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STRATIGRAPHY OF THE LOWER OLIGOCENE NUMMULITIC LIMESTONES, NORTH OF SONQOR (NW IRAN)

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Abstract. The lower Oligocene hyaline and porcellaneous larger foraminifera of a carbonate platform setting, north of Sonqor, were studied for high-resolution biostratigraphy in the context of European standard zonation (Shallow Benthic Zones). According to the geological map of Kermanshah, these beds were previously ascribed to the Miocene. The identified larger foraminifera include *Nummulites fichteli* Michelotti, *Nummulites vascus* Joly & Leymerie, *Operculina complanata* (Defrance), *Asterigerina rotula* (Kaufmann), *Planorbulina bronnimanni* Bignot & Decrouez, *Discogypsina discus* (Goës), *Gypsina mastelensis* Bursch, *Halkyardia maxima* Cimerman, *Stomatorbina concentrica* (Parker & Jones), *Praerhapydionina delicata* Henson, *Penarchaias glynnjonesi* (Henson), *Austrotrillina* aff. *paucialveolata* Grimsdale, and *Haddonia heissigi* Hagn, associated with the coralline alga *Subterraniphyllum thomasii* Elliott. The foraminiferal association characterises the SBZ 21 Zone (early Rupelian).

Introduction

The Oligocene-Miocene deposits of the Asmari and Qom formations are predominantly composed of shallow water marine carbonates which are often rich in hyaline and porcellaneous larger foraminifera. These two formations constitute the main reservoirs of southern and central Iran (e.g., James & Wynd 1965; Stöcklin & Setudehnia 1991). The Asmari Formation is widely distributed in the Zagros Mountains, and the Qom Formation also crops out in many localities in Central Iran, Sanandaj-Sirjan Zone, and Uromia-Dokhtar Magmatic Arc where it forms a series of carbonate and mixed siliciclastic-carbonate deposits (e.g., Stöcklin & Setudehnia 1991; Agard et al. 2005). Several studies dealing with litho- and biostratigraphy of the Asmari Formation have been carried out and are still in progress (e.g., Seyrafian & Hamedani 1998; Seyrafian 2000; Vaziri-Moghaddam et al. 2006; Amirshahkarami et al. 2007; Ehrenberg et al. 2007; Van Buchem et al. 2010; Sadeghi et al. 2011; Rahmani et al. 2012) whereas there are only a few published stratigraphic information for the Qom Formation (e.g., Rahaghi 1973; Reuter et al. 2009; Hadavi et al. 2010; Yazdi-Moghadam 2011; Mohammadi et al. 2013, 2015; Yazdi-Moghadam et al. 2018). The lower Oligocene *Nummulites*-bearing carbonates of the Qom Formation cropping out at north of Sonqor, NW Iran are the target of this study for stratigraphy (Fig. 1). The proposed biozonation schemes for shallow water marine strata of the Mediterranean, the Middle East, and the Indo-West Pacific (IWP) regions are mainly based on larger foraminifera (e.g., Adams 1970; Schaub 1981; Adams 1984; Drooger & Laagland 1986; Cahuzac & Poignant 1997; Boudagher-Fadel & Banner 1999; Renema 2007; Özcan et al. 2010; Less et al. 2011). The widespread distribution of lower Oligocene *Nummulites*-bearing facies in the Tethys Ocean from Europe and the circum-Mediterranean area through the Middle East and western Indo-Pacific allows a biostratigraphic correlation for these deposits to be carried out throughout the Tethys. In Iran, however,

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except for Yazdi-Moghadam (2011) who correlated the lower Oligocene foraminiferal association of south Uromia (NW Iran) with the Shallow Benthic Zone 21, no attempt has been made to ascribe the larger foraminiferal association of this age to a standard biozonation scheme. Therefore, this study aims to set the Qom Formation beds in a global time framework through establishing the global SB system of biochronozones as proposed by Pignatti & Papazzoni (2017).

Stratigraphical and paleontological background

The first studies on the Oligocene-Miocene marine strata of Central Iran were focused on the general stratigraphy of these deposits (e.g., Loftus 1855; Tietze 1875; Von Abich 1878). The earlier workers used local informal names for these beds, e.g., marine formation (Gansser 1955). The name of the Qom Formation was first informally introduced by Dozy (1945). Through studying several sections at the type locality, south of the Qom city, Furrer & Soder (1955) divided the formation into six members by letters (a-f) including: (a-Member) basal limestones, (b-Member) sandy marlstones, (c-Member) alternating marlstones and limestones, (d-Member) evaporites, (e-Member) green marlstones, and (f-Member) top limestones. Then Soder (1959) further subdivided the c-Member into four sub-members as c_1, c_2, c_3, and c_4. The Qom Formation as a formal name (including its members) was accepted by the National Iranian Stratigraphic Committee (NISC) in 1975 (Stöcklin & Setudehnia 1991) and it is used in the Iranian literature since that time. Bozorgnia (1965), introduced the shallow water marine *Nummulites*-bearing carbonates of the Qom Formation elsewhere outside the type locality in the central part of the basin. He considered these lower Oligocene strata, completely unknown at the type locality, as a part of the Qom Formation and correlated them with their time equivalent "Lower Asmari" of southern Iran. Bozorgnia (1965) called these deposits as "Unnamed Member". Works of Rahaghi (1973, 1976, 1980, 1984) on larger foraminifera of Central Iran were the first major contributions to report and describe the LF associations of the Qom Formation. However, his interpretations for dating the foraminiferal assemblages were based on the definition of Oligocene-Miocene stages at that time and must be updated now. Recently, the Oligocene-Miocene deposits of Central Iran have been the target of several stratigraphic studies (e.g., Reuter et al. 2009; Yazdi-Moghadam 2011; Mohammadi et al. 2013; Amirshahkarami & Karavan 2015; Mohammadi et al. 2015; Daneshian & Ghanbari 2017; Daneshian & Ramezani Dana 2017). However, there is still no agreement on applying a unified standard biozonation scheme for larger foraminiferal associations, and most of the previous studies are based on local zonations.

