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Authors: Changaei, Khadijeh, Babazadeh, Seyed Ahmad, Arian, Mehran, and Pirbaloti, Borzou Asgari

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Systematic paleontology of Bartonian larger benthic Foraminifera from Shahrekord region in High Zagros, Iran

KHADIJEH CHANGAEI[1], SEYED AHMAD BABAZADEH[2], MEHRAN ARIAN[1] AND BORZOU ASGARI PIRBALOTI[3]

[1]*Department of Geology, Islamic Azad University, Science and Research Branch, Po. Box 147789355, Tehran, Iran*
[2]*Department of Science, Payame Noor University, Po. Box 19395-3697, Tehran, Iran (e-mail: seyedbabazadeh@yahoo.com)*
[3]*Oil Engineering Group, Islamic Azad University, Masjed Soleiman, Iran*

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Abstract. The Jahrum Formation is characterized by abundant benthic Foraminifera in carbonate beds, partly marly and dolomitic limestones in the Kuh-e-Soukhteh (Shahrekord region). This formation covers a huge stretch of the Zagros Zone which is a part of the central Tethyian realm during the Paleogene time. Biostratigraphic analysis of the larger benthic Foraminifera distinguishes one assemblage zone assigned to the late middle Eocene (Bartonian). This new biostratigraphic range is represented by the index fossil *Rhabdorites malatyaensis* (Sirel) and is correlated with calcareous rocks in the Shiraz area (south Iran), Dhofar section (Oman), and Socotra Island (Yemen). The Jahrum Formation is dominated by rich miliolids-agglutinated Foraminifera with rare small rotaliids and without *Nummulites* Lamarck and *Alveolina* d'Orbigny indicating that the formation was deposited in a shallow water environment (nearshore lagoonal zone) with low energy.

Keywords: Bartonian, Iran, Jahrum Formation, Larger benthic Foraminifera, Shahrekord, Systematics

Introduction

The separate continental blocks of the Iranian platform are jointed by ophiolitic units. The geological zonation of this platform represents various sedimentary basins such as Alborz, Kopet Dagh, Central Iran, Zagros, Sanandaj-Sirjan, Urumieh-Dokhtar, Lut Block, eastern Zone, and Makran (Figure 1A). Because of different oil-formations, various facies analyses and stratigraphical studies have been carried out on the Zagros sedimentary basin, especially Jahrum Formation (James and Wynd, 1965; Rahaghi, 1978, 1980, 1983; Kalantari, 1980; Stocklin and Setudehnia, 1991; Vaziri-Moghaddam *et al.*, 2010). The Jahrum Formation consists of a succession of thick layers to massive calcareous sedimentary rocks, thin and medium marls, and dolomites with intercalation of yellow medium bedded limestones. The lower contact of this formation with the Pabdeh Formation is faulted and the upper contact with the Asmari Formation is unconformable. This work provides new biostratigraphic data on a Bartonian stratigraphic interval of the Jahrum Formation in the study area. The foraminiferal assemblage allows comparison with another biostratigraphic scheme for the adjacent areas (Fars area). The aim of this paper is to examine in detail the microbiostratigraphy of the Jahrum Formation and to introduce the systematic descriptions of larger Foraminifera.

Geological setting

The geology of Shahrekord is controlled by numerous faults and consists of three zones: Northeast (Zayandehrud), Southwest (Karun), and Central zones (Zahedi and Rahmati Ilkhechi, 2006). The Central Zone (Z2) is a part of the high Zagros, located between the thrust faults (Saman - Fereidoon Shahr) (F1) and (Bazoft Fault) (F3) and divided into two smaller subzones (Z2a) and (Z2b) by the main Zagros thrust fault (Figure 1B). These two sub-zones are located in the Shahrekord region and consist of Cretaceous to Paleogene red clastic rocks, gray to cream limestone, and marl correlated to the Jahrum, Pabdeh, and Asmari formations. The Z2b sub-zone encompasses the high Zagros and is located between the main Zagros thrust fault (F2) and the Bazoft thrust fault (F3) (Zahedi and Rahmati Ilkhechi, 2006). The stratigraphic section is exposed on the roadside and located in Kuh-e-Soukhteh at coordinates 32°00′00″N to 32°01′21″N and 50°55′51″E to 50°56′80″E (Figure 1C).

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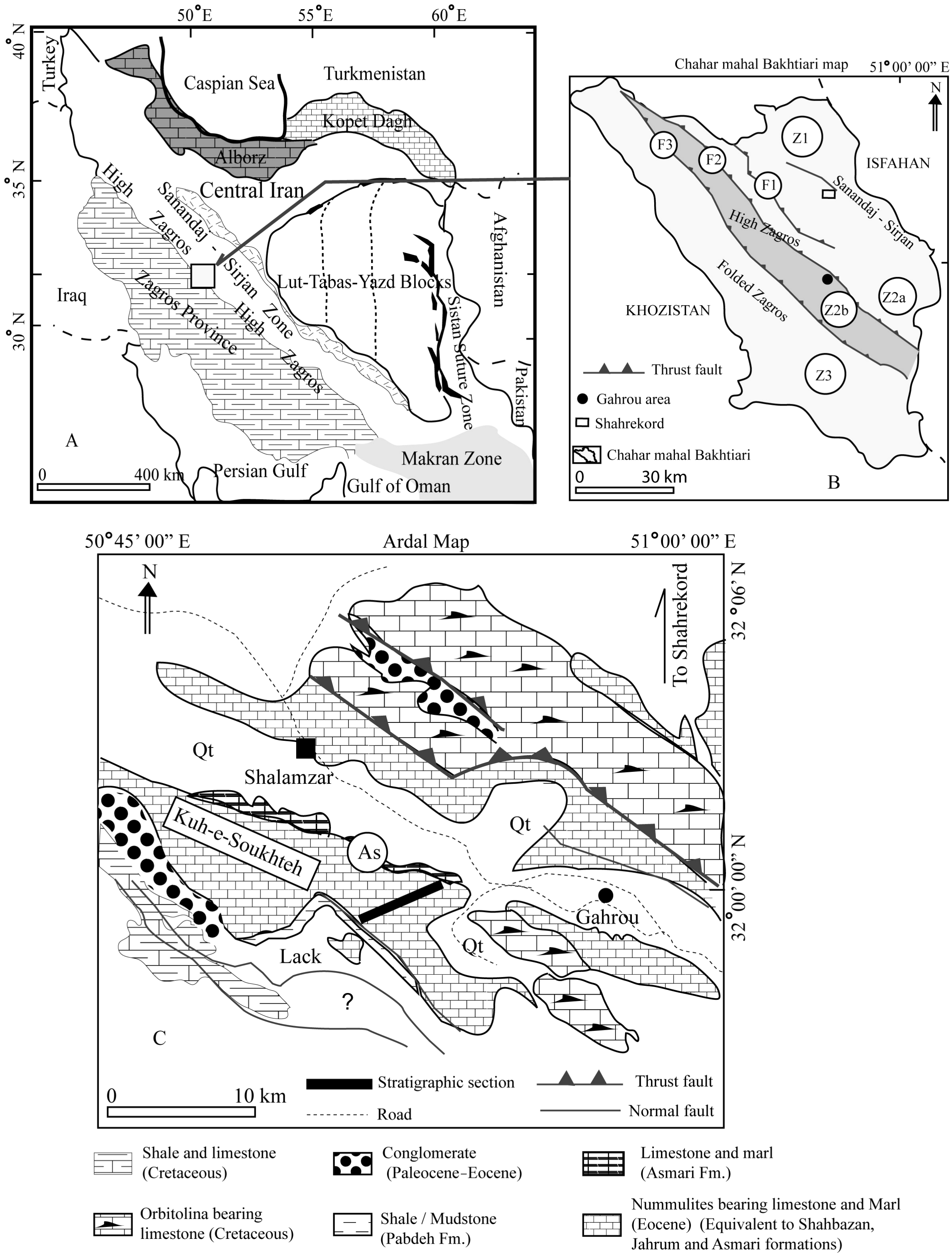

