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Foraminiferal biostratigraphy and paleoecology of the late Santonian-early Paleocene in the eastern Tethys, Northern Iran

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Abstract

The late Santonian-early Paleocene sequences were investigated at the Galanderud section, to recognize the biostratigraphy scheme paleoenvironmental changes in eastern Tethys. This section mainly consists of green and gray marl, marly limestone, and limestones. A high-resolution study based upon benthic and planktic foraminiferal assemblages has been used. The planktic foraminifera were diverse and abundance, where 56 planktic species belonging to 27 genera have been recognized. In this study, first and last appearances of the planktic foraminifera have been used as major bio events to identified different biozonation. Planktic foraminiferal zonation from bottom to top of the section consists of fifteen zones include: i. Dicarinella asymetrica, ii. Globotruncanita elevata, iii. Globotruncana ventricosa, iv. Radotruncana calcarata, v. Globotruncanella havanensis, vi. Globotruncana aegyptiaca, vii. Gansserina gansseri, viii. Racemiguembelina fructicos, ix. Pseudoguembelina hariaensis, x. Pseudoguembelina palpebra, xi. Plummerita hantkeninoides, xii. Guembelitria cretacea, xiii. Parvularugoglobigerina eugubina, xiv. Parasubbotina pseudobulloides, xv. Subbotina triloclinoides. Also, three distinct zones have been defined based on benthic foraminifera morphotypes and Cibicidoides spp. First zone (Dicarinella asymetrica to Gansserina gansseri biozones) is dominated by Infauna morphotype and less abundance of Cibicidoides spp. indicating high food availability and lower oxygen condition. The second zone, with the increase of epifauna morphotype and Cibicidoides spp. show decreasing in organic matter. Finally, high abundance of epifauna species and Cibicidoides spp. indicate a collapse of food availability after the extinction of primary producers that may cause by asteroid impact after Cretaceous- Paleogene boundary mass extinction.

Keywords: Biostratigraphy, Paleoecology, Santonian, Paleocene, Foraminifera, Alborz, Iran, Tethys.

Introduction

This section in the Alborz Mountain located in southern Caspian Sea and extends for about 2000km from Armenia to eastern Afaghanistan[1] (Figure-1). The Galanderud section is placed on a Galanderud road south of the Noor city (36°31′30″ N, 51°45′30″ E), in the southwestern Noor Province (Figure-1). Late santonian-early Paleocene sediments include of pelagic marls, interbedded with limestones rich in foraminifera and other microfossils[2-6]. The aim of this paper is to provide a biostratigraphical scheme and the paleoecological change for the Galanderud section by using planktic and benthic foraminifera across the late Santonian-early Paleocene.

Materials and methods

I collected samples along a ~440 m thick succession during the late Santonian-early Paleocene stages (Figures-2 and 3). Samples were washed through 125µm and 63µm sieves, and one hundred three samples were used for planktic and benthic foraminifera biostratigraphy. Also, at least 300 specimens of planktic and benthic foraminifera were picked from the > 125 µm and 63µm sieve fractions, and benthic foraminiferal morphotypes and *Cibicidoides* spp. are used to define paleo environmental reconstruction[7,8].

Results and discussion

Planktonic foraminifera biostratigraphy: A variety of planktic foraminiferal biozonation have been suggested, and Keller[9,10], Arenillas[11], Berggren and Pearson[12] are the most well-known. In this paper, I used the biostratigraphy of Keller[9,10] for the Santonian to Maastrichtian successions, and Berggren and Pearson[12] for the early Paleocene. Additionally, benthic foraminiferal morphotypes have been applied to understand the paleoenvironmental change. Li and Keller[13] subdivided the Maastrichtian into eight Cretaceous Foraminiferal (CF) zones as (CF8) to (CF1) from the base to the top of the section. This biozonation presented a higher resolution compare to previous biozonation and their age estimation was also correlated with magnetochron ages by Berggren[14]. The planktic and benthic foraminifera identification in this paper for the late Santonian-early Paleocene interval[14-21]. Additionally, *Abathomphalus mayaroensis* in late Maastrichtian are very rare or absent in shallow sites and sections[22]. Therefore, in this study, Li and Keller zonation[13] was used instead of *A. mayaroensis* Zone to avoid ambiguous situation about first and last appearance event in late Maastrichtian. Planktic foraminifera is abundant and diverse during the late Santonian-early Paleocene stages at the studied section. In this study, 27 genera and 56 species of planktic foraminifera were recognized. Based on planktic foraminiferal distribution, fifteen zones were defined from bottom to top of the section.

