


Biometric study of late Oligocene larger benthic Foraminifera (Lepidocyclinidae and Nummulitidae) from the Qom Formation, Central Iran (Tajar-Kuh section)

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Abstract.—The Oligocene strata of the Qom Formation from the Tajar-Kuh section, Central Iran, are rich in various Larger Benthic Foraminifera (LBF). Morphometric studies of the internal features of the LBF tests were carried out based on matrix-free specimens from seven samples. The LBF assemblage studied in 24 populations mainly contains representatives of two nummulitid (the reticulate *Nummulites bormidiensis* Tellini, 1888, only in the lower three samples, and the radiate *Nummulites kecskemetii* Less, 1991 in all samples) and of two lepidocyclinid lineages. Of the latter, *Nephrolepidina praemarginata* (R. Douvillé, 1908) occurs in all the samples, whereas *Eulepidina formosoides* H. Douvillé, 1925 is present in the lower six samples. In the upper sample, the slightly more advanced *Eulepidina ex. interc. formosoides* H. Douvillé, 1925 et *dilatata* (Michelotti, 1861) is recorded. Due to the very similar taxonomic composition of the Tajar-Kuh section with their coeval faunas of the Mediterranean, the age was evaluated in the frame of the Western Tethyan Oligo-Miocene shallow benthic zonation (SBZ). Although the presence of *E. formosoides* suggests late Rupelian (SBZ 22A Zone) age, the occurrence of *Heterostegina assilinooides*, *N. kecskemetii*, *N. bormidiensis*, and *Planolinderina* sp. preferably represents the SBZ 22B Zone of the early Chattian. Based on the obtained results, at least the lower six samples can indicate the very basal part of the Chattian. More advanced *Eulepidina* from the uppermost sample suggests a slightly younger but still early Chattian age.

Introduction

The present work is the first comprehensive taxonomic study of the Late Oligocene LBF (nummulitids and lepidocyclinids) from shallow-marine strata of the Qom Formation (Central Iran) in the Tethyan Seaway (Reuter et al., 2007) based on a morphometric approach. In the north-eastern coast of the Tethyan Seaway, the Oligocene deposits of the Qom Formation are characterized by the dominance of shallow-marine carbonates (Reuter et al., 2007), often rich in LBF, which are the most important components of sediments in Cenozoic platforms (Pomar and Hallock, 2007; Renema, 2007; Boudagher-Fadel, 2018). Their high variety and abundance are very important in reconstruction of the paleoenvironment, detection of changes in environmental parameters (due to their sensitivity to changes in environmental conditions such as light, nutrition, sedimentation, and water energy; Hottinger, 1997), and reconstruction of paleobiogeography (Hallock, 1987; Hallock et al., 1991; Langer and Hottinger, 2000; Hottinger, 2001; Hohenegger, 2005, 2009; Hallock and Pomar, 2008; Renema et al., 2008; Pomar et al., 2017; Förderer et al., 2018).

The LBF are considered as important tools for biostratigraphy, classification, and evolution of species because of their rapid evolution, high abundance, widespread appearance, and sudden extinction of species or communities (Schaub, 1981; Hottinger, 1983; Less, 1987; Drooger, 1993; Cahuzac and Poignant, 1997; Serra-Kiel et al., 1998; etc.). Therefore an accurate description of their morphology and internal structures using morphometric methods is very important for identifying the taxonomic composition and to determine their age by correlation with other coeval deposits.

In biostratigraphic studies on the Oligo-Miocene of the Mediterranean, the Middle East, and the Indo-West Pacific basins, the defined biozonation framework is often based on LBF (e.g., Adams, 1970, 1984; Drooger and Laagland, 1986; Jones and Racey, 1994; Cahuzac and Poignant, 1997; Boudagher-Fadel and Banner, 1999; Renema, 2007; Boukhary et al., 2010; Özcan et al., 2010a; Yazdi-Moghadam, 2011; Less et al., 2018; Yazdi-Moghadam et al., 2018a, 2018b). The majority of the LBF biozones are based on subsequent morpho-species of evolutionary lineages subdivided from each other by morphometric limits (see Less, 1987; Pignatti, 1998; Pignatti and Papazzoni, 2017). However, these lineages often evolved simultaneously in semi-isolated sub-basins that were connected with each other occasionally. Therefore, the speed

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of evolution within lineages could be slightly different in the different sub-basins. Because the species-limits within the lineages are arbitrarily chosen, they can easily be diachronic.

The biometrical approach applied to different groups of Cenozoic LBF consists of lepidocyclinids and miogypsinids (Drooger, 1993 and papers cited therein), orthophragminids (Less, 1987), and nummulitids (Laagland, 1990; Less and Özcan, 2008; Less et al., 2018). Our information about the biometry, taxonomy, and phylogenetic records of the Oligocene LBF in the Tethys is based on the data obtained from different locations from the circum-Mediterranean/European region and Western India (Drooger, 1993). To date, there have been no data from the Iranian part of the Tethys.

The present paper, therefore, pays special attention to the detailed taxonomic description of the LBF from the Late Oligocene deposits of the Tethyan seaway based on a precise morphometric approach. Also, this part of the Tethys is an important area for the comprehension of marine connections between the Indo-Pacific and Mediterranean provinces. Interestingly, according to some studies (e.g., Drooger, 1993; Rögl, 1997; Harzhauser et al., 2002), the faunal composition of comparable horizons from the two provinces have significant differences and variable time extensions. Study of Late Oligocene LBF, which are extensively distributed in the Tethys ocean within the Middle East and the Western Indo-Pacific, allows biostratigraphical correlation of these deposits with other parts of the Tethys.

Geological setting

The Iranian plate, based on differences in sedimentary sequence, age of magmatism and metamorphism, nature, structural characters, and mechanism of major faults, is subdivided into different parts (Alavi, 2004, 2007; Walker and Jackson, 2004). On a division based on structural trends, Stöcklin and Nabavi (1973) differentiated this plate into eight units, including Zagros fold, Zagros thrust belt, Uromia-Dokhtar Magmatic Arc, Sanandaj-Sirjan, Central Iran, Alborz, Koppeh-Dagh, and eastern Iran (Fig. 1).

Oligocene–Miocene marine rocks of Central Iran are generally called the Qom Formation. During this time, tectonic and plutonic activities originated from subduction and final collision of the Arabian Plate with the Iranian Plate that began during the Mesozoic (Colman-Sadd, 1982) have been activated in Central Iran. The important outcome of this collision was closure of the Tethyan Seaway during the Miocene and the end of marine fauna migration between the eastern Mediterranean and the Western Indo-Pacific (Harzhauser et al., 2002). The Qom Formation is mainly made up of limestone, marlstone evaporates, and siliciclastics, with different thicknesses in many places. At the type locality, the marine layers of the Qom Formation are mostly sandwiched between two non-marine formations: the Lower Red Formation at the bottom and the Upper Red Formation at the top (Furrer and Soder, 1955; Gansser, 1955).

The Qom Formation is synchronous in age with the Asmari Formation, a fractural oil reservoir in Southern Iran (Bozorgnia, 1966; Seppehr and Cosgrove, 2004). Both of these formations have recorded evidence of the so-called Terminal Tethys Events

because after the collision of the Arabian plate with Iranian plate, the connection between the Western and the Eastern Tethys was removed and the Qom Basin as a seaway was located in the northern Tethys (Harzhauser et al., 2002).

The Tajar-Kuh section studied in the present work is located ~26 km to the NW of Kashan city (Figs. 1, 2). The coordinates of the section are 34°04'0.1"N, 51°05'45.3"E for the base and 34°04'11.3"N, 51°05'34.6"E for the top (Fig. 2). The measured section is an incomplete sequence of late Oligocene (early Chattian) shallow marine deposits that record only the lower part of the Qom Fm. It is 175 m thick and mainly consists of limestone, marl, and marly limestone representative of the lower part of the Qom Formation (Fig. 3). It overlies unconformably the Eocene volcanic rocks with an erosional surface. The upper boundary is an erosional contact with the Upper Red Formation that usually overlies the formation (Bozorgnia, 1966), although it does not appear here.

The measured section can be divided into three units (Fig. 3): Unit 1 begins with a conglomeratic erosional surface and forms the lower 32 m of the section. It is composed of white to green marl, massive to thin-bedded, gray-brown limestone and marly limestone. Unit 2 is 50 m thick (32–82 m) and consists of mainly gray-brown massive to thick-bedded limestones. Unit 3 is 93 m thick (82–175 m) and includes gray massive to thick-bedded limestone. All matrix-free specimens for this study were collected from units 1 and 2. Specimens from Unit 3 could not be isolated.

Materials and methods

The morphometric analysis presented here is based on matrix-free specimens. A total of 117 samples with 1–2 m sampling interval were collected to cover the whole sequence under study (Fig. 3). Most samples came from cemented hard rocks; although we made thin sections, they were not perfect for biometrical analysis. Therefore, our morphometric data come from seven samples very rich in LBF and containing matrix-free specimens. Since morphometric analysis is elaborated for megalospheric (A) specimens, in this paper, we do not deal in detail with the much rarer microspheric (B) forms. We only mention their presence/absence in the systematic part. External features of the LBF were studied typologically, whereas their internal characteristics were mostly investigated morphometrically in the equatorial plane of matrix-free specimens, which was exposed either by splitting or by sectioning.

Surface properties and the internal morphology in the equatorial section are the two most important features for identifying species in the genus *Nummulites*. Biometrical analysis on reticulate *Nummulites* (*N. bormidiensis*) is based on a series of measurements and parameters introduced by Drooger et al. (1971) and Less (1999). We measured and counted seven parameters on 53 megalospheric specimens (described in the header of Table 1 and shown in Fig. 5.1). This system is widely used in the subsequent papers by Less and Özcan (2008), Less et al. (2011, 2018), and Özcan et al. (2009a, 2010a, 2010b), therefore these results can easily be compared with each other. We did not use the system elaborated by Hohenegger (2011) for recent nummulitids because the obtained data cannot be compared with

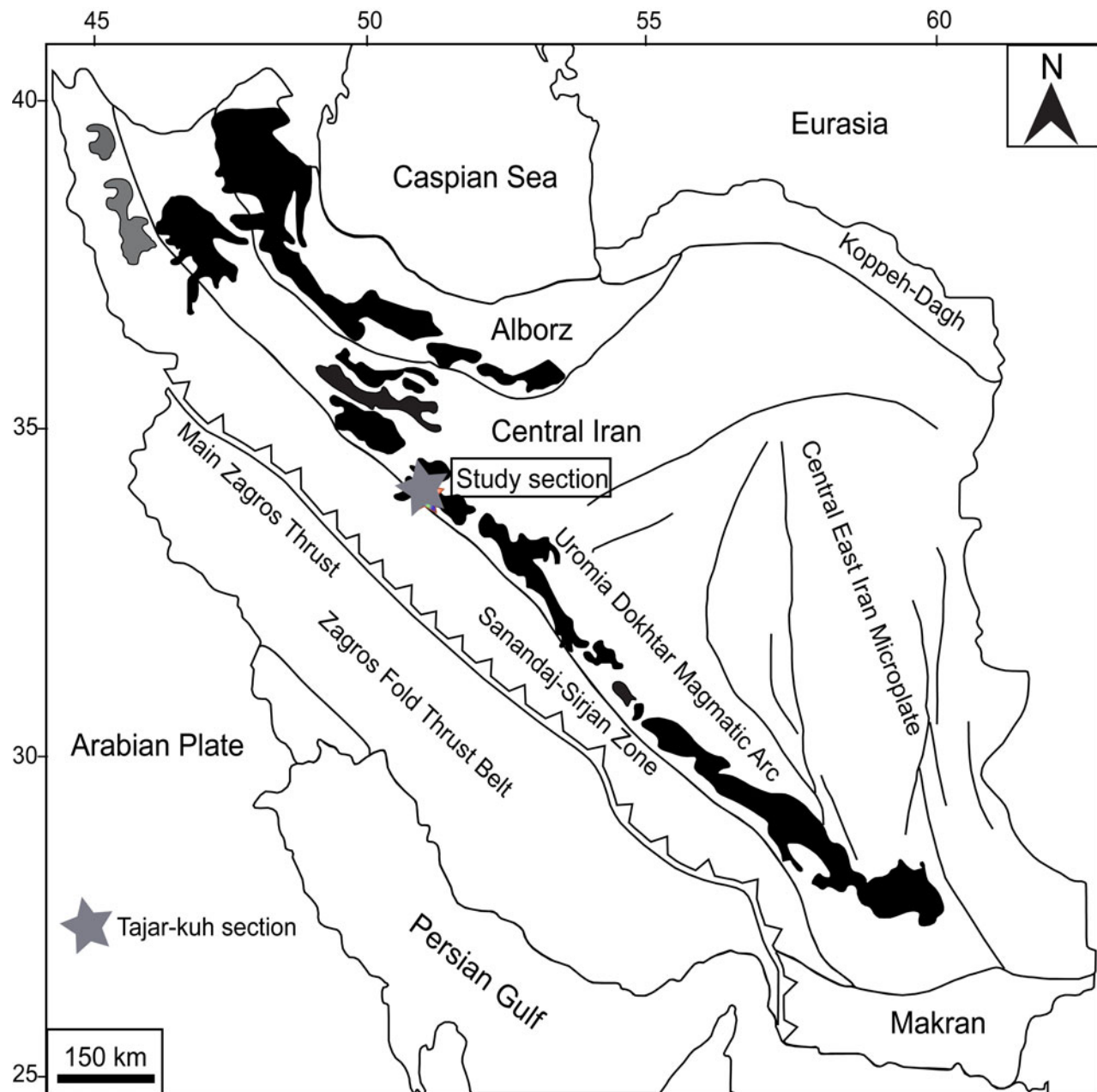


Figure 1. Simplified geological map of Iran (modified after Agard et al., 2011) showing the main tectonic subdivisions and approximate location of the studied section.

ours and it is tested only on relatively small number of specimens. Two populations consisting Taj-11 and Taj-12 lie very close to each other (see the lithostratigraphic log of the section in Figure 3) and show similar results of morphometrical parameters; thus, they were treated jointly as a composite sample. Mean values were evaluated for all parameters based on the total number of specimens. These data are marked with bold letters in Table 1.