Figure 1. Schematic maps showing the studied area. (**A**) Iran map showing the several sedimentary basin zones; (**B**) Location of the study area (Kuh-e-Soukhteh) in the High Zagros Zone on the Chaharmahal Bakhtiari Province (Zahedi and Rahmati Ilkhechi, 2006); (**C**) Location of the study area in Ardal geological map (1: 250 000). F1, Saman Thrust Fault; F2, Zagros Thrust Fault; F3, Bazoft Thrust Fault; Z1, Sanandaj-Sirjan Zone; Z2, Central Zone; Z3. Folded Zagros Zone; As, index which represents the Kuh-e-Soukhteh, F3, Qt, Quaternary.

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Material and methods

The study is based on thin sections of cemented carbonate rock. The stratigraphic section of 157 m was measured from the sedimentary rocks in the Kuh-e-Soukhteh. A total of 80 rock samples was collected for the systematic study and precise identification of foraminiferal species. The microscopic analysis of specimen was carried out in the Geological Laboratory of Payame Noor University. The stratigraphic column and foraminiferal plate are done with Adobe Illustrator software. All thin sections are housed in the Payame Noor University Laboratory.

Biostratigraphy

Based on the larger benthic Foraminifera, the Eocene foraminiferal assemblage zones of Jahrum Formation are established by James and Wynd (1965), Adams and Bourgeois (1967), and Hottinger (2007) in the Zagros Zone. In the current study, 18 species of benthic Foraminifera have been identified for the first time. The major taxa are found in the Jahrum Formation while some taxa such as *Coskinolina* Stache, *Haymanella* Sirel, and *Austrotrillina* Parr have been reported in other parts of Iran, such as the Alborz Mountains and eastern Iran (Babazadeh, 2003). The benthic foraminiferal association is the same as the foraminiferal fauna of central Neo-Tethys such as the Shiraz area (south Iran) (Hot3tinger, 2007), Dhofar (Oman), and Socotra Island (Yemen) (Serra-Kiel *et al.*, 2016). The Jahrum Formation is assigned to the Bartonian based on the concurrent range zone of the benthic foraminiferal association while in some previous works, this formation was considered Ypresian and Lutetian (early-middle Eocene) in the study area (Zahedi and Rahmati Ilkhechi, 2006; Babazadeh *et al.*, 2015). This association is collected from the gray to cream-colored thin to thick-bedded limestones and argillaceous limestones and occurred in one columnar section (Kuh-e-Soukhteh section). The distribution of selected benthic Foraminifera is shown in the stratigraphic section in Figure 2.

Systematic descriptions

Class Tubothalamea Pawlowski *et al.*, 2013
Order Miliolida Delage and Herouard, 1896
Family Hauerinidae Schwager, 1876
Genus ***Nurdanella*** Özgen, 2000
Nurdanella* cf. *boluensis Özgen, 2000

Figure 3A

Type species.—*Nurdanella boluensis* Özgen, 2000.

Description.—In the recorded species, the axial and equatorial diameters of the test are 1.2–1.7 mm and 1.0–1.3 mm, respectively. The early chambers are arranged in a quinqueloculine pattern and the later adult chambers are coiled in a planispiral mode.

Remarks.—*Nurdanella boluensis* Özgen differs from *Nurdanella paleocenica* Sirel in its larger size with high chambers. There are two chambers in the last whorl of the holotype of *Nurdanella* Özgen (2000). Whereas, the *N. boluensis* has 5 to 6 chambers in the last whorl of the microspheric form. The recorded species is close to *N. boluensis* in size. The measurement of the embryonic apparatus is not possible consequently the term of *confer* is used for this specimen. The *N. boluensis* occurs in the Thanetian and Lutetian limestones of Turkey (Özgen, 2000; Sirel, 2013) but the biostratigraphic range of this species reaches to the Bartonian stage in the study area.

Family Hauerinidae Schwager, 1876 or Family Austrotrilinidae Loeblich and Tappan, 1987
Genus ***Austrotrillina*** Parr, 1942
Austrotrillina eocaenica Hottinger, 2007

Figure 3B

Type species.—*Trillina howchini* Schlumberger, 1893.

