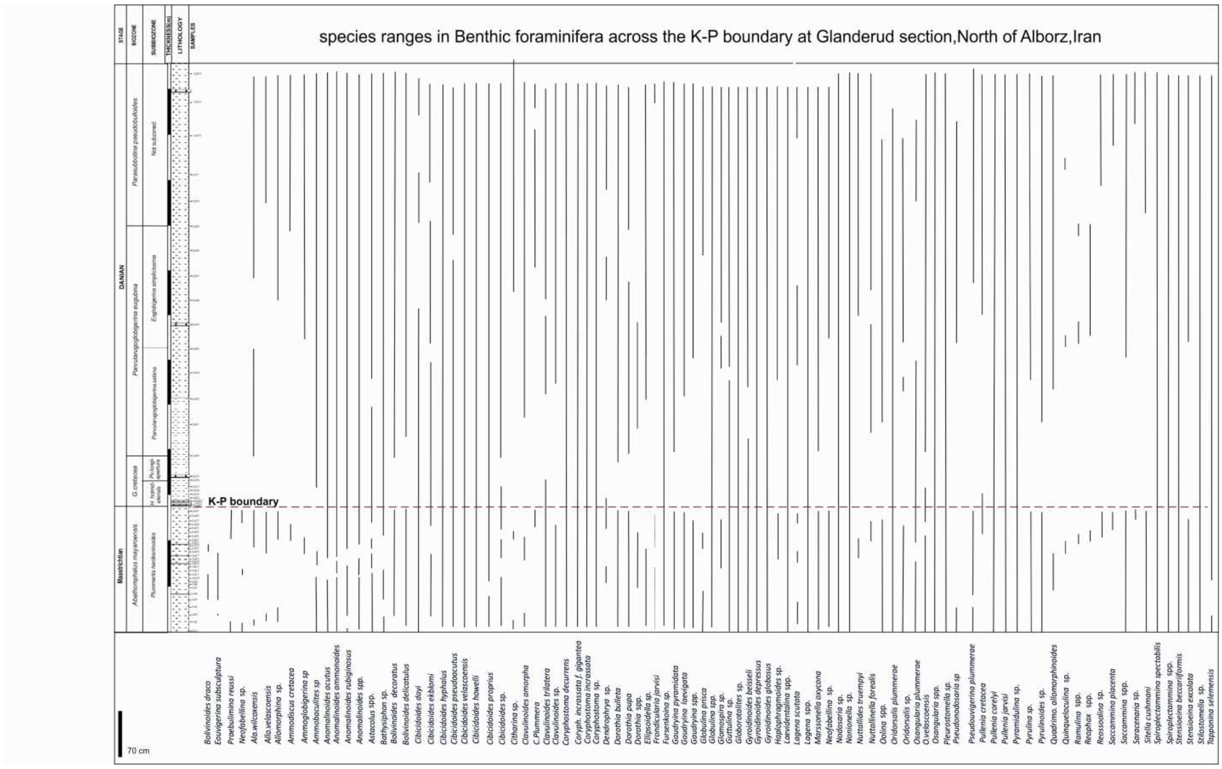

Figure 3. Species range of benthic foraminifera across the K/Pg boundary.