For the identification of the radiate *Nummulites kecskemetii*, previously identified as *Operculina complanata* (Defrance, 1822), we measured two parameters on the equatorial section of 91 megalospheric specimens summarized in Table 1. The complete measurement system for *Nummulites*

applied in the case of *N. bormidiensis* (see above) was not possible to perform here because specimens usually did not contain three complete whorls. Unfortunately, the equatorial sections do not allow clear identification of the generic affiliation of these specimens, although forward-directed multiple secondary apertures on the septa (diagnostic for *Operculina* and lacking in *Nummulites*) cannot be seen. However, the preservation of the Tajar-Kuh material is much poorer than that of from Hungary (Less, 1991; Less and Özcan, 2008) and SW Aquitaine (Benedetti et al., 2018), where the presence/absence of these apertures is well visible in split equatorial sections. Nevertheless, we demonstrate on Figure 12.4 (the best preserved split

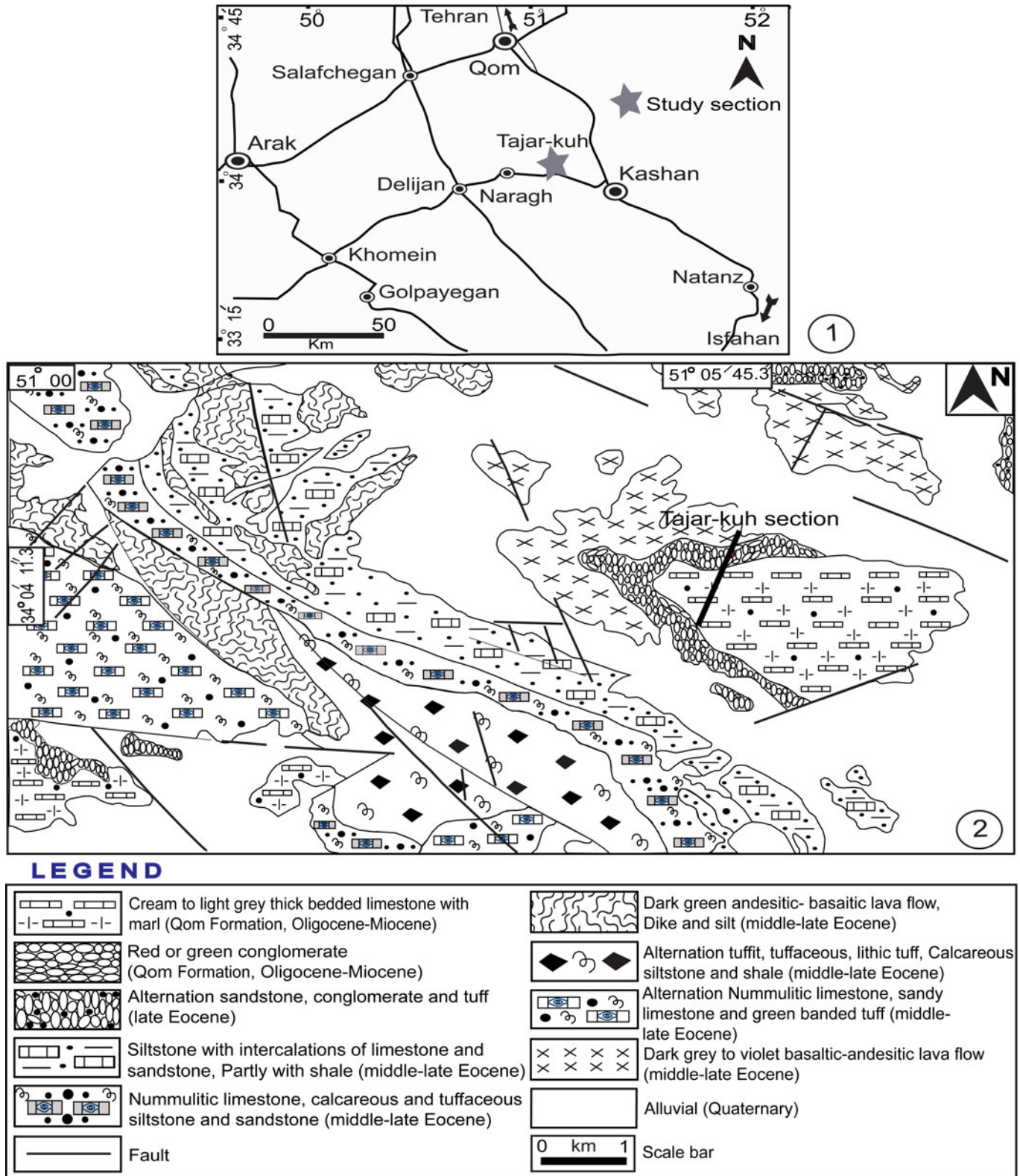


Figure 2. (1) Road map showing the position and locality of the Tajar-Kuh section. (2) Geological map of the studied area (simplified from the geological map of Aran, scale 1:100,000; Amini et al., 1996). Scale bars are (1) 50 km; (2) 1 km.

equatorial section of *Nummulites kecskemetti* from sample Taj-33) that we could not identify any forward-directed multiple secondary apertures on the septa. Therefore, we rely

mostly upon the vertical sections (Fig. 12.18–12.22) where the involute character of the shells and the well-developed alar prolongation, both characteristic for *Nummulites* rather

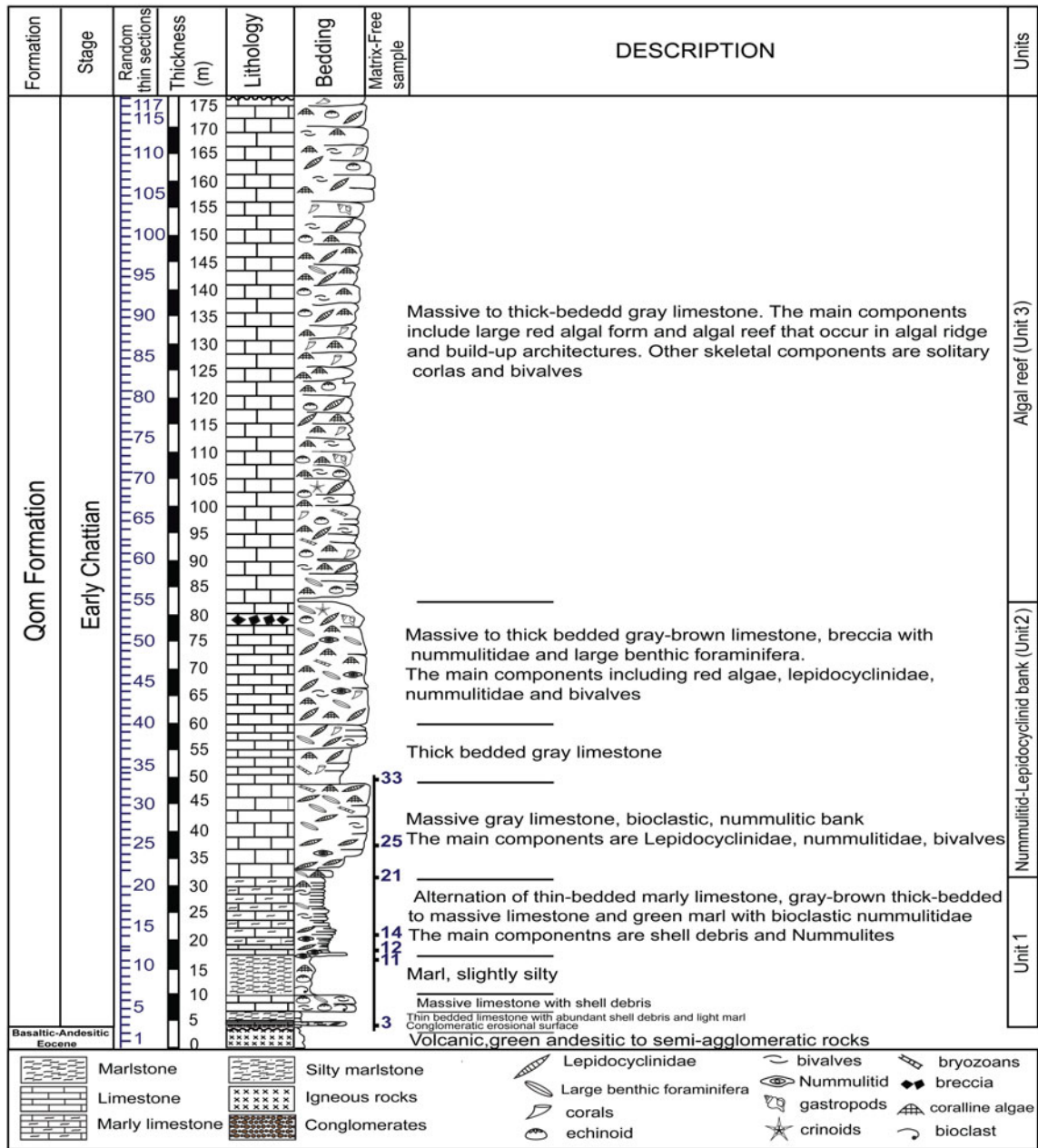


Figure 3. Lithostratigraphic log of the Tajar-Kuh section.

than for *Operculina*, can be clearly seen. It is worth mentioning that the size of the proloculus of the Tajar-Kuh specimens fits also with *Nummulites kecskemetii* and not with *Operculina complanata*.

Nummulitids with secondary chamberlets are very rare and only one single specimen of *Heterostegina assilinoidea* Blanckenhorn, 1890 has been recorded. Therefore, statistical analysis of morphometric data listed in the systematical description of this species was not performed.

In order to determine both lepidocyclinid genera (*Nephrolepidina* and *Eulepidina*), the terminologies offered by van der Vlerk (1959), Drooger and Socin (1959), and updated by Özcan et al. (2009b) were adapted. Accordingly, five parameters (Table 3; Fig. 5.2) were measured on 70 and

109 megalospheric forms, respectively, for *Eulepidina* and *Nephrolepidina*. The auxiliary chambers (parameter C) were not measured for *Eulepidina* because, according to Adams (1987), they are not necessarily positioned in the equatorial plane, so they are often difficult to detect with certainty. Because samples Taj-11, Taj-12, and Taj-14 were taken close to each other, their lepidocyclinid contents were first evaluated one by one and then as a joint population. For the genus *Nephrolepidina*, the same procedure was applied for samples Taj-21 and Taj-25.

Reticulate *Nummulites* and species of *Eulepidina* and *Nephrolepidina* were identified according to the morphometric limits of species for populations detailed in the systematic part. Where the mean value for a given population varied

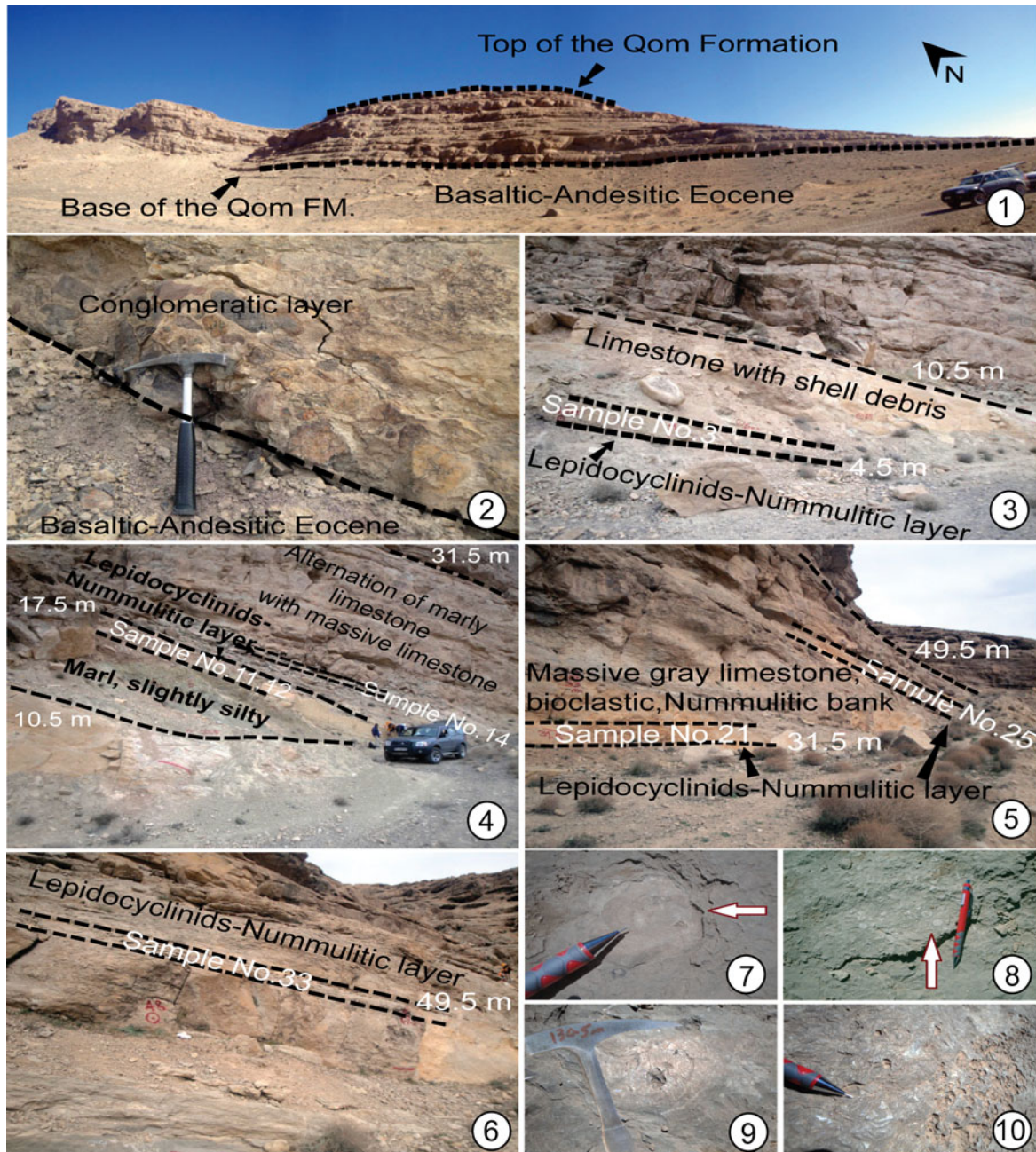


Figure 4. Outcrops of the Qom Formation at Tajar-Kuh. (1) General view of the Qom Formation overlying the basaltic-andesitic Eocene; (2) unconformity between the conglomerate basal layer and basaltic-andesitic Eocene; (3–6) a view of the layers containing matrix-free specimens, including samples 3, 11, 12, 14, 25, and 33; and (7–10) coralline red algae.

between two neighboring species by less than one standard error (s.e.), we used an intermediate denomination. In these cases, we adopted Drooger's (1993) proposal in using the notation 'exemplum intercentrale' (abbreviated as ex. interc.), followed by the names of the two subspecies on either side of the limit that the biometric parameters are closer to the first name.