Description.—*Austrotrillina eocaenica* Hottinger is a true miliolid with an alveolar exoskeleton and thickened basal layer recorded from the early ? Lutetian−Priabonian of Shiraz in Iran (Hottinger, 2007), of Lampione Island near Sicily (southern Italy) (Di Carlo and Pignatti, 2009), of western Dhofar in Oman and Socotra Island in Yemen (Serra-Kiel *et al.*, 2016). The megalospheric forms of *Austrotrillina eocaenica* Hottinger show a subtriangular outline with a rounded margin in the axial section. The outline in the longitudinal section is ovate. The basal layer is thick. The maximum length in the axial sections for megalospheric forms is between 1.0 and 1.3 mm in the recorded species.

Remar ks.—The morphology of Eocene austrotilinas is different from the Oligocene taxon. *Austrotrillina eocaenica* Hottinger differs from *Austrotrillina paucialveolata* Grimsdale and *Austrotrillina brunni* Marie (Oligocene forms) in a larger size, increased diameter of the proloculus, axial length in megalospheric forms, and the thicker basal layer. *A. eocaenica* has the same kind of alveoli as *A. paucialveolata*. This species differs from *Austrotrillina asmariensis* Adams (Oligocene form) in reduced diameter of axial length in megalospheric forms. In Oman and Iran, *A. eocaenica* occurs in association with most of the conical agglutinated species as *Coskinolina perpera* (Hottinger, 2007). According to Adams (1968), *Austrotrilina* Parr ranges from lower Oligocene to lower Miocene (Loeblich and Tappan, 1987). Hottinger (2007) extended the biostratigraphic range of *A. eocaenica* from Lutetian to Priabonian (SBZ 17–18). The recorded speci-

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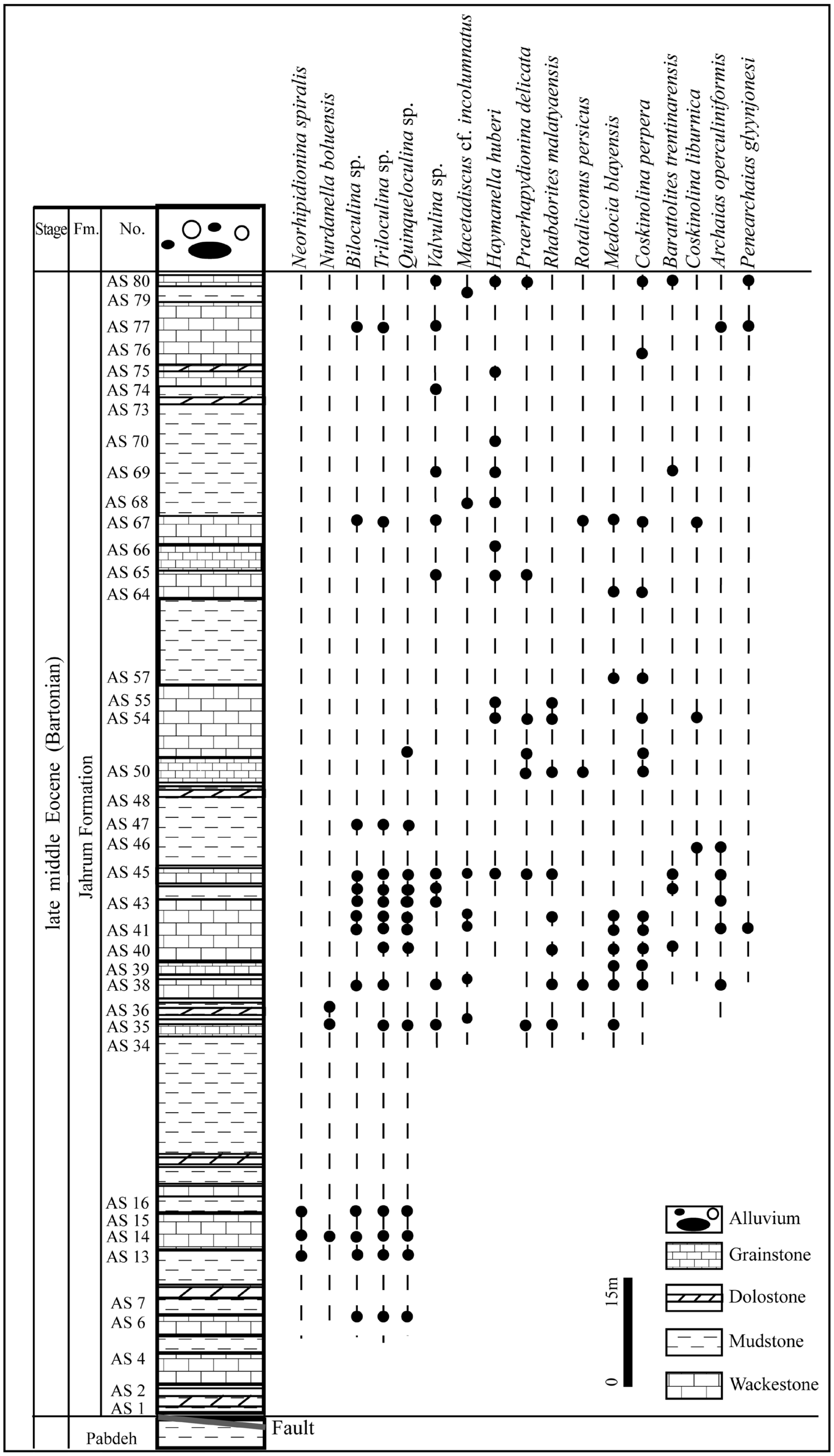

Figure 2. Distribution of selected benthic Foraminifera on stratigraphic section. Fm, Formation; As, index which represents the Kuh-e-Soukhteh.