Dicarinella asymetrica Total Range Zone: This zone was firstly defined by Postuma[23], and it includes a total range of nominated species. In this section, the uppermost part of this biozone just has been recognized, and it consists of 24m (samples 1-6) thick green marl and limestone in this section (Figure-2). This assemblage characterized by the presence of *Archeoglobigerina bosquensis*, *Archeoglobigerina cretacea*, *Contusotruncana fornicata*, *Contusotruncana pateliformis*, *Dicarinella asymetrica*, *Dicarinella canaliculata*, *Globigerinelloides alvarezi*, *Globigerinelloides bolli*, *Globotruncana linneiana*, *Globotruncanita elevata*, *Hedbergella holmdelensis*, *Hedbergella simplex*, *Heterohelix globolusa*, *Heterohelix carinata*, *Leaviheterohelix pulchera*, *Marginotruncana coronata* and *Marginotruncana marginata*. The age for this zone is late Santonian to latest Santonian-earliest Campanian[24].

Globotruncanita elevata Partial Range Zone: This zone as indicates the stratigraphical interval between the last occurrence (LO) of *Dicarinella asymetrica* and the first occurrence (FO) of *Globotruncana ventricosa*. This zone is characterized by the first appearance of *Globotruncana lapparanti*, *Gontusotruncana pateliformis*, *Globotruncana bulloides* and *Contusotruncana fornicata*, and it consists of 20m (samples 6-11) thick green and gray marl and marly limestone (Figure-2). This zone characterized by the presence of *Heterohelix globulosa*, *Contusotruncana fornicata*, *Globotruncana arca*, *Globotruncanita elevata*, *Globotruncana linneiana*, *Leaviheterohelix dentata*, Pseudotextularia *nuttalli*, *Rugoglobigerina rugosa* and *Globotruncana lapparenti.* This biozone shows the early Campanian-early middle Campanian age based on the Premoli-Silva and Sliter[25].

Globotruncana ventricosa Interval Zone: This zone defines the interval from FO of *Globotruncana ventricosa* to the FO of *Radotruncana calcarata.* This section consists of 8m (samples 1-13) thick gray marl and marl limestone, and characterized by the presence of *Globotruncana arca*, *Globotruncana lapparenti*, *Globotruncana linneiana*, *Globotruncanita elevata*, *Rugoglobigerina rugosa*, *Contusotruncana fornicata* and *Pseudotextularia nuttalli*. The age for this biozone is middle Campanian (Figure-2).

Radotruncana calcarata Total Range Zone: This zone with thickness of 12m (between samples 13 to 16) was defined by the total range of nominated species (Figure-2). This species is easily recognizable by a stout peripheral spine in all chambers (Plate-1). The first appearance of this zone is characterized by *Archaeoglobigerina certacea* and *Globotruncanita stuartiformis,* and dominated species in this zone are *Globotruncana lapparenti*, *Globotruncana linneiana, Pseudotextularia nuttalli, Contusotruncana patelliformis, Globotruncana arca, Globotruncana mariei, Globotruncana orientalis, Globotruncana ventricosa, Globotruncanita stuartiformis, Rugoglobigerina rugosa, Archaeoglobigerina cretacea* and *Radotruncana calcarata.* This biozone show the age of early part of late-Campanian.

Globotruncanella havanensis Partial Range Zone: The zone is defined as the interval from the LO of *Radotruncana calcarata* to the FO of *Globotruncana aegyptica*. The lower part of this zone is characterized as an indicator of Campanian-Maastrichtian boundary by Robaszynski and Caron[15,16]. The thickness of the biozone is 16m (samples 16-20) and contains marly limestone. The predominant planktic foraminifera in this zone are *Globotruncana orientalis*, *Globotruncana linneiana*, *Globotruncana mariei*, *Globotruncana ventricosa*, *Globotruncanita stuarti*, *Pseudotextularia nuttalli*, *Rugoglobigerina rugosa* and *Globotruncanita stuartiformis*.

Globotruncana aegyptiaca Partial Range Zone (CF 8): This zone was initially defined and described by Caron[16] as indicators of early Maastrichtian, and it is characterized by the interval from the FO of the *Globotruncana aegyptiaca* to the FO of *Gansserina gansseri*. Later, Li and Keller and Premoli Silva and Verga[13,21] suggested late Campanian age for this biozone. This section consists of 16m (samples 20-24) thick green and gray marl and marly limestone and high diversity of planktic foraminiferal species are recorded here include *Contusotruncana fornicata*, *Globotruncana bulloides*, *Globotruncana orientalis*, *Contusotruncana patelliformis*, *Globigerinelloides subcarinatus*, *Globotruncana arca*, *Rugoglobigerina rugosa*, *Pseudotextularia nuttalli*, *Pseudoguembelina costulata*, *Contusotruncana plummerae*, *Globotruncanita stuartiformis* and *Planoglobulina acervulinoides*. The age estimation of this biozone indicates late Campanian[13,21].

