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BIOSTRATIGRAPHY AND PALEOECOLOGY OF MAASTRICHTIAN AND PALEOCENE SEDIMENTS IN THE NORTHERN ALBORZ, IRAN, USING FORAMINIFERA

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ABSTRACT

In this study, the late-Maastrichtian and early-Paleocene transition at the Ziarat-Kola section has been investigated to recognize the biostratigraphy and paleoenvironmental changes. We applied a high-resolution quantitative study by using planktic foraminifera taxa and benthic foraminiferal morphotypes. Sixty-five species belong to twenty-eight genera were identified and seven biozones were differentiated. These biozones are 1. *Racemiguembelina fructicosa*, 2. *Pseudoguembelina hariaensis*, 3. *Pseudoguembelina palpebra*, 4. *Parvularugoglobigerina eugubina*, 5. *Parasubbotina pseudobulloides*, 6. *Subbotina triloclinoides*, 7. *Globonomalina compressa-Preamurica inconstans*. In the late Maastrichtian, benthic and planktic foraminifera are well mixed of epifauna/infauna morphotypes and diversified suggesting a stable and mesotrophic environment. By contrast, the early Paleocene is marked by high values of epifaunal benthic morphogroups, and extinction of Cretaceous species suggesting highly unstable and variable conditions, partly due to the dramatic collapse of calcareous primary producers. Additionally, four different zones were determined based on the benthic foraminifera morphogroups that show several changes in oxygen and organic matter flux during this time. Also, analysis of planktic foraminifera genera in this section indicating a close similarity with assemblages in Tethyan provinces.

Contribution/Originality: This study contributes a new methods to understand the biostratigraphy and ageing the rock samples in late Cretaceous of eastern Tethys. Also, This study is one of very few studies which have investigated the pal ecology and oxygen changes in Campanian-Maastrichtian sediments by using the plank tic and benthic foraminfera that are small microorganism.

1. INTRODUCTION

The Alborz range comprises Precambrian to Quaternary rocks, which contain unconformities in Paleozoic and Mesozoic formations (Alavi, 1996). Late Cretaceous succession has been poorly studied in northern Iran but strong variability in the sedimentary environments among sections has been observed (Asgharian *et al.*, 2009;2012;2013a;2013b;2018). The very high rate of sediment accumulation in the studied area created a great potential for biostratigraphy and evaluating the timing of environmental changes during this age. The Ziarat-Kola section is located about 8 km south of Ziarat-Kola village, south of Neka city in the northern flank of Central Alborz Mountains (36°31′30″ N, 51°45′30″ E) (Figure 1). Late Maastrichtian and Paleocene strata are consisting of monotonous green to light grey marl, interbedded with marly limestones that are rich in foraminifera, ostracods and other microfossils (Asgharianrostami *et al.*, 2009;2012). In the last decades, one of the most utilized fossil groups to address the environmental change has been known as planktonic and benthic foraminifera. Planktonic foraminifera are very sensitive to climatic and oceanographic changes and their dramatic event has been documented by many specialists in several sections and sites (Luterbacher and Premoli-Silva, 1964; Molina *et al.*, 2005; Gallala *et al.*, 2009; Asgharian *et al.*, 2009;2011;2012;2013a;2013b;2014;2018; Frontalini *et al.*, 2016; Menichetti *et al.*, 2016; Martin *et al.*, 2017; Amao *et al.*, 2018; Rodelli *et al.*, 2018). The aim of this paper is to provide a biostratigraphical scheme and the paleoenvironmental change in the Ziarat-Kola section (Northern Alborz, Iran) by using planktic and benthic foraminifera across the late Maastrichtian- early Paleocene.

2. MATERIALS AND METHODS

For this study, we collected ninety-one samples along a ~212-meter thickness at 2-2.5 meters intervals. The samples were disaggregated in tap water and washed through 125 µm and 63 µm sieves and dried at 50 °C. All the samples were used for planktic foraminifera biostratigraphy and some of them for quantitative analyses of planktic and benthic foraminifera. At least 300 specimens of planktic foraminifera were picked from the > 125 µm and 63-125 µm fractions, and 300 specimens of benthic foraminifera were picked from >125 µm fraction. The relative abundance of foraminiferal species is defined as follows: abundant (> 20%), common (> 5–20%), few (1–5%), and rare (< 1%) (Asgharian *et al.*, 2018). A variety of late Maastrichtian and early Paleocene planktic foraminiferal biozonation schemes have been proposed in the literature, among them, Berggren *et al.* (1995); Olsson *et al.* (1999); Ben Abdelkader *et al.* (1992) and Berggren and Pearson (2005) are the most commonly used. Here, we adopted the zonal schemes of for the uppermost Maastrichtian, and Berggren and Pearson (2005) for the Danian. Additionally, benthic foraminiferal morphotypes have been used to infer microhabitat and reconstruct the paleoenvironmental condition (Corliss and Chen, 1988; Alegret *et al.*, 2003).

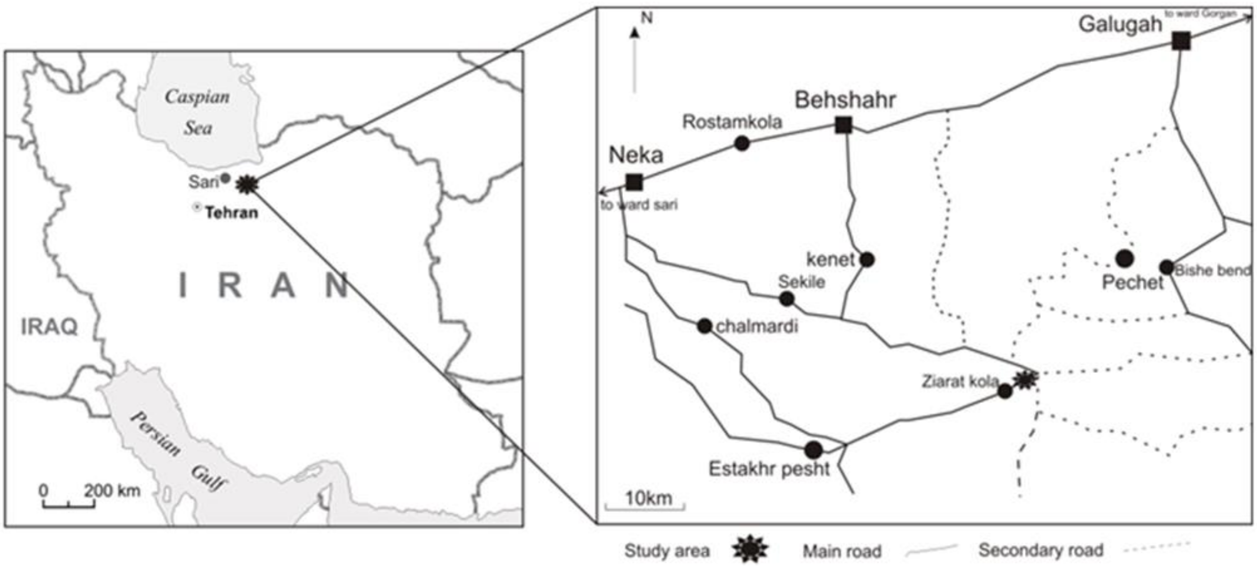

Figure-1. Map of the northern Iran and location of studied area.

3. RESULT AND DISCUSSION

3.1. Planktonic Foraminifera Biostratigraphy

Planktic foraminifera are one of the best groups for studying biostratigraphy, paleoecology, and paleogeography especially at the end of Cretaceous due to having high diversity, great preservation, and global distribution. Planktic foraminifera biostratigraphy of upper Cretaceous in Tethys basin has been studied by Caron (1985) that was subsequently revised by Robaszynski *et al.* (1995). Later, Li and Keller (1998a;1998b) divided the Campanian-Maastrichtian interval to ten biozones named as (CF, Cretaceous foraminiferal) based on the planktic foraminifera. Finally, the upper Cretaceous biozones in Tethys basin were revised by Petrizzo (2003) and Arenillas *et al.* (2004). Additionally, Paleocene biostratigraphy by planktic foraminifera has studied by Berggren *et al.* (1995); Keller *et al.* (1995); Olsson *et al.* (1999) and Berggren and Pearson (2005). Here, we adopted the zonal scheme of Li and Keller (1998a;1998b) for the upper Maastrichtian and Berggren and Pearson (2005) for the Paleocene (Figures 2, 3, and 4; Plates 1-6). Planktic foraminifera in the Ziarat-Kola section are abundant and very well-preserved. On the basis of a high-resolution study of planktic foraminiferal, seven planktic foraminiferal biozones have been recognized through the late Maastrichtian- early Paleocene. In this study, classification and taxonomy of the planktic *foraminifera* are based on Postuma (1971); Caron (1985); Loeblich and Tappan (1988). These biozones are 1) *Racemiguembelina fructicosa* Zone (CF4), 2) *Pseudoguembelina hariaensis* (CF3) Zone, 3) *Pseudoguembelinapalpebra* (CF2)Zone, 4) *Parvularugoglobigerina eugubina* Zone, 5) *Parasubbotina pseudobulloides* Zone, 6) *Subbotina triloculinoides* Zone and 7) *Globanomalina compressa/Praemurica inconstans* Zone (Figures 2 and 3; Plates 1-6). Most researchers define the late Maastrichtian interval by introducing *Abathomphalus Mayaroensis* Zone (Caron, 1985; Petrizzo, 2003). Then, Li and Keller (1998a;1998b) divide *A. Mayaroensis* Zone into four zones for better identification of high thickness of late Maastrichtian interval. Additionally, *A. mayaroensis* is known as a poor biostratigraphic marker due to *diachroneity* (Li and Keller, 1998a;1998b; Petrizzo, 2003).

