

A new evidence of passing the Maastrichtian–Paleocene boundary by larger benthic foraminifers: The case of *Elazigina* from the Maastrichtian Tarbur Formation of Iran

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Consorti, L. and Rashidi, K. 2018. A new evidence of passing the Maastrichtian–Paleocene boundary by larger benthic foraminifers: The case of *Elazigina* from the Maastrichtian Tarbur Formation of Iran. *Acta Palaeontologica Polonica* 63 (3): 595–605.

We describe a new Maastrichtian species of the benthic foraminifer *Elazigina siderea* from Tarbur Formation. Its main characters are the presence of heavy feathered umbilical sutures, a wide umbilical plug, and umbilical piles. This species, formerly reported from Turkey as *Smoutina cruysi*, constitutes the oldest known record of the genus *Elazigina*. *Elazigina siderea* sp. nov. comes from the Arabian domain and its presence is probably related to the migration of the Cretaceous foraminifer *Orbitokathina*. Prior to this study, the oldest representatives of this genus were only known from the Paleocene. Therefore, the presence of the new taxon in the Maastrichtian suggests the genus *Elazigina* passed the Cretaceous–Paleogene boundary, and survived to the environmental crisis associated with a great biosphere mass extinction that wiped out most of the Late Cretaceous larger foraminifers. This is supported by shell features displayed by *Elazigina siderea* sp. nov., interpreted as adaptation to thrive under elevated trophic levels, like the species of another benthic foraminifer *Laffitteina*.

Key words: Foraminifera, Globobulimina, Rotaliida, extinction, Cretaceous, Iran.

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Received 16 April 2018, accepted 8 August 2018, available online 23 August 2018.

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Introduction

The Cretaceous–Paleocene (K–Pg) boundary represents one of the most important biological crises in the Phanerozoic (Raup and Sepkoski 1986). Most Cretaceous planktonic foraminifers have been wiped out at the K–Pg boundary (Berggren and Norris 1997; Molina et al. 1998; Fuqua et al. 2008; Alegret and Thomas 2009 among others), whereas the small benthic foraminifers from bathyal or shallow-water settings were apparently less affected (Culver 2003; Alegret and Thomas 2013).

The complex-shelled symbiont bearing foraminifers (so-called larger foraminifers) also experienced severe changes at the K–Pg boundary (Brasier 1988; MacLeod et al. 1997). Several alveolinids, miliolids, rhapydioninids, loftusids, siderolitids, orbitolinids, rotaloinans, and orbitoids disappear toward the end of the Cretaceous, with 83% loss of the total Maastrichtian assemblage (Boudagher-Fadel 2008;

Goldbeck and Langer 2009). This is arguably associated to changes in shallow shelves that have affected the photosynthetic potential or those environmental parameters critical for larger foraminifers existence (Leutenegger 1984; Hallock and Schlager 1986; Hohenegger 1995; Hallock 1999). The end-Maastrichtian lowstand and cooling (Keller et al. 1997; Hallam and Wignall 1999; Habib and Saeedi 2007; Haq 2014; Chenot et al. 2018) have possibly been the mechanisms reducing suitable larger foraminifers niches. Furthermore, the studies that have dealt with larger foraminifers in K–Pg carbonate platform series (Tewari et al. 2007; Ogorelec et al. 2007) report enhancing of terrestrial carbon input and possible shallow-water eutrophication. Nevertheless, demise of larger foraminifers seems not coincident with the Chicxulub asteroid impact and Deccan traps eruptions that are usually associated with the K–Pg mass extinction (Ogorelec et al. 2007; Font et al. 2018).

There are few examples of larger foraminifers, however, attesting the survival through K–Pg; one of them is the genus

