Microbiostratigraphy of the Lower Cretaceous strata from the Bararig Mountain, SE Iran

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ABSTRACT

The Barremian-Aptian sediments in the Bararig section (Southwest of Kuhbanan) consist of an alternation of marl and limestone. The palaeontological analysis led to identification of twenty seven taxa of benthic foraminifera and algae in the section studied. Diverse assemblages of benthic foraminifera and also the low planktonic/benthic (P/B) ratio show that the sedimentary environment in the study area was oxygenated and shallow.

Key words: microbiostratigraphy, palaeoecology, Lower Cretaceous, Bararig section, Kerman Province, Iran.

RESUMEN

Los sedimentos del Barremiano-Aptiano en la sección Bararig section (al suroeste de Kuhbanan) consisten en una alternancia de margas y calizas. El análisis paleontológico permitió la identificación de 27 taxa de foraminíferos bentónicos y algas en la sección estudidad. Diversas asociaciones de foraminíferos bentónicos y la baja relación de planctónicos/bentónicos (P/B) indica que el ambiente sedimentario en el área de estudio fue oxigenado y somero.

Palabras clave: microbiostratigrafía, paleoecología, Cretácico Inferior, sección Bararig, Provincia Kerman, Irán.

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INTRODUCTION AND GEOLOGICAL SETTING

Lower Cretaceous sediments in some areas of the Kerman region, Iran, such as Baghin, Ekhtiyar-Abad and Kuhbanan, are marlstones and limestones with intercalations of marl. The first studies in the Kerman region were done by Pilgrim (1924). Huckreide *et al.* (1962) comprehensively studied the geology of the Kerman region and delineated the Cretaceous palaeogeography of this region. Cretaceous foraminifera of the Kerman region have been studied by Mahanipoor (2003), and Arab (2003, 2004, 2005). Vaziri (2003) studied the distribution of foraminifera and the paleoecology of the Cenomanian deposits. Hosseinipour *et al.* (2003), Arab *et al.* (2004, 2005) and Vaziri *et al.* (2006) studied the Albian-Cenomanian deposits in two stratigraphic sections (Henouj and Chenaroieh) in the western part of the Kerman region, and, eventually, biostratigraphic and paleoecologic studies were done by Ahmadi *et al.* (2010). Cretaceous outcrops in the Kerman Province are shown in the Figure 1.

This paper presents the results of a palaeoecological study based on the microfossil content of samples collected in the Lower Cretaceous Bararig section, along the Zarand-Kuhbanan-Deh Ali road, Karman province (Figure 2).

Structural units of Iran

Fundamental differences in the crustal character and age of basement consolidation allow three major structural units to be recognized in the studied area, separated by ophiolite-bearing sutures. Other criteria such as structural style, the age and intensity of deformation, and the age and nature of magmatism are used to subdivide these major zones into smaller elements. The three major units and their main constituents are as follows: 1) the southern unit, with a crystalline basement consolidated in Precambrian time, platform-type Paleozoic sediments and younger deposits. This unit comprises the Zagros fold belt; 2) the central unit, interpreted as an assemblage of marginal Gondwana fragments, originally united with the main continent and separated from the North (Eurasian) continent during the Paleozoic. In Mesozoic times, these fragments were detached from Gondwana and attached to Eurasia. During the Late Cretaceous they rejoined the Gondwanic Afro-Arabia. This unit comprises Central Iran and the Alborz; 3) the northern unit, markedly separated from the central unit by ophiolites of the North Iran suture. The continental crust includes remnants of more or less cratonized, former (Paleozoic) oceanic crust possibly that of the Paleotethys. The northern unit represents a marginal strip of the Hercynian realm of Central Asia, broadly overlapped by the Alpine realm. It was deformed and largely consolidated by strong Early Cimmerian and Late Alpine folding (Stocklin, 1968). The Northern Unit comprises the South Caspian Depression and the Kopet-Dagh Range (Figure 3).

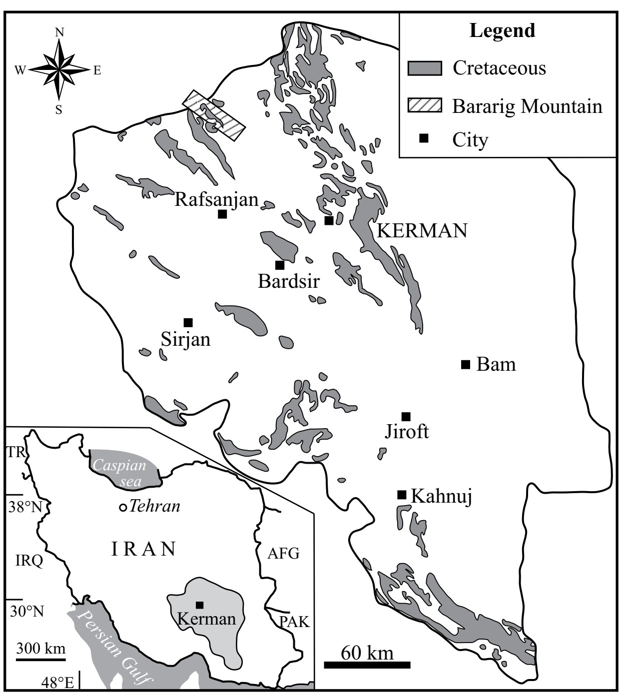

Figure 1. Cretaceous outcrops in the Kerman province (Bakhtiari, 2007, 2007, with minor changes). AFG: Afghanistan, PAK: Pakistan, IRQ: Iraq, TR: Turkey.