3.1.1. Racemiguembelina Fructicosa Partial range Zone (CF4) (Li and Keller, 1998a;1998b)

This zone was named by Li and Keller (1998a) and it is defined as a stratigraphic interval limited by the LO (lowest occurrence) of *R. fructicosa* and the LO of *Pseudoguembelina hariaensis* (Li and Keller, 1998a;1998b). This zone spans about 1.5 My (68.33-66.83) that showing upper Maastrichtian and beginning of this zone is approximately simultaneous with appearance *Abathomphalus mayaroensis* species *(Caron, 1985)*. It consists of 22 m thick brown marlstone in this section. The dominant species in this zone are: *Racemiguembelina fructicasa*, *Racemiguembelina powelli*, *Globotruncanella havanensis*, *Globotruncanella petaloidea*,*Rugoglobigerina rugosa* ,*Pseudotextularia intermedia*, *Abathomphalus mayaroensis*, *Contusotruncana patelliformis*, *Gansserina gansseri*, *Gansserina wiedenmayeri*, *Globotruncana aegyptiaca*, *Globotruncana arca*, *Globotruncana dupeublei*, *Globotruncana mariei*, *Pseudoguembelina costulata*, *Pseudoguembelina palpebra*, *Pseudotextularia nuttalli* and *Trinitella Scotti* (Figures 2 and 3; Plates 1-4). The age estimation of this biozone by (Li and Keller, 1998a) is early- late Maastrichtian.

3.1.2. Pseudoguembelina Hariaensis Partial Range Zone (CF3) (Li and Keller, 1998a;1998b)

This zone characterized by the first appearance of *Pseudoguembelina hariaensis* at the base and the HO (Highest occurrence) of *Gansserina gansseri* at the top (Li and Keller, 1998a) This biozone spans about 1.4 My (66.8-65.45 Ma) that showing late-Maastrichtian stage (Li and Keller, 1998a). This zone spans 66 m of brown marl and limy marl. The dominant species in this zone are *Gansserina gansseri*, *Globotruncana aegyptiaca*, *Globotruncana arca*, *Globotruncanella havanensis*, *Globotruncanella petaloidea*, *Planoglobulina carseyae*, *Planoglobulina riograndensis*, *Pseudoguembelina costulata*, *Pseudoguembelina excolata*, *Pseudoguembelina palpebra*, *Pseudotextularia elegans*, *Pseudotextularia intermedia*, *Rugoglobigerina rugosa*, *Trinitella Scotti*, *Racemiguembelina powelli*, *Heterohelix globoulos* and *Laeviheterohelix glabrans* (Figures 2 and 3; Plates 1-4). This biozone is placed in the middle of Late-Maastrichtian by Li and Keller (1998a).

3.1.3. Pseudoguembelina Palpebra Partial Range Zone (CF2) (Li and Keller, 1998a;1998b)

This zone has been limited between the LO of *Gansserina gansseri* to LO of *Plummerita hantkeninoides* Zone (Li and Keller, 1998a). However, due to lack of *Plummerita hantkeninoides* species, this zone defined by last appearance of *Gansserina gansseri* to the HO of Cretaceous taxa. Lack of *Plummerita hantkeninoides* can be due to unconformity in this section. This biozone spans about 0.45 My (65.45-65.00) that showing uppermost part of Maastrichtian. This partial range zone comprises 136 m of grey marl and limy marl. The dominant species in this zone are *Globotruncana arca*, *Globotruncana mariei*, *Globotruncanella havanensis*, *Pseudoguembelinapalpebra*, *Pseudotextularia e egans*, *Pseudotextulariaintermedia*, *Rugoglobigerina hexacamerata*, *Rugoglobigerina rugosa*, *Trinitella Scotti*, *Racemiguembelina powelli*, *Heterohelix globoulos*, *Laeviheterohelix glabrans*, *Globigerinelloides Bollii*, *Globigerinelloides subcarinata* and *Schackoina multispinata* (Figures 2 and 3; Plates 1-4). The age estimation of this biozone show late Maastrichtian based on (Li and Keller, 1998a). Absent of *Plummerita hantkeninoides and Guembelitria cretaceoua Zones* and stratigraphic evidence show an *unconformity between Cretaceous* and Paleocene succession in the Ziarat-Kola section Northern Alborz. Additionally, it is possible these zones have been missed due *to* low-resolution sampling.

3.1.4. Parvularugoglobigerina Eugubina Total Range Zone (Pα)

This zone firstly introduced as the total range of the *Pv.eugubina* species by Luterbacher and Premoli-Silva (1964). Later, this zone was emended by Toumarkine and Luterbacher (1985); Molina *et al.* (1996) and Arenillas *et al.* (2004) that indicated the top part of *Pv.eugubina* Zone in correspondence of the first appearance of *Parasubbotina pseudobulloides* Zone. The age estimate for this zone is between 64.981 and 64.945 Ma (Berggren and Pearson, 2005). At Ziarat-Kola section, this zone is 1m thick, and *Parvularugoglobigerina eugubina*, *Eoglobigerina edita*, *Parasubbotina aff. Pseudobulloides* , *Hedbergella holmdelensis*, *Hedbergella monmothoensis*, *Globoconusa daubjergensis*, *Chiloguembelina morsei* and *Parvularugoglobigerina alabamensis* dominated the planktic foraminiferal assemblages (Figures 2 and 3; Plates 5-6). The age of this zone is defined as early Danian.

3.1.5. Parasubbotina Pseudobulloides Partial Range Zone (P1a)

This zone has been defined as the partial-range zone from the HO of *P. eugubina* to the LO of *Subbotina triloculinoides*. This zone was firstly introduced by Leonov and Alimarina (1961) as *Globigerina pseudobulloides-Globigerina daubjergensis* Zone, and Bolli (1966) changed the name to *G. pseudobulloides* Zone. This zone was defined by Toumarkine and Luterbacher (1985) as HO of *Pv. eugubina* and the LO of *Acarinina trinidadensis*. Later, this zone emended by Molina *et al.* (1996) and was defined as the LO of *Ps. pseudobulloides* and LO *Globanomalina compressa* species. This biozone spans about (64.8–64.3 Ma) that showing early Paleocene (Danian). At Ziarat-Kola section, the *Parasubbotina pseudobulloides* Zone with a 2 m thickness is dominated by *Eoglobigerina edita*, *E. eobulloides*, *P. pseudobulloides*, *P. pseudoinconstans*, *P. taurica*, *C. morsi*, *G. planocompressa* and *Globoconusa daubjergensis species* (Figure 3; Plates 5-6).

3.1.6. Subbotina Triloculinoides Partial Range Zone (P1b)

This zone is a partial range of *Subbotina triloculinoides* taxon limited by the LO of *S. triloculinoides* and the first appearance of *Globanomalina compressa-Praemurica* (Berggren and Pearson, 2005). The age estimated for this zone spans about 64.3-62.87 Ma that determining early Paleocene (Early to mid-Danian). This biozone also introduced by Berggren (1969); Berggren *et al.* (1995); Berggren and Norris (1997); Olsson *et al.* (1999) and it consists of 5 m brown gray and green clayey marl at the Ziarat-Kola section. The dominated species in this zone include *Eoglobigerina edita*, *Parasubbotina aff. Pseudobulloides*, *Hedbergella holmdelensis*, *Hedbergella monmothoensis*, *Globoconusa daubjergensis*, *Chiloguembelina morsei*, *Parvularugoglobigerina alabamensis*, *Woodringina hornerstownensis* and *Woodringina claytonensis* (Figure 3; Plate 5-6).

3.1.7. Globanomalina Compressa/Praemurica Inconstans Interval Zone

This biostratigraphic interval identified by LO of *Globanomalina compressa* and/or *Praemurica inconstans* and the LO of *Praemurica uncinata* which show middle to late Danian age (62.87- 61.37 Ma) (Berggren and Pearson, 2005). This zone nominated by Shutskaya (1970) at Trinidad and later emended by Berggren (1969); Berggren *et al.* (1995); Berggren and Norris (1997); Olsson *et al.* (1999) and Berggren and Pearson (2005). This biozone is consists of 2 m monotonous grey marl and limestone. The dominated species of this zone are *Parasubbotina Pseudobulloides*, *Parasubbotina aff. pseudobulloides*, *Globoconusa daubjergensis*, *Chiloguembelina morsei*, *Parvularugoglobigerina alabamensis*, *Preamurica psudoinconstans*, *Preamurica inconstans*, *Woodringina hornerstownensis*, *Chiloguembelina midwayensis*, *Chiloguembelina morsei* and *Subbotina triloclinoides* (Figure 3; Plates 5-6).