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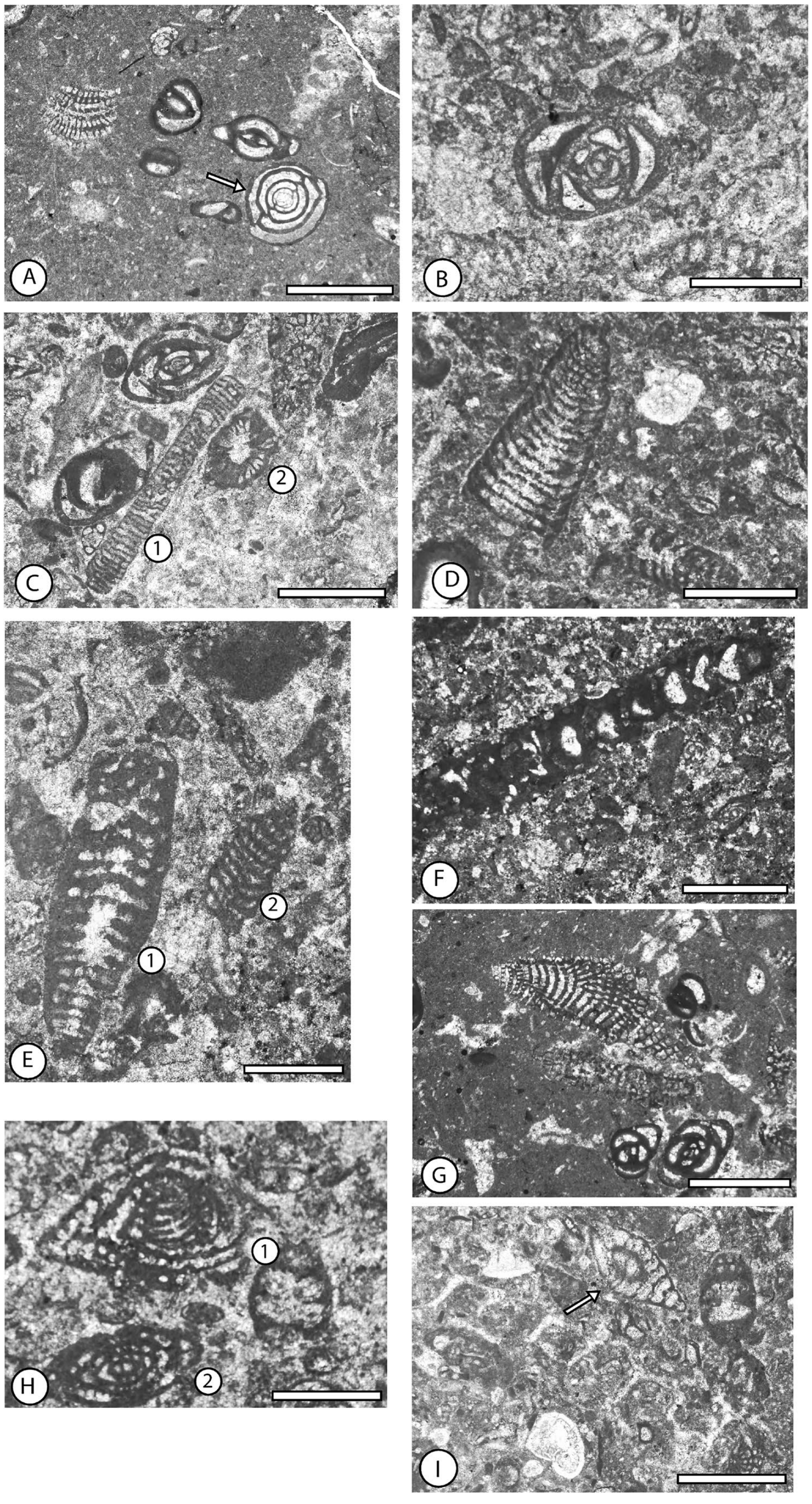

Figure 3. Photographs of foraminiferal species. (**A**) *Nurdanella boluensis* Özgen, equatorial section, As 14; (**B**) *Austrotrilina eocaenica* Hottinger, axial section, As 38; (**C1**) *Macetadiscus* cf. *incolumnatus* Hottinger, subaxial section and (**C2**) *Rhabdorites malatyaensis* (Sirel), equatorial section, As 38; (**D**) *Rhabdorites malatyaensis* (Sirel), axial section, As 43; (**E1**) *Praerhapydionina delicata* Henson, axial section, complete skeleton, As 50 and (**E2**) *Rhabdorites malatyaensis* (Sirel), axial section, As 50; (**F**) *Haymanella huberi* (Henson), axial section, As 55; (**G**) *Neorhipidionina spiralis* Hottinger, subaxial section, As 14; (**H1**) *Archaias operculiniformis* Henson, oblique section, (**H2**) *Penarchaias glynnjonesi* (Henson), axial section, As77; (**I**) *Archaias operculiniformis* Henson, axial section, As 38; Bartonian, Scale bars: 1 mm. The arrow shows the foraminiferal species in a thin section.

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men of *A. eocaenica* in the studied area is associated with *Neorhipidionina spiralis* Hottinger, *Nurdanella boluensis* Özgen, *Quinqueloculina* sp. and other small miliolids. Its biostratigraphic range can be assigned to Bartonian based on faunal association in the studied area.

Family Soritidae Ehrenberg, 1839
Genus ***Macetadiscus*** Hottinger, Serra-Kiel and Gallardo-Garcia, in Serra-Kiel *et al*., 2016
Macetadiscus* cf. *incolumnatus Hottinger, Serra-Kiel and Gallardo-Garcia, in Serra-Kiel *et al*., 2016

Figures 3C1 and 4G2

Type species.—*Macetadiscus incolumnatus* Hottinger, Serra-Kiel and Gallardo-Garcia.

Description.—In megalospheric forms of recorded species, the equatorial diameter is 2.6 mm and the equatorial thickness is 0.3 mm. The microspheric forms were not observed in this study. There are no endoskeletal structures such as pillars or partitions in *Macetadiscus* Hottinger.

Remarks.—*Macetadiscus incolumnatus* Hottinger, Serra-Kiel and Gallardo-Garcia was presented and figured as a new genus and new species in Serra-Kiel *et al*. (2016). The late Paleocene Turkish specimen such as *Mardinella* Meric and Çoruh (type species: *Orbitolites shirazensis* Rahaghi), presented by Meric and Çoruh (1991) is very similar to *Macetadiscus* Hottinger, Serra-Kiel and Gallardo-Garcia based on its morphology. On the other hand, the figured specimen of *Orbitolites* sp. in the late Paleocene of Shiraz area (Rahaghi, 1983, pl. 18, figs. 10–12) resembles *Macetadiscus* Hottinger, Serra-Kiel and Gallardo-Garcia (2016). Certainly, *Mardinella* Meric and Çoruh could not be placed with *O. shirazensis.* However, it seems more likely that the two genera (*Mardinella* and *Macetadiscus*) are synonymous. The biostratigraphic range of *Macetadiscus incolumnatus* Hottinger, Serra-Kiel and Gallardo-Garcia extends from the late Lutetian to the Priabonian (SBZ 16–20) according to Serra-Kiel *et al.* (2016) and Nafarieh *et al.* (2019). In this work, the biostratigraphic range of recorded species can be assigned to the Bartonian stage.