In order to determine their taxonomy, we followed the protocol described in detail by Drooger (1993). In this process, all specimens of a particular lineage coming from the same sample were treated as belonging to the same population, to which a single taxon name was given based on the diagnostic

morphometric parameter(s). Morphometrical parameters are statistically summarized in Tables 1 and 3.

Canvas 11, Past 3, Adobe Illustrator CC 2015.3, and Adobe Photoshop CC 2015.5 software packages were utilized for measurements, statistical analysis, and drawing, respectively. The generic classification of foraminifera is in accordance with the studies of Loeblich and Tappan (1987), Drooger (1993), and Hottinger (2007).

Repository and institutional abbreviation.—All specimens are deposited in the Akbari collection of the Tehran University, Tehran, Iran, under the acronym Taj.

Table 1. Statistical data of populations of Late Oligocene *Nummulites* from the Tajar-Kuh, Central Iran (N_o: number of specimens and s.e.: standard error).

Parameters		Inner cross-diameter of the proloculus		Outer diameter of the first two whorls		Number of post-embryonic chambers in the first two whorls		Index of spiral opening: 3. whorl vs. first 3 whorls		
		P (μm)		d (μm)		E		K = 100×(D-d)/(D-p)		
Taxon	Sample	No.	Range	Mean ± s.e.	Range	Mean ± s.e.	Range	Mean ± s.e.	Range	Mean ± s.e.
<i>Nummulites bormidiensis</i> Tellini, 1888	Taj-3	12	260–550	406 ± 25	1090–1760	1556 ± 52	18–22	21 ± 0.4	25–36	30 ± 0.8
	Taj 11 + 12	41	300–470	396 ± 7	1050–1730	1484 ± 25	17–23	20 ± 0.2	23–40	31 ± 0.5
	Taj-11	19	340–470	403 ± 10	1290–1730	1521 ± 31	17–21	19 ± 0.3	23–40	30 ± 0.9
	Taj-12	22	300–460	390 ± 11	1050–1680	1452 ± 38	17–23	20 ± 0.3	27–39	31 ± 0.6
<i>Nummulites kecskemetii</i> Less, 1991	Taj-3	28	60–110	91 ± 2.5			19–26	22 ± 0.4		
	Taj-11	6	70–120	95 ± 6.7			19–23	21 ± 0.7		
	Taj-12	12	60–110	88 ± 4.2			20–25	22 ± 0.4		
	Taj-14	8	80–120	93 ± 5.3			19–24	22 ± 0.6		
	Taj-21	26	60–120	89 ± 3.4			18–25	22 ± 0.4		
	Taj-25	4	60–110	92 ± 11.1			20–24	21 ± 0.9		
	Taj-33	7	40–80	66 ± 5.3			17–23	21 ± 0.8		

		Third whorl				rel. width of the spiral cord		
		av. length of chambers		av. shape of chambers				
		L = d×π/N(μm)		F = 100×(D-d)/(D-d + 2d*π/N)		m = 100×(D-M)/(D-d)		
Taxon	Sample	No.	Range	Mean ± s.e.	Range	Mean ± s.e.	Range	Mean ± s.e.
<i>Nummulites bormidiensis</i> Less, 1991	Taj-3	12	214–368	282 ± 14	38–54	47 ± 1.3	12–39	25 ± 2.6
	Taj 11 + 12	41	194–343	279 ± 5	36–58	46 ± 0.6	11–41	27 ± 1.1
	Taj-11	19	246–324	287 ± 5	36–55	46 ± 0.9	15–41	27 ± 1.8
	Taj-12	22	194–343	272 ± 8	43–58	47 ± 0.7	11–41	26 ± 1.5

Systematic paleontology

Class Globothalamia Pawlowski, Holzmann, and Tyszka, 2013

Order Rotaliida Delage and Hérouard, 1896

Family Nummulitidae de Blainville, 1827

Genus *Nummulites* Lamarck, 1801

Type species.—*Camerina laevigata* Bruguière, 1792, Paris Basin, France (Bruguière, 1792, p. 395; Schaub, 1981, op. cit. pl. 60, figs. 40, 42–44).

Remarks.—Two diagnostic features for the identification of *Nummulites* are surface characteristics and the internal morphology of the equatorial section. The measurements are based on Drooger et al. (1971) and Less (1999) on 53 and 91 megalospheric specimens of two different species of *Nummulites*, respectively (Table 1; Fig. 5.1). The identified species are *Nummulites bormidiensis* (reticulate forms) and *N. kecskemetii* (radiate forms). Figure 6 shows the distribution of the reticulate *Nummulites* populations on the P-L bivariate plot, which fit very well to the *Nummulites bormidiensis* field. Populations of Western Tethys Oligocene reticulate *Nummulites* investigated by Özcan et al. (2009a, 2010a) and Less et al. (2018) are also shown on the figure for comparison. Statistical results of all measured parameters and their description are summarized in Table 1. *Nummulites bormidiensis* belongs to the *Nummulites fabianii* (Prever in Fabiani, 1905) lineage (Less et al., 2018), which has been revised and subdivided to different species (Table 2) by Özcan et al. (2009a, 2010a, 2010b) and Less et al. (2011, 2018). The type species was described based on material from several European localities.

Nummulites bormidiensis Tellini, 1888

Figures 8, 9

1888 *Nummulites intermedia* var. *bormiensis* n. var. Tellini, p. 219, pl. 8, figs. 14a, 14b, 15, 17.

1970 *Nummulites intermedia* var. *bormiensis*; Roveda, p. 274, pl. 24, figs. 5, 6, 63, 64.

1981 *Nummulites sublaevigatus*; Schaub, p. 130, pl. 50, figs. 19–22; pl. 54, figs. 1–5.

2018 *Nummulites bormidiensis*; Less et al., p. 197, figs. 9/8–27 (with synonymy).

Holotype.—Dego, Costalupara, Oligocene of Ligurian Alps, NW Italy (Tellini, 1888, p. 219, pl. 8, figs. 14a, 14b, 15, 17).

Materials.—Populations of megalospheric forms include samples Taj-3, Taj-11, and Taj-12 (Table 1). Microspheric forms were not detected.

Remarks.—According to Özcan et al. (2009a) reticulate *Nummulites* with the mean value of proloculus diameter >300 μm belong to *N. bormidiensis*, which is characteristic for the early Chattian SBZ 22B zone, in contrast to *N. fichteli* Michelotti, 1841, with considerably smaller proloculus and occurring in the Rupelian SBZ 21 and 22A Zones (Fig. 6). Morphometric parameters of the Tajar-Kuh populations are very similar to each other, and fit very well with those of the *N. bormidiensis* populations from Italy, Turkey, and Kutch (India) (Fig. 6; Tables 1, 2). In addition, the histogram of the inner cross diameter of the proloculus (parameter P) from

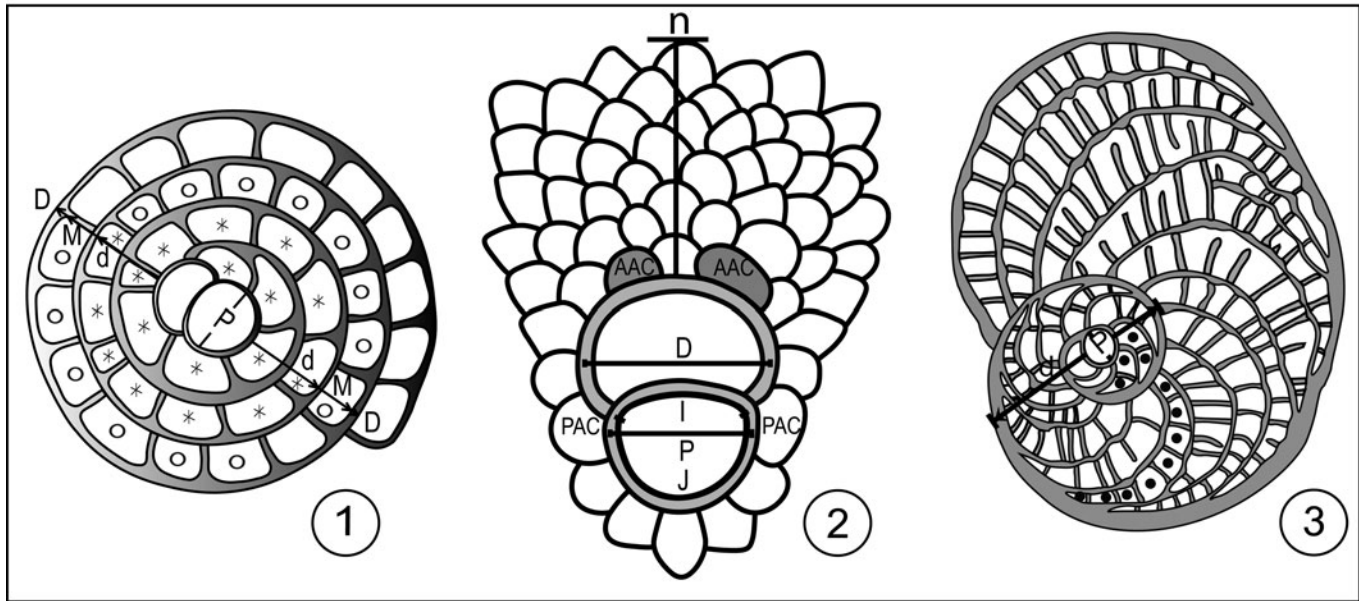


Figure 5. The methods of measurement and calculation parameters of the internal structure in equatorial plane for megalospheric larger foraminifera (most of the parameters are explained in the headers of Tables 1 and 3); P = proloculus. (1) *Nummulites* (D and M: outer and inner diameter of the third whorl; E (number of chambers in the first two whorls labeled by asterisk, E = 17); N (number of chambers in the third whorl labeled by circle, N = 15); (2) *Nephrolepidina* (PAC = Principal Auxiliary Chamberlets (parameter C); AAC = Adauxiliary Chamberlets = 2; I and J: inner perimeter of the protoconch embraced; and n: number of annuli within 1 mm from the deuteroconch along the axis of the embryo); (3) *Spiroclypeus*, d: outer diameter of one and a half whorls; X = number of undivided chambers; S4 + 5 = total number of chamberlets in chambers 4 and 5; S14 = total number of chamberlets in chamber 14; in this figure X = 1, S4 + 5 = 4, S14 = 8 (number of chamberlets indicated by solid dots).

Taj-11 + 12 populations (Fig. 7) shows a distribution close to unimodal, which indicates the presence of a single species in these populations. We could not find any indications for reticulate *Nummulites* other than *N. bormidiensis* from the Tajar-Kuh section (see Fig. 6 and Table 1), in contrast with Kutch (W India) from where Less et al. (2018) reported a population (from sample Kharai 4) with extremely large proloculus and sometimes with unusual shape (Sengupta, 2000; Sengupta et al., 2011) under the name of *N. aff. bormidiensis*. In this study, both the presence and morphometric parameters of typical *N. bormidiensis* are being reported from Iran for the first time.

Nummulites kecskemetii Less, 1991

Figures 11, 12

- 1991 *Nummulites kecskemetii* Less, p. 439, pl. 1, figs. 1–6; pl. 2, figs. 1–3.
 2009a *Nummulites kecskemetii*; Özcan et al., p. 755, fig. 17.6–17.10. (with synonymy)
 2010a *Nummulites kecskemetii*; Özcan et al., p. 479, pl. 4, figs. 23, 24.
 2018 *Nummulites kecskemetii*; Less et al., p. 199, figs. 10/1–5.
 2019 *Nummulites kecskemetii*; Parente and Less, p. 248, figs. 6A, 6B.

Holotype.—Csókás, Upper Oligocene of Bükk Mountains, NE Hungary, (Less, 1991, p. 439–441, pl. 1, figs. 1–6; pl. 2, figs. 1–3).

Description.—*Nummulites kecskemetii* is characterized by a very small proloculus with a mean value between 66–95 µm in Tajar-Kuh. It has curved septa, open and loose spire, narrow and high chambers, and the maximum number of whorls is usually 2–2.5 whorls. This species is the youngest representative of the Tethyan radiate *Nummulites*, known only from the Chattian (SBZ 22B and 23 zones). According to Less et al. (2018), the identification of *Nummulites kecskemetii* is not problematic and can easily be distinguished from co-occurring forms; also, it does not show evolutionary changes through the Chattian. Therefore, no morphometric study is necessary for this species. However, for the first time, two parameters on 91 megalospheric specimens were measured and presented from Iran (Table 1). These data also do not reflect any development of *N. kecskemetii* along the lower part of the Tajar-Kuh section.

Materials.—This species is recorded from all morphometrically studied Tajar-Kuh samples (Table 1). Microspheric forms were not recorded.

