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Microbiostratigraphy of the lower Cretaceous strata from South East of Maragheh, NW Iran

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Abstract
For the microbiostratigraphical studies, a stratigraphical section (named Dareh-Goshayesh) has been selected in southeast of Maragheh, Northwestern Iran. The thickness of successions in the selected stratigraphic section is measured about 223.6 m. The mentioned studied stratigraphic section is composed of two clastic and carbonate units. This succession unconformably overlies the Lar Formation and is overlain by the Upper Cretaceous strata paraconformably. Based on the micropaleontological studies, a diversified assemblage of foraminifera and calcareous algae has been determined and the age of the studied stratigraphic section is inferred as Late Barremian-Late Aptian. Also, during these studies, four biozones are determined as follows: *Palorbitolina lenticularis* Range Zone, *Balkhania balkhanica* range zone, *Orbitolina* (*Mesorbitolina*) *texana* Zone and *Orbitolina* (*Mesorbitolina*) *parva* Zone. This paper presents the first micropalaeontological and lithostratigraphical studies.
Keywords: *Foraminifera, Barremian-Aptian, Eastern Azerbaijan, NW Iran.*

1. Introduction
Azerbaijan area is geologically located between Alborz (=Elborz) Mountain range in the East, Caucasus Mountains in the north and Zagros Mountains in the south (Berberian 1976) and according to Darvishzadeh (1993), is situated in Azerbaijan-Alborz structural zone. The tectonic of Azerbaijan is affected by Caspian oceanic basement in east and the existed Ophiolites in south small Caucasus which continues from Armenia to the west of the Caucasus and the Black Sea. Also, on the western border, it is affected by the north and Eastern Anatolian faults. The rocks of Azerbaijan area is geologically mainly composed of continental crust, Upper Cretaceous to Lower Tertiary Ophiolite, Cenozoic volcanic and sedimentary rocks (Zamani Gharechamani 2013). A relatively large region of Azerbaijan, during the Late Jurassic and Early Cretaceous, has been emerged. The oldest sediments of the Cretaceous sediments are Barremian-Albian *Orbitolina* limestones which indicate the sea precession at this time. The Lower Cretaceous deposits in most areas of the Azerbaijan province record a transgression and consist of clastic deposits such as basal conglomerate which has been gradually replaced by organodetrial limestones in the lower most part. According to Rami et al. (2012), the most complete Cretaceous sections in north Iran are found in the Kopet-Dagh range on the border of Iran and Turkmenistan.

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The lithology consists of marine shales, marls, limestones and sandstones. The sequence reaches a thickness of more than 3000m and seems to represent almost complete Lower Cretaceous sequence (Afshar-Harb 1994). In the Alborz mountains and farther south, Cretaceous limestones and marls are widely distributed but the sections are less complete. Elsewhere, unfossiliferous red clastic basal beds, which in the Ravar-Darband area, northern Kerman province, contain considerable amounts of gypsum, frequently initiate the Cretaceous sequence and are followed by limestones and marls of different ages. The oldest marine beds are *Orbitolina*- bearing limestones (Tiz-Kuh Formation of the Alborz, “*Orbitolina* limestone” in general), which are conventionally regarded as Aptian-Albian but may include stages as old as Barremian and as young as Cenomanian. An unusual shale facies reaching great thickness and containing very rare cephalopods represents the Barremian-Albian in the Biabanak area of Central Iran (Stöcklin and Setudehnia 1991). With the exception of the Kopet Dagh area mentioned above, detailed stratigraphic studies of the Upper Cretaceous deposits have been carried out only in a few limited area such as the central Alborz, Tehran, Jandaq, Esfahan and Kerman. Detrital limestones, reef limestones, marls and shales prevail. However, the marine sequences are frequently interrupted by conglomerates, red beds, sedimentary gaps and unconformities and the sections vary in detail over short distances, reflecting the unstable conditions of the sedimentary environment during the initial phases of the Alpine orogeny.

This and considerable disagreement between interpretations of different authors regarding the stratigraphic significance of the faunas has so far made reliable correlation over any greater distance difficult. A consistent stratigraphic subdivision of the Upper Cretaceous has yet to be established. The Stratigraphic Terminological Committee (STC) of Iran has not recommended any formal stratigraphic names for the Upper Cretaceous strata of the Alborz and central and eastern Iran until more regional information becomes available to clarify the situation, in compliance with this recommendation (Stöcklin and Setudehnia 1991).

Benthic foraminifera are a common tool for paleo-oceanography and paleoenvironmental studies because of their morphological diversity, the narrow ecological tolerance of single species, good preservation potential and abundances in marine sediments. The main factors that influence the distribution of benthic foraminifera in the past and modern oceans are the oxygen content of the bottom water and nutrient availability (e.g. Van der Zwaan et al. 1999; Brüchert et al. 2000). Due to the dependence of larger foraminifera on their algal symbionts (see Leutenegger 1984), we commonly find the fossil remains of these two groups of microorganisms together. Their diversity increases during episodes of reduced oceanic circulation and expansion of nutrient-poor, shallow tropical waters in particular (Hallock 1981; Hottinger 1982). The observation that the symbionts are arranged side by side along the portion of the test proving the light supports the idea that compress ed tests with the large surface areas are well adapted to symbiosis. They provide the algae with photic zone (Leutenegger 1984). As nutrient supplies and oceanic waters decrease, especially in shallow waters, diversity of calcareous algae and benthic foraminifers increase as sediment constituents (Hallock 1981; Hottinger 1982). High level nutrients reflect unique environmental factors operating on a board scale. It is attributed to elevated to nutrient levels and environmental instability within the small epicontinental sea, during the sea-level lowstand (Wood 1993; Elias and Young 1998). Fisher and Arthur (1977) have concluded that rising sea levels will reduce the concentration and amount of nutrients. *Orbitolina* is important benthic foraminifers of Lower-Mid Cretaceous strata and typical indicator of the shallow and warm waters (Flügel 2010). Discoidal Orbitolinids are common in deep sea waters, comprising conical Orbitolinids (Di lucia et al. 2007).