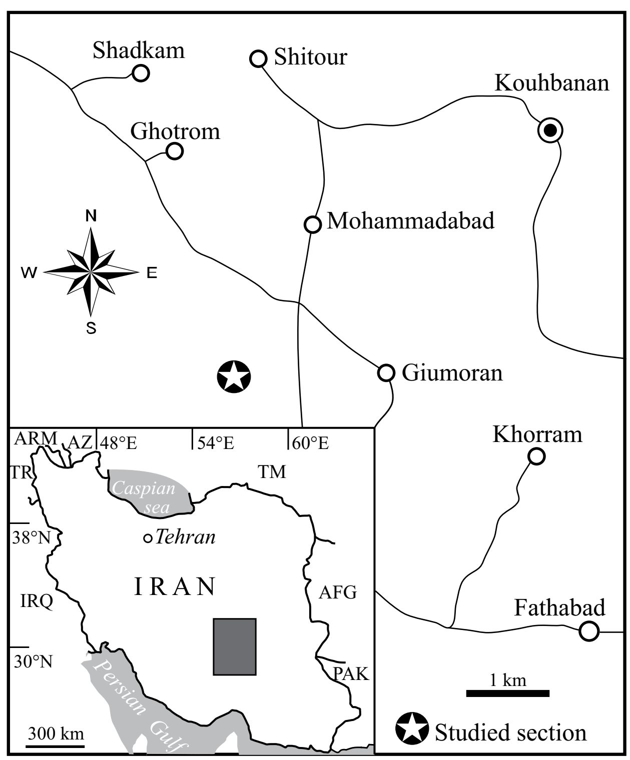

Figure 2. Location of the studied section in the Bararig Mountain, SE Iran (Bakhtiari, 2007, with minor changes). AFG: Afghanistan, PAK: Pakistan, IRQ: Iraq, TR: Turkey, TM: Turkmenistan, ARM: Armenia, AZ: Azerbaijan.

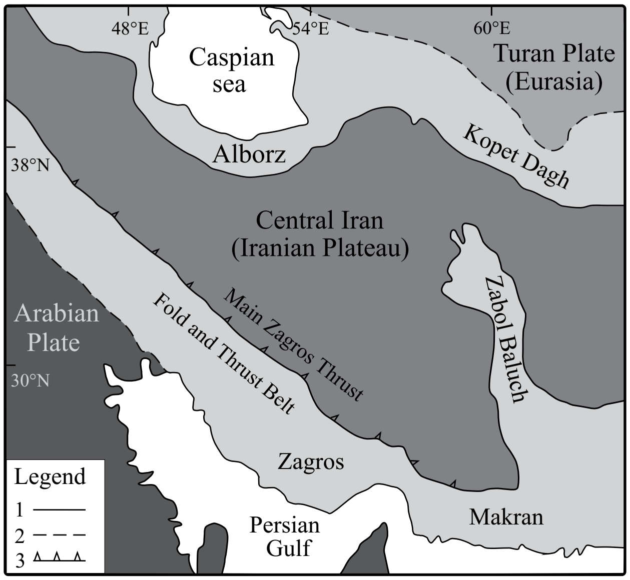

Figure 3. Structural units of Iran (after Berberian and King, 1981 and Taherpour *et al.*, 2011). Legend: 1: Border between different sedimentary basins; 2: collision zones of plates; 3: thrust fault boundary.

A brief comparison of Cretaceous deposits in different parts of Iran

The most complete Cretaceous sections in North Iran are found in the Kopet-Dagh range on the border of Iran and Turkmenistan. The rocks consist of marine shales, marls, limestones and sandstones. The sequence reaches a thickness of more than 3000 m and seems to represent all major parts of the Lower Cretaceous strata (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 (Stocklin 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 areas such as the central Alborz, Tehran, Jandaq, Esfahan and Kerman areas. 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 and a consistent stratigraphic subdivision of the Upper Cretaceous has yet to be established. The Stratigraphic Terminological Committee (STC) of Iran has recommended not introducing any formal stratigraphic names for the Upper Cretaceous strata of the Alborz and of central and eastern Iran until more regional information becomes available to clarify the situation, in compliance with this recommendation (Stocklin and Setudehnia, 1991).

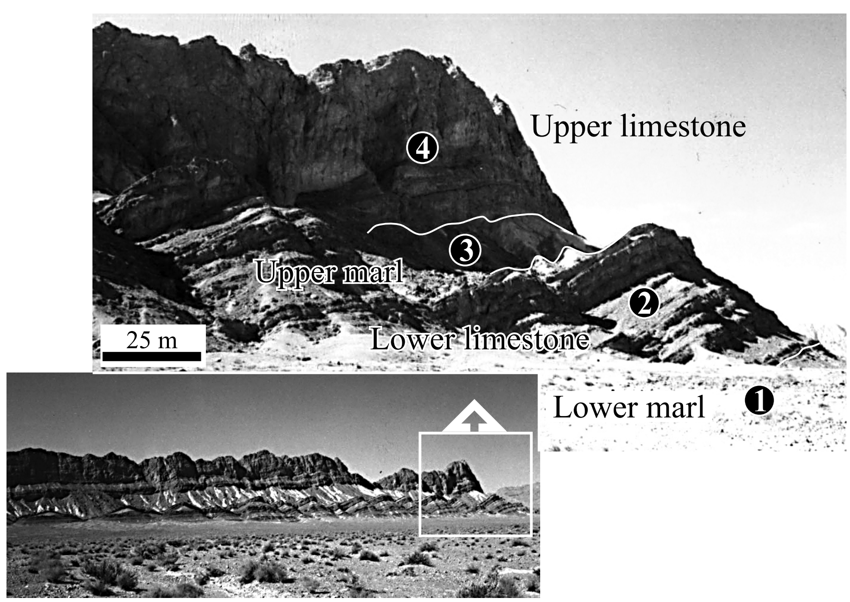

Figure 4. The lithological units in the Bararig stratigraphic section.