Remarks.—*Nummulites kecskemetii* is regarded as an immigrant from the Western Hemisphere (Less, 1991; Less et al., 2018). It was reported from Kutch (West India) as *Operculina complanata* by Biswas (1992) and Reuter et al. (2013). However, these two genera can be easily separated based on the vertical section (see above), and by the mean inner diameter of the proloculus for *O. complanata*, which is 100–250 µm. Histogram of the inner cross-diameter of proloculus (parameter P) from Taj-3 population (Fig. 10) does

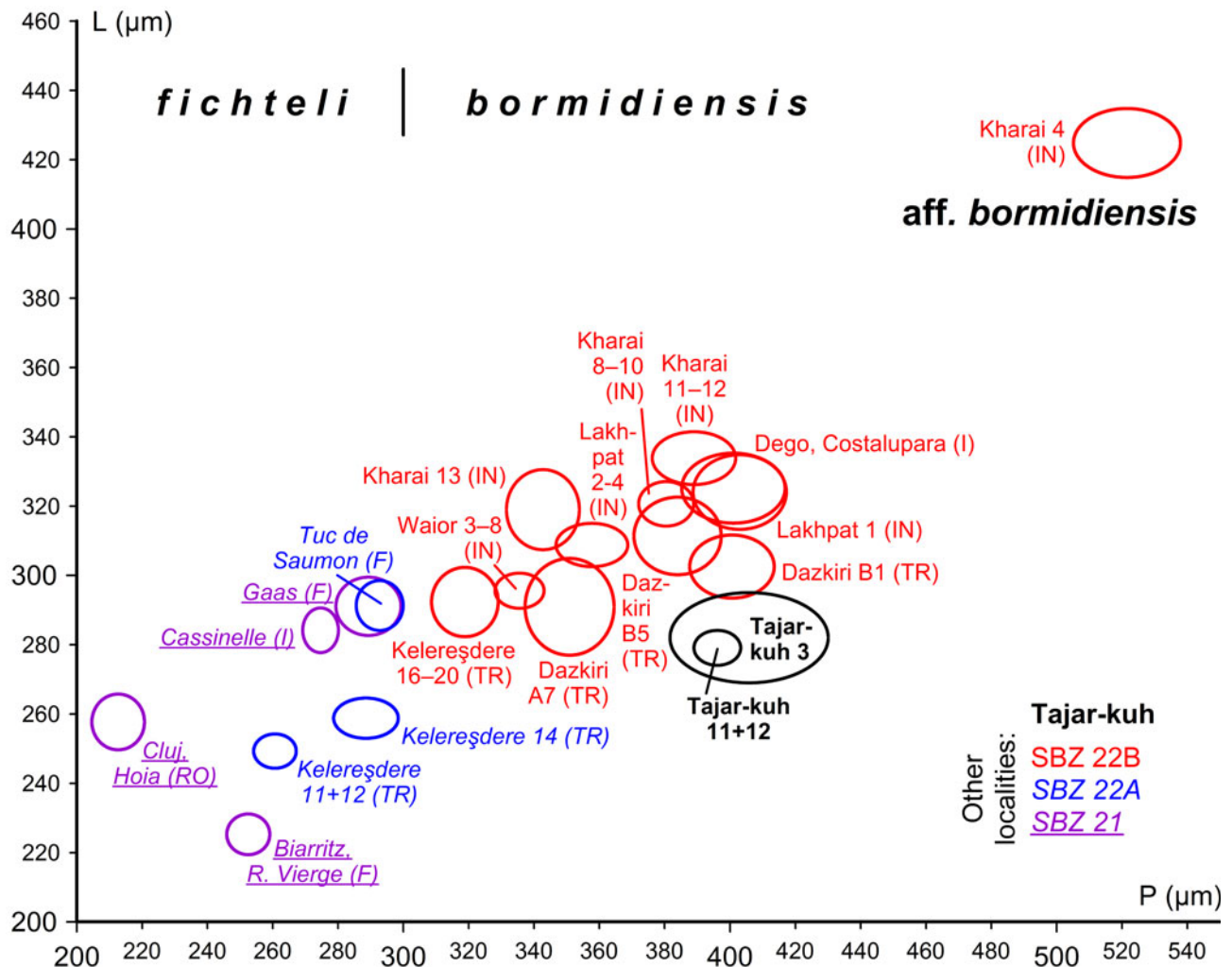


Figure 6. Bivariate P-L plot (proloculus diameter vs. chamber length in the third whorl) (mean values at the 68% confidence level) for Oligocene reticulate *Nummulites* populations from Tajar-Kuh (for statistical results see Table 1) and some other Tethyan localities (for numerical and source data, see Less et al., 2018).

Table 2. Subdivision of the *Nummulites fabianii*-lineage in the Bartonian to early Chattian time-span (Özcan et al., 2010b modified by Less et al., 2018).

Taxon	P mean (μm)	Surface	Stage	SBZ zone
<i>N. bullatus</i>	65–100	Granules, no reticulation	Late Lutetian to basal Bartonian	SBZ 16 to early SBZ 17
<i>N. garganicus</i>	100–140	Heavy granules + reticulation	Early to middle late Bartonian	Late SB 17 to SBZ 18B
<i>N. hormoensis</i>	140–200	Heavy granules + umbo + reticulation	Late Bartonian	SBZ 18
<i>N. fabiani</i>	200–300	Weak granules + umbo + heavy reticulation	Priabonian to early Rupelian	SBZ 19–20
<i>N. fichteli</i>	200–300	Weak reticulation to irregular mesh	Late Priabonian to late Rupelian	SBZ 21–22A
<i>N. bormidiensis</i>	300	Irregular mesh	Early Chattian	SBZ 22B

not suggest the presence of two different taxa. Also, for many years (until Less, 1999 separated them from each other), this species was determined as *Nummulites bouillei* de la Harpe, 1879 (Butt, 1966; Cahuzac and Poignant, 1997). The difference between *N. kecskemetti* and *N. bouillei* is shown on Figure 19 in Özcan et al. (2009a).

The occurrence of *N. kecskemetti* in Tajar-Kuh section is unique, because it occurs with *N. bormidiensis*, *Heterostegina assilinoidea*, and *Planolinderina* sp., which indicates the early Chattian SBZ 22B Zone. On the other hand, it is accompanied with *Eulepidina formosoides*, which has so far been known from the late Rupelian SBZ 22A Zone. This contradiction is discussed in detail later where we describe *Eulepidina*

formosoides. Here, we only predict that at least the lower six Tajar-Kuh samples belong most likely to the basal part of the Chattian, thus the presence of *N. kecskemetti* in these samples is very probably one of the oldest occurrences of this taxon in the Tethys.

Genus *Heterostegina* d'Orbigny, 1826

Type species.—*Heterostegina depressa* d'Orbigny, 1826, St. Helena Island, South Atlantic Ocean (d'Orbigny, 1826, p. 305, pl. 17, figs. 5–7).

Remarks.—A detailed review of the representatives of this genus from the Tethyan Oligocene can be found in Less et al.

Table 3. Statistical data of the Oligocene lepidocyclinid populations from the Tajar-Kuth section, Central Iran (N: number of specimens and s.e.: standard error).

Parameters	Medium cross-diameter of the embryonic chambers			Degree of embracement of the protoconch by the deuteroconch			Number of the adauxiliary chambers (AAC)			Number of annuli in 1 mm from the embryo's rim					
	P(μm)			D(μm)			A = 100x/(l+j)			C			n		
	Range	Mean ± s.e	No.	Range	Mean ± s.e.	No.	Range	Mean ± s.e.	No.	Range	Mean ± s.e.	No.	Range	Mean ± s.e.	No.
<i>Nephrolepidina praemarginata</i> (R. Douville, 1908)	Taj-3	130–240	172 ± 4.5	32	170–340	232 ± 6.0	29–42	36 ± 0.60	1–3	2 ± 0.12	26–32	30 ± 0.35			
	Taj-11–14	100–270	173 ± 5.9	33	160–370	240 ± 7.5	32–42	38 ± 0.43	1–4	2 ± 0.11	26–36	31 ± 0.48			
	Taj-11	140–210	173 ± 7.2	10	200–300	247 ± 8.2	36–41	39 ± 0.54	2–4	3 ± 0.20	26–34	30 ± 0.93			
	Taj-12	100–260	167 ± 8.8	16	160–340	231 ± 10.8	32–41	37 ± 0.72	1–3	2 ± 0.13	26–36	31 ± 0.57			
	Taj-14	150–270	187 ± 14.7	7	190–370	251 ± 21.2	35–42	39 ± 0.89	2–4	3 ± 0.22	27–36	31 ± 1.43			
	Taj-21 + 25	130–290	176 ± 5.2	36	140–360	233 ± 6.9	31–42	37 ± 0.42	1–3	2 ± 0.12	22–34	31 ± 0.42			
	Taj-21	130–290	175 ± 5.8	25	140–290	230 ± 6.7	31–41	36 ± 0.51	1–3	2 ± 0.14	28–34	31 ± 0.40			
	Taj-25	140–260	178 ± 10.7	11	200–360	241 ± 16.2	32–42	37 ± 0.76	1–3	2 ± 0.19	22–32	29 ± 1.03			
	Taj-33	140–260	170 ± 13.7	8	180–370	241 ± 19.6	34–44	38 ± 1.18	2–3	2 ± 0.13	28–32	30 ± 0.59			
	<i>Eulepidina formosoides</i> H. Douville, 1925	Taj-3	260–580	408 ± 20	17	550–980	736 ± 23	68–92	79 ± 1.73	12–15	14 ± 0.29				
Taj-11–14		230–660	446 ± 18	31	390–1170	798 ± 28	55–90	77 ± 1.50	12–17	14 ± 0.26					
Taj-11		230–530	370 ± 48	5	550–960	734 ± 61	66–87	81 ± 3.98	14–16	15 ± 0.37					
Taj-12		370–660	496 ± 23	14	670–1170	867 ± 33	55–87	76 ± 1.99	12–15	14 ± 0.32					
Taj-14		250–550	419 ± 25	12	390–1010	744 ± 49	58–90	77 ± 2.83	12–17	14 ± 0.48					
<i>Eulepidina ex. interc. formosoides</i> H. Douville, 1925 et dilatata (Michelotti, 1861)	Taj-21	300–520	403 ± 13	15	640–930	735 ± 22	60–83	71 ± 1.94	13–17	15 ± 0.32					
	Taj-25	500–910	720 ± 97	3	760–1370	1097 ± 146	72–80	76 ± 2.07	12–14	13 ± 0.67					
	Taj-33	360–950	735 ± 112	4	700–1420	1198 ± 145	78–90	86 ± 2.84	12–14	13 ± 0.48					

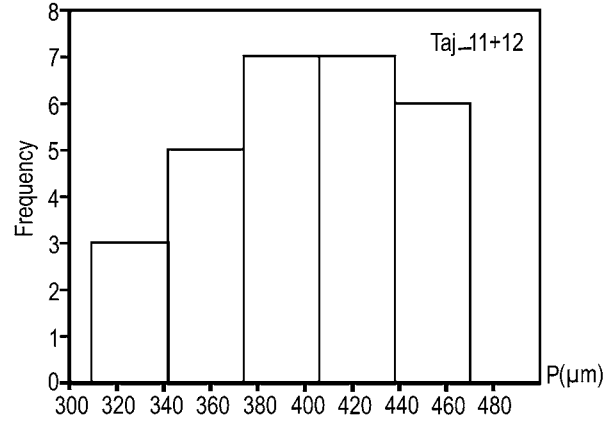


Figure 7. Histogram of the inner cross-diameter of proloculus (P) in the *Nummulites bormidiensis* population from samples Taj-11 + 12.

(2018). Because only a single specimen of *Heterostegina* was found in our material, we could not perform any statistical analysis.

Heterostegina assilinoidea Blanckenhorn, 1890 emend.
Henson 1937
Figure 20.12

1890 *Heterostegina assilinoidea* Blanckenhorn, p. 342, pl. 17, fig. 5 (non figs. 4, 6).

1937 *Heterostegina assilinoidea* emend. Henson, p. 48, pl. 4, figs. 1–5, pl. 6, fig. 2, tables 1, 2.

2018 *Heterostegina assilinoidea* Less et al., p. 200–201, figs. 10.6–10.13 (with synonymy).

2019 *Heterostegina assilinoidea* Parente and Less, p. 249, fig. 6E–6L.

Holotype.—Stunden, east of Aintab, Turkish Syria (Blanckenhorn, 1890, p. 342, pl. 17, fig. 5).

Description.—This involute species is recently described in detail in Less et al. (2018) and in Parente and Less (2019). Based on the measurement and parameter system introduced by Drooger and Roelofsen (1982) and updated by Less and Özcan (2008) (Fig. 5.3), morphometric data of our one single specimen are as follows:

- Size of the proloculus (P): 180 μm.
- Number of post-embryonic pre-hetero-steginid (X): 1.
- Total number of chamberlets in the fourth and fifth chambers (S₄₊₅): 4.
- Number of chamberlets in the fourteenth chamber (S₁₄): 8.
- Outer diameter of the first whorl (d): 1290 μm.
- Index of spiral opening (K): 45.

All the measurements well fit within the variations of *H. assilinoidea* reported by Less et al. (2018).

Materials.—This taxon has only been recorded from sample Taj-3 (one megalospheric specimen).

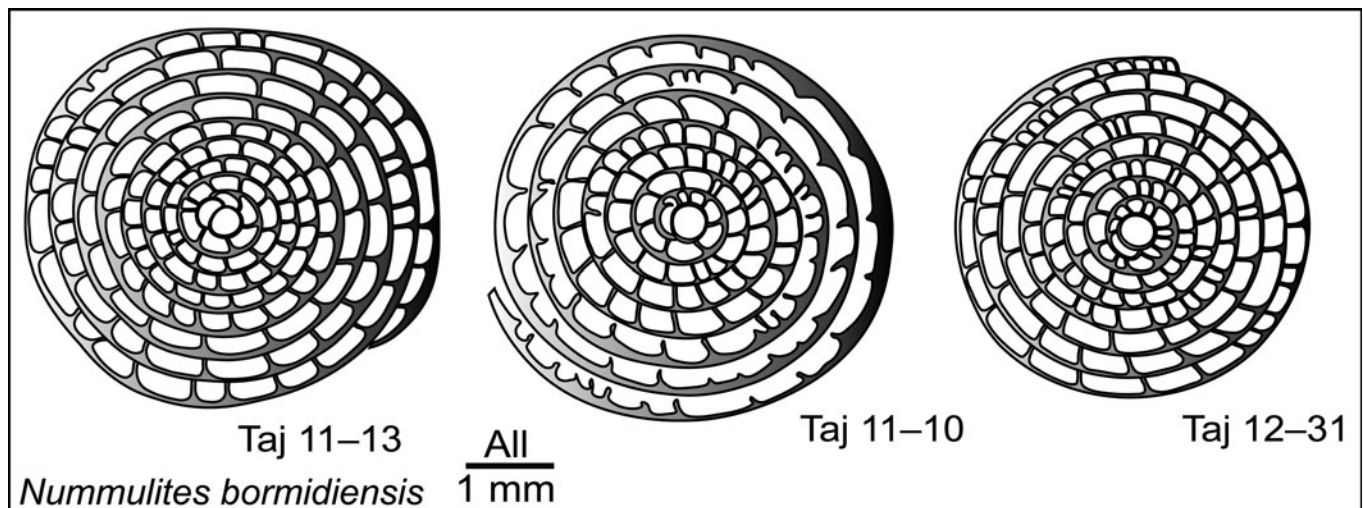


Figure 8. Drawing view of embryonic-nepionic alignment in *Nummulites bormidiensis* from two populations in the Tajar-Kuh section.

Remarks.—We found only one specimen of *Heterostegina assilinooides*.