Geological setting

Iran is composed of different structural units including Zagros fold and thrust belt, Sanandaj-Sirjan Zone (SSZ), Uromia-Dokhtar Magmatic Arc (UDMA), Central Iran, Alborz, Kopet Dagh, and eastern Iran (e.g., Stöcklin & Nabavi 1973) (Fig. 1A). The Oligocene-Miocene marine deposits of Central Iran are generally referred to as the Qom Formation in Iranian literature. Lithologically, the Qom Formation consists mainly of bioclastic limestones, marine marlstones, evaporites and siliciclastics varying in thickness in different areas and exceeding ~1 km at its type locality near the city of Qom (Bozorgnia 1965; Stöcklin & Setudehnia 1991; Reuter et al. 2009). The main area of Central Iran, north of the Uromia-Dokhtar Magmatic Arc, is characterised by flat-lying topography with occasional low hills (Morley et al. 2009). As a part of the Alpine-Himalayan orogenic belt, Central Iran exhibits complex structural features that are the result of long structural history from Palaeozoic time up to the present (Letouzey & Rudkiewicz 2005; Zanchi et al. 2009, 2016; Zanchetta et al. 2013, 2018)). The opening of Neotethys Ocean led to the separation of Central Iran from Zagros during the late Palaeozoic. Following the subduction of the Neotethys which started during the Late Triassic, the northward migration of Arabian plate continued up to the continental collision with the Eurasian/Iranian plate at Oligocene/Miocene (Berberian & King 1981). The extensive Eocene volcanism in Central Iran is a record of these subduction processes (Berberian & King 1981; Bina et al. 1986; Stampfli & Borel 2002; Agard et al. 2005). In Central Iran, a thick series of Eocene

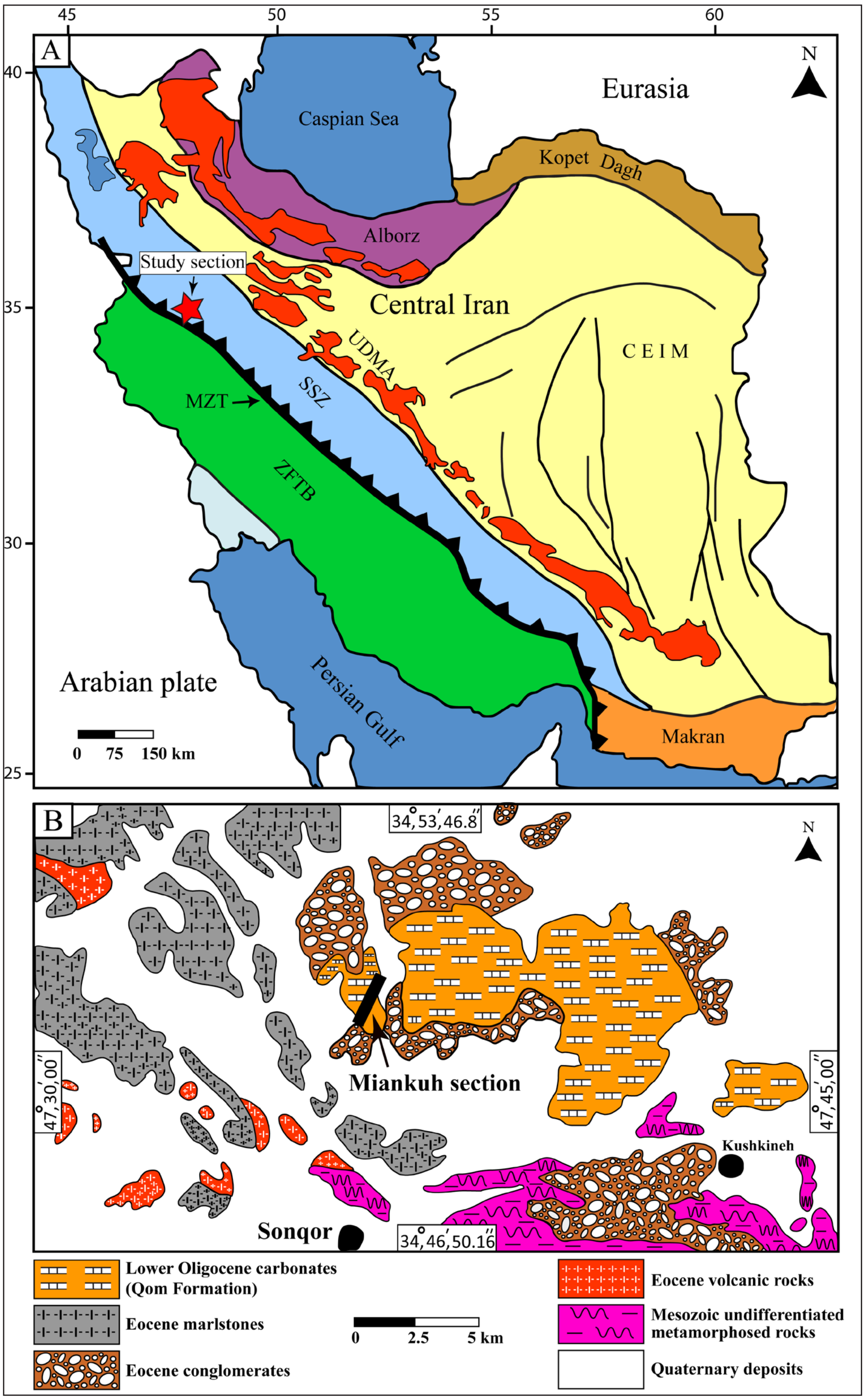


Fig. 1 - A) Simplified geological map of Iran (modified after Agard et al. 2011) showing the main tectonic subdivisions and location of the studied section. B) Geological map of the study area. Simplified from the geological map of Kermanshah, scale 1:250,000 by Braud & Aghanabati (1978). CEIM: Central East Iran Microplate, MZT: Main Zagros Thrust, SSZ: Sanandaj-Sirjan Zone, UDMA: Uromia Dokhtar Magmatic Arc, ZFTB: Zagros-Fold-Thrust Belt.

volcanic and volcaniclastic deposits with subordinate marine carbonates and evaporites unconformably underlies the Oligocene-Miocene succession of the Qom Formation (Berberian & King 1981; Bina et al. 1986; Agard et al. 2005). The Eocene series in turn unconformably overlies the Cretaceous and Jurassic sedimentary and metasedimentary rocks. In many places, the Eocene series begins with a basal conglomerate, followed by volcanic rocks with a calc-alkaline composition which are interbedded with nummulitic and evaporite beds (Stöcklin 1968). The SSZ is characterised by moderately metamorphosed rocks of Jurassic age, unconformably overlain by Barremian-Aptian "*Orbitolina*" limestones (Stöcklin 1968). The collision of Arabia and Eurasia led to significant deforma-

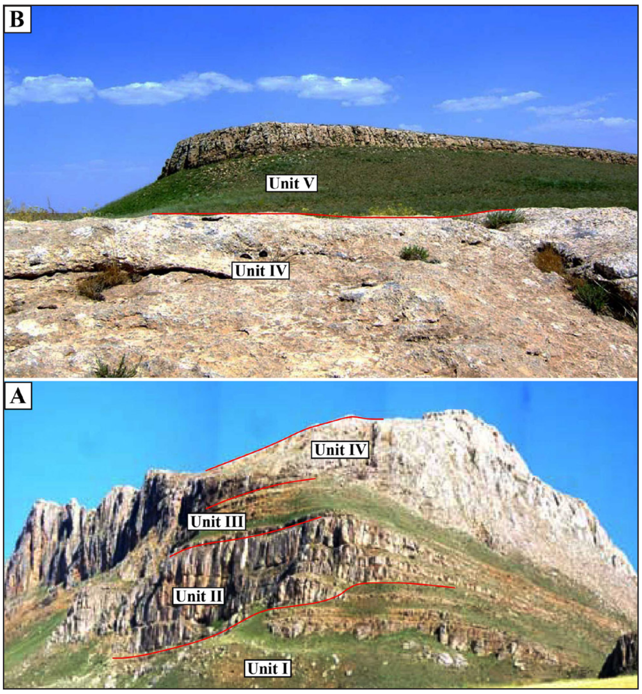


Fig. 2 - Outcrops of the Qom Formation at Miankuh. (A) General view of the lower and middle parts of the section including the Units I-IV. (B) General view showing the top part of Unit IV, Unit V, and the boundary between them.