Stratigraphy of the Bararig section

The Bararig section is situated in the NW-SE striking Bararig mountains, at approximately 60 km southwest of Kuhbanan city (Kerman Province), and is accessible by the Zarand-Kuhbanan-Deh Ali road (Figure 2). The section is 190 m thick and is composed of two lithological associations, marls and limestones, which were deposited alternatively (Figure 4). The section from the lower to the upper part is as follows: green marls (90 m), gray limestones with intercalation of marls (40 m), light green marls (25 m) and gray, thick-bedded limestones (35 m). The mentioned units contain ostracods, benthic foraminifera and macrofossils. In order to conduct palaeontological studies, samples

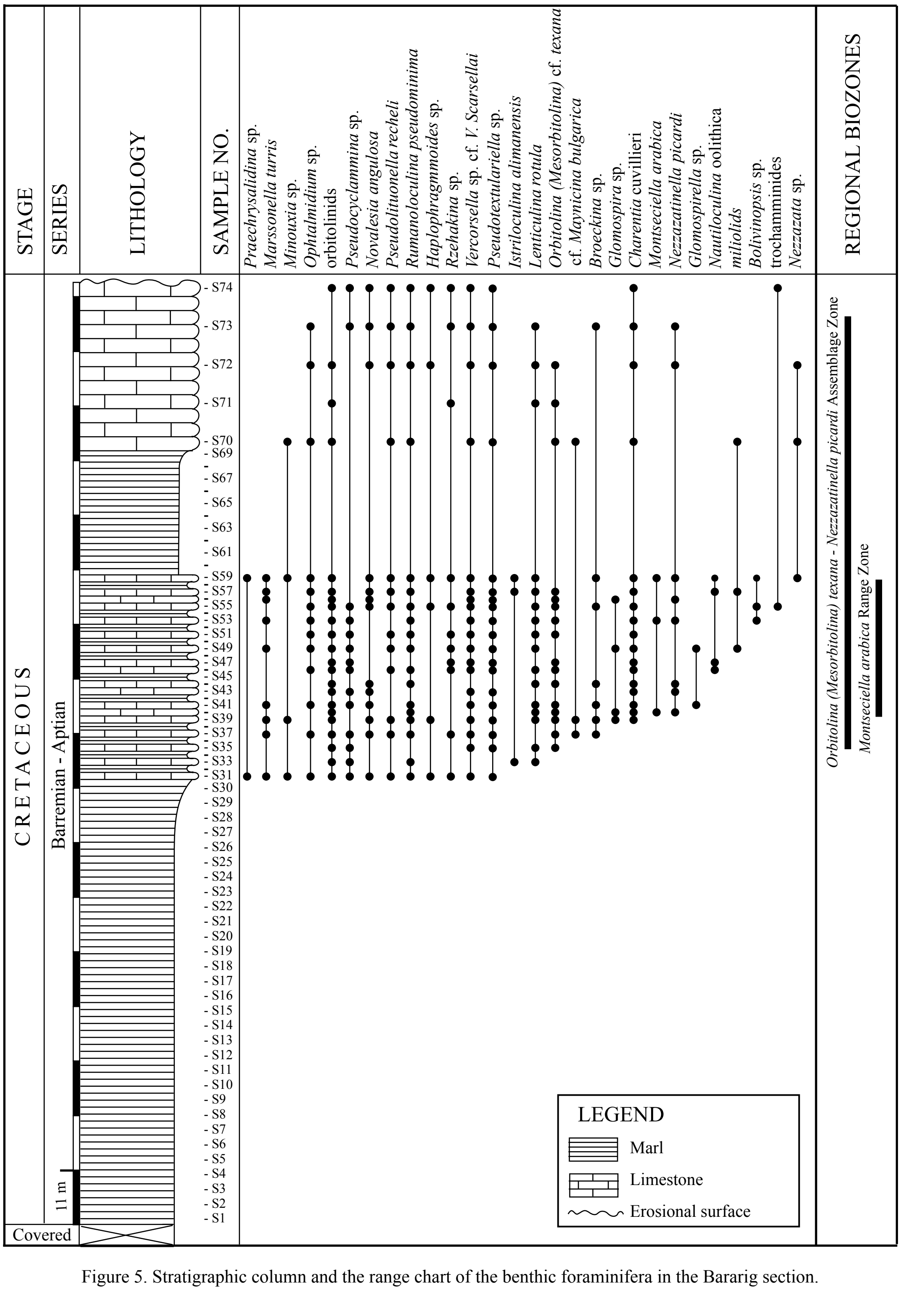

Figure 5. Stratigraphic column and the range chart of the benthic foraminifera in the Bararig section.

from marls and limestones were collected. Due to lack of foraminifera in the marly layers, thin-sections of limestones have been made. The stratigraphic column and the range chart of benthic foraminifers are shown in Figure 5.

MATERIALS AND METHODS

This paper is based on the study of the Bararig section along the Zarand-Kuhbanan-Deh Ali road. The Barremian-Aptian succession was measured and sampled. Microfossil content of the samples was studied in 37 thin sections with an optical microscope. These allowed the identification of the vertical foraminiferal distribution and establishment of two regional biozones. The palaeoecological study determined three benthic foraminiferal groups. All rock samples and thin sections are housed in the Department of Geology, Shahid Bahonar University of Kerman.

The taxonomic determination of the foraminifers is based on the latest changes in the foraminiferal classifications: Loeblich and Tappan (1988, 1992) and Kaminski (2004), and takes into account the following works: Jones and Charnock (1985), Koutsoukos *et al.* (1990), Baud *et al.* (1994), Cherchi and Schroeder (1999), Yilmaz (1999), Granier *et al.* (2003), Masse *et al.* (2004, 2009).

SYSTEMATIC PALEONTOLOGY

***Cylindroporella* sp. cf. *Cylindroporella sugdeni* Elliott, 1957**
Figure 6-1

Description. Oblique-transversal section shows a cylindrical thallus, with primary branches connecting to the main axis with a short peduncle. The inner diameter is about 0.17 mm; whereas it shows an outer diameter of approximately 0.55 mm. Primary laterals are followed by large spherical gamete production. The secondary branches arise from the sterile primary branches. It presents a calcified sheath composed of calcite covering the strikethrough.
Total range. Hauterivian – Aptian.
Occurrence. S45, S47 (see sample position in Figure 5).
Stratigraphic distribution. Hauterivian–Aptian of Switzerland, Portugal, France, and Aptian of Iran.