Family Lepidocyclinidae Scheffen, 1932

Genus *Nephrolepidina* H. Douvillé, 1911

Type species.—*Nummulites marginata* Michelotti, 1841, Turbin, Italy (Michelotti, 1841, p. 253–302, pl. 3, figs. 4a–b).

Remarks.—This genus has been widely reported from both the Mediterranean (e.g., Douvillé, 1925; Lange, 1968; de Mulder, 1975; Less, 1991; Özcan et al., 2009a, 2010a) and Western Pacific (e.g., van der Vlerk, 1928; Scheffen, 1932; Caudri, 1939; van Vessel, 1978) provinces. Based mainly on de Mulder's (1975) and van Vessel's (1978) data, Drooger (1993) concluded that this genus shows a different path of evolution between the two provinces. Similarly to Kutch (Western India, Less et al., 2018) we found that the Tajar-Kuh populations of *Nephrolepidina* rather belong to the Western Tethyan (Mediterranean) province. The main *Nephrolepidina* lineage from the Mediterranean was subdivided by de Mulder (1975) based on the parameters A and C into three species:

N. praemarginata $1 < C_{\text{mean}} \leq 3$ and $35 < A_{\text{mean}} < 40$
N. morgani $3 < C_{\text{mean}} \leq 5.25$ and $40 \leq A_{\text{mean}} < 45$
N. tournoueri $C_{\text{mean}} > 5.25$ and $A_{\text{mean}} \geq 45$

The stratigraphic range of *N. praemarginata* is late Rupelian to early Chattian and defines the SBZ 22 Zone. However, *N. morgani* (Lemoine and Douvillé, 1904) and *N. tournoueri* (Lemoine and Douvillé, 1904) have a long-range overlap with each other. *Nephrolepidina morgani* is specific from the late Chattian to early Burdigalian, SBZ 23 to the basal part of SBZ 25, while *N. tournoueri* spans the latest Aquitanian to late Burdigalian, latest SBZ 24 to SBZ 25. The morphometrical data for *Nephrolepidina*

populations from the Tajar-Kuh section correspond to *N. praemarginata* of the Western Tethyan lineage, according to the above categorization (Fig. 13; Table 3).

Nephrolepidina praemarginata (R. Douvillé, 1908)

Figures 15, 16

1908 *Lepidocyclina praemarginata* R. Douvillé, p. 91, figures 1, 2, 4a.

1975 *Lepidocyclina (Nephrolepidina) praemarginata*; de Mulder, p. 62, pl. 3, figs. 6–8; pl. 4, figs. 8–11.

2010a *Nephrolepidina praemarginata*; Özcan et al., p. 474, pl. 2, figs. 20–26. (with synonymy)

Holotype.—Lower Oligocene of Dego, Piedmont, Italy (Douvillé, 1908, p. 88–95, figs. 1, 2, 4a).

Diagnosis.—Populations of the *Nephrolepidina praemarginata-morgani-tournoueri* lineage with $1 < C_{\text{mean}} < 3$ and $A_{\text{mean}} < 40$

Materials.—109 equatorial sections of megalospheric specimens from seven samples (Taj–3, Taj–11, Taj–12, Taj–14, Taj–21, Taj–25, and Taj–33).

Remarks.—The presence of this taxon in Iran and its biometric data are reported for the first time here. This species was determined using the biometric results from seven Tajar-Kuh populations (Table 3). The histogram of the medium cross-diameter of the protoconch (parameter P from Taj–3 population (Fig. 14) is clearly unimodal and confirms the presence of a single species. According to Cahuzac and Poignant (1997), the stratigraphic range of *N. praemarginata* is the SBZ 22A and 22B Zones, defining the late Rupelian to early Chattian time-span. However, based on the associated fauna (especially *Nummulites bormidiensis*, *N. kecskemetii*, *Heterostegina assilinooides*, and *Planolinderina* sp.), which are restricted to the Chattian SBZ 22B Zone, the

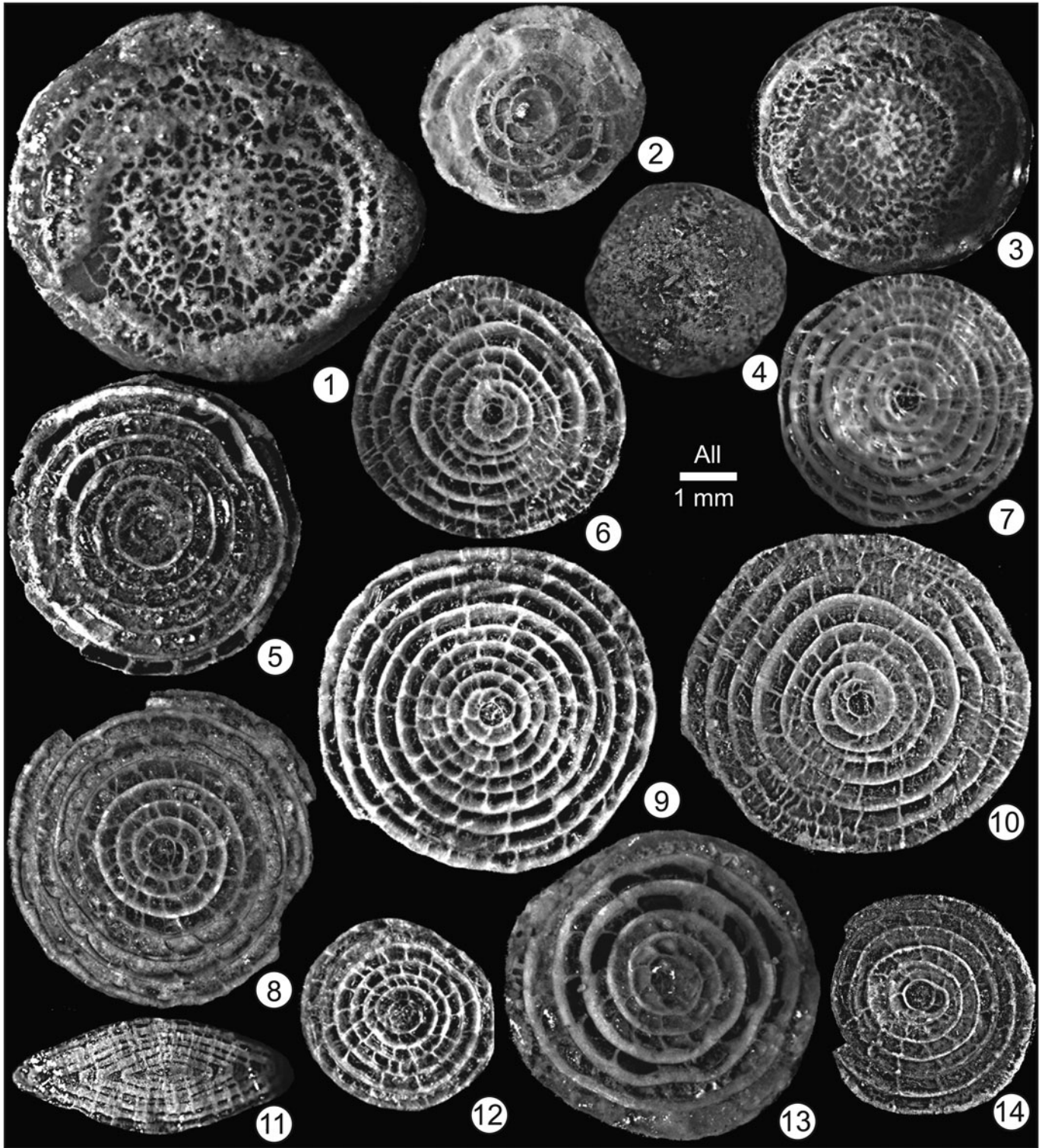


Figure 9. *Nummulites bormidiensis* Tellini, 1888, early Chattian from the Tajar-Kuh section: (1–5, 7, 11, 13) specimen Taj 12 (respectively 12–34, 12–36, 12–35, 12–33, 12–40, 12–31, 12–37, 12–39), (1, 3, 4) external view, (2, 5, 7, 13) equatorial view, (11) vertical view; (6, 8–10, 12) specimen Taj 11 (respectively 11–1, 11–10, 11–21, 11–8, 11–13), all equatorial view; (14) specimen Taj 3 (3–7), equatorial view.

Tajar-Kuh populations rather indicate this age. Moreover, the simultaneous presence of *Eulepidina formosoides* confirms that the lower six samples represent the lowest part of the SBZ 22B Zone.

Genus *Eulepidina* H. Douvillé, 1911

Type species.—*Orbitoides dilatata* Michelotti, 1861, Piedmont, north Italy (Michelotti, 1861, p. 1–83, pl. 1, figs. 1–2).

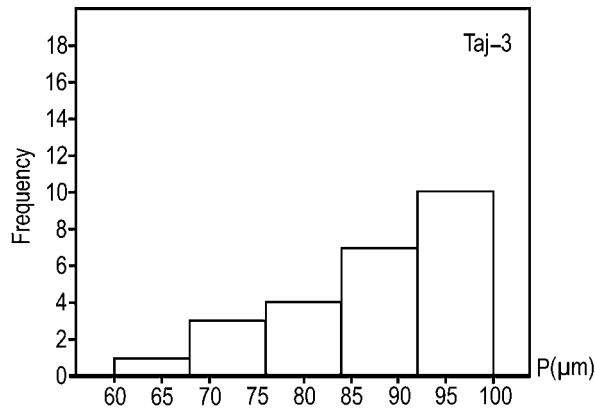


Figure 10. Histogram of the inner cross-diameter of the proloculus (P) in the *Nummulites kecskemettii* population from sample Taj-3.

Remarks.—As discussed in detail in Less et al. (2018), the Oligocene representatives of this genus from Spain to Western India (Kutch) belong most likely to the Western Tethyan bioprovince, where *Eulepidina* is better documented than from the Western Pacific bioprovince. Three Oligocene lineages are distinguished, with two of them (*Eulepidina anatolica* and *E. elephantina*) known only from the uppermost Oligocene. The main *E. formosoides-dilatata* lineage (introduced by Drooger, 1993) spans the late Rupelian to the late Chattian (Parente and Less, 2019). Özcan et al. (2009a, 2010a) proposed $A_{\text{mean}} = 83$ and $D_{\text{mean}} = 1250 \mu\text{m}$ to delimit the two successive species of the lineage from each other. However,

based on the study of populations of *Eulepidina* from Kutch (India), Less et al. (2018) proposed that these morphometric limits should be later reconsidered, but no new values have been proposed yet.

Based on the currently accepted boundaries, our morphometrical data of *Eulepidina* (Table 3; Fig. 17) from the lower six samples of the Tajar-Kuh section indicate (provided they belong to Western Tethyan lineage) *E. formosoides*, while the parameters of the uppermost population from sample Taj-33 already suggest transitional *Eulepidina* ex. interc. *formosoides* et *dilatata*.

Eulepidina formosoides Douvillé, 1925
Figures 19, 20.1–20.11, 20.13–20.14

1925 *Lepidocyclina* (*Eulepidina*) *formosoides*; Douvillé, p. 75, pl. 3, figs. 2–4.

2010a *Eulepidina formosoides*; Özcan et al., p. 476, pl. 3, figs. 1–8. (with synonymy)

Holotype.—Lower Oligocene of Santander, Spain (Douvillé, 1925, p. 75, pl. 3, figs. 2–4).

Diagnosis.—Populations of *Eulepidina* with $D_{\text{mean}} < 1250 \mu\text{m}$ and $A_{\text{mean}} < 83$.

Materials.—Sixty-four equatorial sections of megalospheric specimens from all samples (Taj-3, Taj-11, Taj-12, Taj-14, Taj-21, and Taj-25).

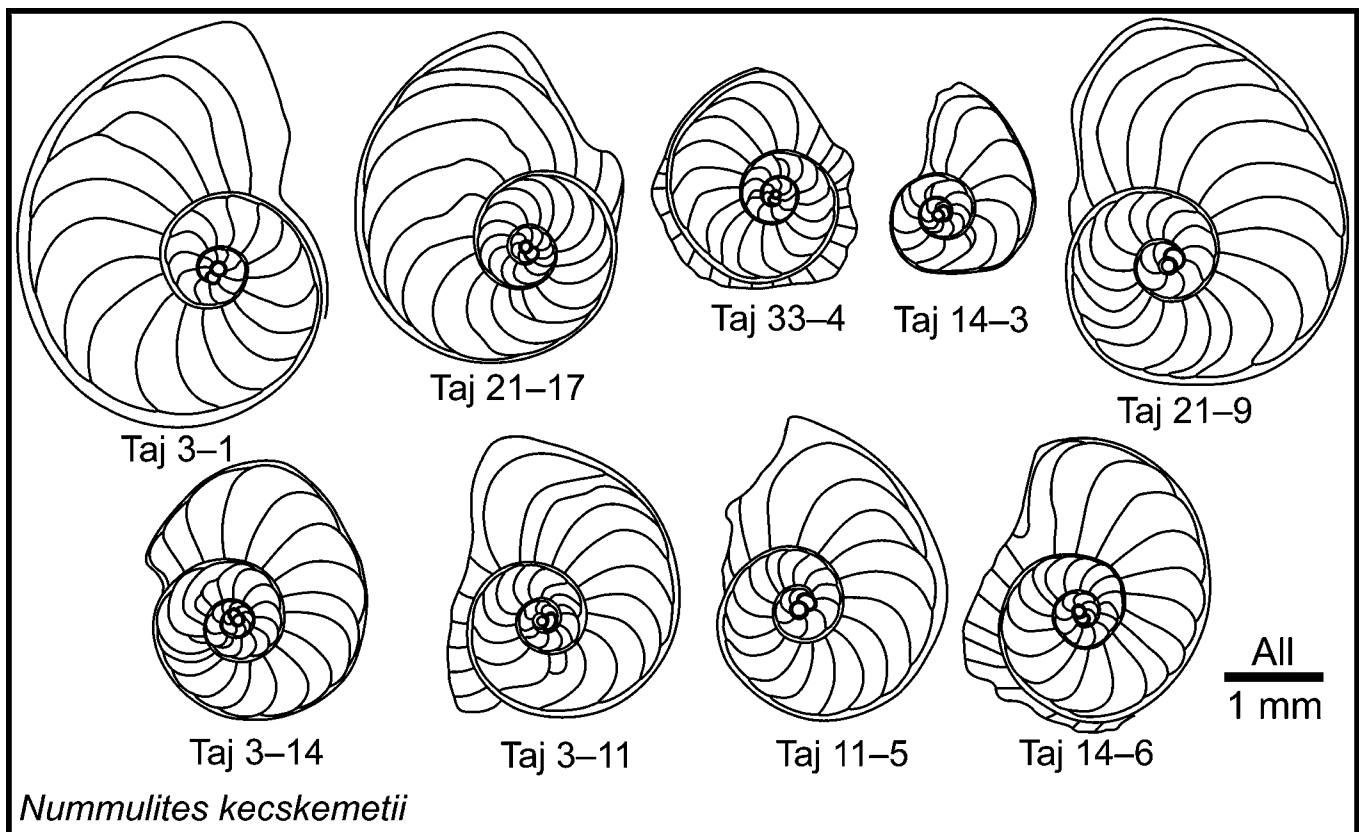


Figure 11. Drawing view of embryonic-nepionic alignment in *Nummulites kecskemettii* from five populations in the Tajar-Kuh section. scale bar = 1 mm.