3.2. Paleoenvironmental Reconstruction

Benthic foraminifera are critical tool for determining of environmental conditions, such as bathymetry, sea level change, water mass, productivity and oxygenation (Culver, 2003; Asgharianrostami *et al.*, 2013a;2014; Frontalini *et al.*, 2016; Menichetti *et al.*, 2016; Amao *et al.*, 2018; Rodelli *et al.*, 2018). Based on quantitative analysis of the late Maastrichtian and early Paleocene benthic foraminiferal morphotypes (Epifauna/Infauna) two distinct assemblages were recognized (Figure 5). The comparison of fossil and recent communities of benthic foraminifera, in addition to morphotype analysis (Corliss and Chen, 1988) allows us to monitor probable microhabitat preferences and environmental parameters such as the nutrient availability to the seafloor and seawater oxygenation (Bernhard, 1986; Jorissen *et al.*, 1995; Alegret *et al.*, 2003). We divided all benthic foraminiferal taxa to epifauna and infauna morphogroups by using Corliss and Chen (1988) and Alegret *et al.* (2003). In general, benthic foraminifera with plano-convex, biconvex, rounded trochospiral, tubular, coiled flattened, as well as milioline and palmate tests are inferred to have an epifaunal mode of life (living at the sediment surface or in upper few centimeters). Infaunal morphotype living in the deeper layers of the sediment (4-10 cm within the sediment) and have cylindrical flattened tapered, spherical, rounded planispiral, flattened ovoid, globular unilocular and elongate multilocular shape tests. Generally, benthic foraminifera epifauna indicates well oxygenated and decrease food supply condition and infauna show high food supply condition. The first assemblage characterizes the late Maastrichtian interval which is highly diversified and composed of a mixture of epifaunal and infauna morphogroups, though epifaunal are less abundant (Figure 5). Based on high diversity and high infauna percentage, this assemblage suggests stable and mesotrophic to moderately eutrophic conditions with high availability of food at the seafloor. Additionally, the relatively high percentages of the agglutinated test might indicate high supply of terrigenous material in this part. At the second assemblage (early Paleocene), a dramatic change in the benthic foraminiferal morphotypes and tests was recognized (Figure 5). At this part, the relative abundances of infauna morphotype decreased drastically (~30% of the assemblages). This assemblage is mostly composed of epifaunal species that account up to ~70% that clearly reflects a drastic collapse in the food supply to the seafloor and oligotrophic condition. This pattern was also reported in many sections and sites above the K/Pg boundary (Alegret *et al.*, 2003; Coccioni and Marsili, 2007; Alegret and Thomas, 2009; Asgharian *et al.*, 2018). Additionally, this change may suggest mainly oligotrophic conditions and a lowered food supply to the sea floor that probably related to the mass extinction of calcareous plankton include nannoplankton and planktic foraminifera.

3.3. Paleogeography

Planktic foraminifera are not only applied for biostratigraphy, paleoecological and palaeoceanographical but they can also use for paleogeography studies. During the Cretaceous, the temperature gradient from equator to pole was less than today and Boreal and Tethyan basins were separated from each other by a warm water mass current (Bailey and Hart, 1979; Caron, 1985). The cold boreal and austral provinces characterized by planktic foraminifera forms like globular chambers and thin walls such as Hedbergella, Globigerinelloids, Heterohelix, Whiteinella, Archaeoglobigerina and Rugoglobigerina (Caron, 1985) (Table. 1). On the other hand, the warm water provinces are characterized by species with thick-walled and ornamented by keels. These taxa include Marginotruncana, Globotruncuna and Globotruncanita and Gansserina that occupy the Tethyan province (Table 1). Based on the study of planktic foraminifera genera at the Ziarat-Kola section, Globotruncana and Globotruncanita genera are dominated at this section compare to Globogerinoides and Hedbergella. Therefore, these data suggest this section has a close similarity with the planktic foraminifera genera in the Tethyan provinces.

Table-1. Biogeography of Ziarat-Kola section by using genus of planktic foraminifera

Genus of cold water	Genus of warm water	Abundance genus in this section
Archaeglobigerina *Globigerinelloides* *Heterohelix* *Hedbergella* *Whiteinella*	*Dicarinella* *Globotruncana* *Globotruncanita* *Marginotruncana* *Planomalina* *Rotalipora* *Helvetoglobotruncana*	*Globotruncana* *Globotruncanita* *Heterohelix* *Globigerinelloides*

Source: (Modified from Bailey and Hart (1979); Caron (1985)).

4. CONCLUSION

Sixty-five species belong to twenty-eight genera were identified and seven zones were differentiated. These zones include 1. *Racemiguembelina fructicosa*, 2. *Pseudoguembelina hariaensis*, 3. *Pseudoguembelina palpebra*, 4. *Parvularugoglobigerina eugubina* ,5. *Parasubbotina pseudobulloides*, 6. *Subbotina triloclinoides* 7. *Globonomalina compressa-Preamurica inconstans*. Based on these zones, late Maastrichtian-early Paleocene age is determined for this section. Additionally, two zones were defined by using benthic foraminifera morphogroups. The first zone indicates a normal and mesotrophic condition with low oxygen and high food supply. However, in the second zone, increasing epifauna show oligotrophic condition with high oxygen and collapse of food availability. Also, comparing planktic foraminifera genera recovered from this section with those of Cretaceous biogeographical provinces indicate a close similarity with assemblages in Tethyan basin.

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REFERENCES

Alavi, M., 1996. Tectonostratigraphic synthesis and structural style of the Alborz mountain system in Northern Iran. Journal of Geodynamics, 21(1): 1-33. View at Google Scholar | View at Publisher

Alegret, L., E. Molina and E. Thomas, 2003. Benthic foraminiferal turnover across the cretaceous/paleogene boundary at Agost (Southeastern Spain): Paleoenvironmental inferences. Marine Micropaleontology, 48(3-4): 251-279. View at Google Scholar | View at Publisher

Alegret, L. and E. Thomas, 2009. Food supply to the seafloor in the pacific ocean after the cretaceous/paleogene boundary event. Marine Micropaleontology, 73(1): 105-116. View at Google Scholar | View at Publisher

Amao, A.O., M.A. Kaminski, R.M. Asgharian, G.M.H. Mahmudy, R. Lak and F. Frontalini, 2018. Distribution of benthic foraminifera along the Iranian coast. Marine Biodiversity: 1-14.

Arenillas, I., J.A. Arz and E. Molina, 2004. A new high-resolution planktic foraminiferal zonation and subzonation for the lower Danian. Lethaia, 37(1): 79-95. View at Google Scholar | View at Publisher

Asgharian, R.M., B. Darvishzad and N.E. Ghasemi, 2009. Planktonic foraminifera response to sudden global warming in Late Maastrichtian, a case study from Ziyarat-Kola, Central Alborz, Iran. Journal of Sciences, Islamic Republic of Iran, 20(3): 233-242.

Asgharian, R.M., N.E. Ghasemi, A.M. Shafiee and B. Balmaki, 2011. Biostratigraphy and studying the hypothesis uses of rugoglobigerina in appointing the paleosalinity in Central Alborz, Maastrichtian. Geoscience, 20(80): 23-32.

Asgharianrostami, M., M. Vahidinia and N.E. Ghasemi, 2012. Paleoenvironmental reconstruction using benthic foraminiferal assemblages across the Cretaceous/Palaeogene boundary in the Alborz Basin, Northern Iran. Journal of American Science, 8(13): 53-55.

Asgharianrostami, M., R.M. Leckie and E. Font, 2013a. High stress environment across the cretaceous/paleogene boundary at the galanderud section (Northern Alborz, Iran): Geological Society of America Annual Meeting, Denver, Colorado, USA.

Asgharianrostami, M., M. Vahidinia, N.E. Ghasemi and A. Sadeghi, 2013b. Biostratigraphy and mass extinction pattern across the Cretaceous/Paleogene boundary, Northern Alborz, Iran. Open Journal of Geology, 3: 33-38. *View at Google Scholar* | *View at Publisher*

Asgharianrostami, M., M.R. Leckie, E. Font, F. Frontalini and C. Koeberl, 2014. Turnover and paleoenvironmental changes across the cretaceous/paleogene boundary at the Galanderud section (Northern Alborz, Iran) based on benthic foraminifera. EGU General Assembly, Vienna, Austria.

Asgharian, R.M., R.M. Leckie, E. Font, F. Frontalini, D. Finkelstein and C. Koeberl, 2018. The cretaceous-paleogene transition at Galanderud (Northern Alborz, Iran): A multidisciplinary approach. Palaeogeography, Palaeoclimatology, Palaeoecology, 493: 82-101. *View at Google Scholar* | *View at Publisher*

Bailey, H.W. and M.B. Hart, 1979. The correlation of the early Senonian in Western Europe using foraminiferida: Aspekte der Kreide Europas, IUGS ser, 4: 15949.

Ben Abdelkader, O.B., A.B. Ben Haj, H. Ben Salem and S. Razgallah, 1992. International workshop on Cretaceous- Tertiary Transitions at E1 Kef: Part II Field Trip Guide Book. pp: 25.

Berggren, W.A., 1969. Rates of evolution in some cenozoic planktonic foraminifera. Micropaleontology, 15(3): 351-365. *View at Google Scholar* | *View at Publisher*

Berggren, W.A., D.V. Kent, C.C. Swisher and M.P. Aubrey, 1995. A revised cenozoic geochronology and chronostratigraphy. SEPM (Society for Sedimentary Geology), 54: 129-212. *View at Google Scholar* | *View at Publisher*

Berggren, W.A. and R.D. Norris, 1997. Biostratigraphy, phylogeny and systematic of paleocene trochospiral planktic foraminifera. Micropaleontology, 43: 1-116. *View at Google Scholar* | *View at Publisher*

Berggren, W.A. and P.N. Pearson, 2005. A revised tropical to subtropical paleogene planktonic foraminiferal zonation. Journal of Foraminiferal Research, 35(4): 279-298. *View at Google Scholar* | *View at Publisher*

Bernhard, J.M., 1986. Characteristic assemblages and morphologies of benthic foraminifera from anoxic, organic-rich deposits, jurassic through holocene. Journal of Foraminiferal Research, 16(3): 207-215. *View at Google Scholar* | *View at Publisher*

Bolli, H.M., 1966. Zonation of cretaceous to pliocene marine sediments based on planktonic foraminifera. Boletín informativo de la Asociación Venezolana de Geología Minera y Petrolera, 9(1): 3-31. *View at Google Scholar*

Caron, M., 1985. Cretaceous planktic foraminifera. In: Bolli H.M., Saunders J.B., Perch Nielsen, K., Plankton Stratigraphy. Cambridge University Press. pp: 17-86.