***Nautiloculina oolithica* Mohler, 1938**
Figure 6-4

Description. Longitudinal section shows a lenticular shape and planispiral coil, which is involute. Proloculus is globular and followed by three small chambers. Chambers increase gradually in size. Wall agglutinated, microgranular and single layered.
Total range. Oxfordian-Aptian.
Occurrence. S46, S47, S57, S59.
Stratigraphic distribution. Aptian of Iran and Late Oxfordian-Berriasian of Ukraine.

***Marssonella turris* d'Orbigny, 1840**
Figure 6-5

Description. Subaxial section shows biserial stage of a trochospiral. Diameter of chambers increases rapidly and the terminal chamber becomes flattened. Wall agglutinated with organic lining in calcareous particles.
Total range. Early to Late Cretaceous.
Occurrence. S31, S37, S39, S41, S49, S53, S56, S57, S59.
Stratigraphic distribution. Cosmopolitan in the Early to Late Cretaceous. Aptian of Iran.

***Novalesia angulosa* Magniez, 1974**
Figure 6-6

Description. Axial section represents biserial stage of coiling with seven rows of chambers. Radial beams are not clear, wall agglutinated with relict of interio-marginal slit aperture.
Total range. Late Aptian to Albian.
Occurrence. S31, S37, S39, S41, S44, S55, S56, S57, S59, S72, S73, S74.
Stratigraphic distribution. Late Aptian–early Albian of Spain and France. Albian of Croatia. Aptian of Iran.

***Charentia cuvillieri* Neumann, 1965**
Figure 6-7

Description. Transversal section shows planispirally enrolled test with biumbonate to lenticular shape. The last chambers have tendency to uncoil. Laterally compressed and periphery nearly rounded. Wall finely agglutinated.
Total range. Hauterivian-Cenomanian.
Occurrence. S39, S41, S43, S44, S46, S47, S49, S51, S53, S55, S57, S59, S70, S72, S73, S74.
Stratigraphic distribution. Upper Barremian-Cenomanian of France, Spain, Crimea, Texas and Egypt. Aptian of Iran.

***Pseudolituonella recheli* Marie, 1955**
Figure 6-8

Description. Test conical elongate. Early portion with a short trochospiral stage in the type species but more elongate in geologically younger species, later stage with broad and low uniserial chambers. The wall is calcareous, microgranular, imperforate and single layered.
Range. In this study, the late Aptian is considered as the age of this taxon in the studied section.
Occurrence. S31, S37, S39, S46, S49, S51, S55, S57, S59, S70, S72, S73, S74.
Stratigraphic distribution. Cenomanian-Campanian