Gansserina gansseri Interval Range Zone (CF7): This zone is indicated by the interval between the FO of *Gansserina gansseri* and the LO of *Contusotruncana contusa* (Plate-1 and Figure-2). This zone placed at the Campanian-lower Maastrichtian[26,27]. This section consists of 72m (Samples 24-40) thickness of brown marly limestone and associated species in this zone are *Globotruncana linneiana, Globotruncana orientalis, Globotruncanella petaloidea, Globotruncanita stuartiformis, Planoglobulina brazoensis, Pseudotextularia nuttalli, Pseudoguembelina costulata, Laeviheterohelix glabrans, Rugoglobigerina rugosa* and *Contusotruncana patelliformis.* The age estimation of this biozone shows late Campanian-early Maastrichtian age.

Racemiguembelina fructicosa Interval Range Zone (CF6): First and the last appearance of *A. mayaroensis* is diachronous and is rarely present in shallow section due to adaption to deeper environmental[13,18]. For this reason, it is more accurate to use the new biozonation of Cretaceous foraminifera (CF) proposed by Li and Keller[13] that divided to the *A. mayaroensis* Zone to four zones (*R.fructicosa*, *P. hariaensis*, *P. palpebra*, *P. hantkeninoides*), to improve age estimate for the late Maastrichtian. *Racemiguembelina fructicosa* zone (CF4) was introduced by Li and Keller[13] as a biostratigraphic interval between FO of *Racemiguembelina fructicosa* at the base and FO of *Pseudoguembelina hariaensis* at the top. This section consists of 96m (Samples 40-64) thick brown marl and marly limestone, and associated species in this are *Contusotruncana fornicata*, *Contusotruncana patelliformis*, *Globotruncana mariei*, *Globotruncanella petaloidea*, *Globotruncanita stuarti*, *Globotruncanita stuartiformis*, *Planoglobulina acervulinoides*, *Gansserina gansseri* and *Pseudoguembelina costulata.* The age estimation of this zone indicates early-late Maastrichtian stage.

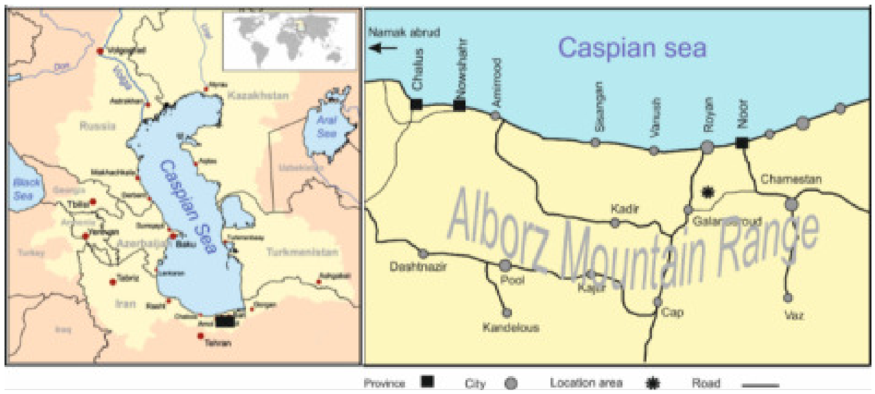

Figure-1: Location map of the studied area in Alborz mountain, Northern of Iran.