tion of SSZ which occurred before the sedimentation of the Qom Formation. UDMA is marked by almost continuous calc-alkaline magmatic activity from Eocene to present, peaked during the Oligocene-Miocene (e.g., Berberian & Berberian 1981; Berberian & King 1981; Bina et al. 1986; Agard et al. 2011). Despite complexities from pre-Pan-African times or Palaeotethys closure, Central Iran, UDMA, and SSZ together are considered to represent the upper plate domain during most of the recent convergence history leading to the Zagros orogeny (Agard et al. 2011). At the type locality, the marine strata of the Qom Formation are bounded by two red units (the Lower Red and Upper Red formations) comprising non-marine continental and clastic deposits (Furrer & Soder 1955; Gansser 1955; Abaie et al. 1964; Bozorgnia 1965). The occasional presence of marine fossils points to episodic marine conditions during the deposition of Lower Red and Upper Red formations. The carbonates which are the subject of this study are fossiliferous *Nummulites*-bearing rocks of the Qom Formation cropping out north of Sonqor, NW Iran, in an area belonging to Sanandaj-Sirjan Zone, based on the literature (e.g., Hassanzadeh & Wernicke 2016; Davoudian et al. 2016) (Fig. 1A).

Material and Methods

The material of this study comes from one section located at the north of Sonqor, NW Iran (34° 50´ 00˝ N, 47° 37´ 10.99˝ E) (Fig. 1A-B). Except for a few levels in which naturally split specimens of nummulitids were collected, the remaining samples were studied in random thin sections. Several thin sections were made from most of the samples to obtain oriented sections of larger foraminifera. The generic classification of foraminifera follows Loeblich & Tappan (1987) and Hottinger (2007). All the samples and thin sections presented in this paper are deposited in the collection of National Iranian Oil Company Exploration Directorate (NIOCEXP), Tehran, Iran and labeled under the acronym of MJL.

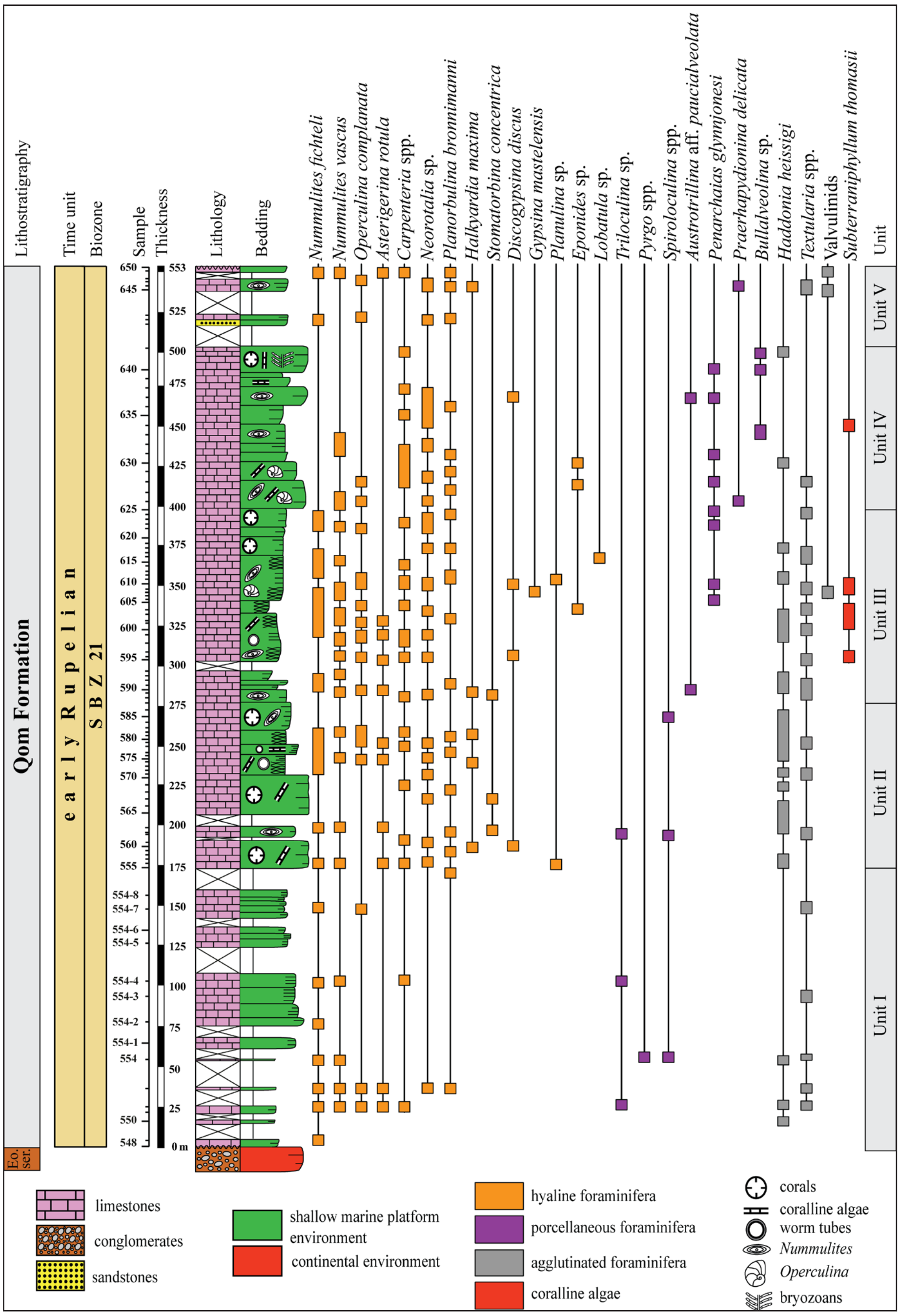
Results

Miankuh section

At Miankuh, the shallow water marine carbonate strata of the Qom Formation lay unconformably on the Eocene series which comprises mafic intrusions, shallow water marine bioclastic limestones, and pelagic limestones. The Eocene series is capped by Lutetian-Bartonian flysch deposits (Agard et al. 2011). The upper contact of the Qom Formation at Miankuh is erosional, and the Upper Red Formation is not present in the study area.