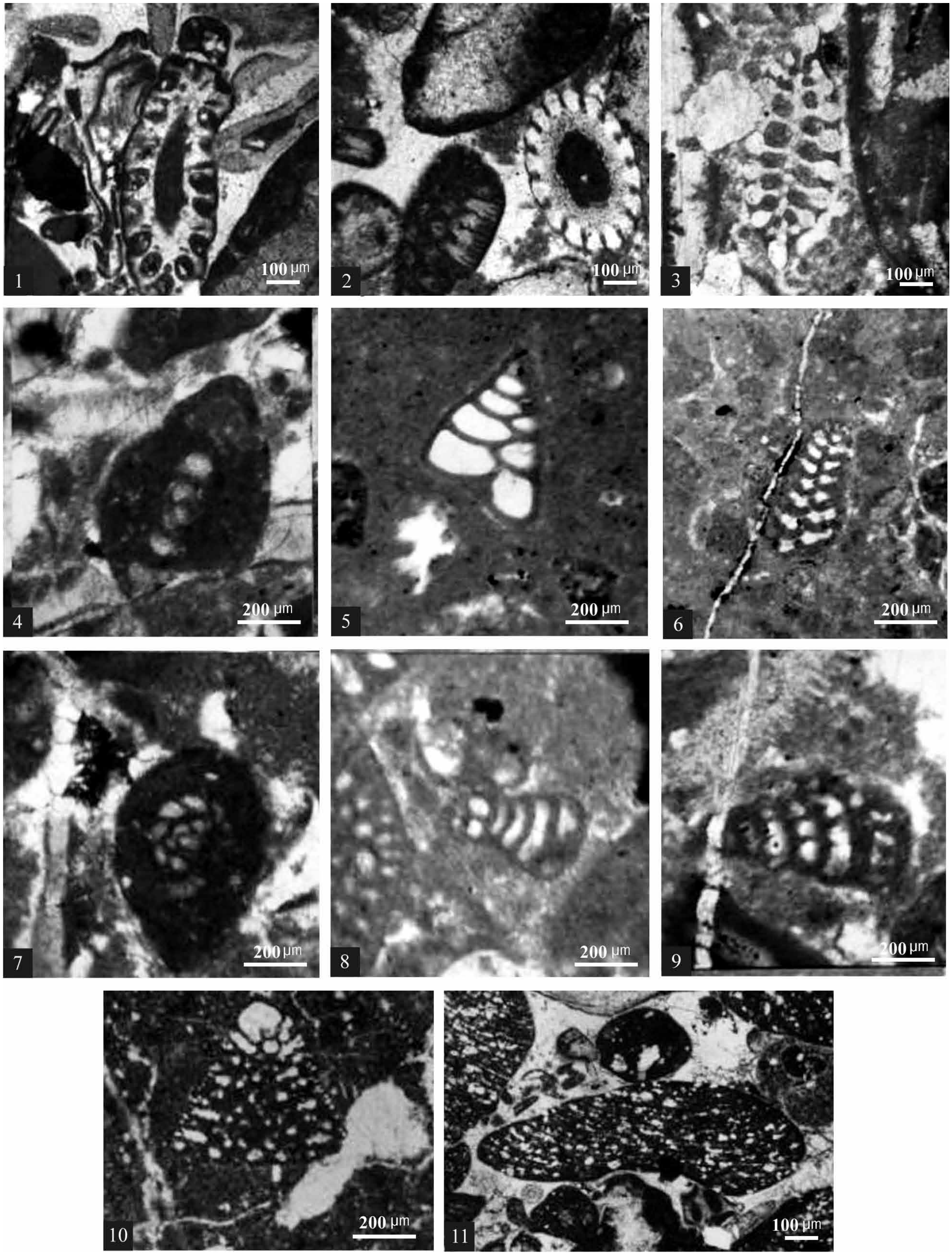

Figure 6. 1: *Cylindroporella* sp. cf. *Cylindroporella sugdeni*; 2 and 11: Orbitolinids; 3: Bryozoa; 4: *Nautiloculina oolithica*; 5: *Marssonella turris*; 6: *Novalesia angulosa*; 7: *Chrentia cuvillieri*; 8: *Pseudolituonella recheli*; 9: *Vercorsella* sp. cf. *Vercorsella scarsellai*; 10: *Orbitolina* (*Mesorbitolina*) cf. *Orbitolina* (*Mesorbitolina*) *texana*.

of France, Spain, Turkey. Aptian of Iran. Lutetian of Libya.

***Vercorsella* sp. cf. *Vercorsella scarsellai* De Castro, 1963**
Figure 6-9

Description. Axial section reveals a small, elongate and conical test. Apical angle about 20°. Initial trochospiral stage consists of a rounded protoconch, a small deuteroconch, and one chamber, followed by a biserial stage with up to eight chambers, slightly compressed parallel to the plane.
Total range. Barremian to Albian.
Occurrence. S31, S35, S37, S39, S41, S43, S46, S47, S49, S51, S53, S55, S56, S57, S59, S70, S72, S73, S74.
Stratigraphic distribution. Early Hauterivian-Bedoulian of France and Italy. Aptian of Iran.

***Orbitolina* (*Mesorbitolina*) cf. *Orbitolina* (*Mesorbitolina*) *texana* Roemer, 1849**
Figure 6-10

Description. The embryonic apparatus of macrospheric forms, which is very important for an exact determination, is preserved as well and is composed of protoconch, deuteroconch, 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.
Occurrence. S31, S33, S35, S37, S39, S40, S41, S43, S44, S46, S47, S49, S51, S53, S55, S56, S57, S59, S70, S70, S72, S73, S74.
Stratigraphic distribution. Albian-Early Cenomanian of USA, Italy, Spain, China, Tibet and Indian. Aptian of Iran.

cf. *Mayncina bulgarica* Laug, Peybernès and Rey, 1980
Figure 7-1

Description. Equatorial section shows numerous chambers, about ten chambers per whorl, in a planispiral coiling. Chambers arrangement reveals height increase and a tendency to uncoil of the last two or three chambers. The wall is finely agglutinated.
Total range. Late Hauterivian-Aptian.
Occurrence. S37, S39, S70.
Stratigraphic distribution. Cenomanian of France. Aptian of Iran. Tithonian-Barremian of Ukraine.

***Pseudocyclammina* cf. *Pseudocyclammina lituus* Yokoyama, 1890**
Figure 7-2

Description. Sub-equatorial section shows planispirally enrolled, the early stage may be streptospiral and represents uncoiling later. Wall coarsely agglutinated with sub epidermal network.
Total range. Oxfordian-Aptian.
Occurrence. S31, S33, S35, S37, S41, S43, S46, S47, S49, S51, S53, S55, S73, S74.
Stratigraphic distribution. Early Jurassic-Late Cretaceous of Morroco, Libya, France, Italy, Poland, Mexico and Ukraine. Aptian of Iran.

Rumanoloculina pseudominima Bartenstein and **Kovatcheva, 1982**
Figure 7-3

Description. Transversal sections show the typical “Y” and somewhat loose mode of chamber arrangement and subacute periphery of the test.
Total range. Berriasian-Albian.
Occurrence. S31, S33, S37, S39, S40, S41, S44, S46, S49, S51, S53, S55, S57, S59, S70, S72, S73, S74.
Stratigraphic distribution. Late Cretaceous of Poland. Berriasian and Aptian of Iran.

***Derventina filipescui* Neagu, 1968**
Figure 7-5

Description. Axial section shows quinqueloculine arrangement in the early stage, becomes later planispriral. Wall calcareous imperforate.
Total range. Late Barremian-Early Aptian.
Occurrence. S41, S42, S43, S44, S45.
Stratigraphic distribution. Barremian of Romania. Aptian of Iran.

***Istriloculina* sp. cf. *Istriloculina alimanensis* Neagu, 1984**
Figure 7-6

Description. The sample shows globular shape, with different coiling, quinqueloculine in the early stage, then triloculine to pseudotriloculine. Wall calcareous imperforate.
Total range. Late Barremian-Early Aptian.
Occurrence. S33, S57, S59.
Stratigraphic distribution. Late Barremian-Early Aptian of Iran and Poland.

***Montseciella arabica* Henson, 1948**
Figure 7-11

Description. Sub-axial section shows horizontal subepidermal plates in the marginal zone. The central zone exhibits thin, vermicular partitions forming a labyrinthic structure and bordering relatively spacious hollows.
Total range. Barremian-Aptian
Occurrence. S40, S53, S59.
Stratigraphic distribution. Barremian-Aptian of Romania and Iran.