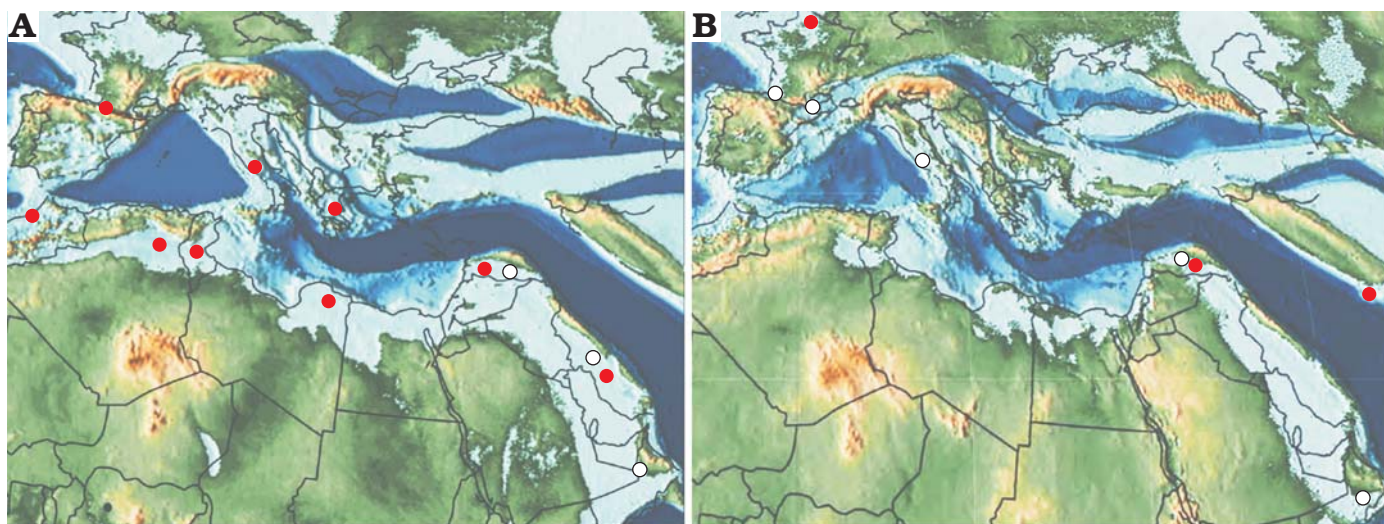


Fig. 1. Paleogeographic distribution of *Elazigina* (open circles) and *Laffitteina* (red circles) in latest Maastrichtian (A) and Paleocene (B). Records for the Maastrichtian are from Rahaghi (1992); Inan (1988, 2005); Schlüter et al. (2008); Goldbeck and Langer (2009); Hottinger (2014 and the references herein); and this work. Records for the Paleocene are from Rahaghi (1992); Inan (2005); Hottinger (2014 and the references herein); Serra-Kiel et al. (2016); and Benedetti et al. (2018). Maps are from Scotese (2013, 2014).

Laffitteina Marie, 1946. Widely present in the Maastrichtian from the Pyrenean basin to the Middle East platforms (Fig. 1), *Laffitteina* occurs also in the Paleocene of the Middle East (Rahaghi 1992; Inan et al. 2005) where its stratigraphic distribution through the Cretaceous and Paleocene carbonates is practically continuous (Hottinger 2014). *Pararotalia* Le Calvez, 1949, *Rotorbinella* Brandy, 1944, *Daviesina* Smout, 1954, and *Rotalispira* Hottinger, 2014, are also listed among the scarce survivors, but they re-appear later in the Paleogene or Eocene, after some million years long community recuperation period (Global Community Maturation Cycle [GCMC]; sensu Hottinger 2001). Notwithstanding, the list of survivors is not exhaustive.

New sampling of the Maastrichtian Tarbur formation from the High Zagros zone (SW Iran) shows the occurrence of a rotalid morphotype surprisingly close to the genus *Elazigina* Sirel, 2012. Until now four species of *Elazigina* (informally referred to Hottinger 2014 as *Plumokathina*) have been described in the Paleocene of the Neotethys (Hottinger 2014): *Elazigina dienii* (Hottinger, 2014), *E. lenticula* (Hottinger, 2014), *E. subsphaerica* (Sirel, 1972) and *E. harabekayisensis* Sirel, 2012, from the Pyrenees to the Middle East (Serra-Kiel et al. 2016; Benedetti et al. 2018). However, no representatives of *Elazigina* have been reported from the Cretaceous.

Previously recorded in Turkey under the name *Smoutina cruysi* by Inan (1988), the Maastrichtian *Elazigina* morphotype is extremely abundant in Tarbur Formation, allowing a detailed architectural study that is here presented, resulting in the description of a new species: *Elazigina siderea* sp. nov. The new record here reported and the spreading of *Elazigina* before and after the K–Pg boundary shed light on the capability of some larger foraminifers to survive the environmental changes associated, in one way or another, to the end-Cretaceous mass extinction.

Institutional abbreviations.—APNU, Ardakan Payame Noor University, Collection Rashidi, Department of Geology, Teheran, Iran.

Other abbreviations.—GCMC, Global Community Maturation Cycle; K–Pg, Cretaceous–Paleogene.

Geological setting

The Tarbur Formation (James and Wynd 1965) crops out in the Zagros basin along the western limb of the Zagros zone, between the main Zagros fault and the Sabzposhan fault (Alavi 2004). The formation, composed of a thick rock pack (20–450 m) of marl and limestone, represents a Maastrichtian carbonate platform mainly characterized by rudists and foraminifers (Piryaei et al. 2010; Bakhtiar et al. 2011). The development of these carbonates ran parallel to the Late Cretaceous migration of the Zagros thrust emplacement deposited along the borders of foreland basin, on the top of forebulge areas and in vertical contact (or sometimes in etheropy) with the shale of Gurpi Formation that represents the foredeep sedimentation (Piryaei et al. 2010; Saura et al. 2011).

Outcrops of the Tarbur formation studied herein are from two localities of the Fars region nearby of Mandegan village (Fig. 2). Here, Tarbur Formation overlies the Gurpi Formation and is overlain by conglomerate deposits of the Bakhtiari Formation (Pliocene). Three lithostratigraphic units encompass the Mandegan section (Fig. 3). The first unit is mostly composed of thick-bedded limestone. The second one comprises medium-bedded limestone with marly limestone intercalations. The third unit, representing the end of Maastrichtian carbonate sedimentation in the area, is characterised by marly lenses. The new species of *Elazigina*



Fig. 2. Position (asterisked) of studied localities in the general map of Iran (A) and position of Rod-Abad section (B).

appears in the middle part of the first unit. The Greenwich coordinates of the Mandegan section base are N 31°25'8.13" and E 51°24'34.58".