This paper presents the results of a microbiostratigraphical study based on the identified microfossils in the Lower Cretaceous Dareh-Goshayesh stratigraphic section, along the Maragheh City, eastern Azerbaijan province.

2. Geological background

The Dare-Goshayesh stratigraphic section is located in southeastern Azerbaijan province, 15 km southeast of Maragheh City (37°55′ N and 46°25′ E) (Alavi and Shahrabi 1975) (Fig 1).

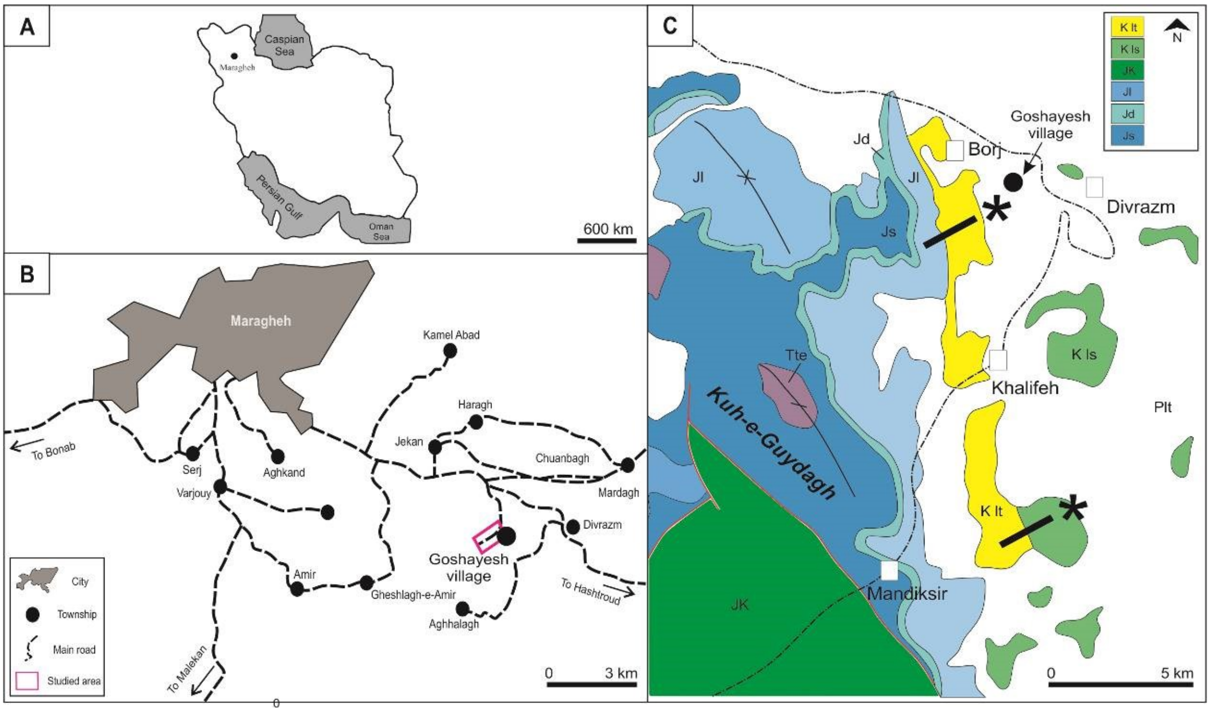

Fig 1. A and B) the location map of the area, C) Geological map of the studied area (After Alavi and Shahrabi 1975. With minor changes). Legend: Js (Shemshak Fm.), Jd (Dalichai Fm.), Jl (Lar Fm.), JK, K ls and K lt (Lower Cretaceous strata). The studied stratigraphic sections are shown with black stars.

