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SOME NEW AND POORLY KNOWN BENTHIC FORAMINIFERA FROM LATE MAATRICHTIAN SHALLOW-WATER CARBONATES OF THE ZAGROS ZONE, SW IRAN

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Abstract Three new larger benthic foraminifera, *Accordiella*? *tarburensis* n. sp., *Spirolina? farsiana* n. sp., and *Pseudonummoloculina kalatantarii* n. sp. are described from the Late Maastrichtian of the Tarbur Formation, Zagros Zone, SW Iran. The rarely observed species *Broeckinella arabica* Henson, *Broeckina* cf. *dufrenoyi* (d´Archiac), *Cuvillerinella*? sp. and *Fleuryana adriatica* De Castro, Drobne & Gušić are also reported. All these forms occur in an internal carbonate platform facies (algal-foraminiferal wackestones-packstones) and are associated with numerous other larger benthic foraminifera (e.g., *Loftusia*, *Neobalkhania*, *Gyroconulina*, *Omphalocyclus*) and dasycladalean green algae.

Keywords: Late Cretaceous, larger benthic foraminifera, systematics, biostratigraphy

INTRODUCTION

The Late Cretaceous Tarbur Formation, named after the village of Tarbur (Fars Province), and cropping out in the SW Zagros basin, represents a predominantly carbonate lithostratigraphic unit that contains rich microfauna and microflora associated with rudists (James and Wynd, 1965). It extends from the northwest to the southeast of the Zagros basin along the western edge of the imbricated Zagros zone, between the main Zagros fault and the Sabzposhan fault to the east (Alavi, 2004). The Tarbur Formation overlies and interfingers (towards the southwest) with the Gurpi Formation (Fig. 1).

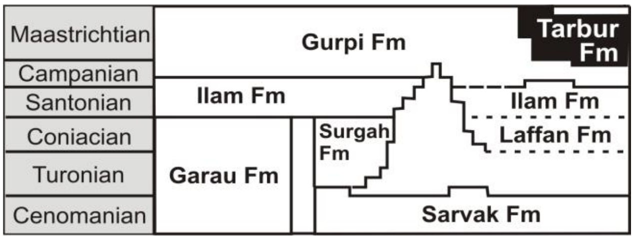

Fig. 1 Lithostratigraphy of the Late Cretaceous of the Zagros Zone, Iran (excerpt and redrawn from the Stratigraphic Chart of Iran published by the Geological Society of Iran in 1995).

In the stratigraphic chart of Iran provided in 1995 by the Geological Society of Iran, the Tarbur Formation is assigned to the Campanian-Maastrichtian interval, following the pioneer work of James and Wynd (1965). The Maastrichtian rudist fauna of the Tarbur Formation has already been described by several authors (e.g., Douvillé, 1904; Kühn, 1932; Khazaei et al., 2010). In contrast, the micropalaeontological content of the Tarbur Formation is still poorly constrained. Some taxa of calcareous algae and benthic foraminifera have been mentioned and/or illustrated in various recently published papers (Vaziri-Moghadam et al., 2005; Afghah, 2009, 2010, 2016; Maghfouri-Moghaddam et al., 2009; Rajabi et al., 2011; Abyat et al., 2012, 2015; Afghah and Farhoudi, 2012; Pirbaluti and Abyat, 2013; Pirbaluti et al., 2013; Afghah and Yaghmour, 2014) but several determinations however are incorrect and need revision.

The first results and critical revisions on the micropalaeontology of the Tarbur Formation have been published recently (Schlagintweit et al., 2016a in press, 2016b, 2017 in press). The present paper represents a further contribution to the study of the micropalaeontological inventory of the Tarbur Formation with the description of the new larger and complex conical agglutinated foraminifera *Accordiella*? *tarburensis* n. sp., as well as the porcelaneous taxa *Spirolina? farsiana* n. sp. and *Pseudonummoloculina kalantarii* n. sp. In addition, some other poorly known taxa are reported, some of them for the first time in Iran.

STUDIED SECTIONS

The foraminiferan-bearing samples studied are from two sections of the Tarbur Formation (Fig. 2):
a) Mandegan section.
The study area, located in the High Zagros Belt, is situated north of Mount Dena, about 65 km south of the town of Semirom. The section of the Tarbur Formation is exposed about 10 km south of the village of Mandegan, and here named Mandegan section (Fig. 3). Here the Tarbur Formation shows a thickness of ~272 m and conformably overlies the Gurpi Formation (Fig. 3c). The top of the section is unconformably overlain by conglomerates of the Pliocene Bakhtiari Formation (see Bahrami, 2009, for details). Based on the lithostratigraphy, the section has been divided into three units (from base to top): unit 1 is dominated by thick-bedded limestones, unit 2 mostly contains medium-bedded limestones with intercalated marly limestone layers, and unit 3 consists of marly limestones (see also Schlagintweit et al., 2016, and in press). The vertical distribution of the described taxa and some index forms of larger benthic foraminifera in the Tarbur Formation of the Mandegan section is shown in Figure 4. The Greenwich coordinates of the section base are N 31º, 25', 8.13" and E 51º, 24', 34.58".