The studied section bearing the type level of the new species of *Elazigina* is located in the Rod-Abad section. The section is positioned 6.5 km far to the NE of Mandegan vil-lage, very close to the village of Ab-Malakh, where the lower first unit could be sampled (Fig. 2). The Rod-Abad section (coordinates at the base: N 31° 8'32.46" and E 51°23'51.30") is very rich in *Elazigina*. It records four short sea-level trans-gressive-regressive pulses represented by four marly levels rich in rudists in living-position intercalated with massive limestone. According to Bakhtiar et al. (2011), the marine paleoenvironment of Rod-Abad is shallower than in Mandegan.

Material and methods

The foraminifers studied herein come from 17 samples of cemented carbonate rocks (labelled Tf1 to Tf15) of the Rod-Abad section (for sample distribution see Fig. 3). Carbonates were processed to obtain thin sections. Additional rocks, labelled Rt53 and Rt55, used for comparison come from the Mandegan section (see also Consorti et al. 2018: fig. 1C). More than 230 random and oriented sections of foraminifers, obtained and photographed from these samples, were taken

into consideration for the present study. All the specimens are illustrated with a fixed enlargement in order to facilitate the comparison of the new taxa with other previously described. The specialised terms used for the architectural analysis of the rotaloidean foraminifers come from Hottinger (2006, 2014). The section orientation has been named according to Billman et al. (1980) and Hottinger (2014).

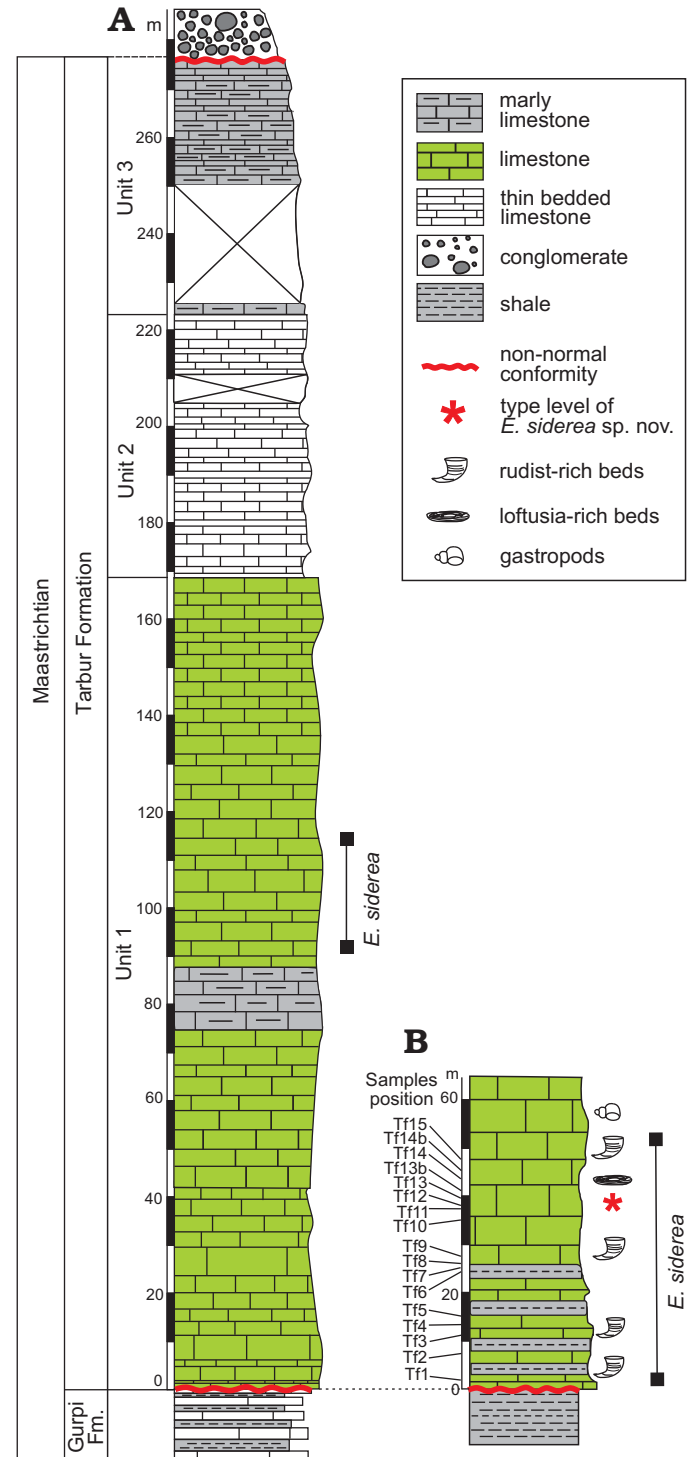


Fig. 3. Stratigraphic columns from Mandegan (A) and Rod-Abad (B) sections with position of the studied samples and distribution of *Elazigina siderea* sp. nov.

Systematic palaeontology

Phylum Foraminifera d'Orbigny, 1826

Class Globothalamea Pawlowski, Holzmann, and Tyszka, 2013

Order Rotaliida Delage and Hérouard, 1896

Superfamily Rotaloidea Ehrenberg, 1839

Remarks.—According to Consorti et al. (2017a) superfamily Rotaloidea includes families Rotaliidae and Pararotaliidae.