The lithological characteristics allowed subdividing the marine succession of the Qom Formation into five units (Figs 2, 3). Unit I includes the lower 175 m of the Qom Formation, composed of thin to medium bedded limestones. There are some covered intervals in this unit which may consist of marine marlstones. Limestones contain an association of hyaline larger benthic foraminifera (Fig. 3). The association includes *Nummulites fichteli* Michelotti (Fig. 4A-I), *Nummulites vascus* Joly & Leymerie (Fig. 5A-J), *Operculina complanata* (Defrance) (Fig. 5K-L), *Neorotalia* sp. (Fig. 6A-C), and *Asterigerina rotula* (Kaufmann) (Fig. 6E). Encrusting foraminifers are represented by *Planorbulina bronnimanni* Bignot & Decrouez (Fig. 6H-K), *Carpenteria* sp. (Fig. 6L-M), *Textularia* spp. (Fig. 7H-K), and *Haddonia heissigi* Hagn (Fig. 7M). The above-noted association is accompanied by *Triloculina* spp. (Fig. 8J-L), *Pyrgo* spp. (Fig. 8M-N), *Spiroloculina* spp. (Fig. 8O-P), and coralline algae. Unit II (175-280 m) reaches to 105 m in thickness and consists mainly of gray massive to medium bedded limestones containing abundant coralline algae, coral rubbles, and worm tubes. In addition to benthic foraminifera of the Unit I that are also present in this unit, the following foraminifera appear: *Halkyardia maxima*

Fig. 3 - Litho- and biostratigraphic log of the Miankuh section. Eo.: Eocene, ser.: series.



Cimerman (Fig. 6F-G), *Discogypsina discus* (Goës) (Fig. 7B-C), *Stomatorbina concentrica* (Parker & Jones) (Fig. 7D), and *Planulina* sp. (Fig. 7E-F). Upsection (280-400 m), the 120-m-thick Unit III comprises gray thin, medium, and thick bedded bioclastic limestones. Coralline algae, corals and worm tubes are common in this unit. The benthic foraminiferal association is similar to the previous unit except for *Eponides* sp. (Fig. 6D), *Gypsina mastelensis* Bursch (Fig. 7A), *Lobatula* sp. (Fig. 7G), *Penarchaias glynnjonesi* (Henson) (Fig. 8A-B), and *Austrotrillina* aff. *paucialveolata* Grimsdale (Fig. 8H-I) that first appear in this unit. The unit is also characterised by the occurrence of coralline alga *Subterraniphyllum thomasii* Elliott (Fig. 9A-D). Unit III is followed by the 100-m-thick Unit IV (400-500 m) consisting of massive to thick bedded reefal limestones. Coralline algae, corals and bryozoans are common. In addition to the above-mentioned benthic foraminifera, *Praerhapydionina delicata* Henson (Fig. 8C-D) and *Bullalveolina* sp. (Fig. 8E-G) also occur in this unit. Finally, the Qom succession is topped by the 53-m-thick Unit V (500-553 m) comprising cream, thin to medium bedded limestones. The foraminiferal association of the unit is similar to that of Unit IV. Coralline algae are subordinate.

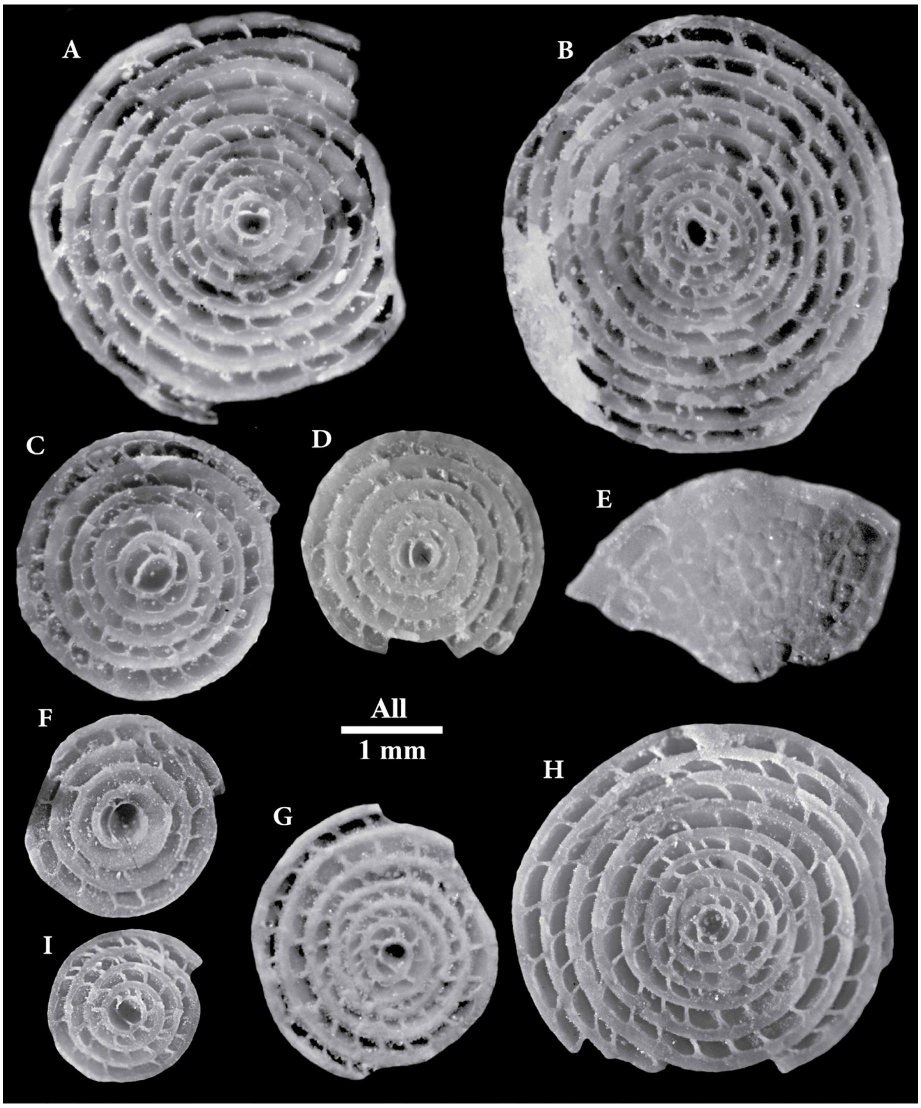


Fig. 4 - *Nummulites fichteli* Michelotti. A-B, G-H, E: MJL 575; C-D: MJL 576; F, I: MJL 649. All the specimens represent A-forms.

Selected taxonomy

As representatives of the genus *Nummulites* are the key taxa for biostratigraphy and biozonation of the examined strata, systematic descriptions for the identified species are given.

Family Nummulitidae de Blainville, 1827
Genus *Nummulites* Lamarck, 1801

Our determination of *Nummulites* is based on the internal features in equatorial sections and surface characteristics of the A-forms. In the Miankuh section, the representatives of the genus *Nummulites* can be classified into two categories based mainly on their surface characteristics. *Nummulites fichteli* belongs to the reticulate group, while *N. vascus* is a member of the radiate forms.