Coccioni, R. and A. Marsili, 2007. The response of benthic foraminifera to the K–Pg boundary biotic crisis at Elles (Northwestern Tunisia). Palaeogeography, Palaeoclimatology, Palaeoecology, 255(1-2): 157-180. *View at Google Scholar* | *View at Publisher*

Corliss, B.H. and C. Chen, 1988. Morphotype patterns of norwegian sea deep-sea benthic foraminifera and ecological implications. Geology, 16(8): 716-719. *View at Google Scholar* | *View at Publisher*

Culver, S.J., 2003. Benthic foraminifera across the cretaceous–Tertiary (K–T) boundary: A review. Marine Micropaleontology, 47(3-4): 177-226. *View at Google Scholar* | *View at Publisher*

Frontalini, F., M.A. Rostami and R. Coccioni, 2016. Paleobathymetric assessments of the upper Albian-lower Danian Gubbio section (Italy): Geological Society of America Special Papers No. 524.

Gallala, N., D. Zaghbib-Turki, I. Arenillas, A.J. Arz and E. Molina, 2009. Catastrophic mass extinction and assemblage evolution in planktic foraminifera across the Cretaceous/ Paleogene (K/Pg) boundary at Bidart (SW France). Marine Micropaleontology, 72(3-4): 196-209. View at Google Scholar | View at Publisher

Jorissen, F.J., H.C. Stigter and J.G.V. Widmark, 1995. A conceptual model explaining benthic foraminiferal microhabitats. Marine Micropaleontology, 26(1-4): 3-15. View at Google Scholar | View at Publisher

Keller, G., L. Li and N. Macleod, 1995. The cretaceous–tertiary boundary stratotype section at El Kef, Tunisia: how catastrophic was the mass extinction?. Palaeogeography, Palaeoclimatology, Palaeoecology, 119: 221-254.

Leonov, V.P. and G.P. Alimarina, 1961. Stratigraphy and planktonic foraminifera of the cretaceous–paleogene transition. Beds of the central part of the North caucasus: Collected Papers Geological Faculty, University of Moscow, to XXI International Geological Congress, 29-60 (in Russian with extensive English summary.

Li, L. and G. Keller, 1998a. Maastrichtian climate, productivity and faunal turnovers in planktic foraminifera in South Atlantic DSDP Sites 525A and 21. Marine Micropaleontology, 33(1-2): 55-86. View at Google Scholar | View at Publisher

Li, L. and G. Keller, 1998b. Abrupt deep-sea warming at the end of the cretaceous. Geology, 26(11): 995-998. View at Google Scholar | View at Publisher

Loeblich, A. and H. Tappan, 1988. Foraminiferal genera and their classification. Van Nostrand Reinhold Company, 970: 1-847.

Luterbacher, H.P. and I. Premoli-Silva, 1964. Biostratigra ¢ a of cretaceous ^ tertiary in the central Apennines. Riview Italy Paleontology, 70(1): 67-117.

Martin, E.E., R.M. Asgharian, K.G. MacLeod, S. Haynes, C.J. Poulsen and G.A. Vande, 2017. Deep-water formation in the North Atlantic during the latest Cretaceous: American Geophysical Union, Fall Meeting.

Menichetti, M., R. Coccioni and A. Montanari, 2016. The stratigraphic record of Gubbio: Integrated stratigraphy of the late cretaceous–paleogene Umbria-marche pelagic basin. Geological Society of America: 1-524.

Molina, E., L. Alegret, I. Arenillas and J.A. Arz, 2005. The cretaceous/paleogene boundary at the agost section revisited: Paleoenvironmental reconstruction and mass extinction pattern. Journal of Iberian Geology, 31(1): 135-148. View at Google Scholar

Molina, E., I. Arenillas and J.A. Arz, 1996. The Cretaceous/Tertiary boundary mass extinction in planktic foraminifera at Agost, Spain. Revue de Micropaléontologie, 39(3): 225-243. View at Google Scholar | View at Publisher

Olsson, R.K., C. Hemleben, W.A. Berggren and B.T. Huber, 1999. Editors & members of the paleogene planktonic foraminifera working group. Atlas of paleocene planktonic foraminifera. Smithsonian Contributions to Paleobiology, 85: 1-252.

Petrizzo, M.R., 2003. Late cretaceous planktonic foraminiferal bioevents in the Tethys and in the Southern Ocean record: An overvie. Journal of Foraminiferal Research, 33(4): 330-337. View at Google Scholar | View at Publisher

Postuma, J.A., 1971. Manual of planktonic foraminifera. London: Elsevier, Amsterdam. pp: 397.

Robaszynski, F., M. Caron, J.M. Gonzales-Donoso and A.A.H. Wonders, 1995. Atlas of Late Cretaceous globotruncanids. Revista Micropaleontologia, 26(3-4): 145-305. View at Google Scholar

Rodelli, D., D. Jovane, E. Özcan, M. Giorgioni, R. Coioni, F. Frontalini, E.S. Rego, A. Brogi, A. Catanzariti, G. Less and M.A. Rostami, 2018. High-resolution integrated magnetobiostratigraphy of a new middle eocene section from the Neo-Tethys (Elazığ Basin, Eastern Turkey). Geology Society of American Bulletin, 130(1-2): 193-207. View at Google Scholar | View at Publisher

Shutskaya, Y.K., 1970. Lower Paleogene stratigraphy, foraminifera and paleogeography of Crimea, the caucasus Foreland, and the Western part of Central Asia: Tr. Vses. Nauchno-Issled. Geolgorazved. Neft. Inst. (VNIGRI): 70.

Toumarkine, M. and H.P. Luterbacher, 1985. Palaeocene and eocene planktonic foraminifera. In: Bolli, H.M., Saunders, J.B., Perch-Nielsen, K. (Eds.), Plankton Stratigraphy: Cambridge University Press. pp: 87-154.

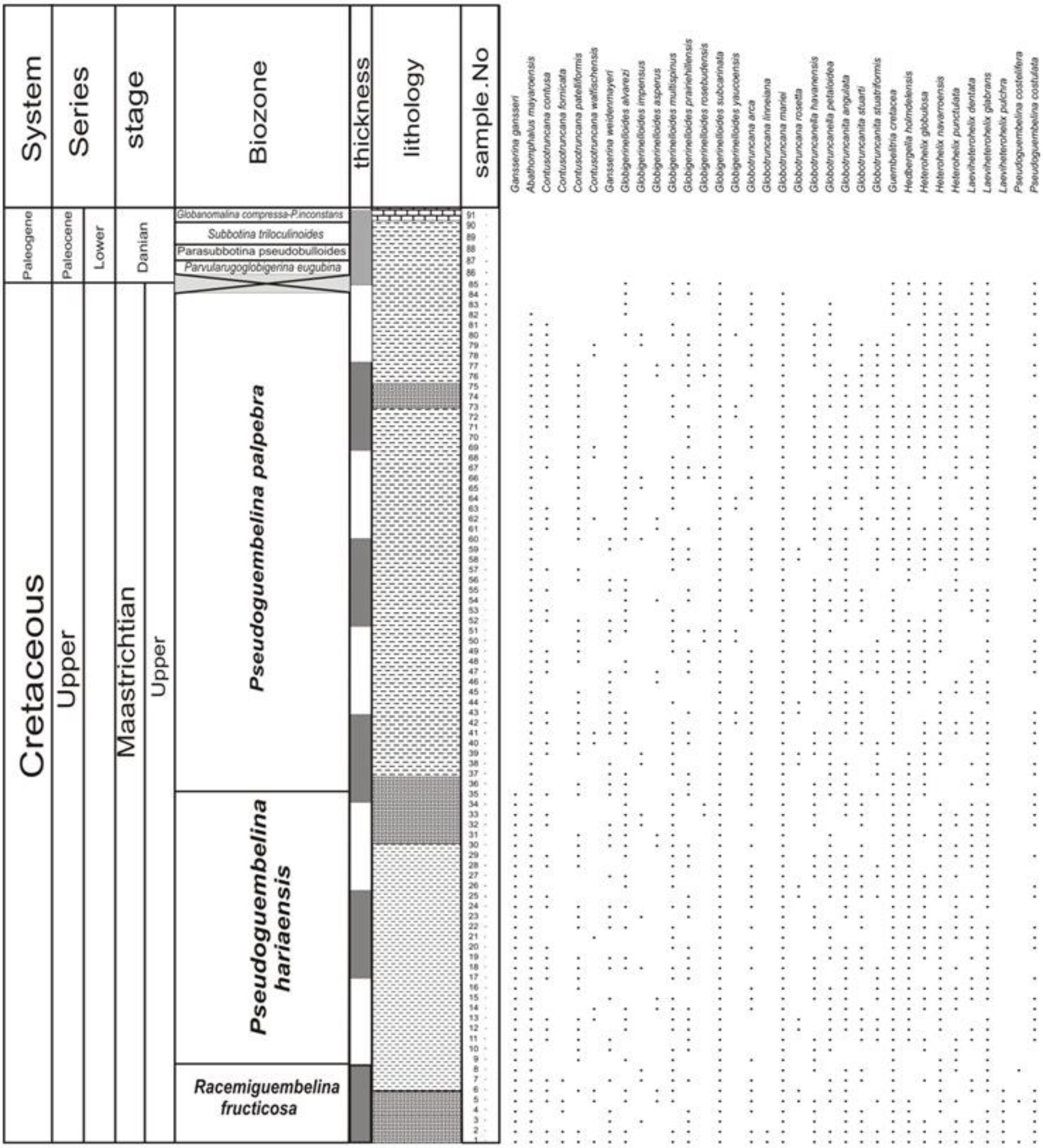

Figure-2. Distribution and planktonic foraminiferal zonation of the Ziarat-Kola section. Scale: 20 meter.