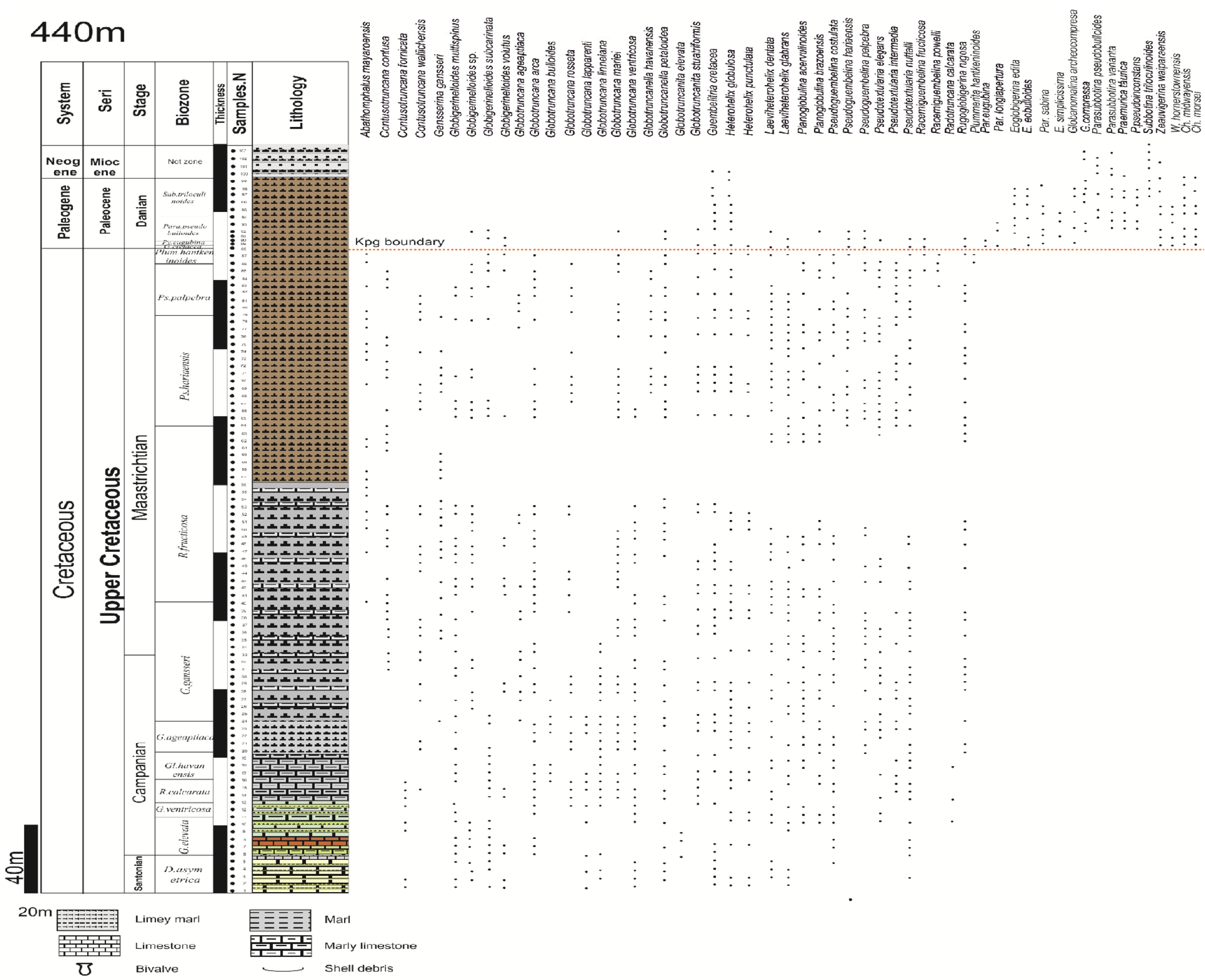

Figure-2: Distribution and planktic foraminiferal zonation of the Galanderud section at Northern Iran.