Nummulites fichteli Michelotti, 1841
Fig. 4A-I

1841 *Nummulites fichteli* Michelotti, p. 44, pl. 3, fig. 7.
1970 *Nummulites fichteli* Michelotti - Roveda, p. 245-249, pl. 22, figs. 1-2, text-figs. 1-3.
1981 *Nummulites fichteli* Michelotti - Schaub, p. 128-130, pl. 50, figs. 5-18. (cum syn.).
2010 *Nummulites fichteli* Michelotti - Özcan et al. p. 478-479, pl. 4, figs. 2-16

Material: 15 equatorial sections of A-forms

This reticulate species belongs to the *N. fabianii* lineage. It is characterised by reticulation on the surface as irregular mesh in A-forms (Fig. 4E), slightly curved septa, and chambers which are broader than high (Fig. 4A-D, F-I). The inner cross diameter of protoconch varies from 0.195 to 0.380 mm with a mean value around 0.267 mm. An early Rupelian to early Chattian (SBZ 21-22B) age is

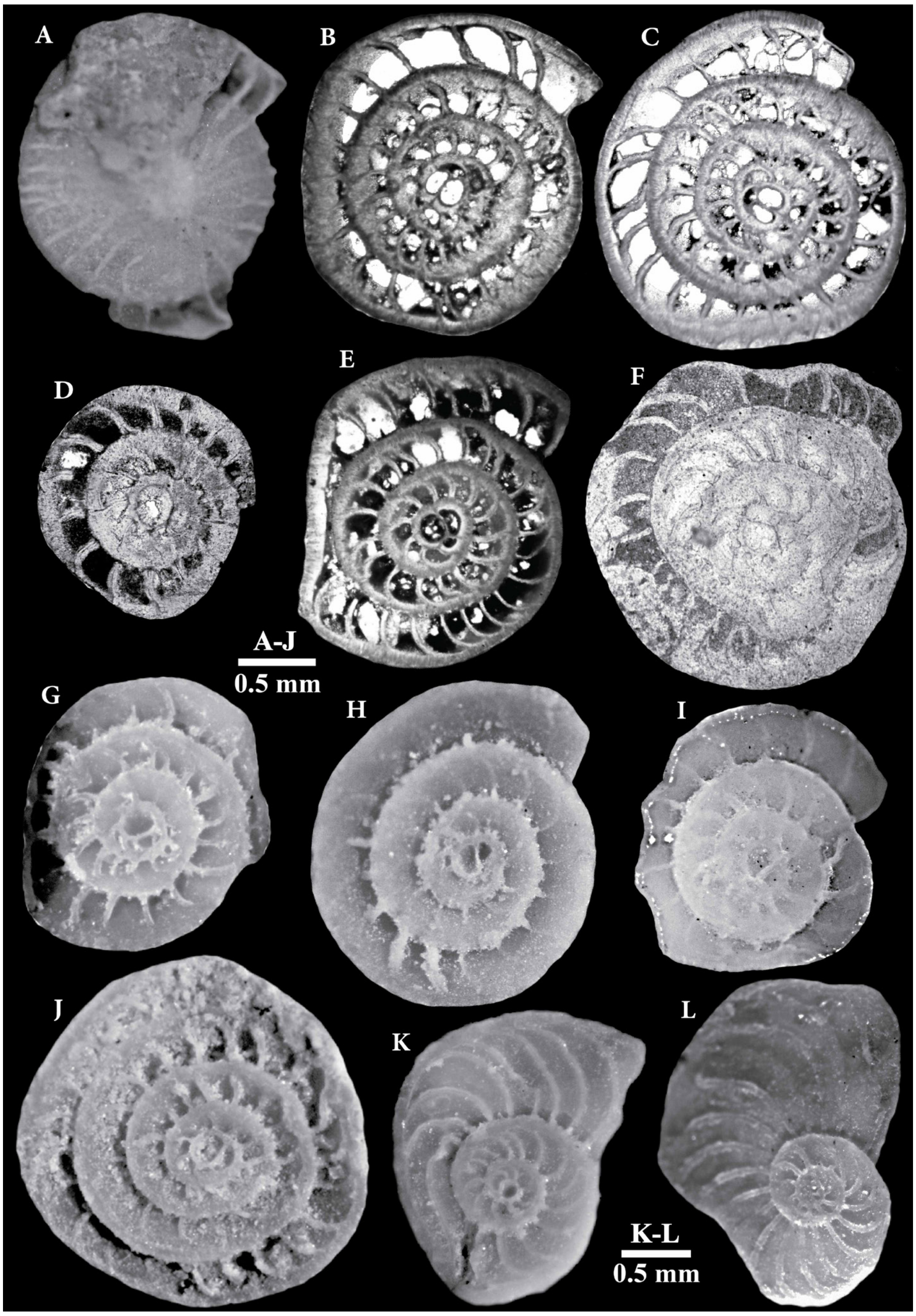


Fig. 5 - A-J) *Nummulites vascus* Joly & Leymerie; K-L) *Operculina complanata* (Defrance). A-C, E, G, K: MJL 554; D, F: MJL 556; H-J: MJL 580; L: MJL 552. (L) represents B-form, all the others are A-forms.

known for *N. fichteli* in Europe and Mediterranean area (e.g., Cahuzac & Poignant 1997; Sirel 2003). This species is so far only known from the lower Oligocene shallow water marine deposits in central and southern Iran (SBZ 21-22A) (e.g., Ehrenberg et al. 2007; Van Buchem et al. 2010; Yazdi-Moghadam, 2011).

Nummulites vascus Jolie & Leymerie, 1848

Fig. 5A-J

1848 *Nummulites vasca* nobis, Joly & Leymerie, p. 38, 67, pl. 1, figs. 15-17, pl. 2, fig. 7.

1981 *Nummulites vascus* Joly & Leymerie - Schaub, p. 123-124, pl. 53, figs. 1-6.

2011 *Nummulites vascus* Joly & Leymerie - Less et al. p. 823, 827, fig. 39s-u, w.

Material: 11 equatorial sections of A-forms

This radiate species is characterised by having straight septal filaments (Fig. 5A), definitely arched septa, and evenly coiled spiral, isometric chambers (Fig. 5B-J). The inner cross diameter of protoconch ranges from 0.190 to 0.266 mm with a mean value around 0.21 mm. An overall range of Rupelian to early Chattian (SBZ 21-22B) is given by Cahuzac & Poignant (1997) for *Nummulites vascus* in Europe.