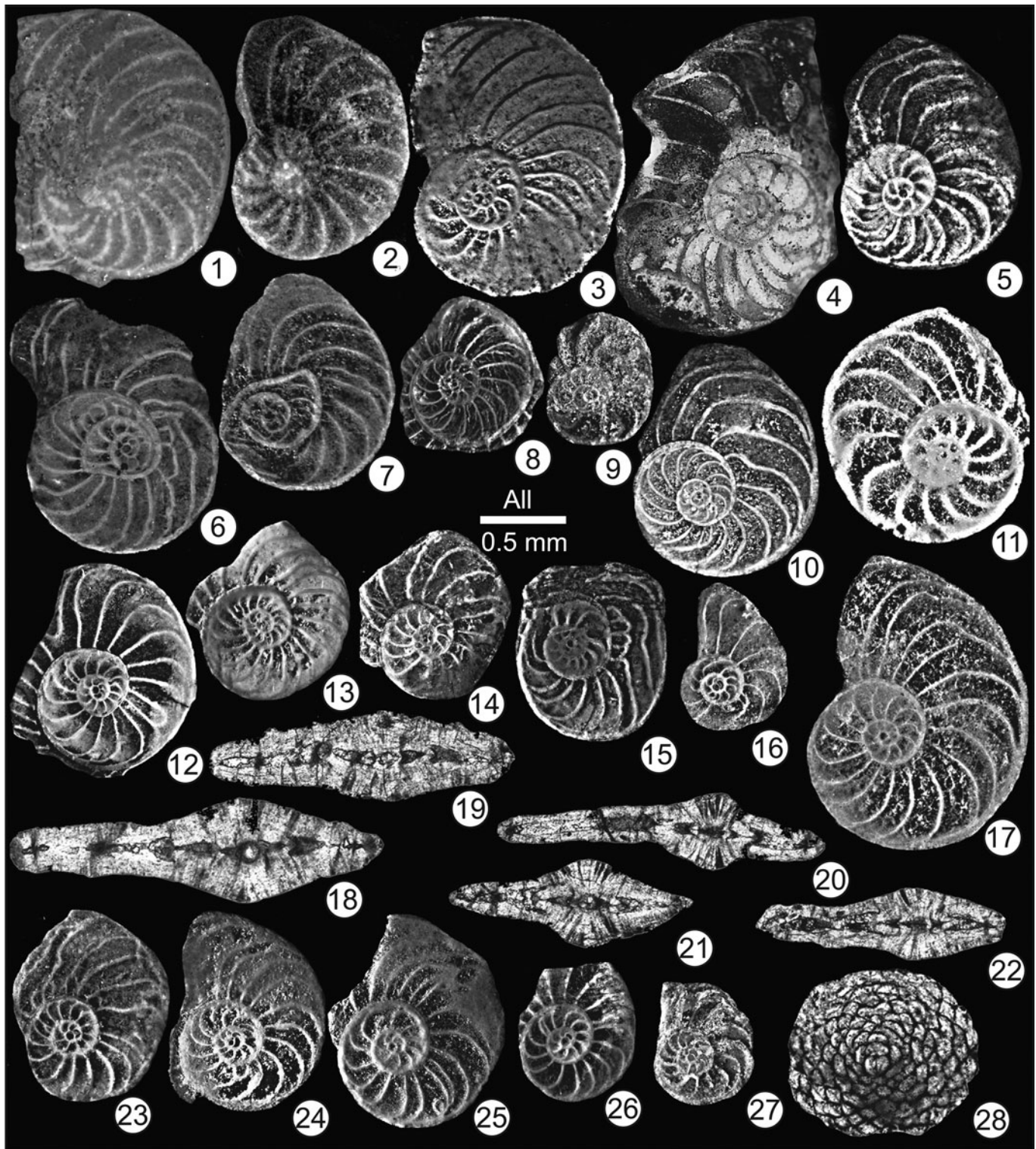


Figure 12. *Nummulites kecskemetti* Less, 1991, early Chattian from the basal Tajar-Kuh section: (1–3, 6, 7, 11, 17, 24, 25, 27) specimen Taj 3 (respectively 3–43, 3–42, 3–29, 3–25, 3–34, 3–2, 3–1, 3–11, 3–18, 3–39), (1, 2) external view; (3, 6, 7, 11, 17, 24, 25, 27) equatorial view; (5, 9, 10) specimen Taj 21 (respectively 21–9, 21–30, 21–17), all equatorial view; (4, 8) specimen Taj 33 (33–8, 33–4), equatorial view; (12, 16, 23, 26) specimen Taj 14 (respectively 14–6, 14–3, 14–10, 14–5), equatorial view; (13–15) specimen Taj 12 (respectively 12–1, 12–2, 12–5), equatorial view; (18, 19) specimen Taj 12 (random thin section), vertical view; (20–22) specimen Taj 25 (random thin section), vertical view; (28) *Planolinderina* sp. from the Tajar-Kuh section, specimen Taj 33 (33–1), equatorial view.

Remarks.—The presence of this taxon in Iran and its biometric data are reported for the first time here. This species is very abundant in the base of the Tajar-Kuh

section. It was precisely determined by the results of the biometric study of six populations (Table 3). The histogram of the medium cross-diameter of the protoconch

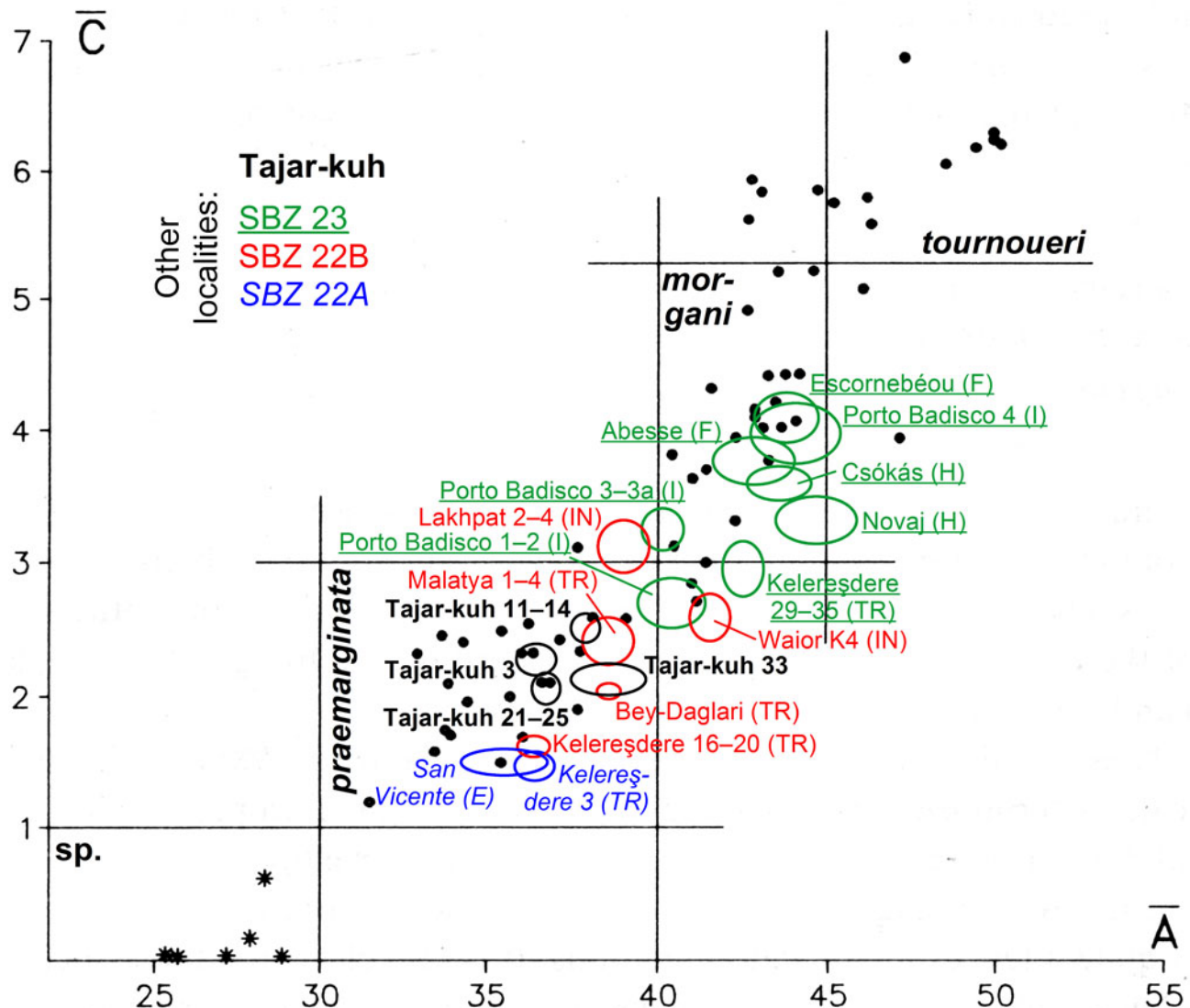


Figure 13. $A_{\text{mean}}-C_{\text{mean}}$ (mean of the degree of embracement of the protoconch by the deutoconch vs. mean of the number of adauxiliary chambers) bivariate plot for Western and Central Tethyan nephrolepinid populations; the populations from Tajar-Kuh and some other localities are represented with ellipses, giving the mean values at the 68% confidence level (for numerical and source data see Parente and Less, 2019). The mean values for the nephrolepinid populations used by Drooger (1993) to illustrate the *N. praemarginata-tournoueri* lineage are marked by dots, while the mean values for populations of *Lepidocyclus* sp. of Freudenthal (1972) are marked by asterisks.

(parameter P) from Taj-11-14 populations (Fig. 18) is unimodal, indicating the presence of a single species. According to Cahuzac and Poignant (1997), the stratigraphic range of *Eulepidina formosoides* is late Rupelian and marks the SBZ 22A Zone. This range is based, however, on data exclusively from the Western Tethys (Spain, SW France, and Turkey). In the more eastern part of the Tethys, in Kutch (Western India), the transitional *E. formosoides-dilatata* have been reported already from the early Chattian SBZ 22B Zone in association with *Nummulites bormidiensis* and *N. kecskemetii*, and above the occurrences of *Heterostegina assilinooides* (Less et al., 2018).

In the lower part of the Tajar-Kuh section, the situation is quite similar with Kutch, because here *Eulepidina formosoides* co-occurs with *Nummulites bormidiensis*, *N. kecskemetii*, and *Heterostegina assilinooides*, known from the early Chattian

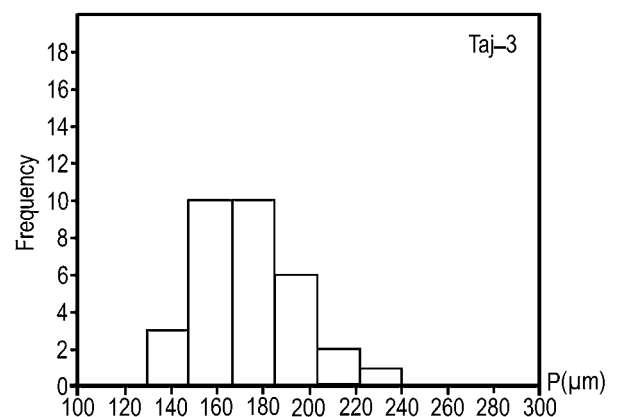


Figure 14. Histogram of the medium cross-diameter of the protoconch (P) in the *Nephrolepidina* population from sample Taj-3.

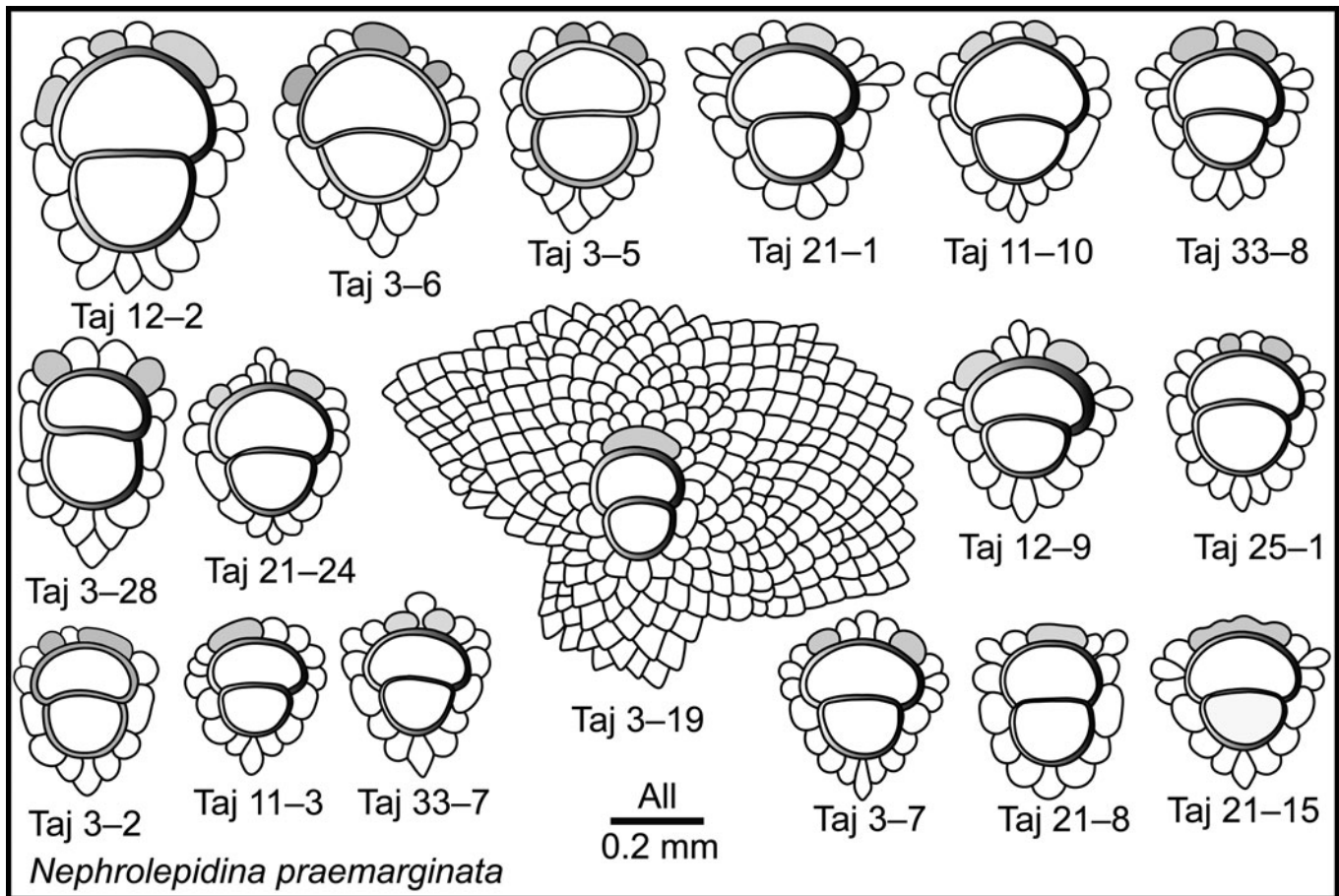


Figure 15. Drawing view of the embryonic-nepionic alignment in *Nephrolepidina praemarginata* from several *Nephrolepidina* populations in the Tajar-Kuh section.