Family Rotaliidae Ehrenberg, 1839

Subfamily Kathininae Hottinger, 2014

Remarks.—This subfamily has been defined by Hottinger (2014: 17) as: “The folia are small, inclined forward. Their tips are fused to each other and with the umbilical fill produced by the previous chambers to form a solid mass perforated by numerous parallel funnels. Some species may have a massive central umbo”. Therefore, the ventral structure in most representatives of this subfamily originates from folia vertical development, similar to what is observed in Lockhartiinae (Consorti et al. 2017a, b). Consequently, the subfamily Kathininae is here included in the Family Rotaliidae and considered sister group of the Lockhartiinae.

Genus *Elazigina* Sirel, 2012

Type species: *Kathina subsphaerica* Sirel, 1972; Turkey, Paleocene.

Remarks.—The main characteristics of the genus are: (i) Low trochospire with smooth dorsal side. (ii) Ventral side occupied by a massive umbilical plug (= central umbo in Hottinger 2014) and surrounded by umbilical piles and funnels. The presence of umbo is not due to folia coalescence. (iii) Absence of a keel. (iv) Spiral interocular space constrained between umbilical plates and the umbilical piles. (v) Massive feathering occupying the ventral intraseptal interocular spaces. See Sirel (2012) and Hottinger (2014) for more information on the shell architecture. See Serra-Kiel et al. (2016) and Benedetti et al. (2018) for remarks on taxonomy.

Elazigina has sometimes been confused with the genus *Smoutina* Drooger, 1960 (e.g., Inan 1988; see Hottinger 2014 for a thorough discussion). The umbilical plug of *Elazigina* is massive, whereas that of *Smoutina* is composed by numerous superposed lamellae (probably folia, see Hottinger 2014: pl. 5.18: 3) and is perforated by funnels. Ventral chamber sutures are feathered in *Elazigina*, unlike *Smoutina*. Furthermore, *Smoutina* is reported only from the Caribbean Paleobioprovince (Hottinger 2014), whereas *Elazigina* comes from the central and eastern Tethys area. The genus *Cideina* Sirel, 1991 from the Maastrichtian of Turkey differs from *Elazigina* by having the flat morphology and no central plug.

Elazigina siderea sp. nov.

Figs. 4, 5.

1988 *Smoutina cruysi* Drooger, 1960; Inan 1988: 471, pl. 1: 1–9.

2008 indet. Foraminifera at upper left side of the picture; Schlüter et al. 2008: 518, fig. 4g.

2013 *Rotalia skourensis* Pfernder, 1938; Vaziri-Moghaddam et al. 2013: 154, fig. 14E.

2016 *Pararotalia?* sp.; Schlagintweit et al. 2016: 177, fig. 7G.

Etymology: From Latin *sidera*, star; due to the typical umbilical outline and from the heavy feathering.

Type material: Holotype: APNU-Tf12, complete specimen sectioned along the axial direction (Fig. 4A). Paratypes: APNU-Tf12, complete specimen sectioned along the subaxial direction (Fig. 4G, K); APNU-Tf11, oblique basal sections of complete specimen (Fig. 5D, H); APNU-Tf14, oblique centred section of a complete specimen (Fig. 5F); all from type locality.

Type locality: Rod Abad section, Fars, Iran.

Type horizon: Base of Tarbur Formation, Maastrichtian, Cretaceous.

Material.—About 150 oriented sections and 80 random sections.

Diagnosis.—Medium-size lamellar perforate shell of chambers arranged in a low trochospire. The dorsal side is low convex. Convexity of the ventral side may be sometimes exaggerated. Periphery unkeeled, slightly acute or somewhat rounded. A large massive umbilical plug occupies the central part of the ventral side. Piles present all around the umbilical plug. Ventral sutures heavy feathered. Folia small and slightly oblique. Presence of spiral, vertical (funnels) and intraseptal interocular spaces.

Description.—A set of 10 to 14 piles bed circularly the umbilical plug, some of these piles are fused with the plug periphery forming a lobed outline. Chamber walls are thick, but the wall of the last chambers may appear thinner. The spiral canal bears between the piles and the umbilical plates. There may be funnels between the piles line and the umbilical plug, but it is sometimes difficult to distinguish the spiral canal from the funnels. The intraseptal interocular space opens to the exterior and is partially subdivided by the branches of the feathering. The feathered space may be very wide, so much to reach the periphery the dorsal side. There are three whorls; the last one is sometimes incomplete. There are seven chambers in the first, 10–11 chambers in the second and 15–16 in the third whorl. Shell diameter of most complete specimens ranges 0.85–0.9 mm and its thickness may vary between 0.5 mm and 0.55 mm; the diameter on axial ratio is around 1.6. The plug diameter at the umbilicus of adult specimens is 0.23 mm, it extends longitudinally for more than 0.4 mm. Feather branches are up to 0.12 mm long and 0.05 mm thick. No microspheric specimens have been found, the diameter of the megalosphere is around 0.06 mm.

Remarks.—Specimens from Turkey described in Inan (1988) display slightly higher diameter and axial values than the Iranian specimens (max. diameter: 1.1 mm; max. axial thickness: 0.67). These measurements are here taken into consideration as intraspecific variability. The last chambers appear frequently well rounded and their wall is thin. This may be due to poor calcification during the last shell growth stage.