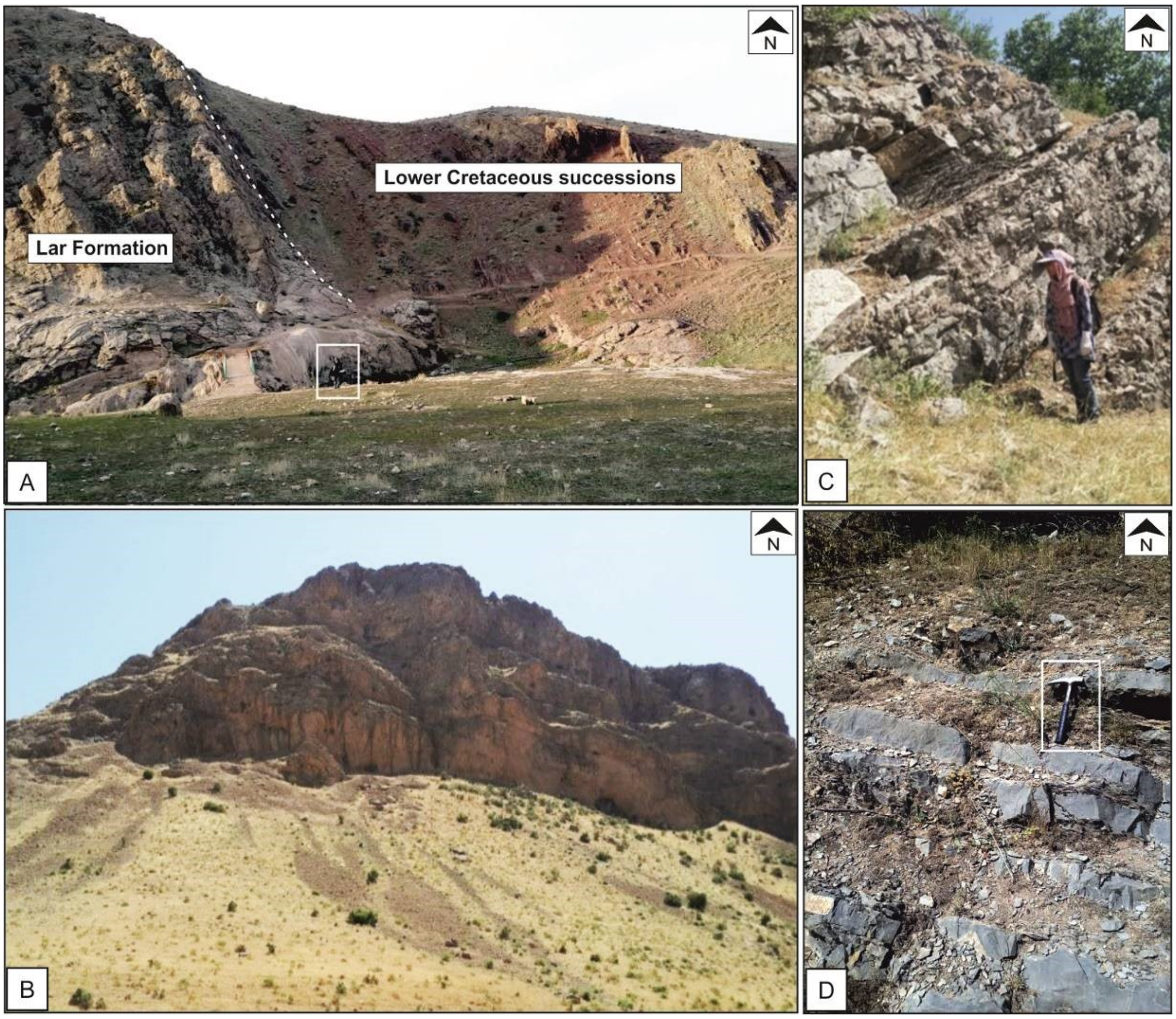

Fig 2. A) the boundary of Jurassic/Cretaceous in the studied stratigraphic section, B and C) Aptian strata in the stratigraphic section, D) Barremian limestones in the studied stratigraphic section. (Scales are shown in white rectangles).

Access to the studied stratigraphic section is possible through asphaltic road of Maragheh-Hashtrood. This stratigraphic section is located to a distance of approximately 1 km, in southwest of Goshayesh village.

3. Lithostratigraphy of the studied section

The studied stratigraphic section is mainly composed of two units as follow: Clastic and carbonate beds (mainly *Orbitolina* beds). The Clastic beds consist of red massive conglomerate, shale and red sandstone which unconformably overlie the Lar Formation (Fig 2). Also, carbonate part includes sandy limestone, shale and thin to thick-bedded gray limestone (Fig.3) underlain by the Dalichai Formation with a fault boundary (Fig 4). For accurate evaluation, the boundary between the mentioned beds and Cretaceous (for more details of its planktonic contents, see Plate 3) units has been studied in Ghermezi-Bulaq village in the southeastern of Maragheh City, and is detected as paraconformity.

4. Materials and methods

This paper is based on the study of the Dareh-Goshayesh stratigraphic section. The Upper Barremian-Upper Aptian succession was measured and sampled (intervals between 1-3 meters from fresh outcrops). Microfossil content of the samples was studied in 76 thin sections and 6 washing samples with an optical microscope. These allowed the identification of the vertical foraminiferal distribution and establishment of three global and one regional biozones. All rock samples, thin sections as well as washing samples are housed in the Geoscience Research Center, Geological survey of Iran, Tehran, Iran.

The taxonomic determination of the foraminifers is based on the latest changes in the foraminiferal classifications: Loeblich and Tappan (1988) and

Kaminski (2004) and takes into account the following works: Jones and Charnock (1985), Koutsoukos et al. (1990) Baud et al. (1994), Cherchi and Schröeder (1999), Yilmaz (1999) and Masse et al. (2004, 2009).

5. Microbiostratigraphy of the studied section

In the present study, 25 genera and 21 species of benthic foraminifera as well as 5 genera and 4 species of calcareous algae were identified. The most important identified benthic foraminifera and calcareous algae are as follow:
Palorbitolina lenticularis, Praeorbitolina cormyi, Orbitolina (Mesorbitolina) subconcava, Orbitolina (Mesorbitolina) parva, Spiroloculina cretacea, Vercorsella arenata, Charentia sp., *Balkhania balkhanica, Everticyclammina hedbergi, Mayncina bulgarica, Marssonella turris, Cuneolina* sp., *Debarina hahounerensis, Dervantina filipescui, Dictyoconus pachymarginalis, Glomospira urgoniana, Istriloculina eliptica, Istriloculina alimanensis, Lenticulina* sp., *Nezzazata* sp., *Pseudocyclammina lituus, Torinosuella peneropliformis, Praechrysalidina infracretacea, Rumanoloculina pseudominima, Rumanoloculina robusta, Lithocodium aggregatum, Permocalculus* sp., *Boueina hochstetteri, Coptocampylodon lineolatus, Marinella lugeoni.*

Subfamily ORBITOLININAE d'Orbigny, 1850
Genus *Palorbitolina* Schröeder, 1963
Palorbitolina lenticularis Blumenbach, 1805
Plate. 1, Fig 3.

Description: Low conical test relatively small, up to 5 mm in diameter, embryonal apparatus consisting of protoconch and deuteroconch, over-lying supraembryonal zone subdivided in the outer part by partial vertical septula, the resulting chamberlets opening into the under-lying proloculus, laterally a periembryonal ring of obliquely arranged chamberlets borders the proloculus and supraembryonal zone, periembryonal chamberlets similarly subdivided by septula in the upper part, later chambers uniserial and discoidal, with thin marginal zone of primary vertical exoskeletal beams and horizontal rafters, and may be accompanied by secondary beams in the later chambers, poorly developed radial zone occupies one-third to one-half the chamber area, the main beams being thick and triangular in section and zigzagging irregularly toward the central region, main partitions irregular and intermittant in the central complex; wall imperforate, of granular calcite, with large quantity of fine-grained agglutinated material near the surface and coarser-grained in the inner zone; apertural pores obscure.
Total range: Latest Barremian-Early Aptian.
Occurrence: Sample no. Zn5, Z14, Z34 and Z57.

Genus *Praeorbitolina* Schröeder, 1965
Praeorbitolina cormyi Schröeder, 1965
Plate. 1, Fig 4.