SBZ 22B Zone. Most probably, the representatives of the *Eulepidina formosoides-dilatata* lineage in the central part of the Tethys (Kutch and most of the recent Iranian territories) could be somewhat separated from those in the Western Tethys, and their evolution could be somewhat slower. Thus, the transition of *E. formosoides* to *E. dilatata* in the central Tethys happened most probably later than in the western part. Therefore, considering the associated LBF fauna, the occurrence of *Eulepidina formosoides* in Tajar-Kuh indicates most likely the basal part of the Chattian SBZ 22B Zone. It is worth mentioning that the population from sample Taj-25 is already somewhat more developed than those from the lower five samples (Taj-3 to Taj-21) and, following this trend, the uppermost population from sample Taj-33 is already transitional between *E. formosoides* and *E. dilatata*.

Eulepidina ex. interc. *formosoides* H. Douvillé, 1925 et *dilatata* (Michelotti, 1861)
Figure 20.15–20.17

2018 *Eulepidina* ex. interc. *formosoides* H. Douvillé, 1925 et *dilatata* (Michelotti, 1861) Less et al., p. 203, figures 14/1–6.

Materials.—This taxon has only been recorded from sample Taj-33 (4 specimens).

Remarks.—Based on Table 3 and Figure 17, the *Eulepidina* population from sample Taj-33 is intermediate between *E. formosoides* and *E. dilatata*, although somewhat closer to the former. According to Figure 17, populations with similar morphometric parameters can be found both in the late Rupelian SBZ 22A Zone from Kelereşdere (Eastern Turkey) and in the early Chattian SBZ 22B zone of Kutch (Western India). Based on the associated *Nummulites kecskemetii* and especially *Planolinderina* sp., the Tajar-Kuh occurrence of these forms is attributed to the early Chattian SBZ 22B Zone.

Discussion

The main fossil components of the early Chattian of the Tajar-Kuh section are larger benthic foraminifera (LBF) consisting of lepidocyclinids and nummulitids that are present in different levels of the sequence. *Nummulites bormidiensis* was recorded in three samples (Taj-3, Taj-11, and Taj-12) (Fig. 21), which are organized into two populations for statistical analysis (Table 1).

Nummulites kecskemetii was recovered from all the samples throughout the stratigraphic column. Rare nummulitids with secondary chamberlets, *Heterostegina assilinoidea*,

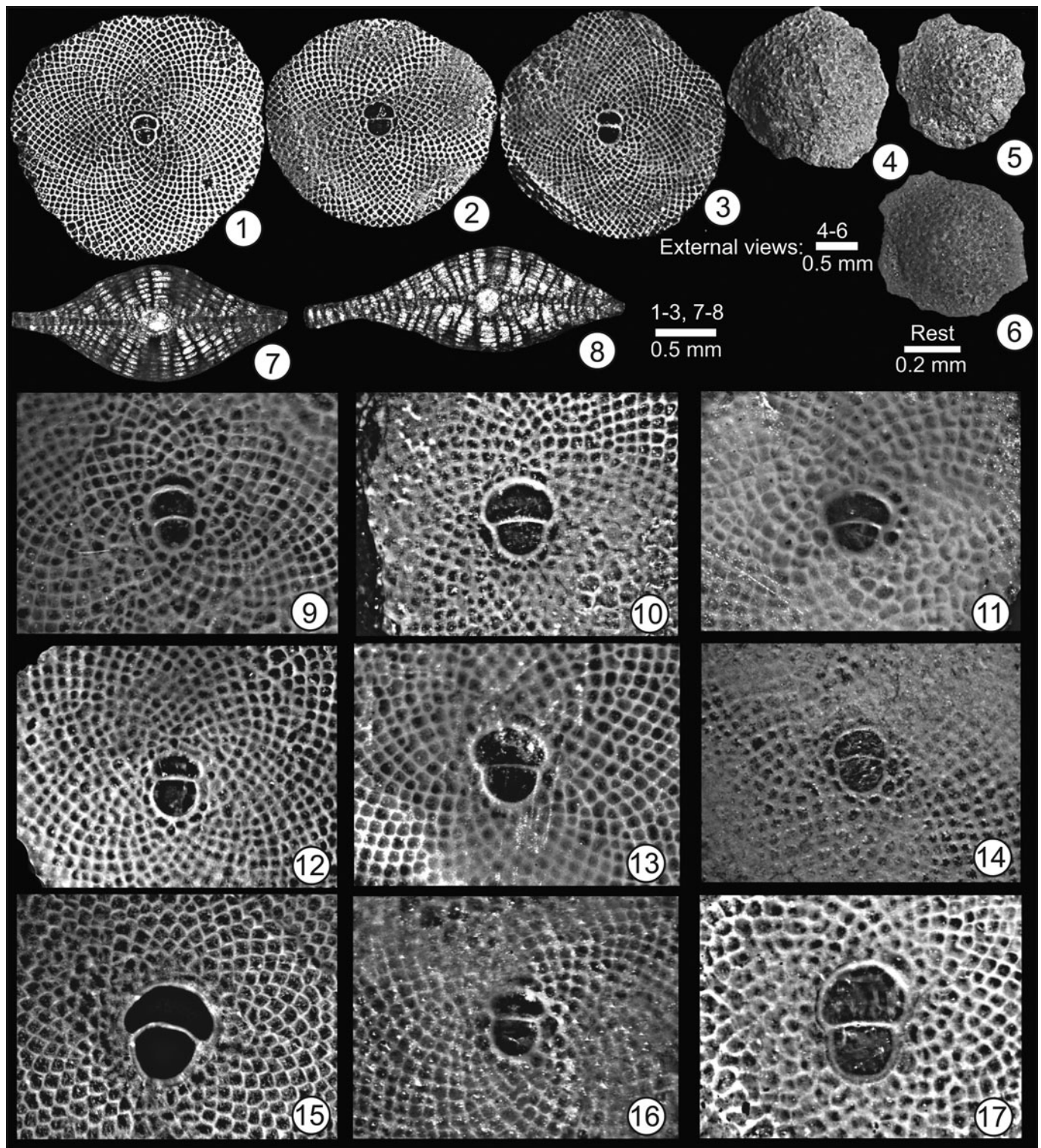


Figure 16. *Nephrolepidina praemarginata* (R. Douvillé, 1908) from the Tajar-Kuh section. (1–3, 9, 10, 14) Specimen Taj 3 (respectively 3–2, 3–5, 3–28, 3–19, 3–24, 3–20), equatorial view; (4–6) specimen Taj 21 (respectively 21–27, 21–28, 21–29), external view; (7, 8) specimen Taj 30 (random thin section), vertical view; (11) specimen Taj 12 (12–9), equatorial view; (12, 13) specimen Taj 21 (21–5, 21–7), equatorial view; (15–17) specimen Taj 25 (25–2, 25–4, 25–5), equatorial view; (1–8). Scale bars as indicated on figure.

were recorded in sample Taj–3. Similar to that of Kutch, Western India (Less et al., 2018), an important feature of the LBF fauna is the absence of *Operculina complanata*, which is widespread in the co-eval assemblages of the

Western Tethys from Spain to Eastern Turkey (Less, 1991; Cahuzac and Poignant, 1997; Özcan and Less, 2009, 2010a; Ferrández-Cañadell and Bover-Arnal, 2017; Less et al., 2018; Parente and Less, 2019).

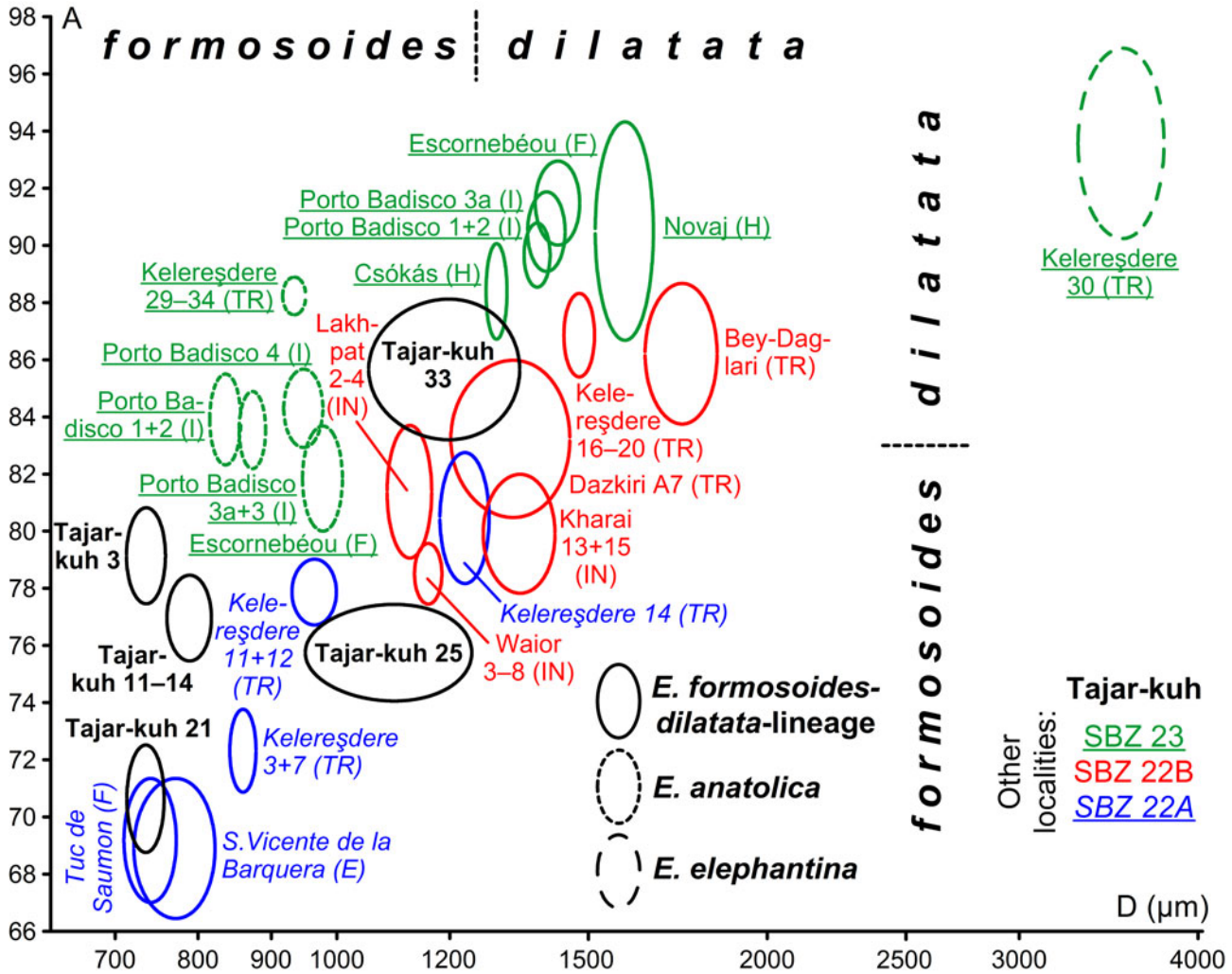


Figure 17. Bivariate D-A plot (medium cross-diameter of the deuteroconch vs. degree of embracement of the protoconch by the deuteroconch; the scale for D is logarithmic) showing mean values at the 68% confidence level for Oligocene *Eulepidina* populations from Tajar-Kuh and some other Western and Central Tethyan localities (see Parente and Less, 2019, for numerical and source data).

Two Western Tethyan lepidocyclinids genera (*Eulepidina* and *Nephrolepidina*) were present in all samples. *Eulepidina* is represented by *Eulepidina formosoides* and the transitional *E. formosoides-dilatata* in the top-most sample Taj-33 (Table 3). *Nephrolepidina* is represented only by *N. praemarginata*, the less advanced species of the main Western Tethyan *N. praemarginata-morgani-tournoueri* lineage (Table 3).