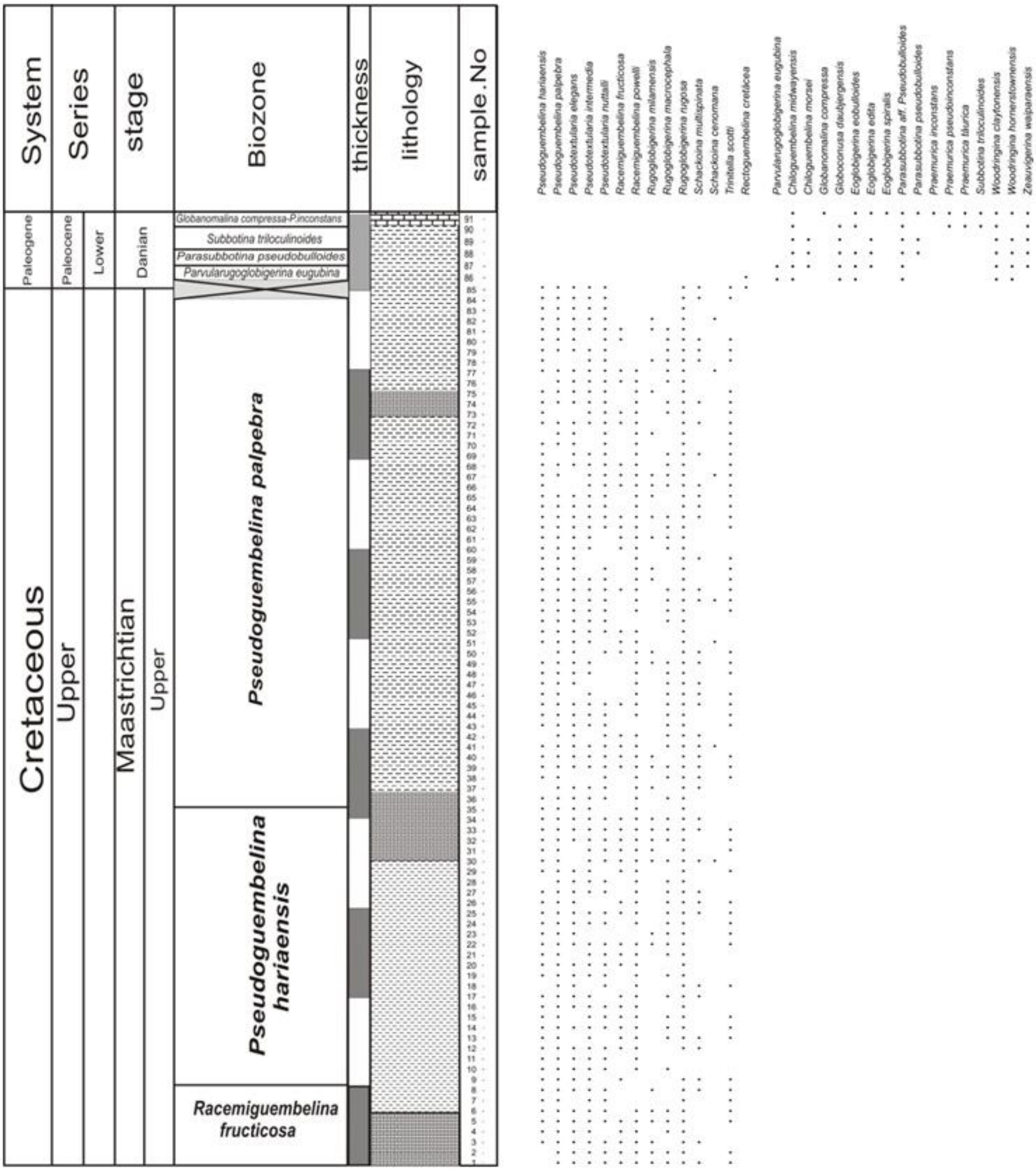

Figure-3. Continue.

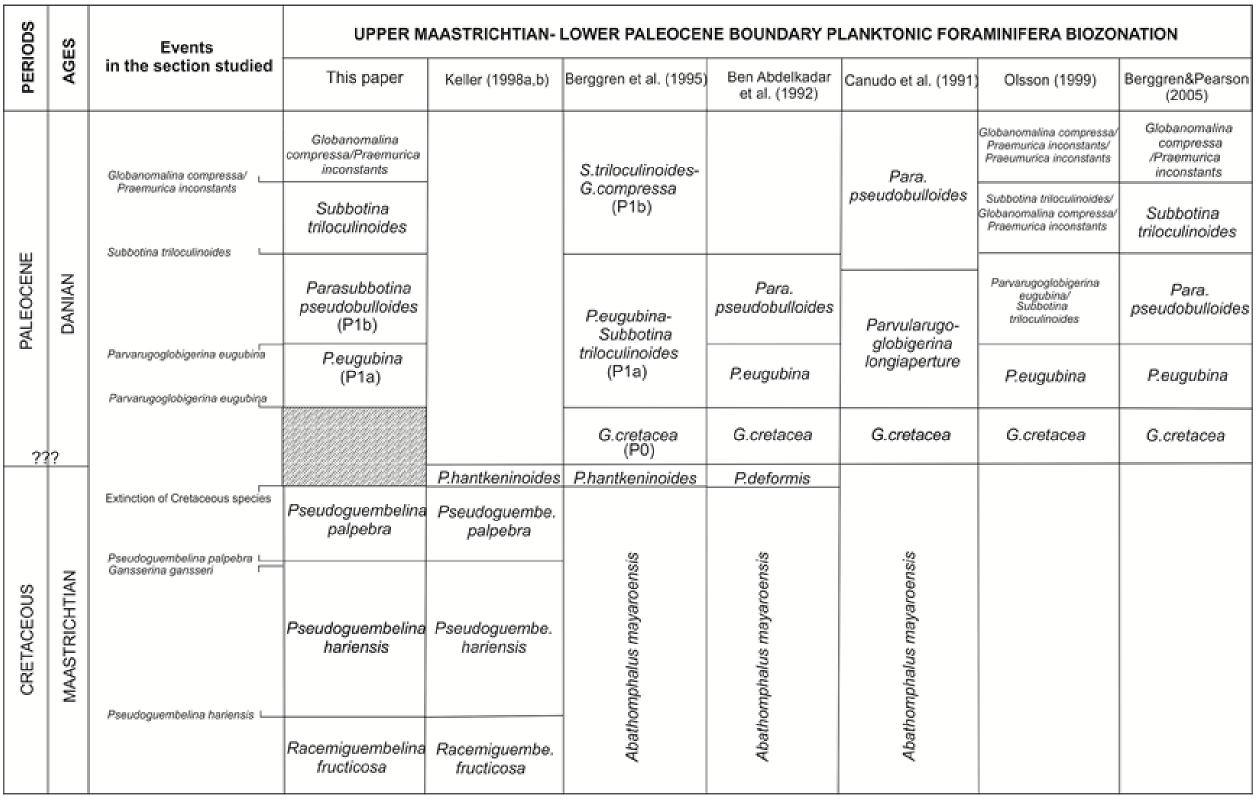

Figure-4. Correlation of the proposed biostratigraphic zonal scheme at this study with other accepted standard biozones of other parts of the world