Overall, the dimensions of *E. siderea* sp. nov. are reduced with respect to the Paleocene representatives, *E. lenticula*



Fig. 4. Rotaliid foraminifer *Elazigina siderea* sp. nov. (A, holotype) from the Maastrichtian of Rod Abad section, Iran; axial (A, B, D, I, K), subaxial (E–H, J, L, N, O), oblique (C), and transversal-basal (M) sections. A–D, G, J–O. APNU-Tf12 (type-level). F, H, N. APNU-Tf11. E. APNU-Tf4. Abbreviations: f, feathers; pi, piles; pl, umbilical plug; sc, spiral canal.

and *E. subsphaerica*. Hottinger (2014) does not provide complete measurements of *E. dienii*, but *E. siderea* appears smaller. *E. dienii* displays also a more acute periphery, less

pronounced feathering and smaller umbo than *E. siderea*. The Middle East *E. harabekayisensis* has a thicker chamber wall, less piles, larger plug and less marked feathers

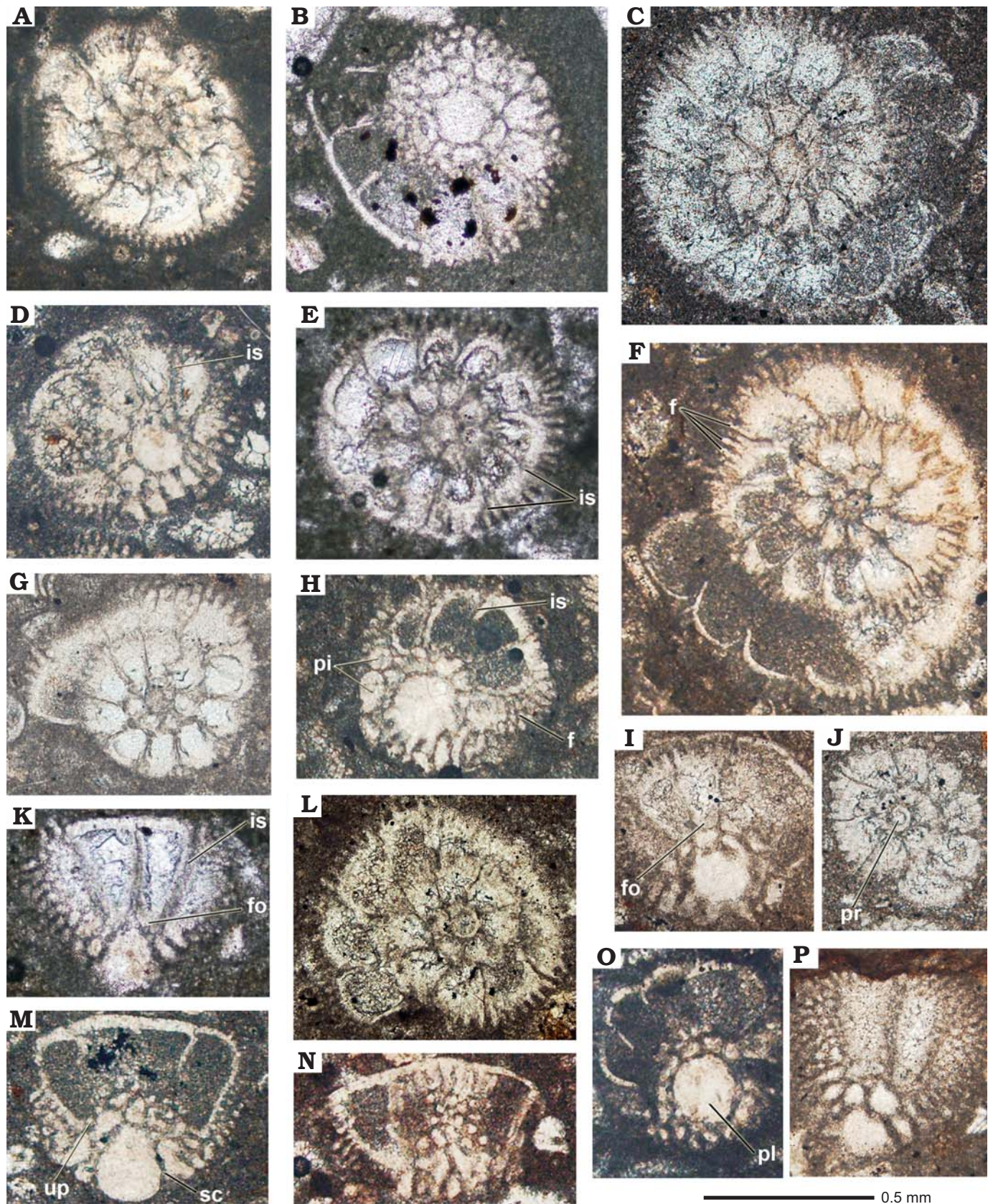


Fig. 5. Rotaliid foraminifer *Elazigina siderea* sp. nov. from the Tarbur Formation of Rod Abad (A, C, D, F–J) and Mandegan (B, E, K) sections, Iran; transversal (A, C, E, J), transversal-basal (B, O), transversal-oblique (D, F–I, L), and tangential (K, M, N, P) sections. C, J, L, M. APNU-Tf12 (type-level). D, G–I, P. APNU-Tf11. A, N. APNU-Tf10. F. APNU-Tf14. O. APNU-Tf4. B, E. APNU-Rt53. K. APNU-Rt55. Abbreviations: f, feathers; fo, folia; is, intraseptal canals; pi, piles; pl, umbilical plug; pr, proloculus; up, umbilical plate; sc, spiral canal.