Genus ***Rhabdorites*** Fleury, 1996
Rhabdorites malatyaensis (Sirel, 1976)

Figure 3C2, 3D and 3E2

Type species.—*Rhapydionina malatyaensis* (Sirel, 1976).

Description.—There are 12–13 chambers in an uniserial arrangement with a diameter of 1.25 mm in the recorded species. The longitudinal and transversal diameters of the test are reached to 3.6 and 0.9 mm, respectively.

Remarks.—The genus *Rhabdorites* Fleury differs from *Praerhapydionina* Van Wessem in the presence of multiple apertures. It differs from *Neotaberina* Hottinger in the absence of pillars in the endoskeleton and more cylindrical morphology. The species *Rhabdorites malatyaensis* (Sirel) was described from the Lutetian of Oman and Yemen as *Rhabdorites minimus* Henson (Serra-Kiel *et al*., 2016). The biostratigraphic range of *R. malatyaensis* extends from Bartonian to Priabonian (Papazzoni and Sirotti, 1995; Serra-Kiel *et al.*, 2016; Nafarieh *et al.*, 2019). This species is associated with the last large *Orbitolites* spp. and *Malatyna vicensis* Sirel (Sirel and Acar, 2008). According to Sirel (2003), *R. malatyaensis* is associated with *Nummulites fabianii* (Perver) and *Nummulites biedai* Schaub in the Arabil and Devely sections, respectively. Therefore, the range of *R. malatyaensis* is shown to overlap that of *N. fabianii.* The co-occurrence of *R. malatyaensis* with *Orbitolites minimus* Henson seems to denote the boundary between middle Eocene and upper Eocene (Hottinger, 2007). According to Romero *et al.* (1999), *R. malatyaensis* occurs in association with *Malatyna vicensis* Sirel and Acar, in Igualada basin of northern Spain during the Bartonian. After Hottinger (2007), *R. malatyaensis* occurs in association with *Globoreticulina iranica* Rahaghi in the Shiraz area (west Iran) and indicates the Bartonian age. In this work, *Rhabdorites malatyaensis* (Sirel) is observed in the Bartonian age. The biostratigraphic range of *R. malatyaensis* is particularly important because most researchers proposed the Bartonian age based on the foraminiferal associations.

Genus ***Praerhapydionina*** Van Wessem, 1943
Praerhapydionina delicata Henson, 1950

Figure 3E1

Remarks.—*Praerhapydionina delicata* Henson differs from *Praerhapydionina huberi* Henson by its small size (less than 2 mm). According to Sirel (2003), *P. delicata* and *P. huberi* have the same biostratigraphic range. For the first time, *P. delicata* was represented in Oligocene from Iran and Iraq (Henson, 1950). After Fleury (1997), the biostratigraphic range of *P. delicata* extends from the middle to late Eocene. This species is reported from the Paleocene in Iran (Rahaghi, 1983). It is also assigned to the Bartonian-Rupelian by Hottinger (2007) and Serra-Kiel *et al.* (2016). Based on foraminiferal association, the recorded species occurred in the Bartonian stage.

Genus ***Haymanella*** Sirel, 1998
Haymanella huberi (Henson, 1950)

Figure 3F

Type species.—*Haymanella paleocaenica* Sirel, 1998.

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Description.—*Haymanella* Sirel differs from the other praerhapydioninid genera by the presence of agglutinated grains in its porcelaneous wall (Sirel, 1998; Hottinger, 2007; Nafarieh *et al.*, 2019).

Remarks.—*Haymanella huberi* (Henson) differs from *Haymanella paleocaenica* Sirel in its shorter nepionic spiral stage in the megalospheric generation and its more complex foramina in the adult. The outline of the foramen is stellar with at least six branches of petaloid extensions. *H. huberi* is about twice the size of *H. paleocaenica. H. huberi* is known from Eocene deposits of Jahrum Formation (Iran) and Eocene deposits of Iraq, Turkey, and Oman (Henson, 1950; Sirel, 1998; Hottinger, 2007). According to Hottinger (2007) and Serra-Kiel *et al.* (2016), the biostratigraphic range of *H. huberi* is assigned to the Bartonian–Priabonian (SBZ 17–20). This species is associated with *R. malatyaensis* indicating the Bartonian age.

Genus ***Neorhipidionina*** Hottinger, 2007
Neorhipidionina spiralis Hottinger, 2007

Figure 3G

Type species.—*Rhipidionina williamsoni* Henson, 1948.

Description.—In the recorded species, the maximum diameter reaches 4.75 mm with a thickness of 0.6 mm.

Remarks.—The taxon found in this work is attributed to *Neorhipidionina spiralis* Hottinger because it is more flattened with respect to *Neorhipidionina urensis* (Henson). The latter species shows an oval outline in cross section and its coils are more inflated and narrow. The megalospheric form of *Neorhipidionina williamsoni* (Henson) is twice as large as *N. spiralis*. The recorded species is characterized by comparatively small size and long spiral early stage of growth followed by a rapidly flaring adult stage. According to Serra-Kiel *et al.* (2016), this species is Lutetian in age. After Hottinger (2007), its biostratigraphic range extends from Bartonian to Priabonian. Based on faunal assemblage, the recorded species is assigned to the Bartonian stage.

Genus ***Archaias*** de Montfort, 1808
Archaias operculiniformis Henson, 1950

Figure 3H1 and 3I

Type species.—*Nautilus angulatus* Fichtel and Moll, 1798.

Description.—The equatorial diameter in megalospheric form reaches 3.2 mm in the recorded specimen.

Remarks.—*Archaias operculiniformis* Henson differs from *Archaias diyarbakirensis* (Sirel) in its smaller test size of and proloculus. This species is characterized by fewer pillars in comparison to *A. diyarbakirensis*. The basal layer ridges in the genus *Penarchaias* Hottinger could not be formed by the pillars. According to Sirel (1998), Hottinger (2007), and Bassi *et al.* (2007), the genus *Praearchaias* Sirel has the same structural elements as *Archaias* De Montfort. Hottinger (2007) mentioned *Archaias operculiniformis* Henson from Bartonian-Priabonian, but Serra-Kiel *et al.* (2016) extended this species to the Rupelian in Oman. In this work, the biostratigraphic range of recorded species can be assigned to the Bartonian stage.