Test conical, megalospheric embryonal apparatus consisting of protoconch, deuteroconch, and subembryonal zone, somewhat eccentric in position and not completely surrounded laterally by the earliest postembryonal chamber, early stage with initial planispire or trochospire, followed by discoidal uniserial chambers subdivided into a narrow marginal zone with intersecting exoskeletal vertical radial beams of two orders and trans-verse rafters that parallel the chamber

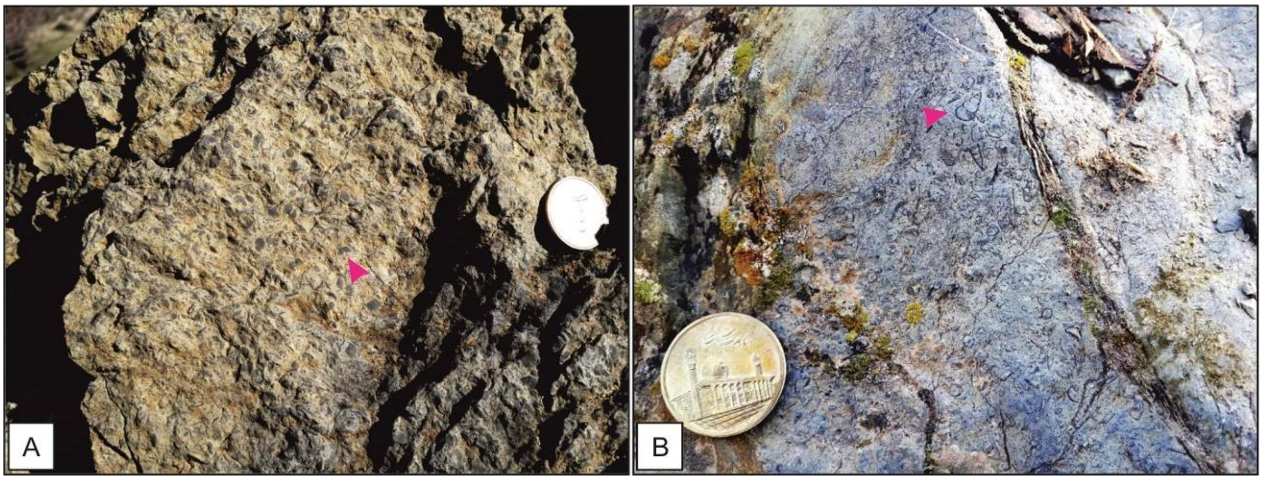

Fig 3. A) *Orbitolina* beds in studied stratigraphic section, B) Aptian limestones containing different allochems such as microgastropods, bivalves, calcareous algae and etc. which resemble Urgonien (=Urgonian) facies types in Switzerland and France. (Orbitolinids and microgastropods are shown by pink arrows).

floor, a slightly broader radial zone in *which* the beams have a distinctly triangular cross-section as seen in tangential thin section, and finally a much wider central reticular zone.
Total range: Early Aptian (Bedoulian).
Occurrence: Sample no. Zn6.

Genus *Orbitolina* d'Orbigny, 1850
Subgenus *Mesorbitolina* Schröeder, 1962

Description: Test a low cone to nearly discoidal, up to 12 mm in diameter, apex rounded to mammilate, large embryonic apparatus, with equally well-developed supra- and subembryonal zones, in contrast to the weakly developed subembryonal zone of *Orbitolina,* both sub and supraembryonal chambers with marginal zone subdivided by numerous exoskeletal beams that are perpendicular to the outer walls, early postembryonic chambers rectilinear, low, and discoidal, marginal zone subdivided by radial beams of two or three orders and by horizontal rafters, resulting in the formation of numerous rectangular chamberlets, well-developed radial zone of continuing first order beams that thicken rapidly at the junction of the marginal and radial zones, becoming triangular in section and zigzag in plan, central zone with thinner and flatter beams that are discontinuous because of the large number of pores in the central area, central zone may be lacking in later chambers that are annular rather than discoidal; wall of fine silt- to clay-sized agglutinated particles, with some large calcite grains; small apertural pores lie in reentrants in the main beams in the radial zone, become more numerous inward to the junction with the central zone, and are abundant in the central zone.
Total range: Albian-Early Cenomanian.

Subgenus *Mesorbitolina* Schröeder , 1962
Orbitolina (Mesorbitolina) subconcava Schröeder , 1962
Plate. 2, Fig 1.

Remarks: Large, weakly conical, megalospheric forms usually occur (apical angle of 140°–160°). Axial sections show typical forms with removed embryonic apparatus.
Total range: latest Late Aptian-Late Albian.
Occurrence: Sample no. Z72**.**

Subgenus *Mesorbitolina* Schröeder , 1962
Orbitolina (Mesorbitolina) parva Schröeder , 1962
Plate. 1, Fig 9.

Remarks: Low test, small semi-conical shape, both convex and concave shapes of the base are present. Thickness of the test is 1.02-5.30 mm and its height is 0.83-0.93 mm. In the last part of the megalospheric forms, it is semi-rounded. Its megalospheric embryonic apparatus is located in central, upper most part of the test and is composed of protoconch, deutroconch and sub-embryonic. The size of deutroconch is twice protoconch. Sub-embryonic part is simple, sub-divided by septula and is smaller than deutroconch.
Total range: early Late Aptian**.**
Occurrence: Sample no. Z57 and Z63**.**

Subgenus *Mesorbitolina* Schröeder, 1962
Orbitolina (*Mesorbitolina*) *texana* Roemer, 1849
Plate. 1, Figs 6-7.