Table 1. Comparison of biometrical measurements (in mm) in the species of *Elazigina*. Abbreviations: ma, megalospheric form; mi, microspheric form.

Species	Shell diameter	Axial thickness	Chambers in the last whorl	Reference
<i>Elazigina subsphaerica</i>	ma: 1.04–1.48 mi: 1.68–2.40	~1.40	~20	Sirel 2012
<i>Elazigina harabekayisensis</i>	1.52–1.88	1.00–1.32	~15	Sirel 2012
<i>Elazigina lenticula</i>	2.00–2.40	0.90–1.00	~22	Hottinger 2014
<i>Elazigina dienii</i>	1.20	0.50–0.60	10–12	Hottinger 2014
<i>Elazigina siderea</i>	0.85–0.90	~0.50	10–16	this work

than *E. siderea*. The piles surrounding the umbilical plug in *E. siderea* are well separated and clearly distinguishable in axial view, unlike most of the Paleocene allies, which piles frequently appear fused to the central plug or extremely reduced in dimension (see Hottinger 2014: pl. 6.8–11). A table comparing the measurements of all *Elazigina* species is presented in Table 1.

Stratigraphic and geographic range.—*Elazigina siderea* sp. nov. is here described from the Maastrichtian of Iran and recognized from equivalent shallow-water carbonates of Turkey and Oman (Schlüter et al. 2008). Potentially, its presence can be extended along the whole Anatolian and Arabian sector. In this work, *Elazigina siderea* sp. nov. characterizes the Rod-Abad section and the upper part of the Mandegan section, beneath the first occurrence of *Palaeoelphidium multiscissuratum* (Smout, 1955) (see the column in Consorti et al. 2018: fig. 1C). *Kathina* sp. reported in Piryaei et al. (2010: fig. 12) at the lower part of Tarbur Formation is probably *E. siderea* sp. nov. and should be taken into consideration as a further record.

Discussion

The Late Cretaceous GCMC (see Hottinger 2001 for full explanation) represents a unit within the long evolutionary history of larger foraminifers (Hottinger 2001; Goldbeck and Langer 2009), characterized by a trend of increasing diversity through the Turonian–Maastrichtian time span. Cretaceous rotaloidean foraminifers, for example, follow such pattern (see Boix et al. 2009; Consorti et al. 2017a, b) and their acme of diversity in Central Tethys and Pyrenean gulf is recorded during the Santonian and the early Campanian (Consorti et al. 2017a). A subsequent pulse of foraminifers diversity was triggered by the middle–late Campanian highstand that generated new niches and the spreading of newcomer genera worldwide (Boudagher-Fadel 2008). This is especially true for the upper Campanian–Maastrichtian carbonate shelves of Arabian and Anatolian plates that represented hot spot of foraminifers diversity and endemism (Özcan 1993; Schlagintweit and Rashidi 2017; Consorti et al. 2018). Furthermore, several endemic foraminifers from these sediments have been described recently (İnan and İnan 2009; Görmüş et al. 2017; Schlagintweit and Rashidi 2017 and the references herein). High diversity in Middle East also

continues in the Paleocene (Hottinger 2014). As the current central Indopacific realm (Langer and Hottinger 2000), high diversity of larger foraminifers in this area was most likely due to wide shelf areas and tropical climate (Scotese 2013) under the humid equatorial belt (Hay and Floegel 2012). The presence of both soft and hard bottoms would have further increased diversity (Hottinger 1988). Contrarily to the Indopacific, however, the shallow-water carbonate production in the upper Cretaceous Middle Eastern shelves did not contain coral frameworks, but was mainly characterized by foraminifers, echinoderms, rudists, red and green algae (see e.g., Schlüter et al. 2008; Piryaei et al. 2010; Bakhtiar et al. 2011). This may suggest possible fluctuation of nutrients in seawater or temperate waters (Simone and Carannante 1988; Ruberti et al. 2006; Carannante et al. 2008).

Notwithstanding the sea level fall trend recorded during the Maastrichtian and the Danian (Haq 2014) that could have reduced shallow-water niches, larger foraminifers in the Tarbur Formation and isochronous series in Iraq (Aqra Formation), Turkey (see e.g., Özcan 1993), Qatar and Oman (Simsima and Qahlah formations) show on-going high productivity and diversity. In this scenario, *Elazigina siderea* sp. nov. is associated with a very rich, mainly undescribed, rotaloidean assemblage, suggesting that its record coincides with the rotaliids (sensu lato) optimum at the final stage of the Late Cretaceous GCMC in Middle East. Among the abundant larger foraminifers of Tarbur Formation (see e.g., Rahaghi 1976; Schlagintweit et al. 2016), the assemblage studied in this work comprises *Pseudomphalocycclus blumenthali* Meriç, 1980, *Fissoelphidium operculiferum* Smout, 1955, *Orbitokathina* sp., and some species of the genus *Loftusia* (Fig. 6).