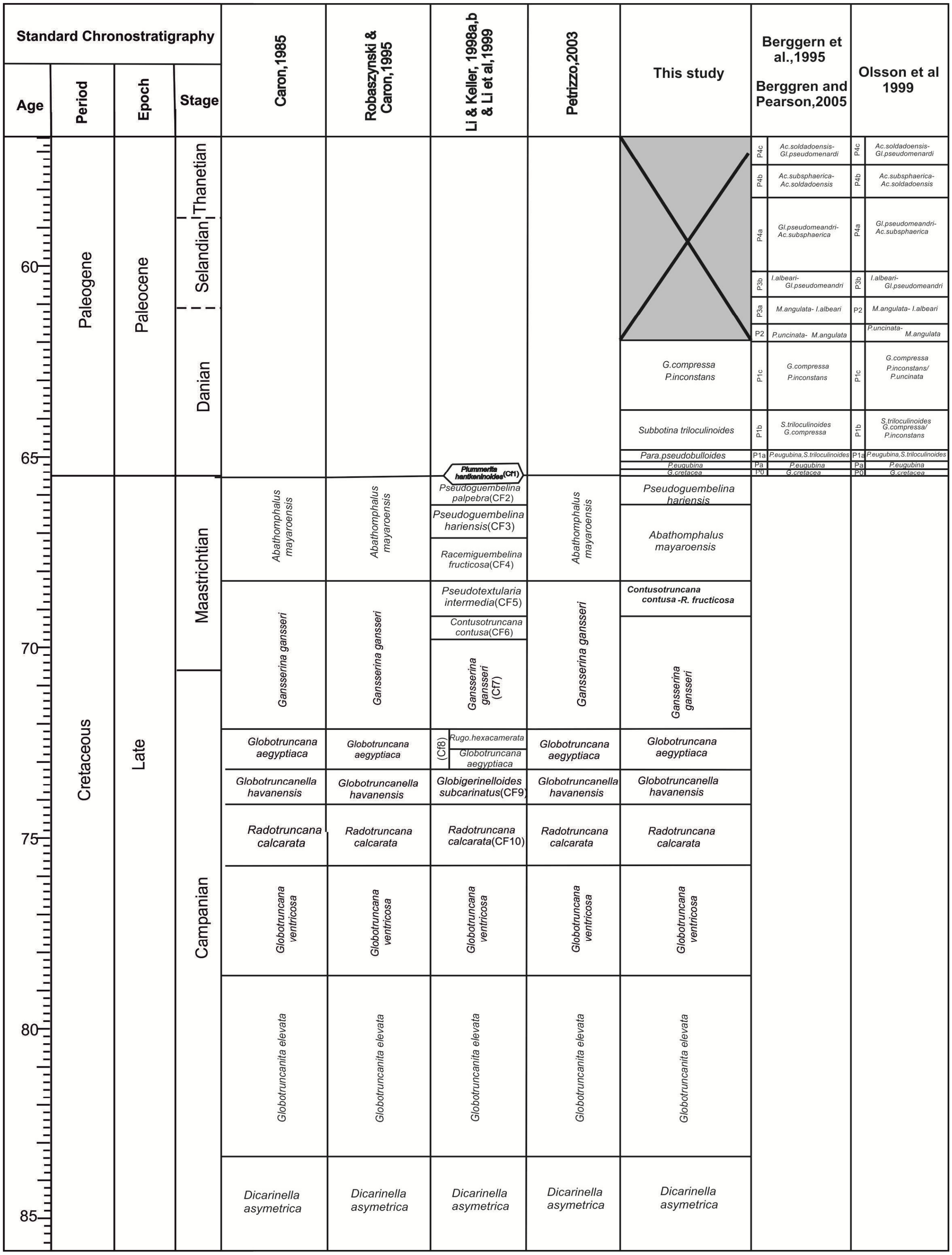

Figure-3: Correlation between the proposed late Santonian-early Paleocene zonations in the Galanderud section and different planktic foraminiferal biozonations.

Pseudoguembelina hariaensis Interval Range Zone (CF3): This zone was defined by Li and Killer[13] as the nominate species between the FO of *Pseudoguembelina hariaensis* and the LO of *Gansserina gansseri* (Plate-1, Figure-2). This zone covers the intervals of 60m (Samples 64-79) of brown marl in the Galanderud section. The associated species in this zone are *Gansserina gansseri, Globotruncana mariei, Globotruncanella havanensis, Planoglobulina carseyae*, *Pseudoguembelina costulata, Pseudoguembelina hariaensis, Pseudotextularia intermedia, Pseudotextularia nuttalli, Rugoglobigerina rugosa, Heterohelix* globulosa, *Laeviheterohelix glabrans* and *Laeviheterohelix dentata*. This zone is placed in the middle-late Maastrichtian.

Pseudoguembelina palpebra Interval Range Zone (CF 2): This zone defined the interval between the LO of *Gansserina gansseri* at the base to the FO of *Plummerita hantkeninoides* at the top[13]. The *Pseudoguembelina palpebra* zone in the Galanderud section show spans 136m (samples 79-86), and brown marl and limestone alternations (Figure-2). Planktic foraminifera assemblage of this zone is characterized by the *Globotruncana arca*, *Planoglobulina carseyae*, *Planoglobulina riograndensis*, *Pseudoguembelina costulata*, *Pseudoguembelina excolata*, *Pseudoguembelina palpebra, Pseudotextularia nuttalli*, *Rugoglobigerina rugosa*, *Trinitella Scotti*, *Racemiguembelina powelli. Heterohelix globoulos*, *Laeviheterohelix glabrans*, *Laeviheterohelix dentata*, *Globigerinelloides Bollii*, *Globigerinelloides subcarinata* and *Schackoina multispinata.* The age estimation of this biozone shows upper part of late Maastrichtian.

Plummerita hantkeninoides Total Range Zone (CF 1): This zone initially defined by the total range of the *Plummerita hantkeninoides* by Pardo[28] as an indicator of late Maastrichtian in Spain. The upper part of this zone correlated with the extinction of large species in the Cretaceous. At this section, this zone covers the 8 m (samples 86 and 88) meters with marl lithology (Figure-2). This zone is recorded from Tunisia, Egypt, Site 525A and Madagascar[29,30]. *H. globulosa, H. navarroensis, H. striata, Laeviheterohelix glabrans L. pulchra, Pseudoguembelina costulata, P. kempensis, P. palpebra, Globigerinelloides aspera, G. subcarinata, G. yaucoensis, Hedbergella holmdelensis* and *H. monmouthensis*. The age of this zone is defined as upper most late Maastrichtian.

Guembelitria cretacea Interval Zone (P0): At the Glandered section, the K/Pg boundary is indicated by a clay layer with ~12% of carbonate percent[6]. This zone was firstly indicated by Smith[31] as the interval between the LO of Cretaceous taxa and the FO of *Parvularugoglobigerina eugubina* whereas Olsson et al.[20] defined the top of this zone with the FO of *Parvularugoglobigerina extensa*. At the Galanderud section, the *G. cretacea* Zone is ~60 cm (samples 88-89) thick of clay layer and is characterized by low diversified assemblages mainly dominated by *Guembelitria* spp.[6]. Very small specimens characterized the assemblages including *Heterohelix navarroensis*, *Hedbergella* sp., *Globigerinelloides* spp., *P. alabamensis*, *P. longiapertura*, *Woodringinaclaytonensis*, *E.fringa* (Figure-2 and Plate-1). The age of this zone is defined as earliest part of Danian.