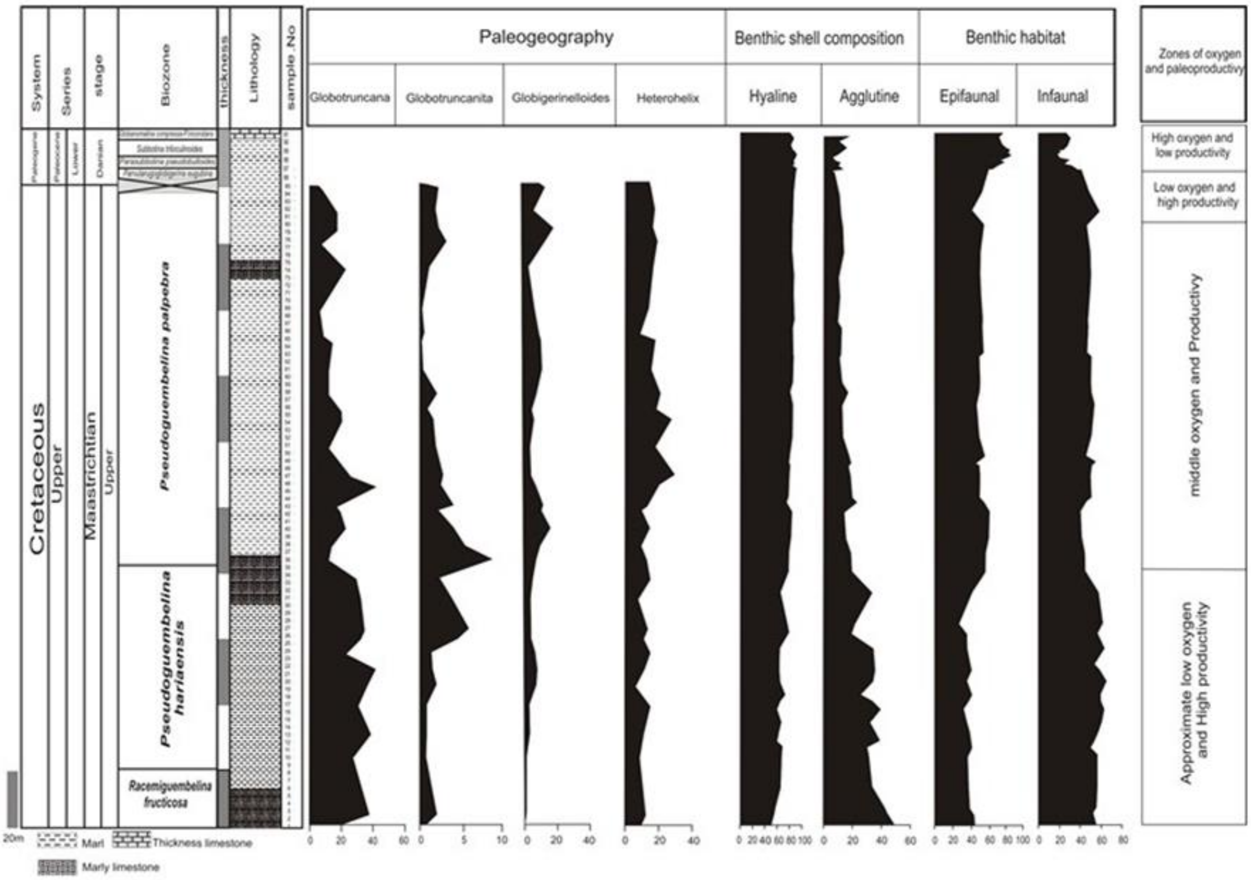

Figure-5. Planktonic foraminifera genus, benthic foraminifera tests and benthic foraminifera morphotypes in Ziarat-Kola section through late Maastrichtian-early Paleocene.

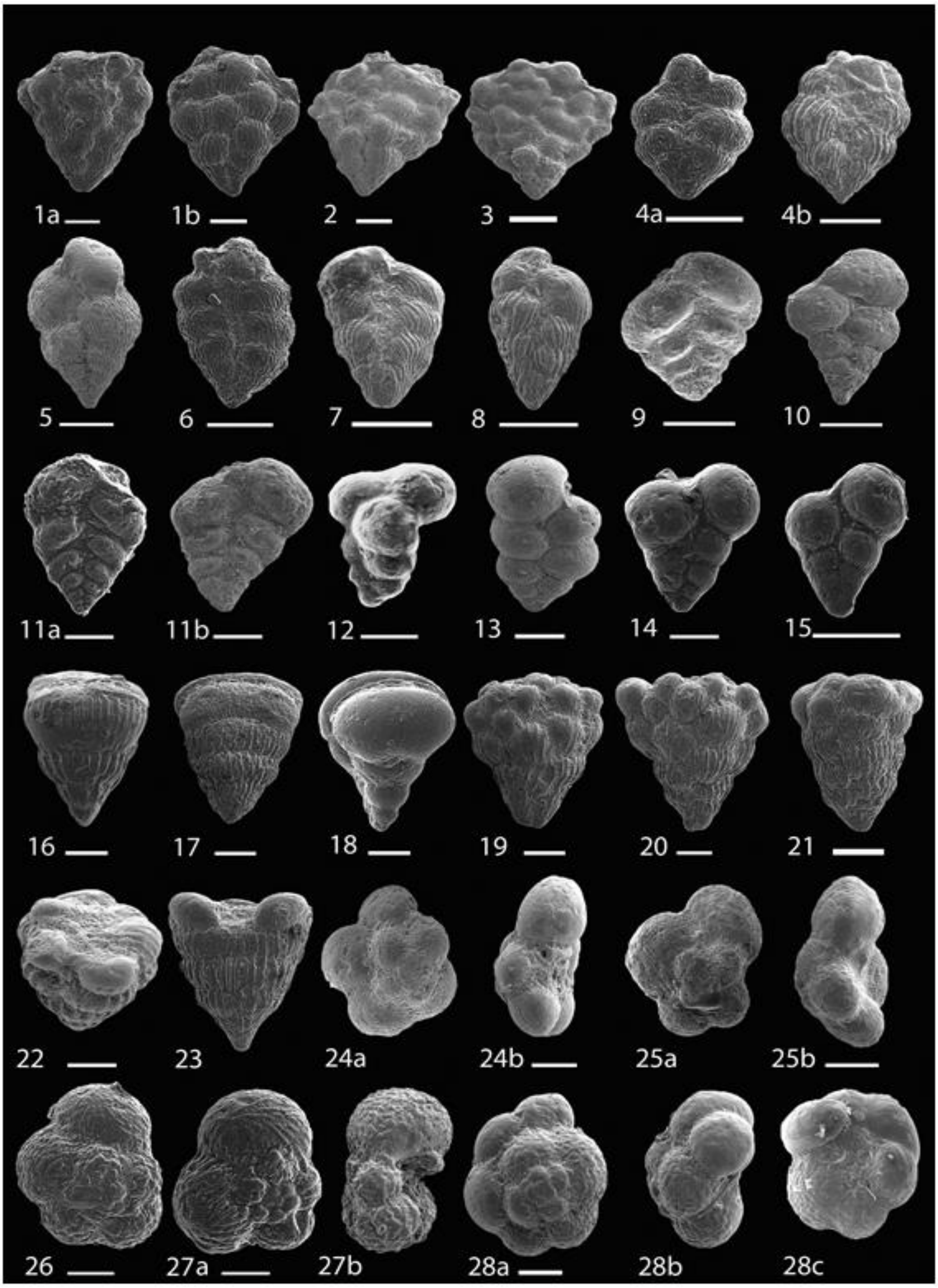

Plate-1. scale bar represents 100 μm

Planoglobulina brazoensis; **2-***Planoglobulina acervulinoides*; **3-** *Planoglobulina manuelensis*; **4-** *Pseudoguembelina palpebra*; **5, 6-** *Pseudoguembelina hariaensis*; **7-** *Pseudoguembelina costellifera*; **8-** *Pseudoguembelina costulata*; **9-** *Laeviheterohelix pulchra*; **10-** *Laeviheterohelix glabrans*; **11a,b-** *Laeviheterohelix dentata*; **12-** *Guembilitria cretacea*; **13-** *Heterohelix punctulata*; **14-***Heterohelix globulosa*; **15-** *Heterohelix navarroensis*; **16, 17-** *Pseudotextularia elegans*; **18-***Pseudotextularia nuttalli*; **19,20-***Racemiguembelina fructicosa*; **21,22-** *Racemiguembelina powelli*; **23-** *Pseudotextularia intermedia*; **24a, b-** *Globotruncanella havanensis*; **25a, b-** *Globotruncanella petaloidea*; **26-** *Rugoglobigerina rugosa*; **27a,b-** *Rugoglobigerina macrocephala*; **28a,b,c:** *Rugoglobigerina milamensis*.