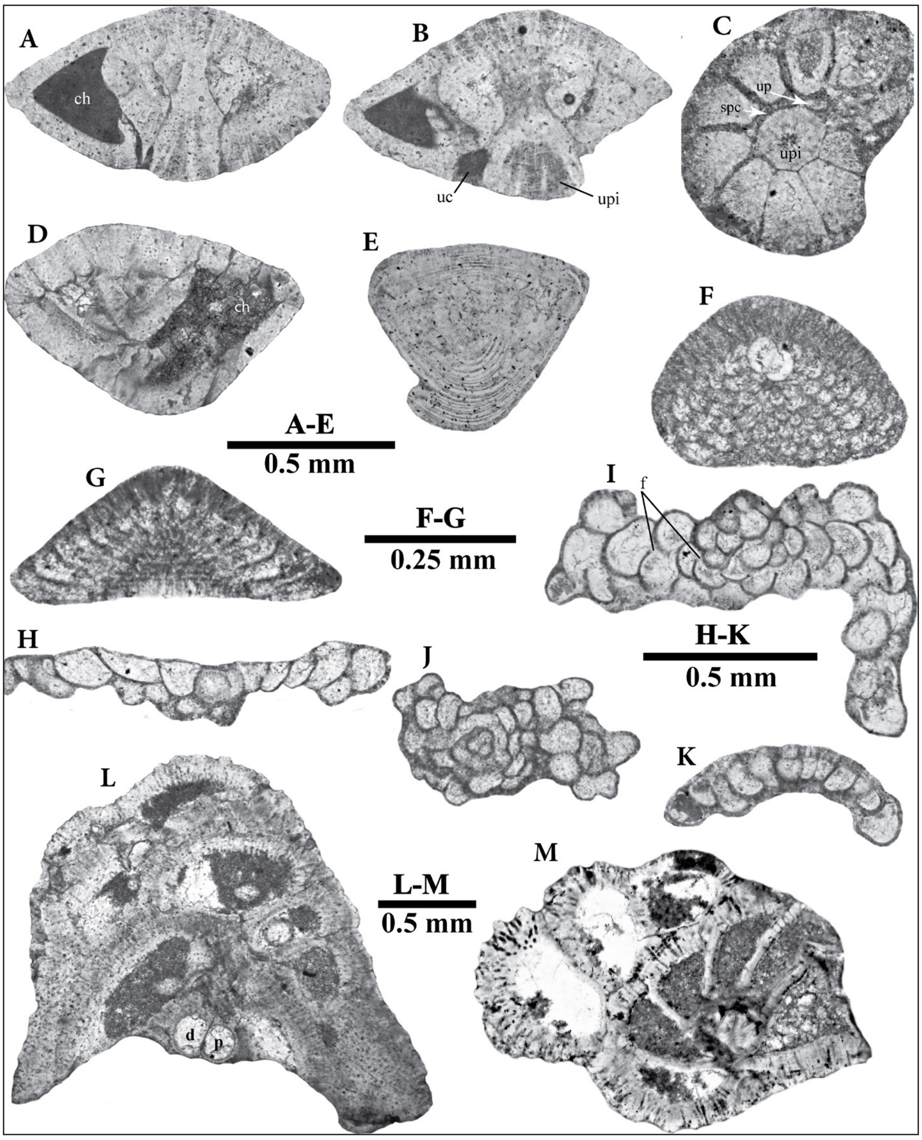


Fig. 6 - A-C) *Neorotalia* sp.; D) *Eponides* sp.; E) *Asterigerina rotula* (Kaufmann); F-G) *Halkyardia maxima* Cimerman; H-K) *Planorbulina bronnimanni* Bignot & Decrouez.; L-M) *Carpenteria* sp.
A-B: MJL 604; C: MJL 554; D: MJL 630; E: MJL 552; F: MJL 559; G: MJL 645; H: MJL 649; I: MJL 581; J: MJL 631; K: MJL 596; L: MJL 610; M: MJL 557.
Abbreviations: ch: chamber, d: deuteroconch, f: foramen, p: protoconch, spc: spiral canal, uc: umbilical cavity, up: umbilical plate, upi: umbilical pillar.

This species is not so far known in strata younger than Rupelian in southern and central Iran (e.g., Ehrenberg et al. 2007; Van Buchem et al. 2010; Yazdi-Moghadam 2011). Less et al. (2011) reported the species from the lower Rupelian (SBZ 21) of Turkey.

Discussion on larger foraminiferal biostratigraphy in the context of European standard shallow benthic zonation (SBZ zonal scheme)

Due to unfavorable environmental conditions, planktonic foraminifera rarely occur and nannofossils are absent in the Miankuh section. Therefore, larger foraminifera remain the only tool for biostratigraphy and age dating of the examined succession. The 553-m-thick deposits of the Qom Formation at Miankuh comprise shallow water marine limestones containing a moderately diverse assemblage of larger foraminifera including *Nummulites fichteli*, *N. vascus*, *Operculina complanata*, *Neorotalia* sp., *Asterigerina rotula*, *Halkyardia maxima*, *Gypsina mastelensis*, *Discogypsina discus*, *Planorbulina bronnimanni*, *Carpenteria* sp., *Praerhapydionina delicata*, *Penarchaias glynnjonesi*, *Bullalveolina* sp., *Austrotrillina* aff. *paucialveolata*, and *Haddonia heissigi*. The Oligocene-Miocene Shallow Benthic Zonation system of Europe and Mediterranean region established by Cahuzac & Poignant (1997) is used in this study. It includes six biozones (SBZ 21-26) defined based on different groups of larger foraminifera. The important biostratigraphic markers within this scheme identified in the Miankuh section are representatives of the genus *Nummulites*. According to Cahuzac &