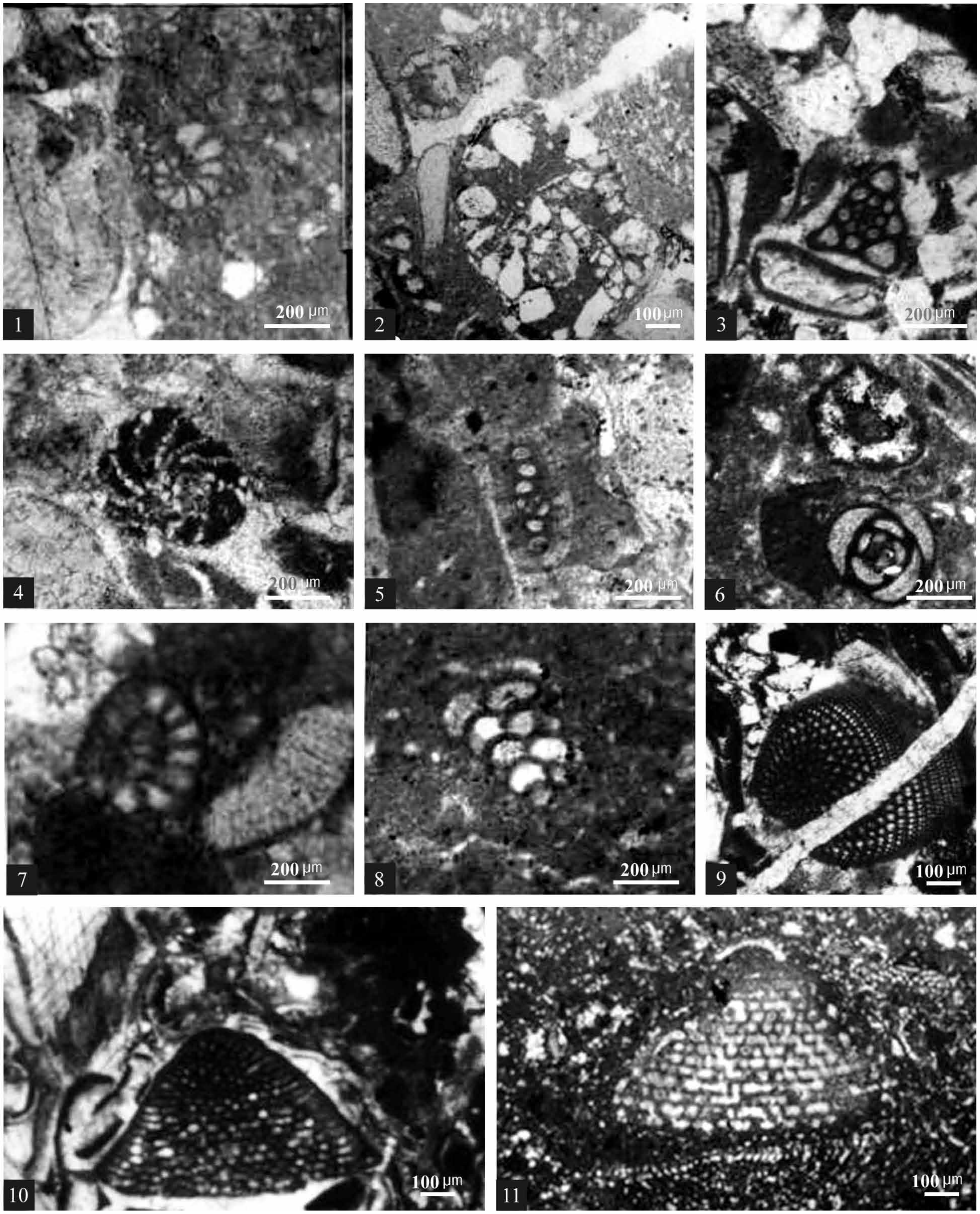

Figure 7. 1: cf. *Mayncina bulgarica*; 2: *Pseudocyclammina* cf. *Pseudocyclammina lituus*; 3: *Rumanoloculina pseudominima*; 4: Cyclamminid; 5: *Derventina filipscui.* 6: *Istriloculina alimanensis* 7: *Nezzazata* sp.; 8: Textularid; 9 and 10: Orbitolinids; 11: *Montseciella arabica.*

IDENTIFIED BIOZONES IN THE BARARIG STRATIGRAPHIC SECTION

According to the studies of thin-sections and identified taxa, two regional biozones are determined and described as follow:

Montseciella arabica **Range Zone**

Biostratigraphic interval represented by the total range of *Montseciella arabica*. This biozone is located in the middle part of the section and suggests a Barremian-Aptian age.

Orbitolina **(*Mesorbitolina*)** ***texana-Nezzazatinella picardi*** **Assemblage Zone**

This assemblage zone contains *Praechrysalidina* sp., *Marssonella turris*, *Minouxia* sp., *Novalesia angulosa*, *Rumanoloculina pseudominima*, *Haplophragmmoides* sp., *Vercorsella* cf. *Vercorsella scarsellai*, cf. *Mayncina bulgarica*, and *Charentia cuvillieri*. The mentioned biozone is defined by the first appearance of *Orbitolina* (*Mesorbitolina*) *texana* taxon and the overthrow of *Nezzazatinella picardi* taxon; it is found in the lower - upper limestones of the studied section and shows the Aptian age for these deposits.

PALAEOECOLOGY

The most abundant foraminifera in the studied section are orbitolinids represented by *Pseudotextulariella*, *Orbitolina* (*Mesorbitolina*), *Pseudolituonella*, miliolids and *Pseudocyclammina*. Paleoecological studies show that, there are three groups of benthic foraminifera associations in the Bararig section, whereas pelagic foraminifera are missing: 1) Epifaunal genera: *Charentia*, *Rzehakina*, *Lenticulina*, *Glomospira*, *Nezzazata Glomospirella, Nezzazatinella*, *Nutiloculina*, *Happlophragmoides*, *Trochamminoides*, *Rumanoloculina*, *Istriloculina, Ophthalmidium*, *Pseudocyclammina.* 2) semi-nfaunal genera: *Orbitolina* (*Mesorbitolina*) and *Orbitolina*. 3) Infaunal genus: *Pseudolituonella*, *Pseudotextulariella*, *Praechrysalidina*, *Minouxia*, *Marssonella*, *Bolivinopsis*, *Novalesia* (Vaziri, 2003).