Parvularugoglobigerina eugubina Total Range Zone (Pα): Luterbacher and Premoli Silva firstly defined the Pα Zone as the total range of the *Pv.eugubina*[32]. At the Galanderud section, the *G. cretacea* Zone is ~4 m (samples 89-90) thick of clay, chalks and marl and is dominated by *Chiloguembelina* spp., *Globoconusa conusa*, *W.claytonensis*, *Guembelitria* spp., *Chiloguembelina midwayensis*, *E. simplicissima, P.taurica*, *E. edita*, *E. eobulloides* (Figure-2 and Plate-1). The age of this zone is defined as early Danian.

Parasubbotina pseudobulloides Interval Zone (P1a): This zone was firstly introduced by Leonov and Alimarina[33] as *Globigerina pseudobulloides–Globigerina daubjergensis* Zone and Bolli shortened the name to *G. pseudobulloides*[34]. Later, this zone emended by Molina et al and was defined as the FO of *Ps. pseudobulloides* and FO *Globanomalina compressa*[35]. At the Galanderud section, this zone with a 20m (samples 90-94) thickness and marl and clay lithology is dominated by *W.hornerstownensis*, *C. midwayensis*, *C. morsi*, *G. archeocompressa*, *G. planocompressa*, *P. pseudoinconstans*, *P. taurica*, *E. eobulloides*, *E. simplicissima* and *E. trivialis, Subbotina triloculinoides.* The early Danian is indicated as the age of this biozone.

Subbotina triloclinoides Interval zone (P1b): In this zone, the biostratigraphic interval between the FO of *Subbotina triloculinoides* at the base and FO of *Globanomalina compressa* at the top was introduced as P1b by Berggren et al.[14]. At the Galanderud section, this zone with a 20m (samples 94-99) thickness and marl and clay lithology is dominated by *Parasubbotina aff. Pseudobulloides, Globoconusa daubjergensis, Chiloguembelina morsei, Parvularugoglobigerina alabamensis, Woodringina hornerstownensis, Woodringina claytonensis, Chiloguembelina midwayensis, Chiloguembelina morsei, Ssubbotina trivalis, Subbotina triloclinoides, Zeauvigerina waiparaensis, Eoglobigerina edita.* The age estimation of this interval based on Magnetic polarity is early Danian.

Paleoenvironment reconstruction: Benthic foraminifera are abundant and well preserved and great indicators for monitoring the environmental condition[6,8,36-39,44-50]. Epifaunal/Infaunal ratios divide the benthic foraminifera into morphotypes typical of species that live at the sediment surface or within a few centimeters of the surface (epifauna) from those who typically live 4-10 cm below the sediment surface (infauna). The morphologies typical of an epifaunal life mode include plano-convex, biconvex, rounded trochospiral, tubular coiled flattened, and palmate tests, while cylindrical or flattened tapered, spherical, rounded planispiral, flattened ovoid, globular unilocular and elongate multilocular morphotypes are typically associated with infauna benthic foraminifera. This ratio is generally interpreted to indicate the flux of organic material to the seafloor and bottom water oxygenation[6,41,42,51-56]. Therefore, changes in the relative proportions of epifaunal and infaunal morphotypes likely indicate changes in deep sea conditions. Additionally, *Cibicidoides* spp. have been marked as an indicator of the bottom water oxygenation at the sea floor[43]. Generally, high abundance of *Cibicidoides* spp. show well oxygen condition at the seafloor condition. Based on Epifauna and Infauna morphotypes, and *Cibicidoides* spp. three zones have been recognized. First zone (*Dicarinella asymetrica to the middle part of Gansserina gansseri*) show a high abundance of infauna and low abundance of epifauna morphotype and *Cibicidoides* spp. that show high flux of organic matter and low oxygen condition to the seafloor. Then, in the second zone (*middle part of Gansserina gansseri until end of Cretaceous)* epifauna morphotype and *Cibicidoides* spp. relatively increase that show increase in oxygen concentration and decrease in food availability at the seafloor. Finally, in the third zone (Paleocene) high abundance of epifauna (>70%) and *Cibicidoides* spp. (>30%) indicate a collapse of food availability and high oxygen availability in this zone (Fig. 4). Additionally, high abundance of *Cibicidoides* spp. as an opportunistic species indicate unstable and high-stress condition[43].