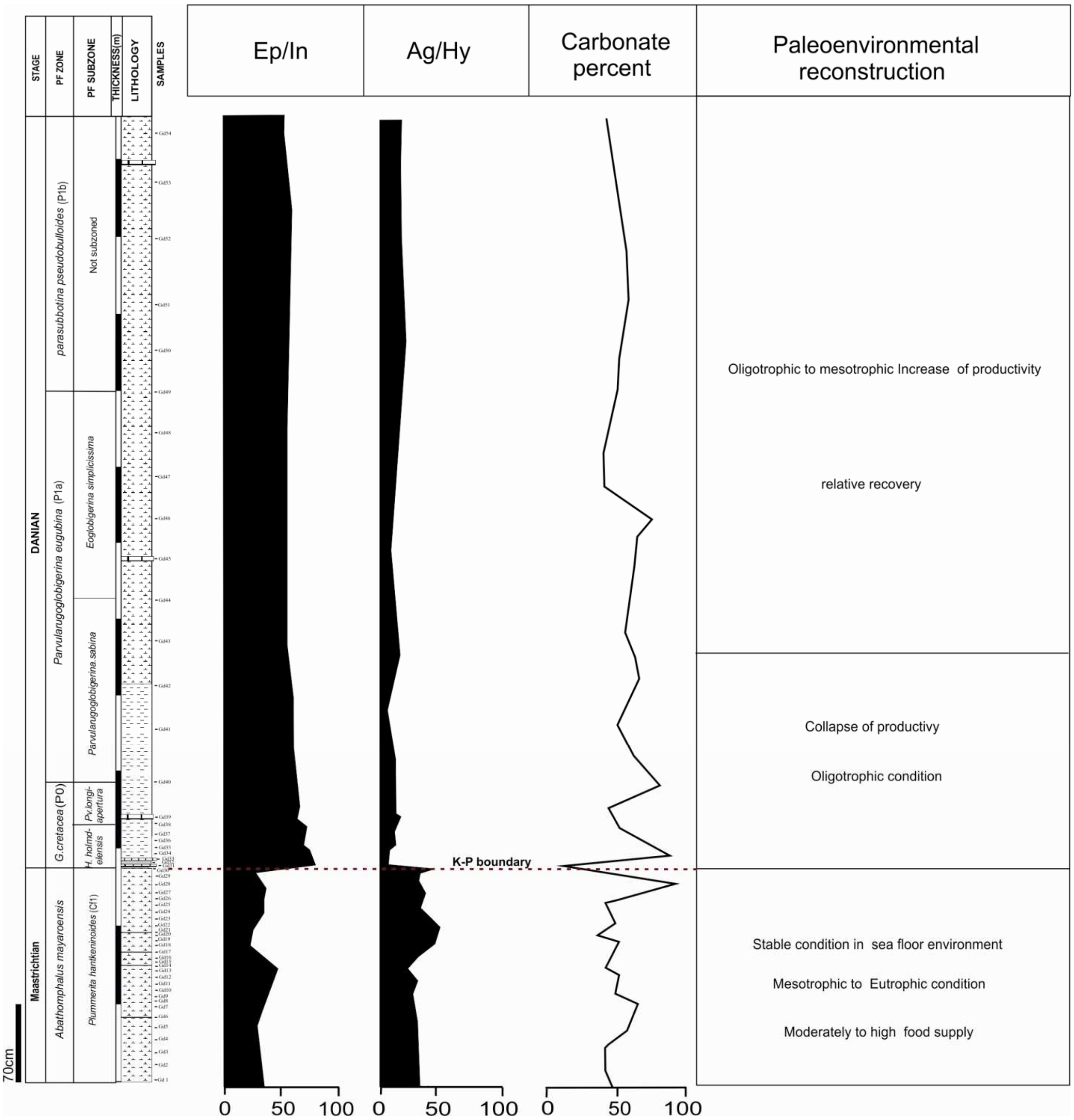

Figure 4. Percentages of benthic foraminifera with calcareous and agglutinated tests, relative abundances of infaunal and epifaunal morphogroups and inferred environmental conditions.

Conclusions

High-resolution quantitative study of benthic foraminifera from the Galanderud section provides detailed data for a paleoenvironmental reconstruction across the K/Pg boundary. Based on our data three assemblages are recognized:

Assemblage 1, located in the *Plummerita hantkeninoides* Subzone, is highly diverse and composed of a mixture of epifaunal and infaunal morphogroups though epifaunal morphogroups are less abundant. This assemblage reflects moderate to high primary productivity.

Assemblage 2, which lies across the K/Pg boundary, indicates dramatic change in the structure of benthic foraminiferal assemblages. This assemblage is composed almost entirely of epifaunal species (mainly Cibicidoides and Anoamlinoides). This assemblage reflects a drastic collapse in food supply to the seafloor, with assemblages primarily dominated by epifaunal suspension feeders. The collapse of the food web may be the result of complete oxidation, collapse of primary productivity and acidification of the seafloor.

Assemblage 3, in the *Parvularugoglobigerina eugubina* and lower part of the *Parasubbotina pseudobulloides* zone, is characterized by a moderate to high diversity and decreasing relative abundance of the epifaunal morphogroups. These faunal changes indicate a gradual increase in the food supply. This assemblage indicates considerable, but not complete environmental recovery.