The shell of *Elazigina siderea* sp. nov., characterized by funnels and heavy feathers, does not display enveloping canals, or dimorphism. Enveloping canals helped *Laffitteina* to thrive in meso- to eutrophic environments, in analogy to the Neogene *Pseudorotalia indopacifica* (Thalman, 1935) shells recovered in deltas of tropical rivers under the influence of organic matter and clay minerals inputs (Billman et al. 1980; Hottinger 2014). Meso- to eutrophic adaptation and occasional shallow infaunal life style allowed *Laffitteina* and small benthic r-strategists survival through K–Pg (Culver 2003; Hottinger 2014). This adaptation is arguably applicable to *Elazigina siderea* sp. nov. The latest Maastrichtian–Danian lowstand phase (Hallam and Wignall 1999; Alegret et al. 2001; Habib and Saeedi 2007; Haq 2014)

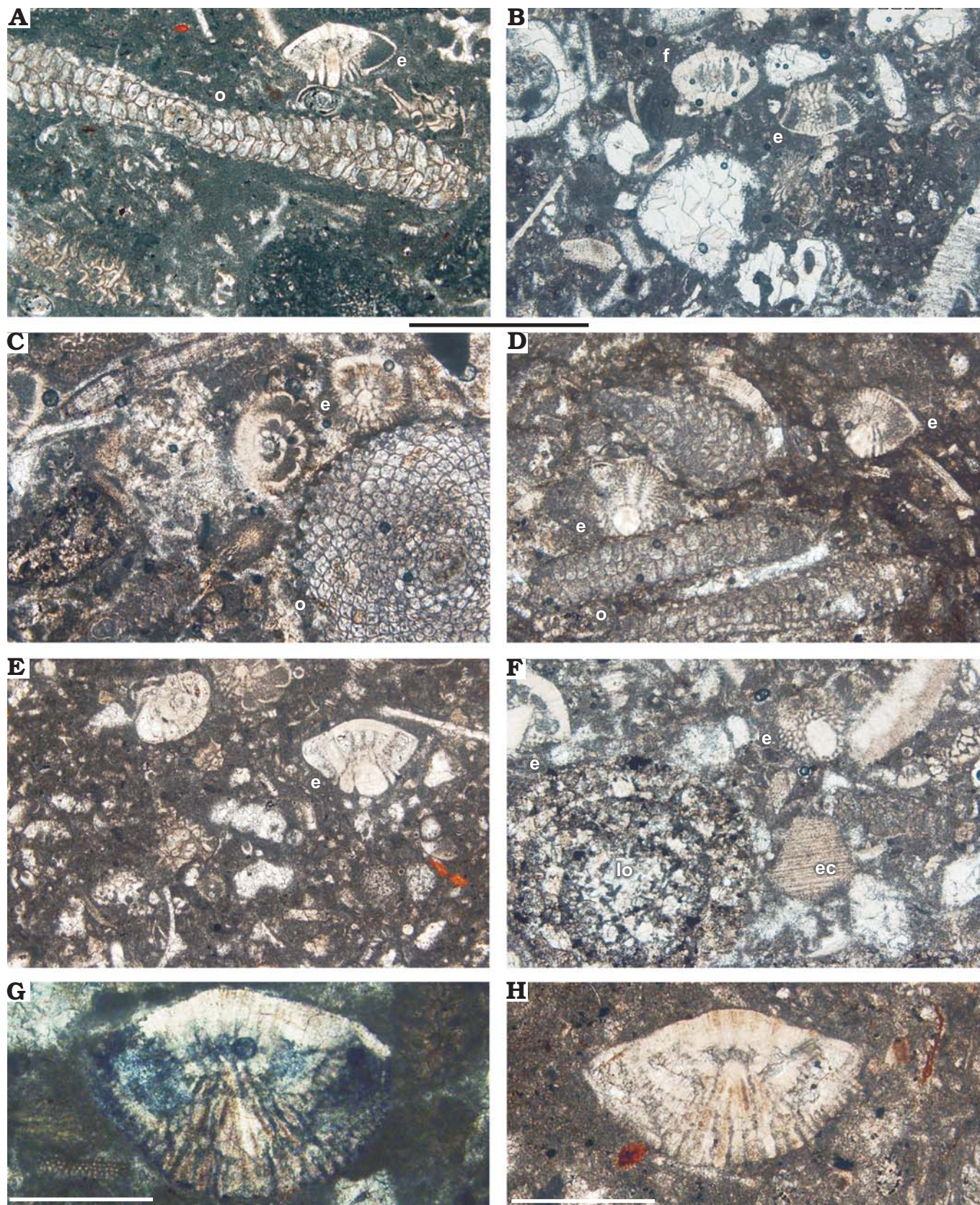


Fig. 6. A–F. Facies from the Tarbur Formation of Rod Abad section, Iran. A, C, D. Packstone with *Pseudomphalocyclus blumenthali* Meriç, 1980 (o) and *Elazigina siderea* sp. nov. (e). B, E. Packstone-wackestone with *Fissoelphidium operculiferum* Smout, 1955 (f), *Elazigina siderea* sp. nov. (e), and mollusc fragments. F. Packstone-grainstone with *Loftusia* (lo) and echinoderm fragments (ec). G, H. *Orbitokathina* sp. G. APNU-Tf14. H. APNU-Tf12. Scale bars A–F, 1 mm; G, H, 0.5 mm.