Description: The embryonic apparatus of macrospheric forms, which is very important for an exact determination, is preserved as well and is composed of protoconch, deu -teroconch, and sub embryonic zone. It is located on the top of the specimen. The thickness of protoconch is about 0.11 mm and embryonic apparatus is about 0.25 mm. Total range. Late Aptian-Early Albian.
Total range: Late Aptian-Early Albian.
Occurrence: Sample no. Zn7**.**

Subfamily DICTYOCONINAE Moullade, 1965
Genus *Montseciella* Henson, 1948
Montseciella arabica Henson, 1948
Plate. 1, Fig. 1

Description: Sub-axial section shows horizontal subepider -mal plates in the marginal zone. The central zone exhibits thin, vermicular partitions forming a labyrinthic structure and bordering relatively spacious hollows.
Total range: Late Barremian-Early Aptian.
Occurrence: Sample no. Z21.

Family CYCLAMMINIDAE Loeblich and Tappan,1982
Subfamily PSEUDOCHOFFATELLINAE Loeblich and Tappan, 1985
Genus *Balkhania* Mamontova, 1966
Balkhania balkhanica Mamontova, 1966
Plate. 1, Fig 8.

Description: Test free, large, up to 15 mm in diameter, discoidal, megalospheric test with large ellipsoid proloculus nearly surrounded by the next three narrow and arcuate rectilinear chambers, nature of microspheric stage uncertain, up to thirty completely annular postembryonal chambers; wall calcareous, with imperforate outer layer and choffatelloid subepidermal network; aperture cribrate, a row of pores in the face in the young stage, with more than one row in the adult.
Remarks: The synonymy of *Pseudochoffatella gigantic* Kaever, 1967 with *Balkhania balkhanica* Mamontova, 1966 was demonstrated by Cherchi and Schröeder (1982). *Balkhania* was included in the subfamily *Pseudochoffatellinae* by Loeblich and Tappan (1988) (For more data, see Taherpour Khalil Abad et al. 2012).
Total range: Early Barremian(?)-Late Barremian.
Occurrence: Sample no. Z20, Z36, Z43, Z49, Z52, Z54.

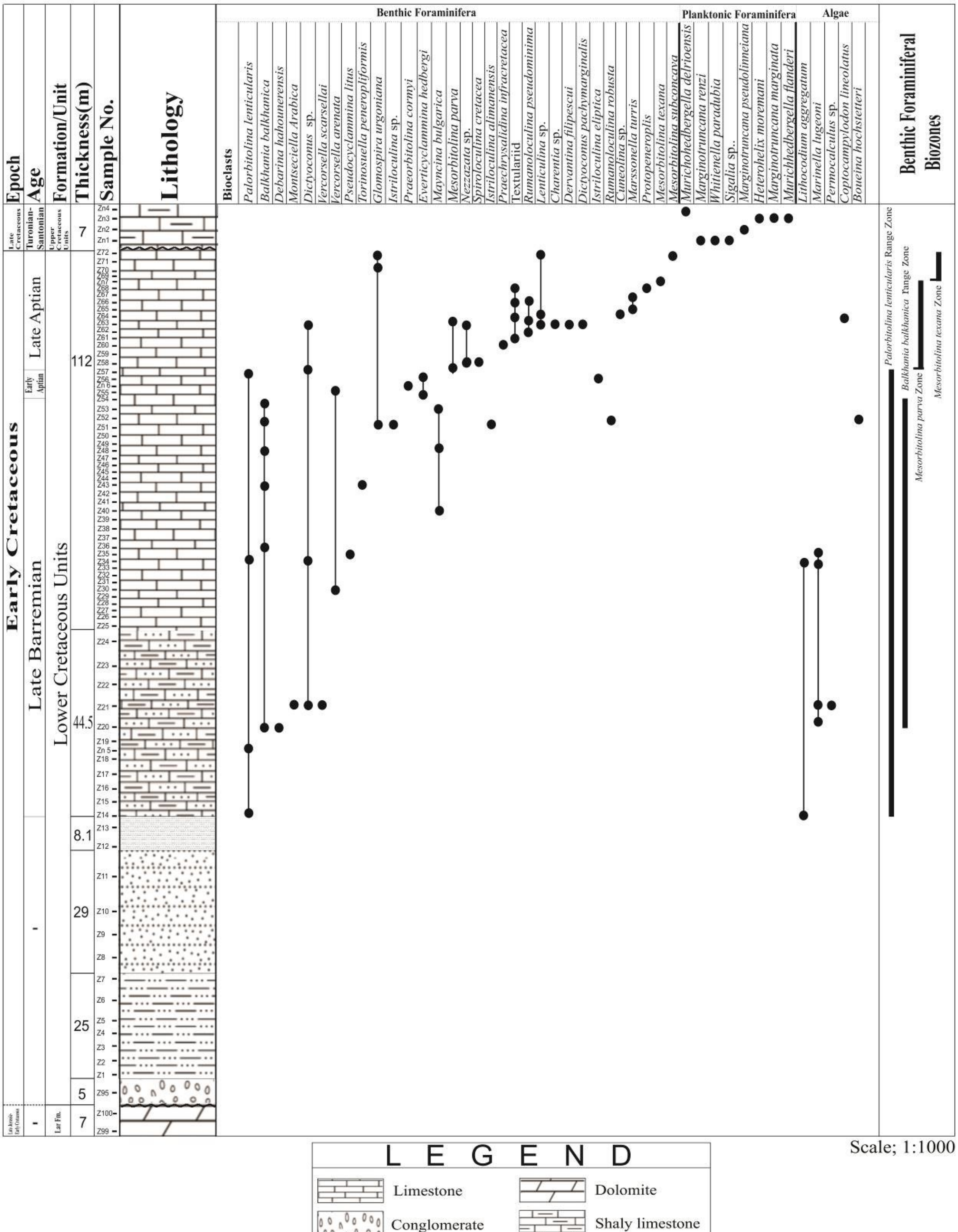

Fig 4. Stratigraphic column of the Dareh-Goshayesh stratigraphic section.