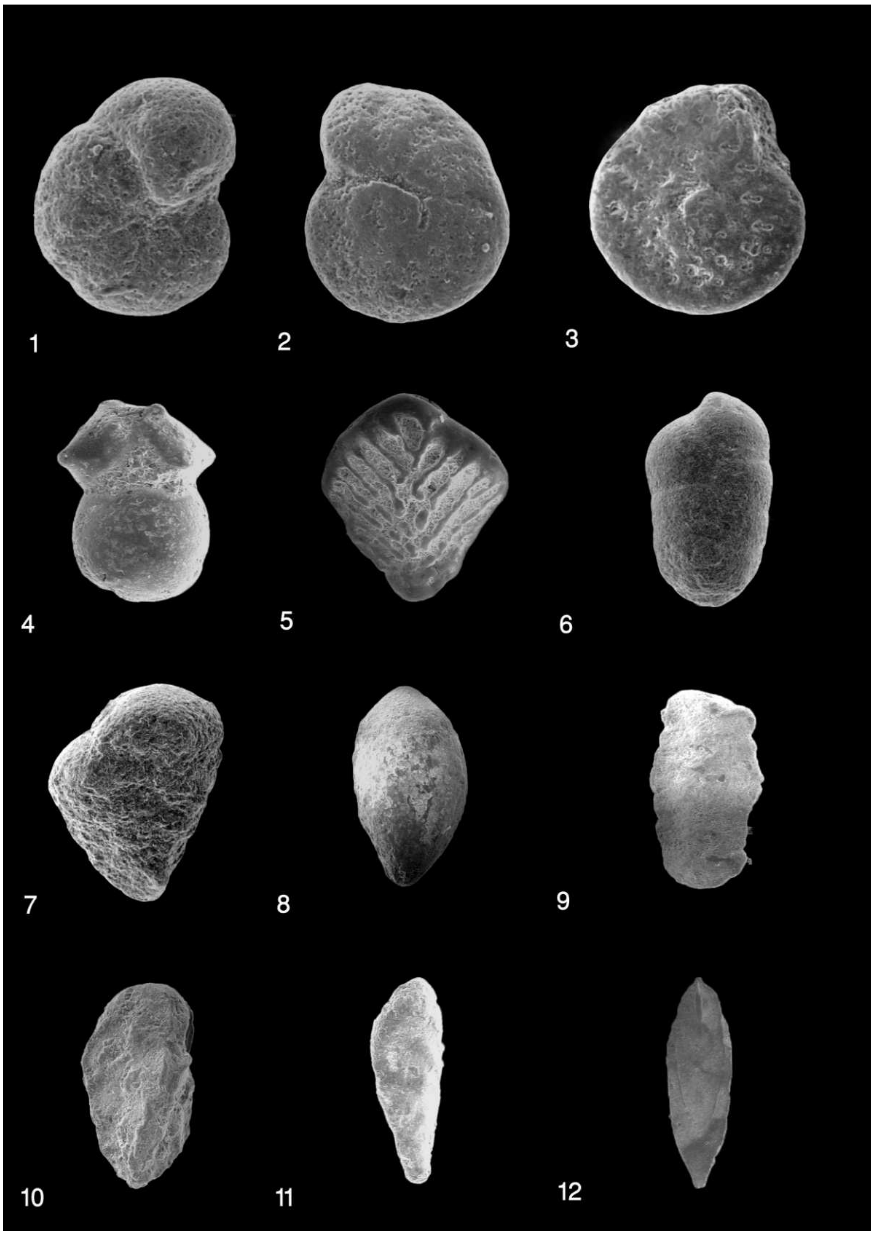

Plate 1: Scale bar 200 micron.

Epifauna: **1,3)** Planoconve trochospiral **2**) biconvex trochospiral **4)** Spherical **5)** Flattened tapered **12)** Palmate

Infauna: 6,8) Cylindrical tapered**. 7,9,10)** Elongate multilocular. **11)** Flattened tapered**.**.

References

1. Alavi, M. Tectonostratigraphic synthesis and structural style of the Alborz mountain system in northern Iran, *J. Geodynamics*, 1996; 21 (1), 1-33.

2. Alegret, L., Molina, E., Thomas, E. Benthic foraminifera at the Cretaceous/Tertiary boundary around the Gulf of Mexico. *Geology*, 2001; 29, 891–894.

3. Alegret, L., Thomas, E. Upper Cretaceous and lower Paleogene benthic foraminifera from northeastern Mexico. *Micropaleontology*, 2001; 47, 269–316.

4. Alegret, L., Thomas, E. Benthic foraminifera and environmental turnover across the Cretaceous/Paleogene boundary at Blake Nose (ODP Hole 1049C, Northwestern Atlantic). *Palaeogeography, Palaeoclimatology, Palaeoecology*, ., 2004; 208, 59–83.

5. Alegret, L., Molina, E., Thomas, E. Benthic foraminiferal turnover across the Cretaceous/Paleogene boundary at Agost (southeastern Spain): paleoenvironmental inferences. *Marine Micropaleontology*, 2003; 48, 251–279.

6. Alvarez, L.W., Alvarez, W., Asaro, F., Michel, H.V. Extraterrestrial cause for the Cretaceous–Tertiary extinction. *Science* 1980; 208, 1195–1108.