Genus ***Penarchaias*** Hottinger, 2007
Penarchaias glynnjonesi (Henson, 1950)

Figure 3H2

Type species.—*Peneroplis glynnjonesi* Henson, 1950.

Description.—In the present species, the equatorial diameter of the test is 1.9–2.2 mm with a thickness of 0.9 mm.

Remarks.—The genus of *Penarchaias* (Henson) differs from *Archaias* De Montfort in the absence of pillars. But with regard to the test chambers and distribution of the foramina, this genus is close to *Archaias* De Montfort. The *Penarchaias glynnjonesi* (Henson) is recorded in the Bartonian stages in the studied area but its biostratigraphic range extends to the Oligocene (Hottinger, 2007; Serra-Kiel *et al.*, 2016).

Class Globothalamea Pawlowski *et al.*, 2013
Order Loftusiida Kaminski and Mikhalevich, in Kaminski, 2004
Family Coskinolinidae Moullade, 1965
Genus ***Coskinolina*** Stache, 1875
Coskinolina perpera Hottinger and Drobne, 1980

Figure 4B and 4C

Type species.—*Coskinolina liburnica* Stache, 1875.

Description.—In the recorded species, the axial length and basal diameter are 1.9–2.0 mm and 1.7–1.9 mm, respectively. The endoskeleton is only represented by irregular pillars and shows a looser aspect. The pillars are discontinuous from one chamber to the next.

Remarks.—Conical agglutinated shell shows pseudokeriothecal wall without beams and intercalary beams. The endoskeleton is only represented by pillars and showing a more open aspect. The wall is thicker than in all other species of the same genus. *Coskinolina perpera* Hottinger and Drobne ranged from late Cuisian to early Lutetian (Hottinger and Drobne, 1980). Hottinger (2007) reported this species from Lutetian to Bartonian of Iran. According to Serra-Kiel *et al.* (2016), the age of this species can be extended to Priabonian in Oman and Yemen. The recorded species is assigned to the Bartonian (SBZ

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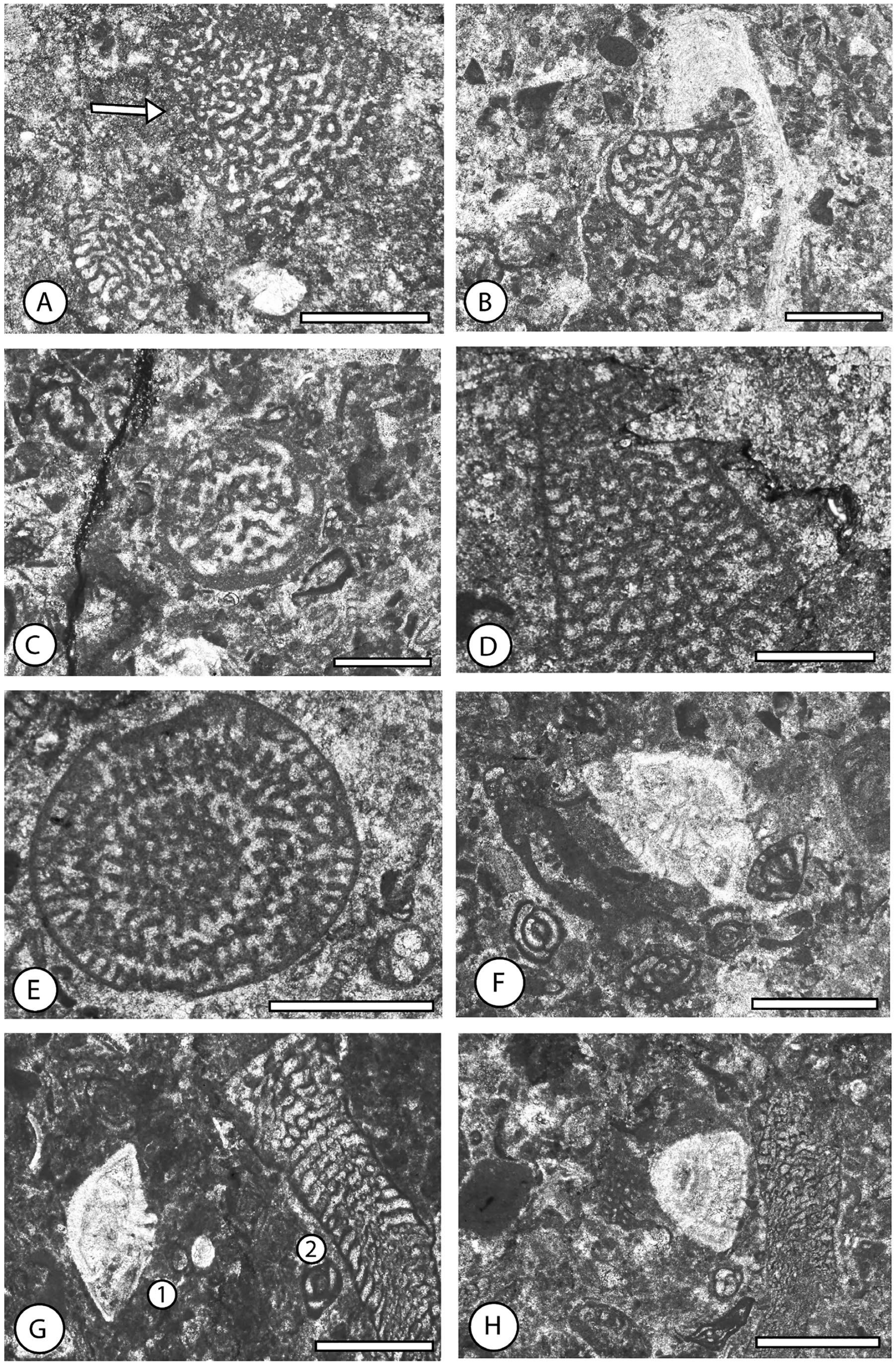

Figure 4. Photographs of foraminiferal species. (**A**) *Coskinolina liburnica* Stache, axial section, As 46; (**B, C**) *Coskinolina perpera* Hottinger and Drobne; B, Axial section, As 40; C, equatorial section, As 38; (**D, E**) *Barattolites trentinarensis* Vecchio and Hottinger; D, subaxial section, As 69; E, equatorial section; (**F**) *Medocia blayensis* Parvati, axial section, As 42; (**G1**) *Medocia blayensis* Parvati, subaxial section, As 41, (**G2**) *Macetadiscus* cf. *incolumnatus* Hottinger, subaxial section, As 41; (**H**) *Rotaliconus persicus* Hottinger, axial section, As 38, Bartonian, Scale bars: 1 mm. The arrow shows the foraminiferal species in the thin section. 1 and 2 in Figure 4G represent hyaline and porcellaneous test respectively.