The lowest assemblage in the base of the section in sample Taj-3 contains four taxa (*Eulepidina formosoides*, *Nephrolepidina praemarginata*, *Nummulites bormidiensis*, and *N. kecskemetti*) in reasonable quantity, allowing statistical evaluation of biometrical data, and one single specimen of *Heterostegina assilinoidea* not sufficient for statistical analysis. Concerning the age, *Nummulites bormidiensis* (early Chattian) and *Nummulites kecskemetti* and *Heterostegina assilinoidea* (early to late Chattian) indicate the SBZ 22B zone, while Western Tethyan occurrences of *Eulepidina formosoides* have been reported so far only from the late Rupelian SBZ 22A Zone. The co-occurrence of these forms suggests most likely the basal part of the SBZ 22B Zone, assuming that the *Eulepidina*

formosoides-dilatata lineage developed in the central part of the Tethys (most of Iran and Kutch-Western India, from where

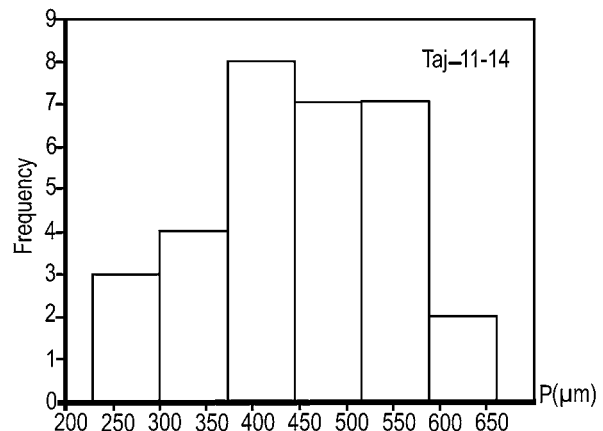


Figure 18. Histogram of the medium cross-diameter of the protoconch (P) in the *Eulepidina* population from sample Taj-11-14.

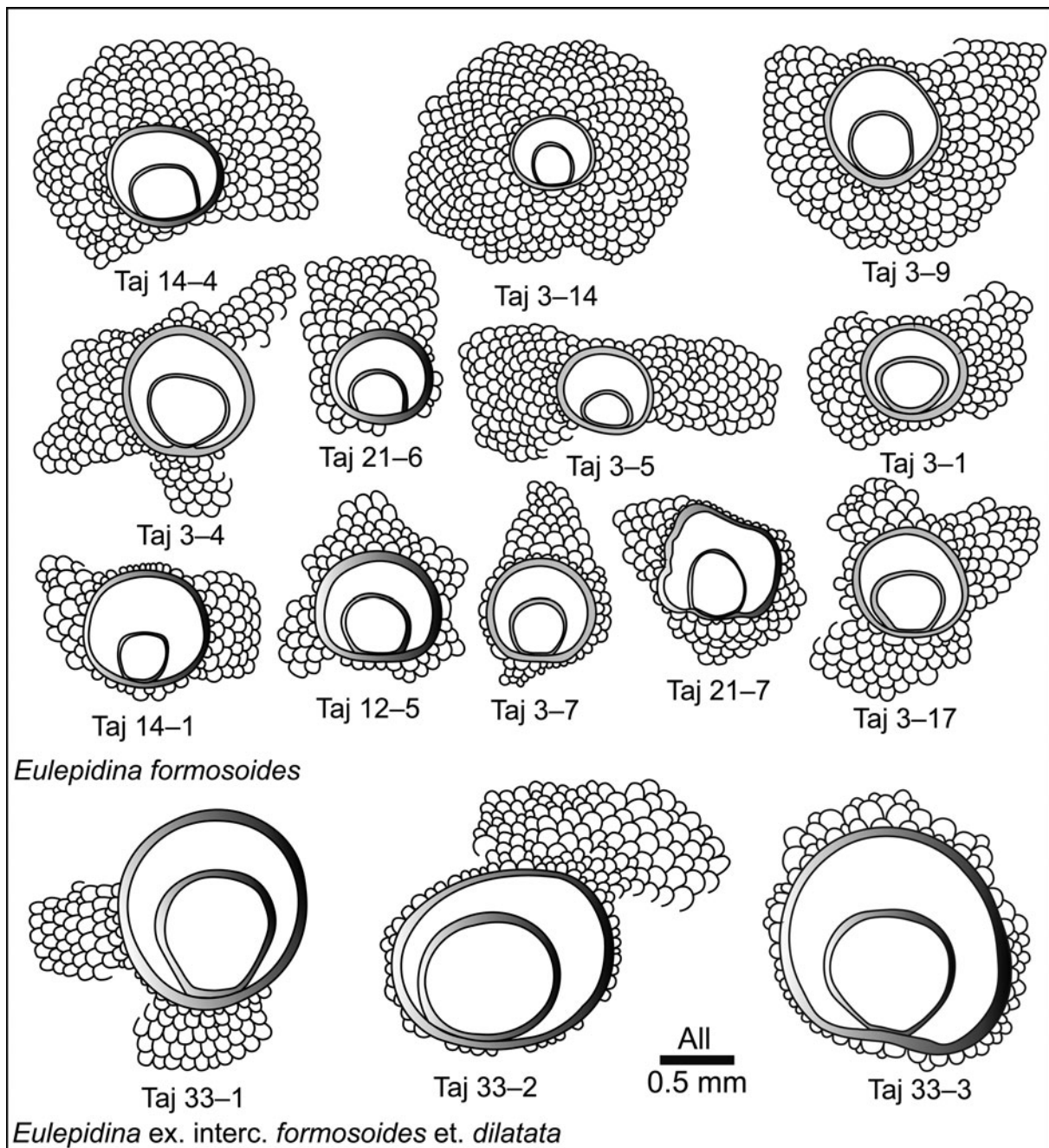


Figure 19. Drawing view of embryonic-nepionic alignment and variation in *Eulepidina formosoides* and *Eulepidina ex. interc. formosoides et. dilatata* from several *Eulepidina* populations in the Tajar-Kuh section.

E. ex. interc. formosoides-dilatata was reported from the SBZ 22B Zone by Less et al., (2018) somewhat slower than in the Western Tethys. Therefore, it is concluded that the transition of *E. formosoides* to *E. dilatata* happened somewhat later in the west.

The composition of the LBF in the overlying levels (samples Taj-11 and Taj-12) is the same as the previous levels, but without *Heterostegina assilinoidea*. So, it is inferred that the age of this part is also basal SBZ 22B. In the overlying strata (samples Taj-14, Taj-21, and Taj-25), *Nummulites bormidienensis* is missing from the assemblages; however, the age of these samples is still basal SBZ 22B.

The uppermost level (sample Taj-33) is characterized by the appearance of the phylogenetically more advanced *Eulepidina ex. interc. formosoides et dilatata*. The lowest appearance of *Planolinderina* sp. is also recorded from this level. This assemblage is already assigned to the main part of the SBZ 22B Zone, corresponding to the early Chattian.

Conclusions

Our study, based on the review of the literature on late Oligocene, LBF shows that the assemblages of the Qom

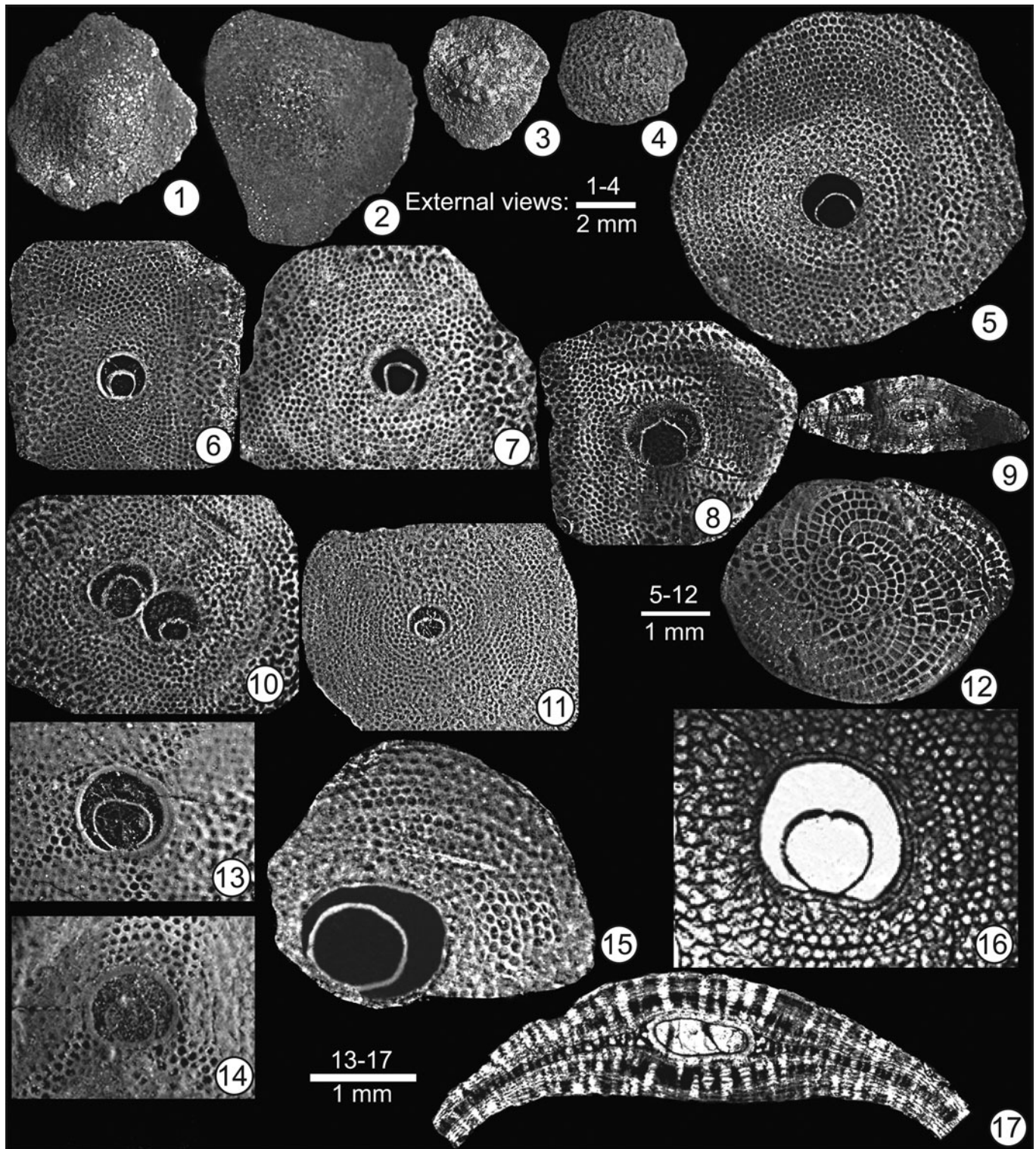


Figure 20. (1–11), (13, 14) *Eulepidina formosoides* Douvillé, 1925, early Chattian from the Tajar-Kuh section: (1, 3, 4) specimen Taj 21 (respectively 21–23, 21–16, 21–15), external view; (5, 7) specimen Taj 14 (respectively 14–4, 14–3), equatorial view; (6, 9, 11) specimen Taj 3 (respectively 3–7, 3–18, 3–1), (6, 11) equatorial view, (9) vertical view; (8, 10, 13, 14) specimen Taj 12 (12–1, 12–2, 12–5, 12–8), equatorial view. (15–17) *Eulepidina ex. interc. formosoides* H. Douvillé, 1925 et *dilatata* (Michelotti, 1861) (15, 16) specimen Taj 33 (33–2, 33–4) equatorial view; (17) specimen Taj 33 (random thin section), vertical view; (2) specimen Taj 33 (33–4) external view; (12) *Heterostegina assilinoidea* Blanckenhorn, 1890 specimen Taj 3 (3–1), equatorial section. (1–4). Scale bars as indicated on figure.

Formation in Central Iran have a strong Mediterranean affinity because all taxa are found in the Western Tethys and are similar to the SBZ 22B assemblages of European (southern France,

southern Spain, and Malta) and Turkish basins, although *Operculina complanata* is missing in Iran. Therefore, we used the SBZ zones of Cahuzac and Poignant (1997) for biozonation

TAJAR-KUH SECTION							
EARLY CHATTIAN							
3	11	12	14	21	25	33	SAMPLES
SBZ 22B						Large Benthic Foraminifera	
■	■	■	■	■	■	■	<i>Nephrolepidina praemarginata</i> R.Douvillé 1908
■	■	■	■	■	■	■	<i>Eulepidina formosoides</i> H.Douvillé 1925
■	■	■	■	■	■	■	<i>Nummulites kecskemetii</i> Less 1991
■	■	■					<i>Nummulites bormidiensis</i> Tellini 1888
■							<i>Heterostegina assilinoidea</i> Blanckenhorn 1890
						■	<i>Eulepidina ex. interc. formosoides</i> H.Douvillé 1925 et <i>dilatata</i> (Michelotti, 1861)
						■	<i>Planolinderina</i> sp.

Figure 21. Distribution of larger benthic Foraminifera in Tajar-Kuh section.

of these coeval sediments at the Tethyan seaway in the Middle East.

The LBF fauna in the Tajar-Kuh section was studied based on a morphometric method for the first time. Five taxa of nummulitids and lepidocyclinids were detected and reported from the Tajar-Kuh section. Two species of *Nummulites* are identified. Reticulate forms from the basal part of the section are identified as *Nummulites bormidiensis*. The other form (i.e., the radiate *Nummulites kecskemetii*), which had previously been assigned to *Operculina complanata*, is recorded from all studied samples.

Lepidocyclinids are the most abundant LBF occurring in all the samples. Morphometric results indicate two developmental stages of the *Eulepidina formosoides-dilatata* lineage: *E. formosoides* and *E. ex. interc. formosoides et dilatata*, the latter only present in the last matrix-free sample, 50 m above the base of the Oligocene. *Nephrolepidina* is represented by *Nephrolepidina praemarginata*, the less advanced taxon of the main Western Tethyan lineage (*N. praemarginata-N. morgani-N. tournoueri*), which is present throughout the studied samples. Based on the presence of *Eulepidina formosoides* (a characteristic species for the late Rupelian SBZ 22A Zone in the Western Tethys) together with *Nummulites bormidiensis*, *N. kecskemetii*, and *Heterostegina assilinoidea* (whose range starts from the early Chattian SBZ 22B Zone), the lower six samples (Taj-3 to Taj-25) are distributed in the basal part of the early Chattian SBZ 22B Zone. The morphometrically studied uppermost sample (Taj-33) already contains the more advanced *Eulepidina formosoides-dilatata* in association with the first appearance of *Planolinderina* sp., and with *Nummulites kecskemetii* and *Nephrolepidina praemarginata* extending from the lower levels, which may belong to the main part of the early Chattian SBZ 22B Zone.

Acknowledgments

This research was supported by the University of Tehran. The work of G. Less was carried out at the University of Miskolc, within the framework of the Thematic Excellence Program funded by the Ministry of Innovation and Technology of Hungary (Grant Contract reg. nr.: NKFIH-846-8/2019). We thank M. Jalali (Tehran) for field assistance and the two anonymous reviewers for their constructive criticism that significantly improved quality of this paper.

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Accepted: 26 January 2020