6. Identified biozones in Dare Goshayesh section

According to the studies of thin-sections and identified taxa, 3 global biozones "*Palorbitolina lenticularis* Range Zone, *Orbitolina* (*Mesorbitolina*) *texana* Zone, *Orbitolina* (*Mesorbitolina*) *parva* Zone" and 1 regional one "*Balkhania balkhanica* range zone, and " are determined and described as follow:

- *Palorbitolina lenticularis* Range Zone

Biostratigraphic interval represented by the total range of *Palorbitolina lenticularis* (Its FO and LO). This biozone has a global value and comprises 98.26 m of the section. This interval is mainly composed of limestone and sandy limestone. It is also presented by Bachman and Hirsch (2006), Conrad and Peybernes (1976) from Lower Cretaceous successions of Switzerland, Schröeder et al. (2010) from Lower Cretaceous successions of Arabian plate, Mousavian et al. (2014) from the Shah-Kuh Formation in Central Iran and Taherpour Khalil Abad (2015) from the Tirgan Formation in Kopet-Dagh sedimentary basin. This interval suggests a Late Barremian-Early Aptian (Bedoulian) age.

Associated biota: *Praeorbitolina cormyi, Balkhania balkhanica, Montseciella arabica, Debarina hahounerensis, Dictyoconus* sp. *Vercorsella scarsellai, Vercorsella arenata, Pseudocyclammina lituus, Torinosuella peneropliformis, Glomospira urgoniana, Everticyclammina hedbergi, Mayncina bulgarica, Istriloculina alimanensis, Istriloculina eliptica, Rumanoloculina robusta, Lithocodium aggregatum, Marinella lugeoni, Boueina hochstetteri*.

- *Balkhania balkhanica* range zone

Biostratigraphic interval represented by the total range of *Balkhania balkhanica* (Its FO and LO). This biozone has a regional value and represents Late Barremian age. The thickness of this interval in the studied stratigraphic section is 87.17 m and is mainly composed of limestone and sandy limestone. This biozone is also previously presented by Taherpour Khalil Abad (2015) from the Tirgan Formation in Kopet-Dagh sedimentary basin. This interval suggests a Late Barremian age.

Associated biota: *Palorbitolina lenticularis, Montseciella arabica, Vercorsella scarsellai, Dictyoconus* sp. *Vercorsella arenata, Pseudocyclammina lituus, Torinosuella peneropliformis, Glomospira urgoniana, Mayncina bulgarica, Istriloculina alimanensis, Rumanoloculina robusta, Lithocodium aggregatum, Marinella lugeoni, Boueina hochstetteri.*

- *Orbitolina* (*Mesorbitolina*) *parva* Zone

This biozone is defined by the first occurrence (FO) of *Orbitolina* (*Mesorbitolina*) *parva* to the first occurrence (FO) of *Orbitolina* (*Mesorbitolina*) *texana*. This biozone has a regional value, represents early Late Aptian age and is previously presented by Schröeder et al. (2010) from Lower Cretaceous successions of Arabian plate. The thickness of this interval in the studied stratigraphic section is about 35.2 m and is mainly composed of limestone.

Associated biota: *Coptocampylodon lineolatus, Orbitolina (Mesorbitolina) parva, Nezzazata* sp., *Spiroloculina cretacea, Praechrysalidina infracretacea, Rumanoloculina pseudominima, Lenticulina* sp., *Charentia* sp., *Dervantina filipescui, Dictyoconus pachymarginalis, Cuneolina* sp., *Marssonella turris, Protopeneroplis* sp.

- *Orbitolina* (*Mesorbitolina*) *texana* Zone

This biozone is defined by the first occurrence (FO) of *Orbitolina* (*Mesorbitolina*) *texana* to the first occurrence (FO) of *Orbitolina* (*Mesorbitolina*) *subconcava*. This biozone has a regional value and represents late Late Aptian age and is previously presented by Schröeder et al. (2010) from Lower Cretaceous successions in Arabian plate. The thickness of this interval in the studied stratigraphic section is about 5.27 m and is mainly composed of limestone.

Associated biota: *Glomospira urgoniana* and *Lenticulina* sp.

7. Conclusions

The studied stratigraphic section is mainly composed of carbonate rocks (silty limestone and mudstone) and clastic rocks (conglomerate, sandstone and shale). According to the determined benthic foraminifera (25 genera and 21 species) and calcareous algae (5genera and 4 species) assemblages in the studied thin sections, four biozones (*Palorbitolina lenticularis* Range Zone, *Balkhania balkhanica* range zone, *Orbitolina (Mesorbitolina) parva* Zone and *Orbitolina* (*Mesorbitolina) texana* Zone) are identified and the age of the studied stratigraphic section is inferred as Late Barremian-Late Aptian.