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17–18) in the studied area.

Coskinolina liburnica Stache, 1875

Figure 4A

Type species.—*Coskinolina liburnica* Stache, 1875.

Description.—The axial length and basal diameter of the recorded specimen are 2.1 mm and 1.9 mm, respectively. The pillars are densely arranged from one chamber to the next. There are no exoskeletal elements (beams and rafters) in the marginal chamber.

Remarks.—The identification of generic forms is distinguished by the lack of exoskeletal structures in trochspiral nepionts. *Coskinolina liburnica* Stache shows an acute cone angle. The uniserial chambers are low and the pillars show a dense internal structure compared to all other species of the same genus. According to Hottinger and Drobne (1980), *C. liburnica* is assigned to the late early Eocene (Cuisian) in the Island of Molat (Melada, Croatian Island in the Adriatic Sea). Serra-Kiel *et al.* (1998) considered its biostratigraphic range to be from middle Cuisian to late Cuisian. Serra-Kiel *et al.* (2016) stated that the co-occurrence of *C. liburnica* Stache with *Nummulites fabianii* (Prever) (SBZ 19) in the western Dhofar (Oman), indicates the Periabonian age. As a result, the species of *C. liburnica* Stache can be extended from the late Ypresian to the Priabonian. In east Iran, *C. liburnica* Stache is reported from the early Eocene (Babazadeh, 2003; Schlagintweit and Hadi, 2018). In this work, this species is found in late middle Eocene (Bartonian) sedimentary rocks.

Family Orbitolinidae Martin, 1890
Genus ***Barattolites*** Vecchio and Hottinger, 2007
Barattolites trentinarensis Vecchio and Hottinger, 2007

Figure 4D and 4E

Type species.—*Barattolites trentinarensis* Vecchio and Hottinger, 2007, figs. 12 a-b, 13 a-b, 14 a-b, 15 a-m, 16 a-m, 17 a-r, 18 a-j.

Remarks.—The genus *Barattolites* Vecchio and Hottinger differs from the genus *Daviesiconus* Hottinger and Drobne in having a long trochospiral early growth stage, the constant occurrence of intercalary beams, and in the absence of marginal apertures. This genus differs from the genus *Dictyoconus* Blanckenhorn and *Fallotella* Mangin due to the absence of horizontal partitions (rafters) and to presence of a simple exoskeleton. It differs from *Coskinolina* Stache in having simple radial partitions (beams and intercalary beams). The stratigraphic range of *Barattolites trentinarensis* Vecchio and Hottinger covers the Ypresian to the early Lutetian (Vecchio and Hottinger, 2007). Based on foraminiferal association, the recorded species is assigned to Bartonian in the studied area.

Order Rotaliida Delage and Herouard, 1896
Family Rotaliidae Ehrenberg, 1839
Genus ***Medocia*** Parvati, 1971
Medocia blayensis Parvati, 1971

Figure 4F and 4G1

Type species.—*Medocia blayensis* Parvati, 1971.

Description.—The diameter of the recorded specimen is larger than 1 mm (ratio of equatorial to axial diameter about 2).

Remarks.—The typical forms of *Medocia blayensis* Parvati are described from the middle Eocene (Lutetian–Bartonian) of France and Iran by Parvati (1971) and Hottinger (2007) respectively. The small forms ($d < 1$ mm) of *Medocia blayensis* Parvati are reported by Vecchio (2003) and Benedetti *et al.* (2011) from Ypresian of central and southern Italy. According to Le Calvez and Blondeau (1978), *Medocia blayensis* Parvati together with *Alveolina elongate* d'Orbigny, *Alveolina fusiformis* Stache and *Orbitolites cotentinensis* Lehmann found in late Lutetian sediments of the Atlantic Coast (Europe). Whereas, in the Trentinara Formation (southern Italy), this species occurs in late early Eocene sediments. After Serra-Kiel *et al.* (2016), the biostratigraphic range of *Medocia blayensis* Parvati is early?-middle Lutetian to Priabonian (SBZ 13?–SBZ 20). The biostratigraphic range of the recorded species is assigned to Bartonian in the studied area.

Genus ***Rotaliconus*** Hottinger, 2007
Rotaliconus persicus Hottinger, 2007

Figure 4H

Type species.—*Rotaliconus persicus* Hottinger, 2007.

Remarks.—*Rotaliconus* Hottinger differs from all other calcarinids in its single interiomarginal aperture and the presence of an enveloping canal system. It differs from rotaliids with umbilici covered by funnel orifices, such as *Kathina* Smout and related forms, in having dorsal orifices of the canal system and in the absence of continuity in the funnels of successive whorls (Hottinger, 2007). In recorded specimens, the axial diameter of the test is larger than 1 mm (ratio of horizontal to axial diameter about 1.4). The diameter of the base of the cone in the final whorl measured 1.25 mm. According to Rahaghi (1980), its biostratigraphic range is Lutetian, but Hottinger (2007) extended its biostratigraphic range to Bartonian (SBZ 17–18). Serra-Kiel *et al.* (2016) reported that the biostratigraphic range of this species could be extended from early?-middle Lutetian to Priabonian (SBZ 13?–SBZ 20). The biostratigraphic range of the recorded species is con-