Epifaunal/infaunal ratio of benthic foraminifera is shown in the Figure 8. According to the thin-sections, epifaunal and semi-infaunal foraminifera make 94.58% of the total percentage of foraminifers in the Berarig section and only 5.42% of foraminifers in this section belong to infaunal forms. It is clear that epifaunal foraminifers are unstable in environments with low amount of oxygen but the infaunal foraminifers are stable in such conditions (Lamolda, 1982; Hart, 1985) therefore, the abundance of epifaunal foraminifers indicates an environment rich in oxygen. Meanwhile, the association of larger benthic foraminifera (such as orbitolinids) with algae shows that the environment is shallow and situated within the photic zone. The available palaeoecological data on miliolids indicates a preference for warm, shallow-water and tolerance between 18 to 36% fluctuations in salinity.

Foraminiferal morphogroups and P/B ratio in the Bararig stratigraphic section

Each microhabitat category has distinct morphological characteristics. Epifaunal taxa are typical with plano-convex or bi-convex cross sections, with trochospiral coiling and with large pores absent or found on only one side. Shallow infaunal taxa are uniserially, triserially, or even planispirally coiled with surface ornamentation present on a number of taxa. The intermediate infaunal taxa are distinguishable with rounded peripheries, with pores over the entire test and with planispiral coiling. The deep infaunal taxa are typical, with general, planispiral or triserial coiling of cylindrical or ovate shaped tests (Corliss, 1991). Although several fluctuations occurred in the generally low planktonic/benthic (P/B) ratio found in the lower limestones, benthic forms are dominating and in 47/06 represent 100% of the whole assemblage. In the upper limestones the rate of oscillation decreased (77/14 to 100%) (see Figures 9 and 10).

DISCUSSION AND CONCLUSIONS

Barremian-Aptian sediments of the Bararig mountain have all the characteristics of shallow-water deposits. The Urgonian succession consists of two depositional sequences characterized by marls and limestones. According to the foraminiferal assemblages found in the Bararig stratigraphic section and their comparison with stratigraphical sections in other parts of the world (specifically Europe) (Luperto-Sinni and Masse, 1986; Mancinelli *et al.*, 2003; Luperto-Sinni, 1979), a Barremian-

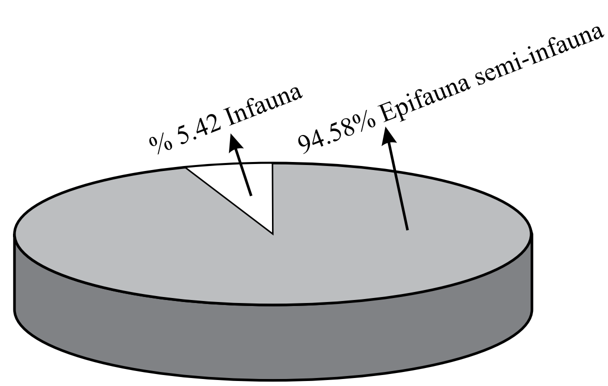

Figure 8. Epifaunal/Infaunal ratio of benthic foraminifera in the Bararig section.