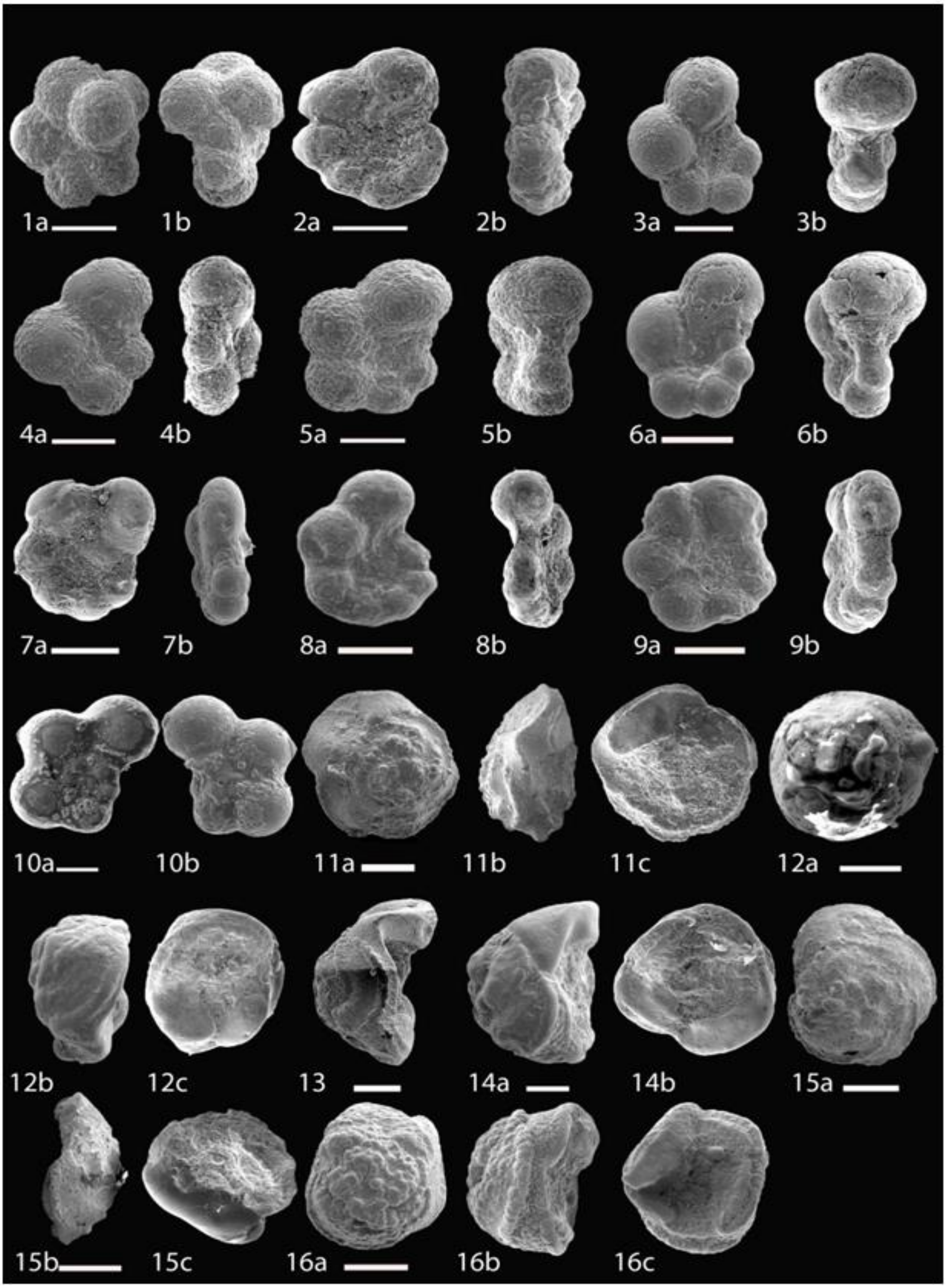

Plate-2. Scale bar represents 100 µm

1a, b-*Globigerinelloides multispinus*; **2a, b-** *Globigerinelloides impensus*; **3a, b-** *Globigerinelloides alvarezi*; **4a, b**: *Globigerinelloides subcarinata*; **5a, b-** *Globigerinelloides asperus*; **6a, b:** *Globigerinelloides prairiehillensis*; **7a, b**: *Globigerinelloides rosebudensis*; **8a, b-***Globigerinelloides yaucoensis*; **9a, 9b-** *Globigerinelloides rosebudensis*; **10a, b-** *Hedbergella holmdelensis*; **11a, b, c:** *Contusotruncana patelliformis*; **12a,b,c-** *Contusotruncana contusa*; **13,14-** *Contusotruncana contusa*; **15a,b,c-** *Contusotruncana* sp. **16a,b,c:** *Contusotruncana walfischensis.*

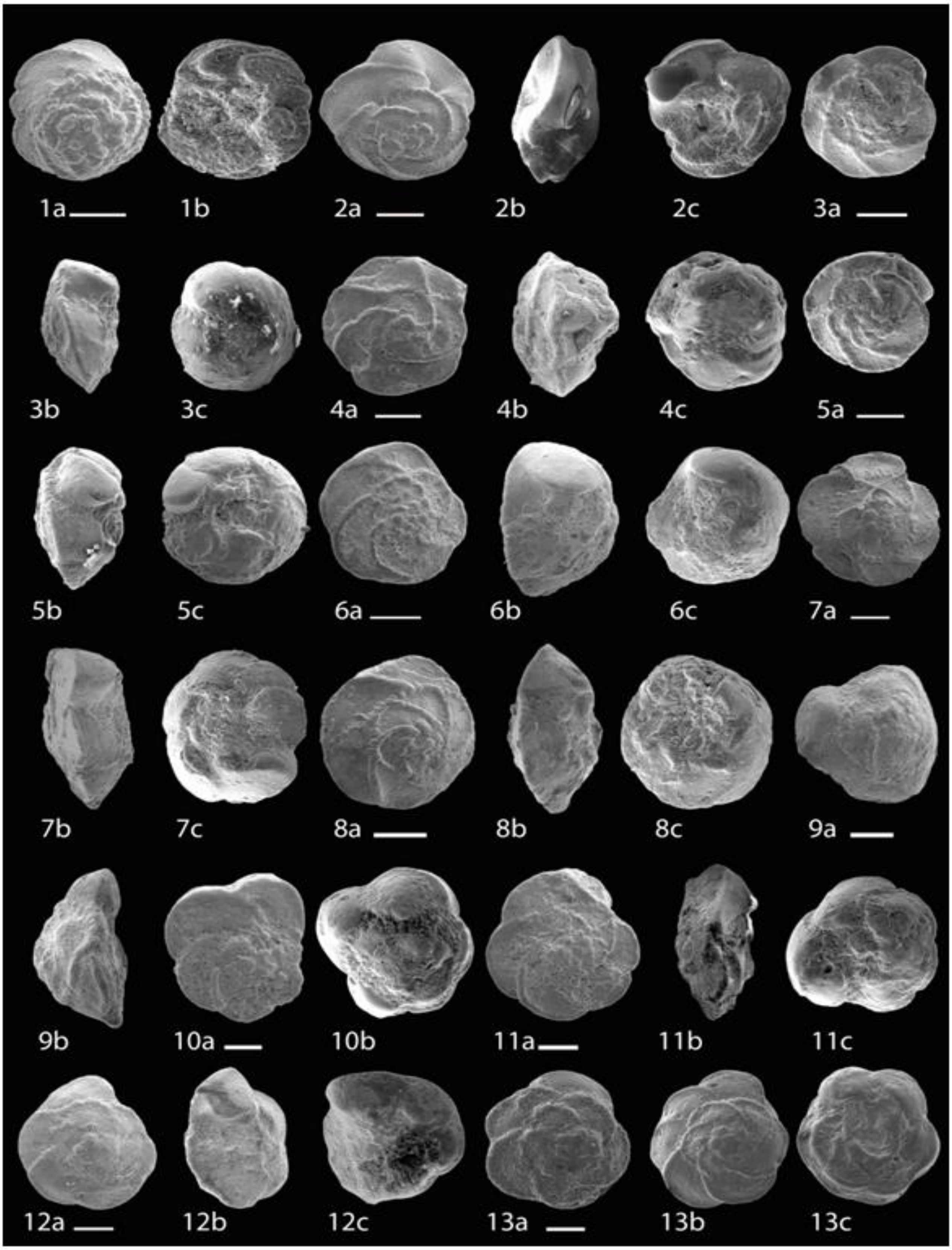

Plate-3. Scale bar represents 100 µm

1a,b - *Contusotruncana patelliformis*; **2a,b,c**- *Contusotruncana fornicata*; **3, 4**- *Globotruncanita stuartiformis*; **5a,b,c**- *Globotruncanita stuarti*; **6a,b,c**- *Globotruncanita angulata*; **7a,b,c**- *Globotruncanita insignis*; **8a,b,c**- *Globotruncanita stuartiformis*; **9a,b**- *Contusotruncana* sp.; **10a, b**- *Globotruncana linneiana*; **11a, b, c**- *Globotruncana mariei*; **12a, b, c**- *Globotruncana rosetta*; **13a, b, c**- *Globotruncana arca.*

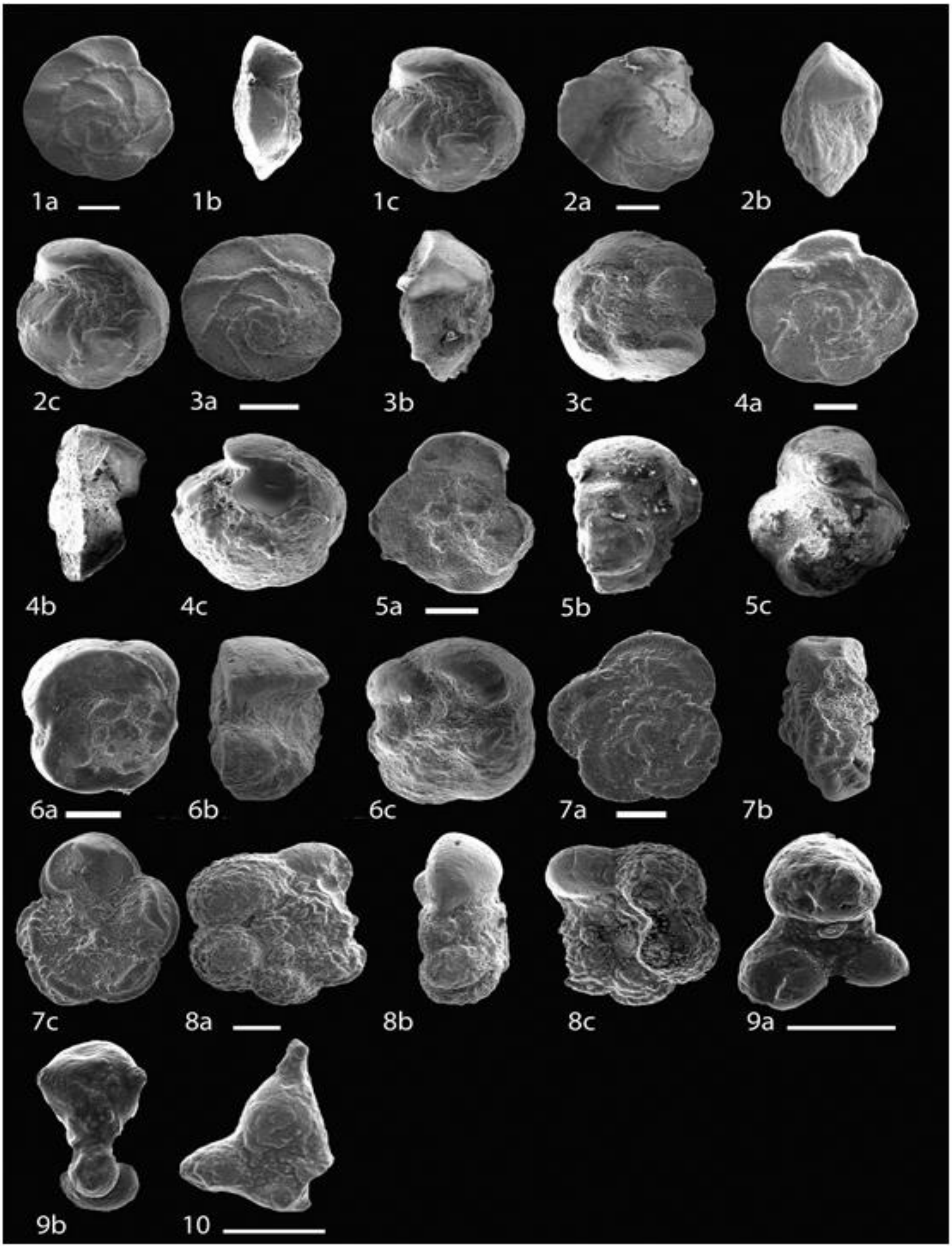

Plate-4. Scale bar represents 100 µm

1a,b,c- *Globotruncanita stuarti*; **2a,b,c-** *Globotruncanita stuartiformis*; **3a,b,c-** *Globotruncanita stuartiformis*; **4a,b,c-** *Gansserina wiedenmayeri*; **5a,b,c-** *Gansserina gansseri* ; **6a,b,c-** *Gansserina gansseri*; **7a,b,c-** *Abathomphalus mayaroensis*; **8a,b-** *Trinitella scotti*; **9a, b-** *Schackoina multispinata*; **10-** *Schackoina cenomana*.