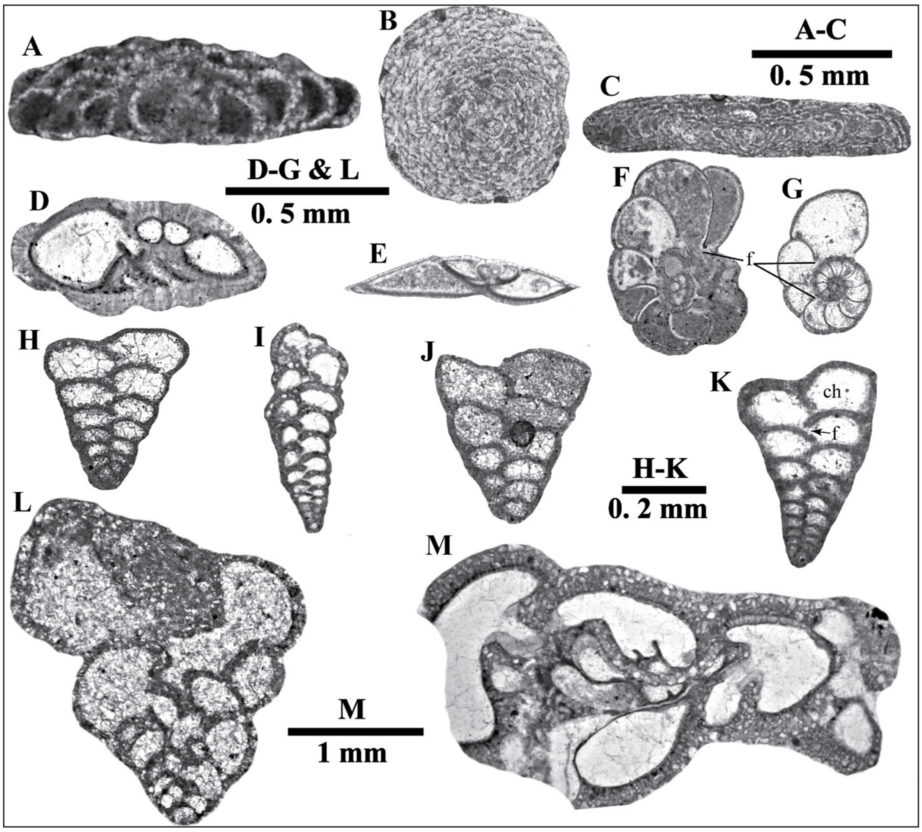


Fig. 7 - A) *Gypsina mastelensis* Bursch; B-C) *Discogypsina discus* (Goës); D) *Stomatorbina concentrica* (Parker & Jones); E-F) *Planulina* sp.; G) *Lobatula* sp.; H-K) *Textularia* spp.; L) valvulinid; M) *Haddonia heissigi* Hagn.
A: MJL 608; B: MJL 637; C: MJL 610; D: MJL 562; E: MJL 556; F: MJL 611; G: MJL 616; H: MJL 625; I: MJL 574; J: MJL 604; K: MJL 613; L: MJL 645; M: MJL 552.
Abbreviations: ch: chamber, f: foramen.

Poignant (1997), both *N. fichteli* and *N. vascus* have similar stratigraphic ranges from SBZ 21 to SBZ 22B corresponding to the Rupelian-early Chattian (Fig. 10). *Nummulites vascus* and *N. fichteli* have been reported from Turkey to range within the SBZ 21 (early Rupelian) and SBZ 22A (late Rupelian) respectively (Sirel 2003; Özcan et al. 2009; Özcan et al. 2010; Less et al. 2011). Adams (1984) considered the range of *N. vascus* and *N. fichteli* to be restricted to the Rupelian. Ehrenberg et al. (2007) based on strontium isotope calibration in southern Iran, considered the LO (last occurrence) of these nummulitid taxa, one million year before the Rupelian/Chattian boundary when they are not accompanied by lepidocyclinids. This dating seems to correspond to SBZ 21 of Cahuzac & Poignant (1997) with an early Rupelian age. Another isotope calibration in southern Iran was carried out by Van Buchem et al. (2010) who considered the whole Rupelian age for the taxa when they associate in their upper range with lepidocyclinids. Based on these latter authors *Nummulites vascus* and *N. fichteli* do not cross the Rupelian/Chattian boundary in Iran. These findings are in agreement with Adams (1984) for the LO of the genus *Nummulites* in Indo-Pacific region. Therefore, *N. vascus* and *N. fichteli* can be considered to range throughout the SBZ 21-22A, corresponding to the Rupelian age, in Iran. The Rupelian age for the Oligocene species of the genus *Nummulites* can be further confirmed based upon the already published biostratigraphic data in Central Iran (e.g., Yazdi-Moghadam 2011). According to Hottinger (2007), *Praerhapydionina delicata* ranges from Bartonian to Rupelian (SBZ 17-22A) and *Penarchaias glynnjonesi* first occurs in the Bartonian and disappears at the end of the early Rupelian (SBZ 17-21) (Fig. 10). The genus *Bullalveolina* is so far monospecific (*B. bulloides*) and seems to be limited to the Rupelian (SBZ 21-22A) (Cahuzac & Poignant, 1997; Sirel 2003). Representatives of the genus *Austrotrillina* rarely occurring in our material attain an equatorial diameter around 0.5 mm and have simple and coarse alveols limited to the last few chambers. These features have already been known in *Austrotrillina paucialveolata* Grimsdale. However, they also exhibit a thickened basal layer similar to *A. eocaenica* Hottinger. This latter species has so far only been known from the middle-upper Eocene (SBZ 16-20) strata of the Jahrum Formation, southern Iran (Hottinger 2007). Consequently, our specimens could be considered as transitional forms between *Austrotrillina eocaenica* and *A. paucialveolata* and are here named as

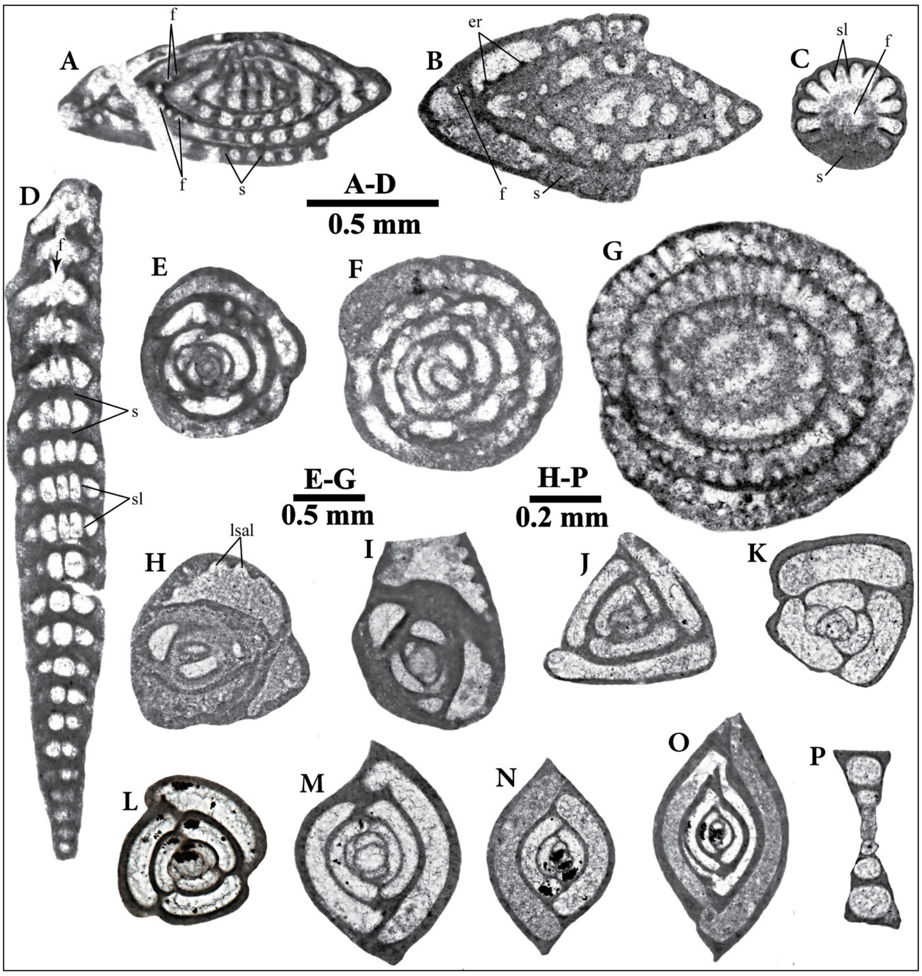


Fig. 8 - A-B) *Penarchaias glynnjonesi* (Henson); C-D) *Praerhapydionina delicata* Henson; E-G) *Bullalveolina* sp.; H-I) *Austrotrillina* aff. *paucialveolata* Grimsdale; J-L) *Triloculina* spp.; M-N) *Pyrgo* spp.; O-P) *Spiroloculina* sp.
A: MJL 608; B: MJL 631; C-D: MJL 626; E: MJL 610; F: MJL 640; G: MJL 634; H: MJL 637; I: MJL 651; J: MJL 552; K: MJL 562; L: MJL 563; M-N: MJL 554; O: MJL 554; P: MJL 562.
Abbreviations: er: endoskeletal ridge, f: foramen, lsal: large simple alveoli, s: septum, sl: septulum.