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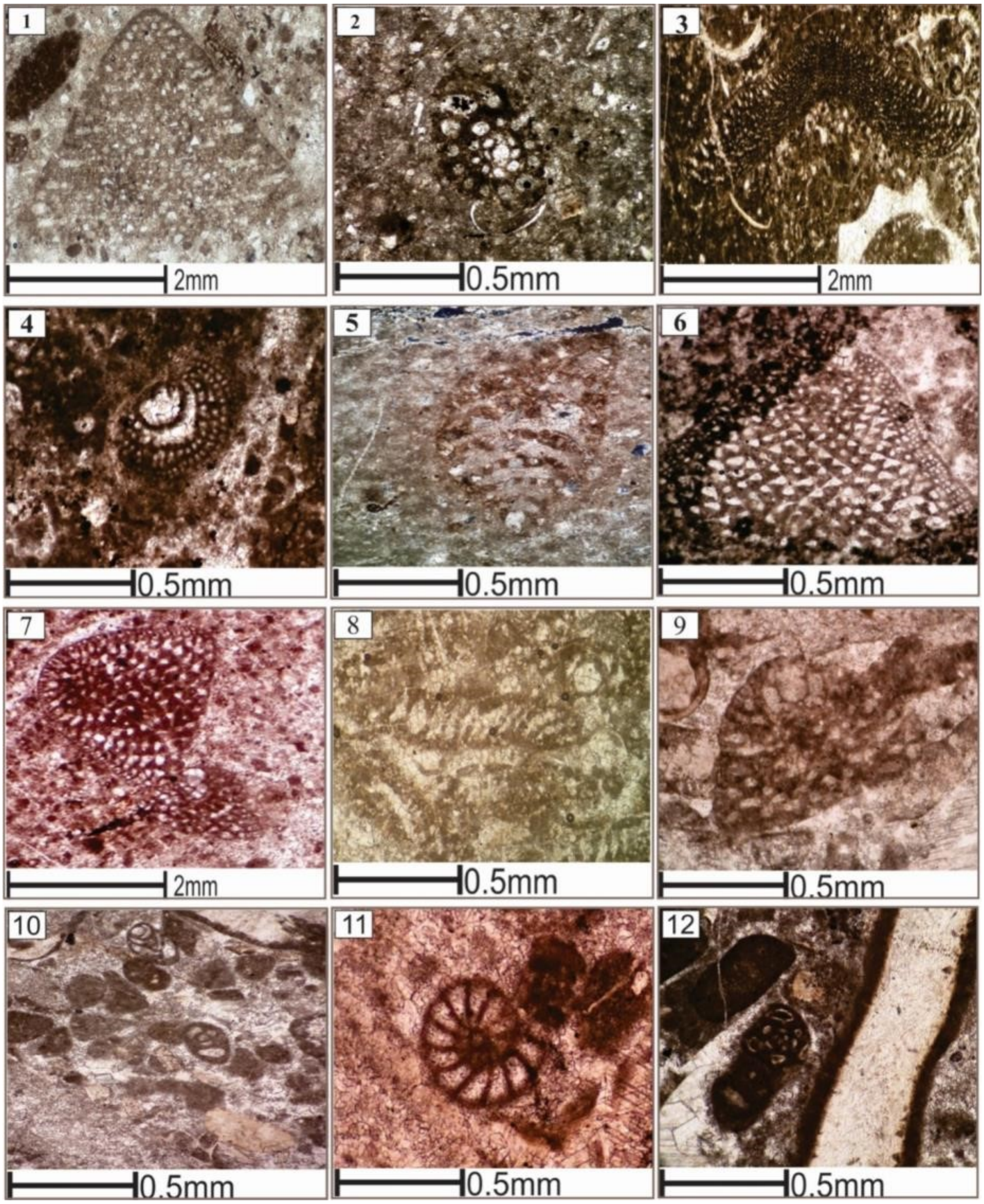

Plate 1: 1. *Montseciella* cf. *arabica* (Sample No. Z21), 2. *Mayncina bulgarica* (Sample No. Z40), 3. *Palorbitolina lenticularis* (Sample No. Z57), 4. *Praeorbitolina cormyi* (Sample No. Zn6), 5. Cyclamminid (Sample No. Z40), 6. *Mesorbitolina texana* (Sample No. Zn7), 7. *Mesorbitolina texana* (Sample No. Zn7), 8. *Balkhania balkhanica* (Sample No. Z43), 9. *Orbitolina (Mesorbitolina) parva* (Sample No. Z64), 10. *Charentia* sp. (Sample No. Z63), 11. *Nezzazata* sp. (Sample No. Z63), 12. *Rumanoloculina robusta* (Sample No. Z52).