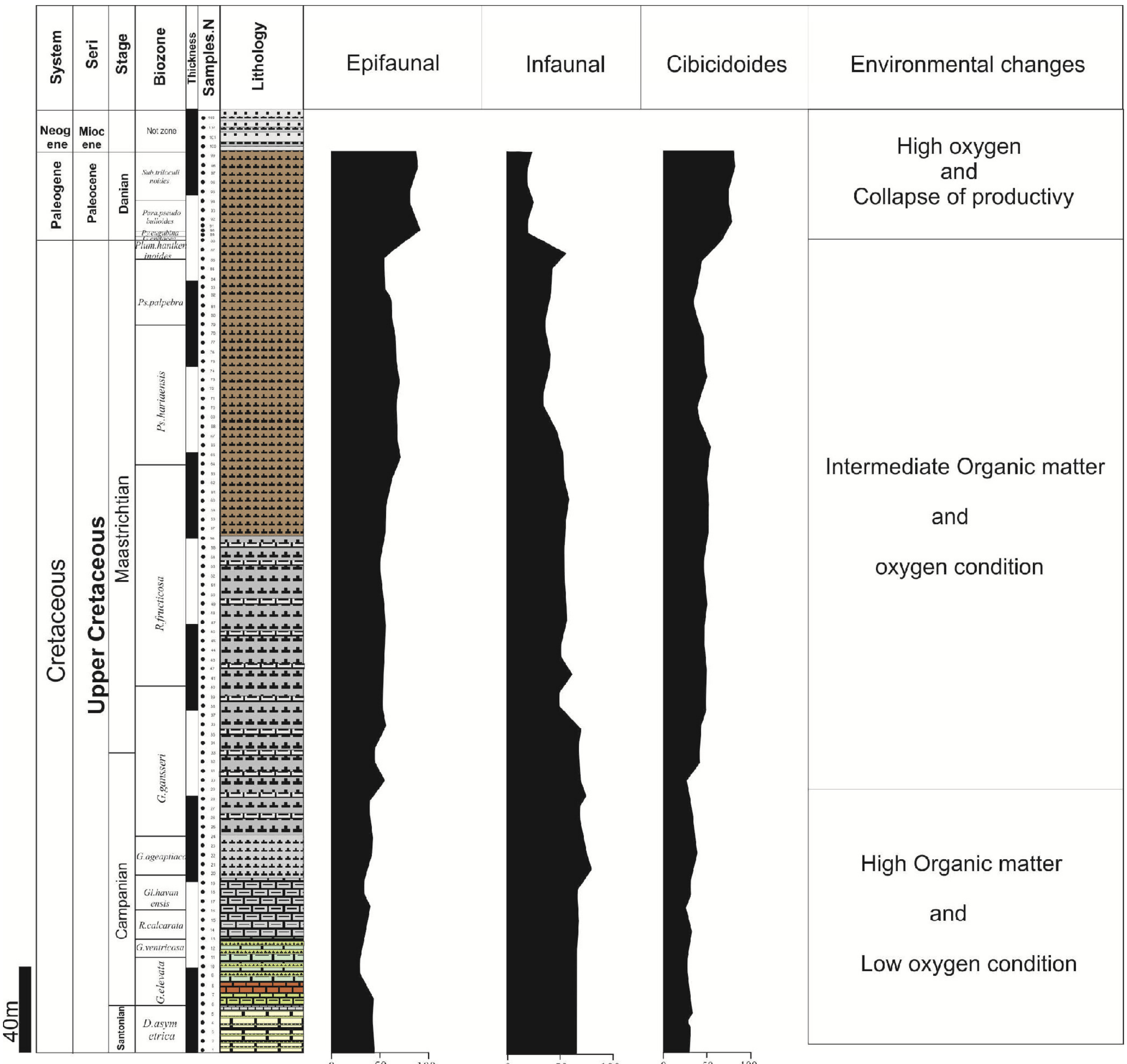

Figure-4: Distribution of epifauna and Infauna morphotypes and abundance of *Cibicidoides* spp. in the Galanderud section.