7. Arenillas, I., Arz, J.A., Molina, E., Dupuis, C. The Cretaceous/Paleogene (K/P) boundary at Ain Settara, Tunisia: sudden catastrophic mass extinction in planktic foraminifera. *J. Foram. Res.* 2000; 30, 202-218.

8. Barrera, E. Global environmental change preceding the Cretaceous–Tertiary boundary: early–late Maastrichtian transition. *Geology*, 1994; 22, 877–880.

9. Barrera, E., and Huber, B.T. Evolution of Antarctic waters during the Maestrichtian: foraminifer oxygen and carbon isotope ratios, ODP Leg 113: in Barker, P.F., Kennett, J.P. et al., *Proc. ODP, Sci. Results*, 113: College Station, TX (Ocean Drilling Program), 1990; 813-823.

10. Bolli, H.M., Beckmann, J.P., Saunders, J.B. Benthic Foraminiferal Biostratigraphy of the South Caribbean Region. Cambridge University Press, Cambridge, 1994; 408 pp.

11. Coccioni, R., Fabbrucci, L., Galeotti, S. Terminal Cretaceous deep-water benthic foraminiferal decimation, survivorship and recovery at Caravaca (SE Spain). *Palaeopelagos* 1993; 3, 3–24.

12. Coccioni, R., Galeotti, S. K–T boundary extinction: geologically instantaneous or gradual event? Evidence from deep-sea benthic foraminifera. *Geology* 1994; 22, 779–782.

13. Corliss, B.H. Microhabitats of benthic foraminifera within deep-sea sediments. *Nature* 1985; 314, 435-438.

14. Corliss, B.H. Morphology and microhabitat preferences of benthic foraminifera from the northeast Atlantic Ocean. *Marine Micropaleontology* 1991; 17, 195-236.

15. Corliss, B.H., Chen, C. Morphotype patterns of Norwegian Sea deep-sea benthic foraminifera and ecological implications. *Geology* 1988; 16, 716-719.

16. Courtillot, V., Besse, J., Vandamme, D., Montigny, R., Jaeger, J. J., Cappetta, H. Deccan flood basalts at the Cretaceous/Tertiary boundary? *Earth Planet. Sci. Lett.* 1986; 80, 361–374.

17. Culver, S.J. Benthic foraminifera across the Cretaceous–Tertiary (K–T) boundary: a review. *Marine Micropaleontology* 2003; 47, 177–226.

18. Jorissen, F.J., Stigter, H.C., Widmark, J.G.V. A conceptual model explaining benthic foraminiferal microhabitats. *Marine Micropaleontology* 1995; 26, 3-15.

19. Kaminski, M.A., and Gradstein, F.M. Atlas of Cosmopolitan Deep-water Agglutinated

20. Foraminifera (Paleogene). Grzybowksi Foundation, Spec. Publ. 10, London, U.K., 2005: 584 pp.

21. Keller, G. Extinction, survivorship and evolution of planktic Foraminifera across the Cretaceous/Tertiary boundary at El Kef, Tunisia. *Marine Micropaleontology* 1988; 13, 239–263.

22. Loeblich A., Tappan H. Foraminiferal genera and their classification; Van Nostrand Reinhold

23. Company, 1988: 970 pp. 847 plates.

24. Molina, E., Alegret, L., Arenillas, I., Arz, J.A. The Cretaceous/Paleogene boundary at the Agost section revisited: paleoenvironmental reconstruction and mass extinction pattern. *Journal of Iberian Geology* 2005; 31, 135–148.

25. Peryt, D., Lahodynsky, R., Durakiewicz, T. Deep-water agglutinated foraminiferal changes and stable isotope profiles across the Cretaceous/Paleogene Boundary in the Rotwandgraben section, Eastern Alps (Austria). *Palaeogeography, Palaeoclimatology, Palaeoecology* 1997; 132, 287–307.

26. Van der Zwaan, G.J., Duijnstee, J.A.P., Den Dulk, M., Ernst, S.R., Jannink, N.T., Kouwenhoven, T.J. Benthic foraminifers: proxies or problems? A review of paleoecological concepts. *Earth-Sci. Rev.*1999; 46, 213-236.

27. Widmark, J.G.V., Malmgren, B. Benthic foraminiferal changes across the Cretaceous–Tertiary boundary in the deep sea; DSDP sites 525, 527 and 465. *Journal of Foraminiferal Research* 1992; 22 (2), 81–113.

28. Yari-Nejad, A. Biostratigraphy of Upper Cretaceous deposits based on Foraminifera, in Galanderud and Zirab sections. Master theses. University of Tehran, 2004: 177 pp.

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