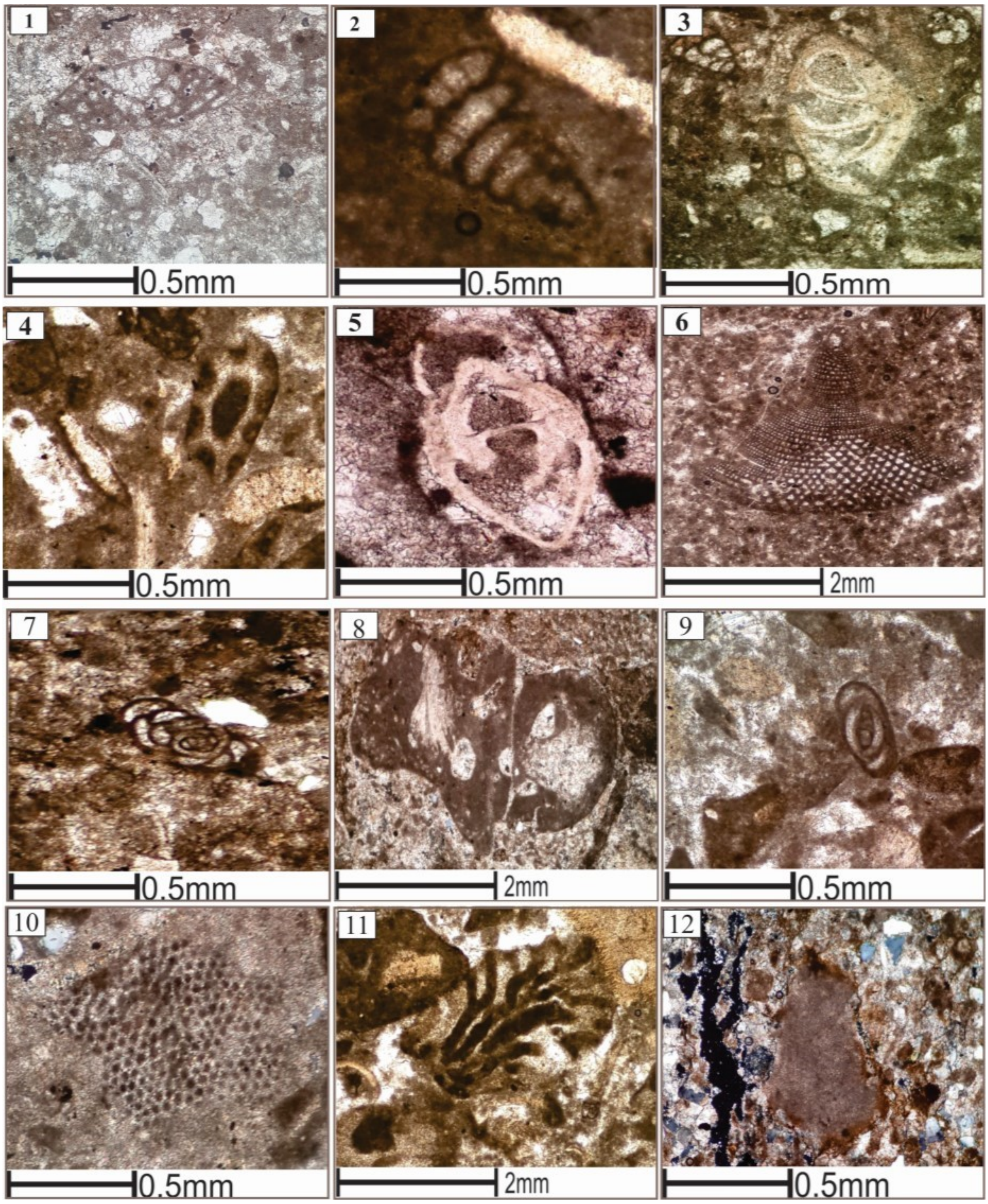

Plate 2: 1. *Orbitolina (Mesorbitolina) subconcava* (Sample No. Z72), 2. *Vercorsella arenata* (Sample No. Z55), 3. *Protopeneroplis* sp. (Sample No. Z68), 4. *Comptocampylodon lineolatus* (Sample No. Z63), 5. *Lenticulina* sp. (Sample No. Z64), 6. *Praeorbitolina* sp. (Sample No. Zn6), 7. *Glomospira* cf. *urgoniana* (Sample No. Z72), 8. *Lithocodium aggregatum/Baccinella irregularis* (Sample No. Z34), 9. *Istriloculina elliptica* (Sample No. Z56), 10. *Permocalculus sp*. (Sample No. Z21), 11. *Boueina cf. hochstetri* (Sample No. Z52), 12. *Marinella lugeoni* (Sample No. Z20).

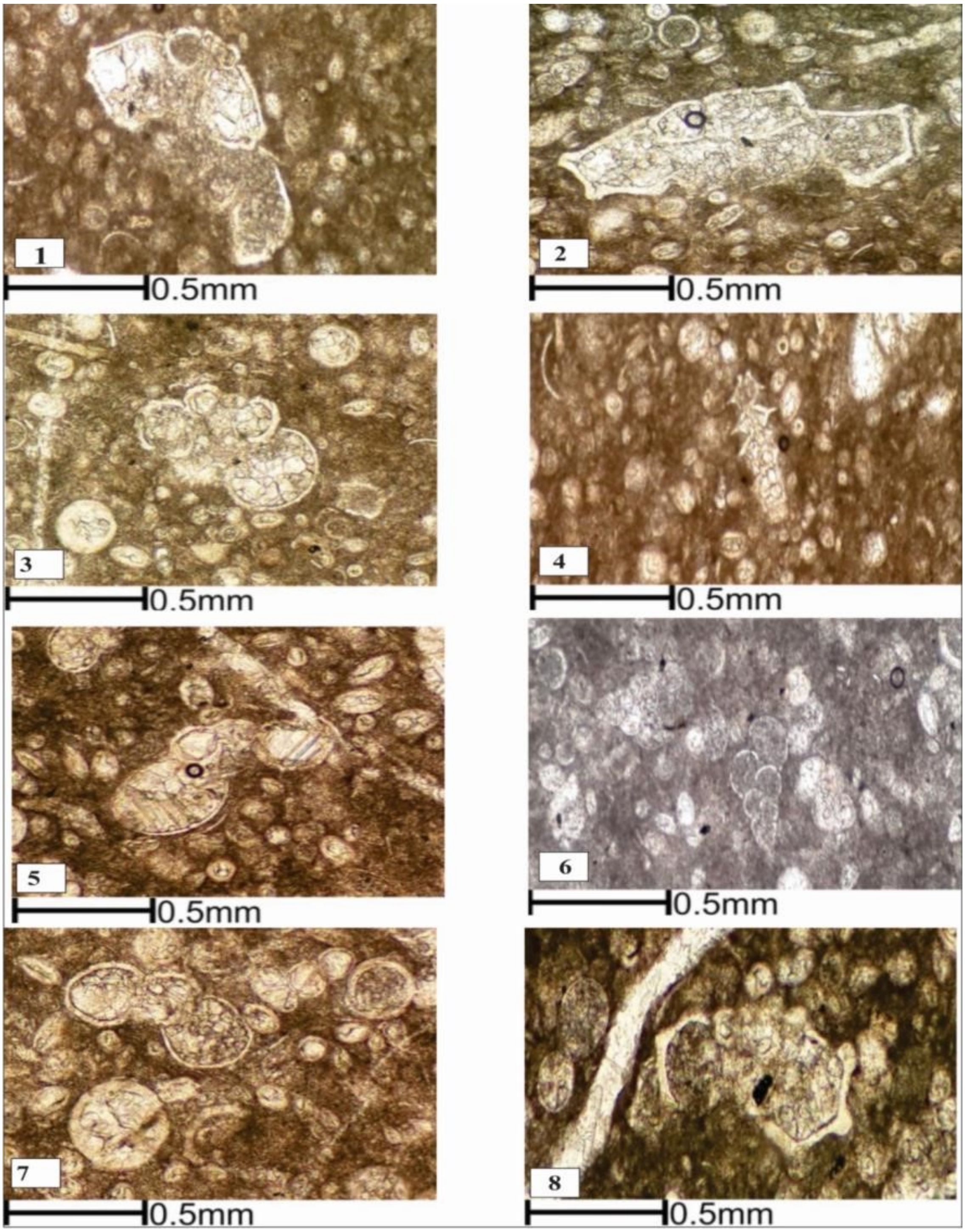

Plate 3: 1. *Marginotruncana renzi* (Sample no. Zn1), 2. *Marginotruncana pseudolinneiana* (Sample no. Zn2), 3. *Whitienella paradubia* (Sample no. Zn1), 4. *Sigalia sp.* (Sample no. Zn1), 5. *Murichhedbergella flanderi* (Sample no. Zn3), 6. *Heterohelix moremani* (Sample no. Zn3), 7. *Murichohedbergella delrioensis* (Sample no. Zn4), 8. *Marginotruncana marginata* (Sample no. Zn3).