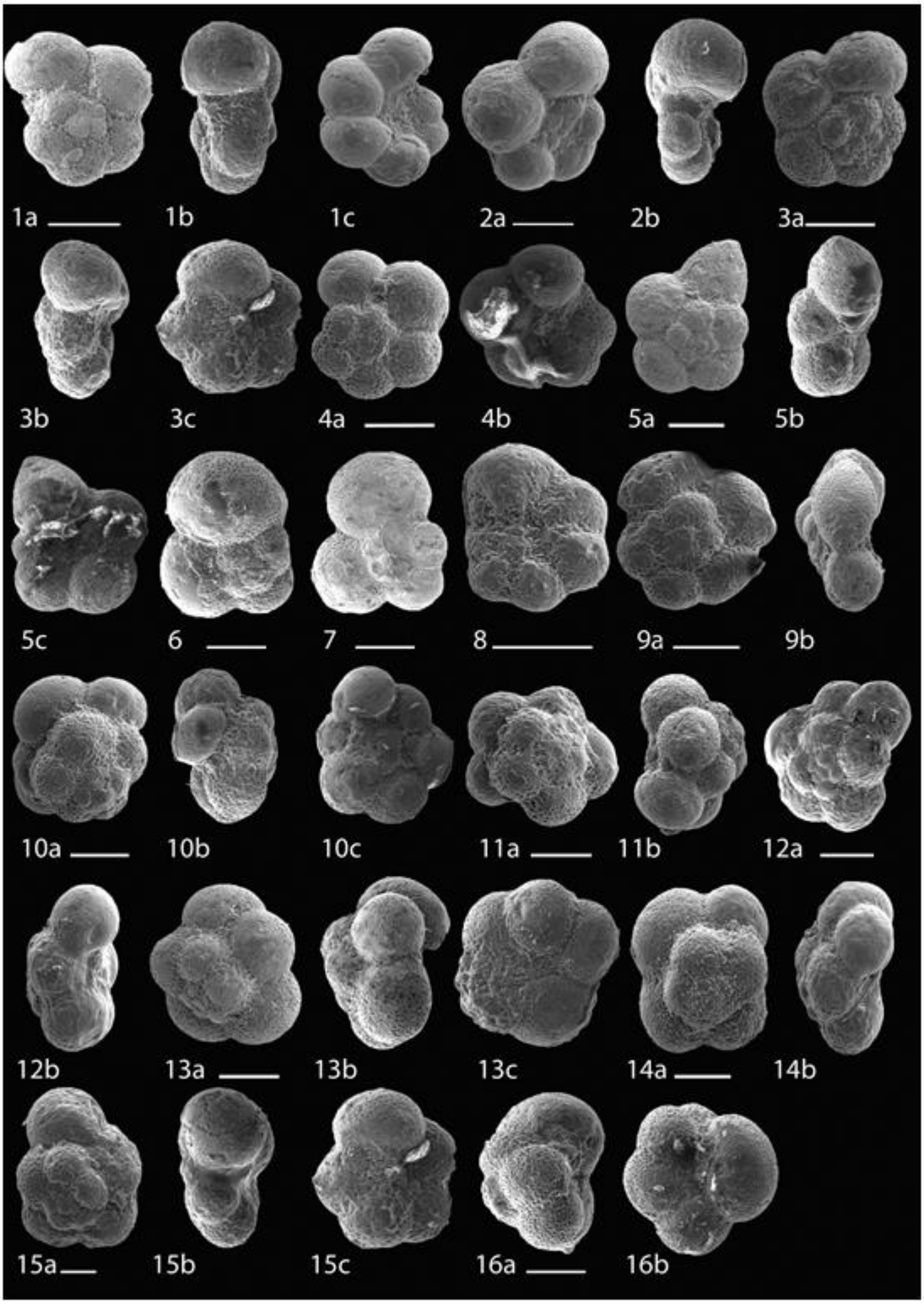

Plate-5. scale bar represents 100 μm

1a,b,c- *Praemurica inconstans*; **2, 3-***Praemurica pseudoinconstans*; **3, 4, 5 -** *Praemurica táurica*; **6, 7-** *Subbotina triloculinoides*; **8-** *Parvularugoglobigerina eugubina*; **9a,b-** *Globanomalina compressa*; **10, 11, 12-** *Eoglobigerina spiralis*; **13,14,15-** *Eoglobigerina edita*; **16a,b-** *Eoglobigerina eobulloides*.

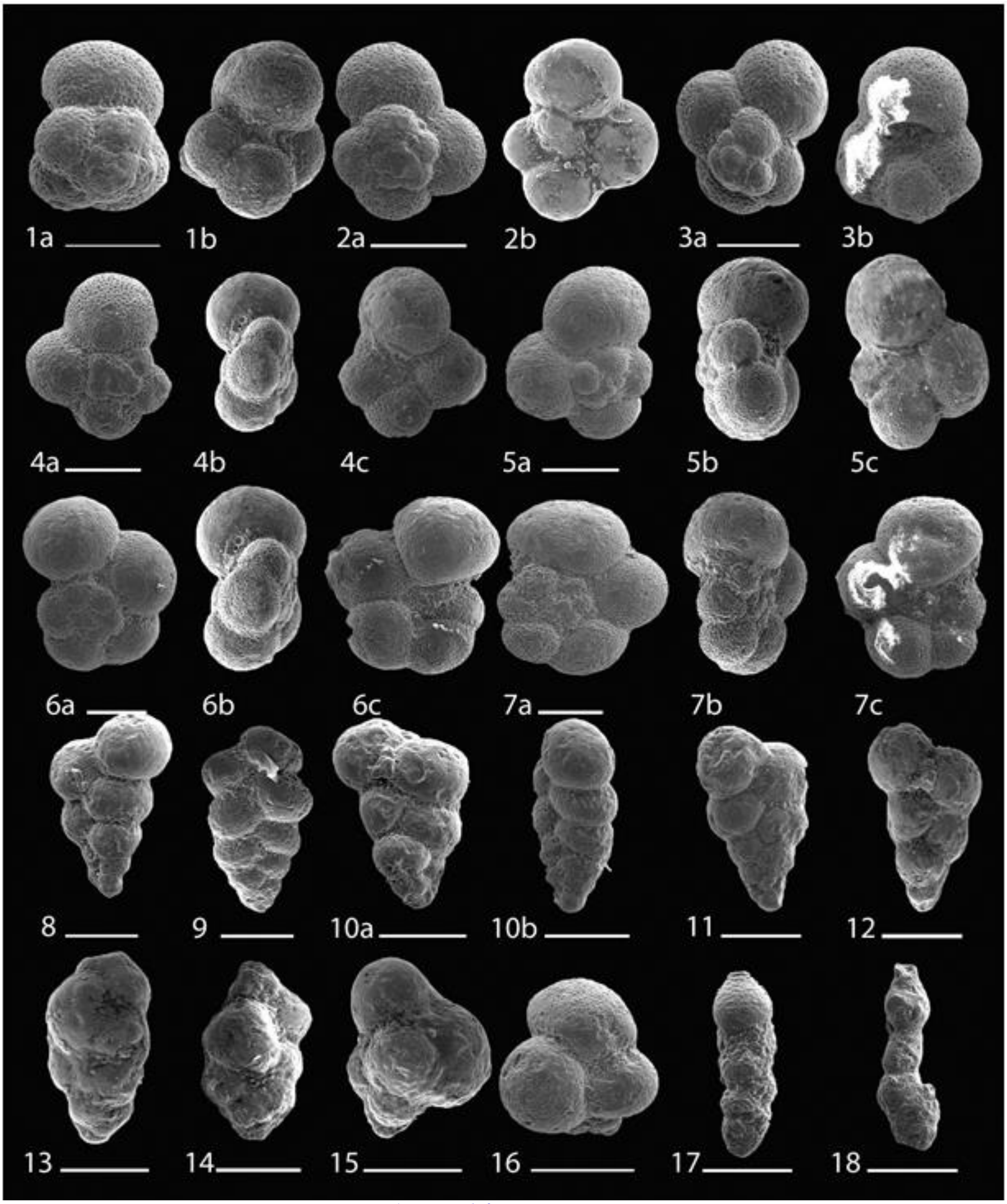

Plate-6. scale bar represents 100 µm

1, 2, 3- *Eoglobigerina eobulloides*; **4, 5-** *Parasubbotina aff. Pseudobulloides*; **6, 7-***Parasubbotina pseudobulloides*; **8-** *Woodringina hornerstownensis*; **9-** *Chiloguembelina morsei*; **10-** *Woodringina claytonensis*; **11, 12-** *Woodringina hornerstownensis*; **13, 14-** *Zeauvigerina waiparaensis*; **15, 16-** *Globoconusa daubjergensis*; **17, 18-** *Rectoguembelina cretácea.*

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