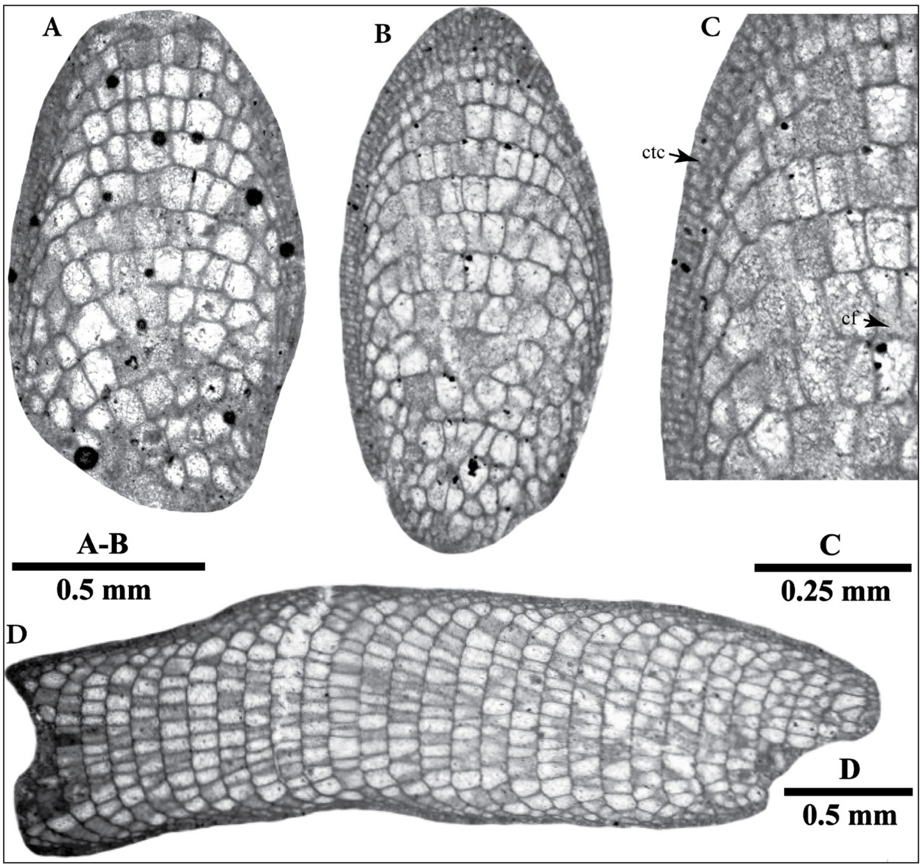


Fig. 9 - *Subterraniphyllum thomasii* Elliott.
A: MJL 604; B-C: MJL 596; D: MJL 601.
(C) is higher magnification of (B) showing details of medulla and cortex.
Abbreviations: cf: cell fusion, ctc: cortex cells.

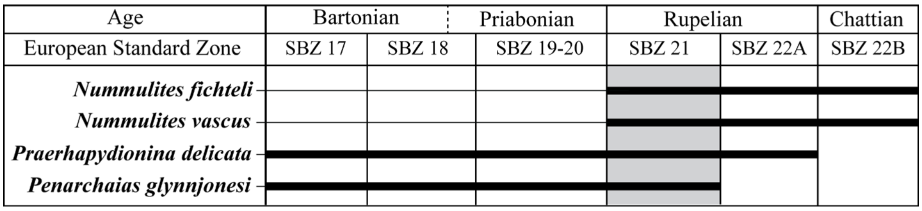


Fig. 10 - Stratigraphic ranges of selected Bartonian-early Chattian hyaline and porcellaneous larger foraminifera based on data from various sources (Cahuzac & Poignant 1997; Sirel 2003; Hottinger 2007; Özcan et al. 2010). Bartonian Priabonian stage boundary is adopted from Papazzoni et al. (2017). The gray area points to the biostratigraphic interval of the Miankuh section.

Austrotrillina aff. *paucialveolata*. The other larger benthic foraminifera recorded in our material including *Operculina complanata*, *Planorbulina bronnimanni*, *Discogypsina discus*, *Gypsina mastelensis*, and *Neorotalia* sp., have wider stratigraphic ranges and are not suitable for biostratigraphy. Usually, SBZ 22A is characterized by the presence of lepidocyclinids including *Nephrolepidina praemarginata* Douvillé and *Eulepidina formosoides* Douvillé in Europe (e.g., Cahuzac & Poignant 1997; Özcan et al. 2010). At Miankuh, both *N. vascus* and *N. fichteli* range to the top of the section, but lepidocyclinids do not appear. Therefore, based on the known chronostratigraphic range of *N. fichteli*, *N. vascus*, *P. delicata*, and *P. glynnjonesi*, and in the absence of lepidocyclinids, the Miankuh section can be confidently dated as lower Rupelian, and its foraminiferal association correlates with the SBZ 21 of Cahuzac & Poignant (1997).

Concluding remarks

A moderately diverse and well-preserved assemblage of hyaline, porcellaneous, and agglutinated benthic foraminifera was found in the lower Rupelian shallow water marine deposits of the Qom Formation at the north of Sonqor, NW Iran. The recognised foraminiferal association includes 21 genera and 13 species. Larger foraminifera, classified under the genera *Nummulites*, *Operculina*, *Halkyardia*, *Planorbulina*, *Neorotalia*, *Asterigerina*, *Praerhapydionina*, *Penarchaias*, and *Haddonia* in this study show close similarity to the coeval assemblages already known from the European and circum-Mediterranean marine sedimentary sequences. This western Tethyan affinity allowed us to apply the standard biozonation scheme of this region (SBZ zonation) for our study area in NW Iran. The early Rupelian age within the context of SBZ 21 Zone by Cahuzac & Poignant (1997) for the Miankuh section is documented by the presence of *Nummulites fichteli*, *N. vascus*, *Praerhapydionina delicata*, and *Penarchaias glynnjonesi* and in the absence of lepidocyclinids.

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