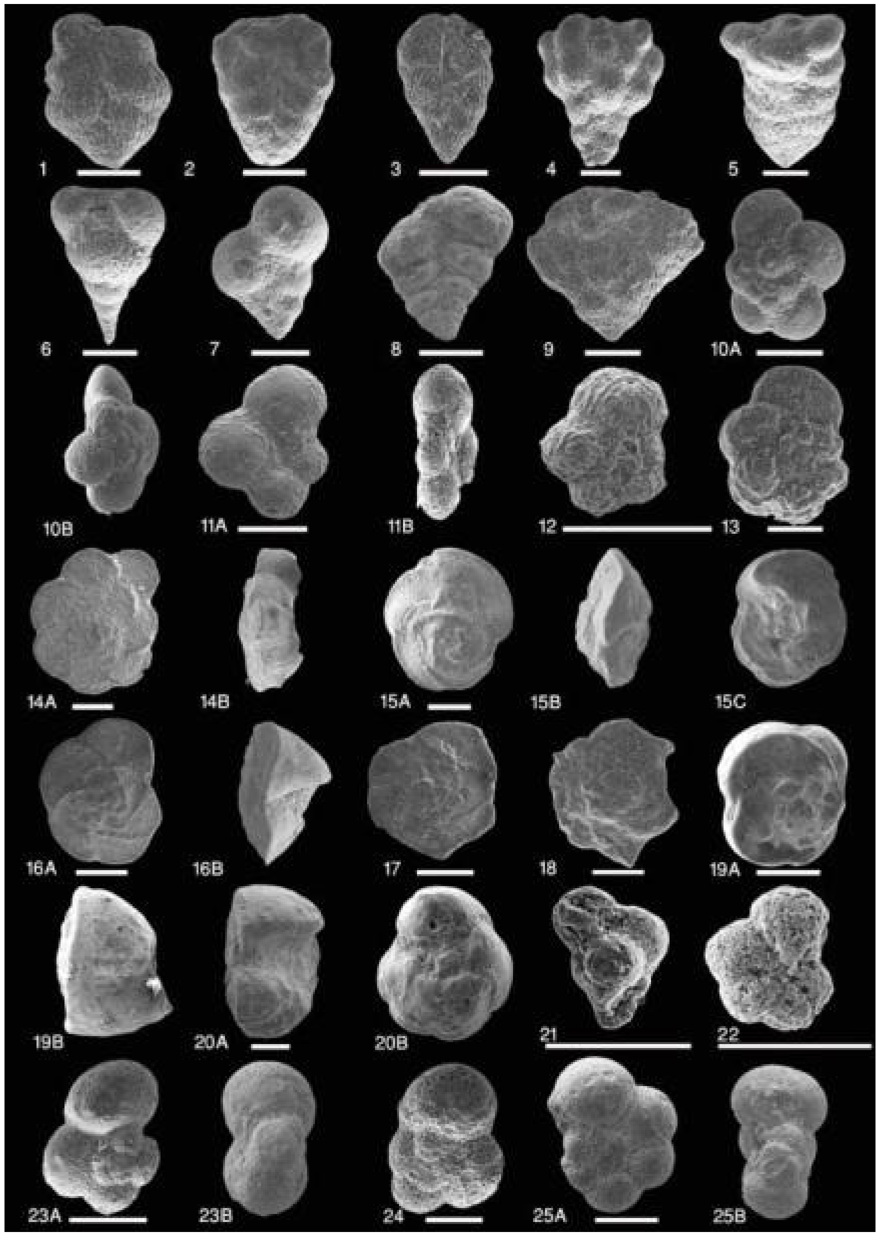

Plate-1: scale bar represents 100 µm

1.Pseudoguembelina palpebra, 2. *Pseudoguembelina hariaensis*, 3. *Pseudoguembelina costulata*, 4. *Racemiguembelina fructicosa*, 5. *Racemiguembelina powelli*, 6. *Pseudotextularia intermedia*, 7. *Heterohelix globulosa*, 8. *Laeviheterohelix dentata*, 9. *Planoglobulina acervulinoides*, 10. *Globotruncanella havanensis*, 11. *Globigerinelloides subcarinata*, 12. *Rugoglobigerina rugosa*, 13. *Tritinella scotti*, 14. *Globotruncana ventricosa*, 15. *Contusotruncana fornicata*, 16. *Globotruncanita eleveta*, 17,18. *Radotruncana calcarata*, 19. *Gansserina gansseri,* 20. *Globotruncana aegyptiaca*, 21. *Guembelitria cretacea*, 22. *Parvularugoglobigerina eugubina*, 23. *Parasubbotina pseudobulloides*, 24. *Subbotina triloculinoides*, 25. *Praemurica uncinata.*

Conclusion

By studying the late Santonian-early Paleocene sequences at the Galanderud section fifteen zones have been defined include i. *Dicarinella asymetrica*, ii. *Globotruncanita elevata*, iii. *Globotruncana ventricosa*, iv. *Radotruncana calcarata*, v. *Globotruncanella havanensis*, vi. *Globotruncana aegyptiaca*, vii. *Gansserina gansseri*, viii. *Racemiguembelina fructicos*, ix. *Pseudoguembelina hariaensis*, x. *Pseudoguembelina palpebra*, xi. *Plummerita hantkeninoides*, xii. *Guembelitria cretacea*, xiii. *Parvularugoglobigerina eugubina*, xiv. *Parasubbotina pseudobulloides*, xv. *Subbotina triloclinoides*. Also, three distinct zones have been defined based on benthic foraminifera morphotypes and *Cibicidoides* spp. showing fluctuations in oxygen concentration and organic matter flux during this time.

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