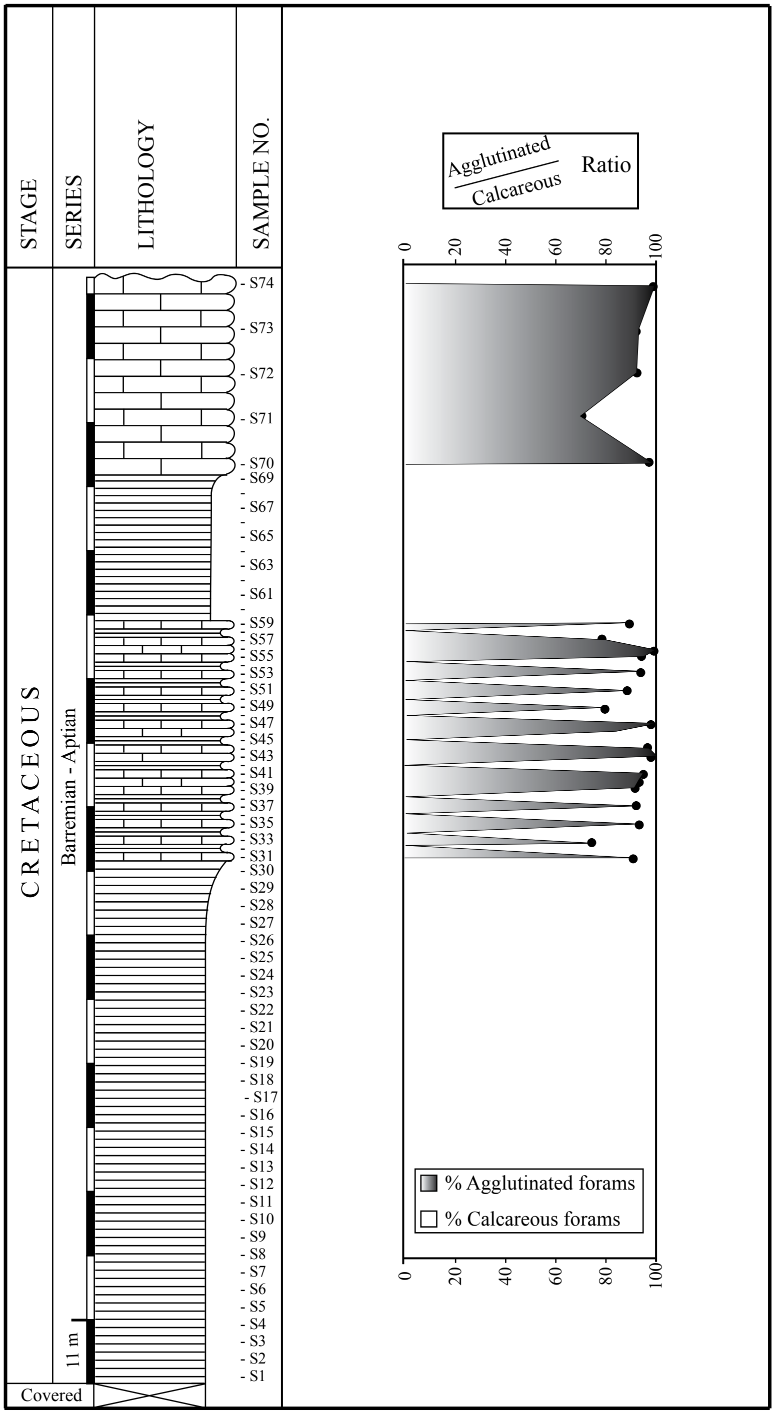

Figure 9. The abundance ratio of agglutinated /calcareous foraminifers in the Bararig section.

Aptian age is suggested for this stratigraphic section.

Also, according to the studies of thin-sections and identified taxa two regional biozones are described: 1) *Montseciella arabica* Range Zone, and 2) *Orbitolina* (*Mesorbitolina*) *texana-Nezzazatinella picardi* Assemblage Zone. The abundance of larger foraminifera indicates good oxygenation of the environment (Kaiho and Hasegawa, 1994). Furthermore, because of the high amount of benthic foraminifera and the low P/B (planktonic/benthic) ratio in the studied section, a low water depth for the environment also is suggested. This is confirmed by the presence of epifaunal and infaunal foraminifers, which are found together in shallow environments (Corliss and Chen, 1988) and also by the presence of algae, also living in shallow, high light, and well aerated environments (Flugel, 1982).

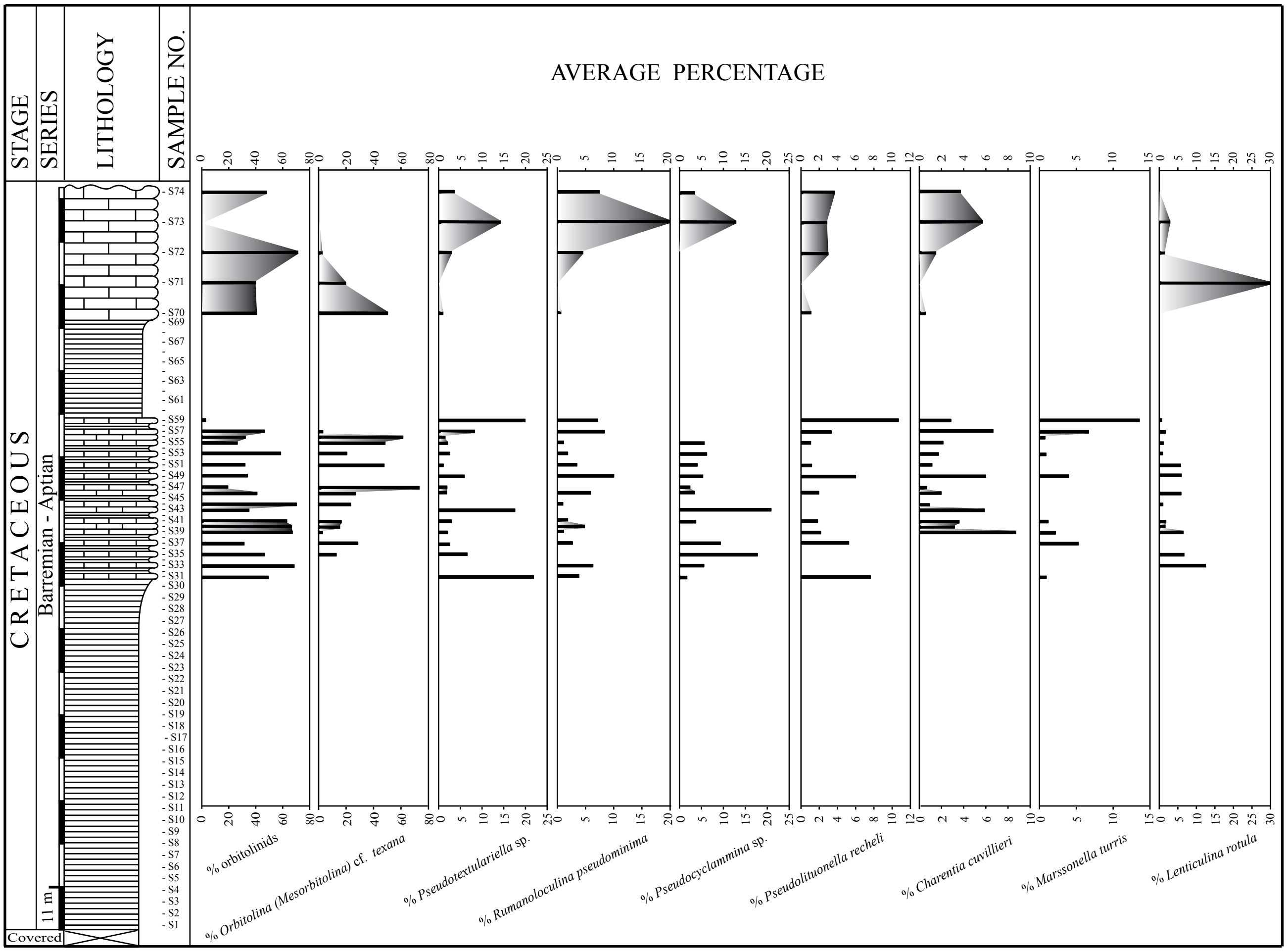

Figure 10. The average percentage of benthic foraminifera found in the Bararig stratigraphic section.

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