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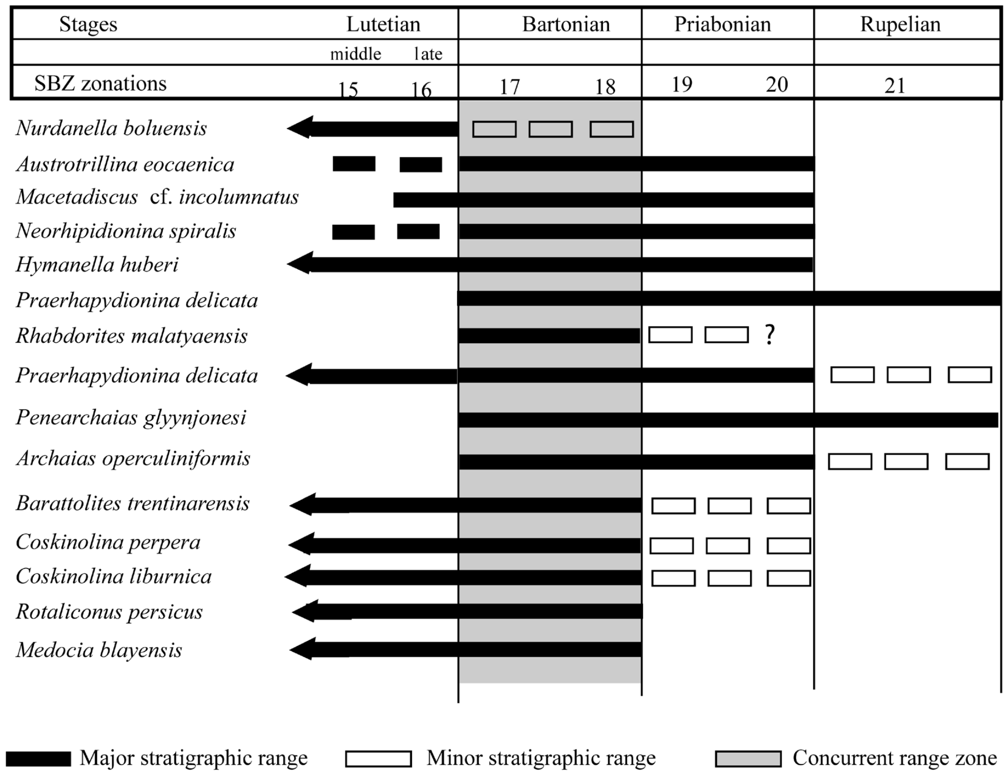

Figure 5. Range chart of selected benthic foraminifera based on Romero *et al.* (1999); Sirel (2003); Hottinger (2007); Serra-Kiel *et al.* (2016); Nafarieh *et al.* (2019) and study area. SBZ zonation according to Serra-Kiel *et al.* (1998), the pale grey area shows concurrent range zone.

sidered as Bartonian in the studied area.

Discussion and conclusion

The present work focused on the benthic foraminiferal biostratigraphy of the Jahrum Formation in the Shahrekord region of southern Iran. According to Rahaghi (1978), the nummulite facies with the *Assilina exponens* group and other nummulitids appear at the lower part of Jahrum Formation during early Eocene (Ypresian) to early middle Eocene (Lutetian) in the type locality of this formation in the Shiraz area. But the upper part of the Jahrum Formation consists of porcelaneous Foraminifera (miliolids), conical agglutinated Foraminifera (coskinolinids), and rare small rotaliids. The miliolids along with small rotaliids represent an oligotrophic community of epifaunal benthos and indicate a low energy depositional setting (Zamagni *et al.*, 2008). This association occurs in nearshore lagoonal environments with muddy substrates and nutrient-enriched conditions. The presence of *Macetadiscus* Hottinger, Serra-Kiel and Gallardo-Garcia suggests relatively shallower water than *Alveolina* d'Orbigny. The *Macetadiscus* bearing facies has a lateral paleoenvironmental relationship with the *Alveolina* facies. Apparently, the upper part of the Jahrum Formation as the same as the Igualada basin (northeastern Spain), is formed in a shallowing upward trend which represents a regressive cycle at the end of the late Middle Eocene (Bartonian). The absence of larger benthic Foraminifera such as *Nummulites* Lamarck and *Alveolina* d'Orbigny in the study area can be matched with different environments because both taxa adapted to a reduced light condition in the open platform and occurred in deeper water or offshore carbonate platform.

In the point of view of biostratigraphy, *R. malatyaensis* is an index fossil for Bartonian because it has a wide geographic distribution from western to central Neotethys (Hottinger, 2007). The co-occurrence of *R. malatyaensis* with *N. fabianii* (Perver) and *N. biedai* Schaub in Arabil and Devely sections (Turkey) indicates that *Rhabdorites malatyaensis* (Sirel) ranged from Bartonian to Priabonian in age (Sirel, 2003). Afterward, some researchers, such as Serra-Kiel *et al.* (2016) and Nafarieh *et al.* (2019), proposed that the biostratigraphic range of *R. malatyaensis* extends from Bartonian to Priabonian age. On the other hand, the occurrence of *R. malatyaensis* seems to mark the level of *G. iranica* in the Shiraz area (west Iran). The range of *R. malatyaensis* is shown to overlap that of *N.*

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fabianii (SBZ 19) (Serra-Kiel *et al.*, 1998). According to Hottinger (2007), the type level of *G. iranica* is older than the range of *N. fabianii* and may be younger than the range of the *Assilina exponens* group (SBZ 13–17), which is younger than SBZ 17. Also, *R. malatyaensis* occurs in association with *M. vicensis*, in the Bartonian sediments of the Igualada Basin of northern Spain (Romero *et al.*, 1999). Therefore, the age of *R. malatyaensis* is assigned to the Bartonian and this species can be considered as an index fossil for Bartonian age. Thus, among the large benthic foraminifera in the study area, only *R. malatyaensis* is known as a well-dated taxon. In the study area, the foraminiferal association represents one concurrent range zone (Figure 5) which is compatible with the biozone introduced by Hottinger (2007). Therefore the similar association of Bartonian benthic foraminifera has been compared with the established assemblage for the Shiraz area (south Iran), Dhofar section (Oman), and Socotra Island (Yemen) (Hottinger, 2007; Serra-Kiel *et al.*, 2016; Nafarieh *et al.*, 2019).

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Author contributions

SAB conducted this study and wrote the paper. KC and SAB collected samples with BAP and contributed laboratory work.

MA prepared the geologic map. SAB and BAP made stratigraphic section as well as field observation. All authors helped to prepare this paper.

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