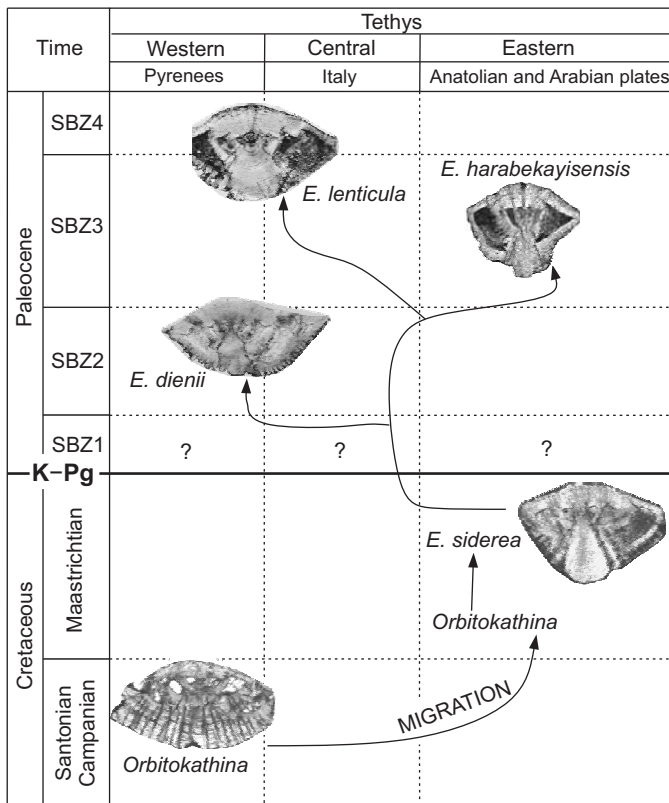


Fig. 7. Schematic representation of *Elazigina* evolution through time. Images not to scale, modified from Boix et al. (2009); Serra-Kiel et al. (2016); Hottinger (2014). Shallow Benthic Zones (SBZ) according to Serra-Kiel et al. (1998).

may have increased the tropism in shallow seas through the establishment of “pools” restricted in water circulation on shelves (as e.g., Ogorelec et al. 2007: fig. 5). This would provide environment for few resistant foraminifers represented by *Laffitteina*, *Elazigina*, and probably *Palaeoelphidium* (Consorti et al. 2018).

The wide umbilical plug in *Elazigina* is interpreted to stabilize the shell immersed in soft substrates (Hottinger 2014). The ventral feathers could have further facilitated shell stability within carbonate mud and during motility, whereas umbilical orifices provided protoplasmic flux to screw in soft substrates, as in *Ammonia catesbyana* d’Orbigny, 1839 (see Langer et al. 1989). Following this interpretation, *Elazigina* would have been capable to withstand sunlight exposure and catch microalgae for photosynthesis or, if necessary, process the organic matter found within the substrate. The Paleocene *Elazigina* species were supposedly K-strategist (Hottinger 2014), but the Maastrichtian *Elazigina siderea* sp. nov. was probably a r-strategist or a moderate K-strategist. This feature allowed the genus to survive during K–Pg and spread again during Paleocene, as testified by the rise of speciation rate and diversification all over the Neotethys (Fig. 7).

Elazigina siderea sp. nov. is most presumably linked to the Maastrichtian migration of the genus *Orbitokathina* Hottinger, 1966 from western Europe (Pyrenees) to Middle

East (Fig. 7). Both taxa, belonging to the Paleocene group of *Kathina*, are closely related and are found together in the same samples. According to diameter measurement (≈ 0.7 mm), the specimens from Iran may be closely related to *Orbitokathina* cf. *campaniana* Boix, Villalonga, Caus, and Hottinger, 2009, but the latter material is not adequate for precise identification. In contrast to the *Orbitokathina* assemblages recovered in the Pyrenees, which comprise both large microspheric B-forms and small macrospheric A-forms, the assemblage from the Tarbur Formation contains only A-forms. The dispersal of *Orbitokathina* was most likely driven by the end-Cretaceous enclosure of the Pyrenean basin that affected the production of marine carbonates with larger foraminifers and promoted sedimentation of continental deposits (Rosell et al. 2001).

Conclusions

The Maastrichtian rotaliid morphotypes of the Tarbur Formation from the Rod-Abad section in Fars region (Iran, Zagros Zone) are attributed to the genus *Elazigina*, and described as *Elazigina siderea* sp. nov. The new taxon is included in the subfamily Kathininae and is distinguished from the previously known species of *Elazigina* by the heavy feathered umbilical chamber sutures, by the presence of well-distinguished umbilical piles and reduced general dimensions.

Prior to this work, the genus *Elazigina* was only known from the Paleocene (SBZ 2–4). The record from the Maastrichtian is of interest because (i) it is the earliest occurrence in the geological record; and (ii) the genus survived across the Cretaceous–Paleogene mass extinction.

The demise of larger foraminifers at K–Pg boundary was most likely linked to the fluctuation of trophic levels in shallow seas, possibly due to Maastrichtian cooling and sea level fall that could have reduced the photosynthetic potential and the ecological niches of the full K-strategists. This would have favoured the survival of occasionally shallow-infaunal r-strategists taxa like *Elazigina*.

Acknowledgments

Comments by the reviewers Felix Schlagintweit (Munich, Germany) and Bruno Granier (University of Brest, France) are highly appreciated.

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