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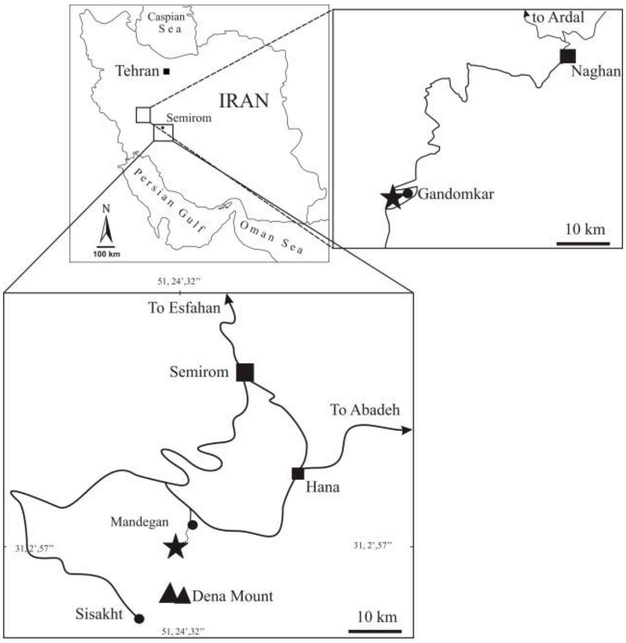

Fig. 2 Location map of the studied area.

b) Naghan section.

The studied area in the folded Zagros belt is located approximately 50 km south west of Naghan town near the Gandomkar village and is here named Naghan section. At this locality, the Tarbur Formation is underlain by the Gurpi Formation and overlying by the Paleocene Sachun Formation. Lithologically, the Gurpi Formation consists of dark, grey carbonatic shale with planktonic foraminifera. The Sachun Formation consists of gypsum, red shales, anhydrite and some layers of carbonates.

The thickness of the Tarbur Formation at the Naghan section is about ~ 274 m. It is composed of medium to thick –bedded grey limestone, shales and marls and can be subdivided into 5 units

- unit 1 (99 m), red to yellow shales
- unit 2 (61 m), medium- to thick-bedded grey limestones with *Loftusia* and rudist debris (calcarenites to calcirudites)
- unit 3 (33 m), intercalation of grey shales and cream to grey, medium- to thick-bedded limestones (cacilutites and calcarenite)
- unit 4 (38 m), thick-bedded to massive, grey to cream-coloured limestones containing broken rudist shells and tests of *Loftusia* (calcarenite, calcilutite, calcirudite)
- unit 5 (~ 41.6 m), shales interbedded with medium- to thick-bedded yellow limestones containing *Loftusia* fragments.

The vertical distribution of the described taxa and some other index forms of larger benthic foraminifera in the Tarbur Formation of the Naghan section is still under investigation and therefore not presented here. The Greenwich coordinates of the section base are N 31°47' 52" and E 50° 32' 53 ".

MATERIAL AND DEPOSITORY

The specimens illustrated in the present contribution are from various thin-sections stored at two different depositories. One part is deposited at the Bayerische Staatssammlung für Paläontologie und historische Geology, Munich, under the official numbers SNSB-BSPG 2016 V 1 to V 20. All other thin-sections are deposited at the Ardakan Payame Noor University, Iran, collection Rashidi, under the original sample numbers with the prefixes Rt for the Mandegan section and Ng for the Naghan section.

SYSTEMATICS

The high-rank classification follows Pawlowski et al. (2013). For the low-rank classification see Kaminski (2014) for the agglutinating taxa, and Loeblich & Tappan (1987) for representatives of the Miliolida. For glossary, report to Hottinger (2006).

Phylum Foraminifera d' Orbigny, 1826
Class Globothalamea Pawlowski et al., 2013
Order Textulariida Delage & Hérouard, 1896
Suborder Textulariina Delage & Hérouard, 1896
Superfamily Chrysalidinoidea Neagu, 1968
Family Chrysalidinidae Neagu, 1968

Remarks: Loeblich and Tappan (1987, p. 185) defined the Chrysalidinidae as possessing a wall "finely agglutinated, canaliculate". A different view was expressed by Banner et al. (1991) regarding the occurrence of proto-canaliculate or canaliculated wall types as a facultative species/genus criterion, of no suprageneric importance in the Chrysalidinidae. Canaliculi (or canaliculated) refer to narrow, regular parallel arranged pores open to the exterior (Banner et al., 1991, fig. 1b). Canaliculi were also named parapores by Hottinger (2006) that per definition "may be branching and anastomising", "may be laterally interconnected" and end "blindly beneath an outer solid pavement". In the chrysalidinid genera *Praechrysalidina*, *Chrysalidina* or *Dukhania*, canaliculi are sometimes restricted to the last chambers only (see discussion in Banner et al., 1991). Banner et al. (1991) stressed that the development of canaliculi appeared in several line ages of benthic foraminifera and therefore concluded that the definition of suprageneric differences based on a sporadically appearing feature is useless. In the recent classification of agglutinated foraminifera of Kaminski (2014), the genus *Accordiella* with its non-canaliculate wall is included in the Chrysalidinidae.

Genus ***Accordiella*** Farinacci, 1962

Type-species: *Accordiella conica* Farinacci, 1962

Accordiella? *tarburensis* n. sp.

Figs. 5a pars, 6–7, 8 pars.

2016 agglutinated foraminifer chrysalinid – Afghah, fig. 6d pars.

Holotype: Axial section of the specimen illustrated in Figure 6a, thin-section Rt 87.

Origin of the name: The species name refers to the village of Tarbur.

Type locality: Mandegan section (Fig. 2).

Type level: Late Maastrichtian of the Tarbur Formation.

Diagnosis: Medium conical possible representative of *Accordiella* with distinct convex apertural face and widely spaced, discrete pillars in the central part of the test.

Description: Test medium conical, low trochospiral, with 3 marginally overlapping chambers (per whorl) arranged in up to 10 whorls and distinctly convex cone base.

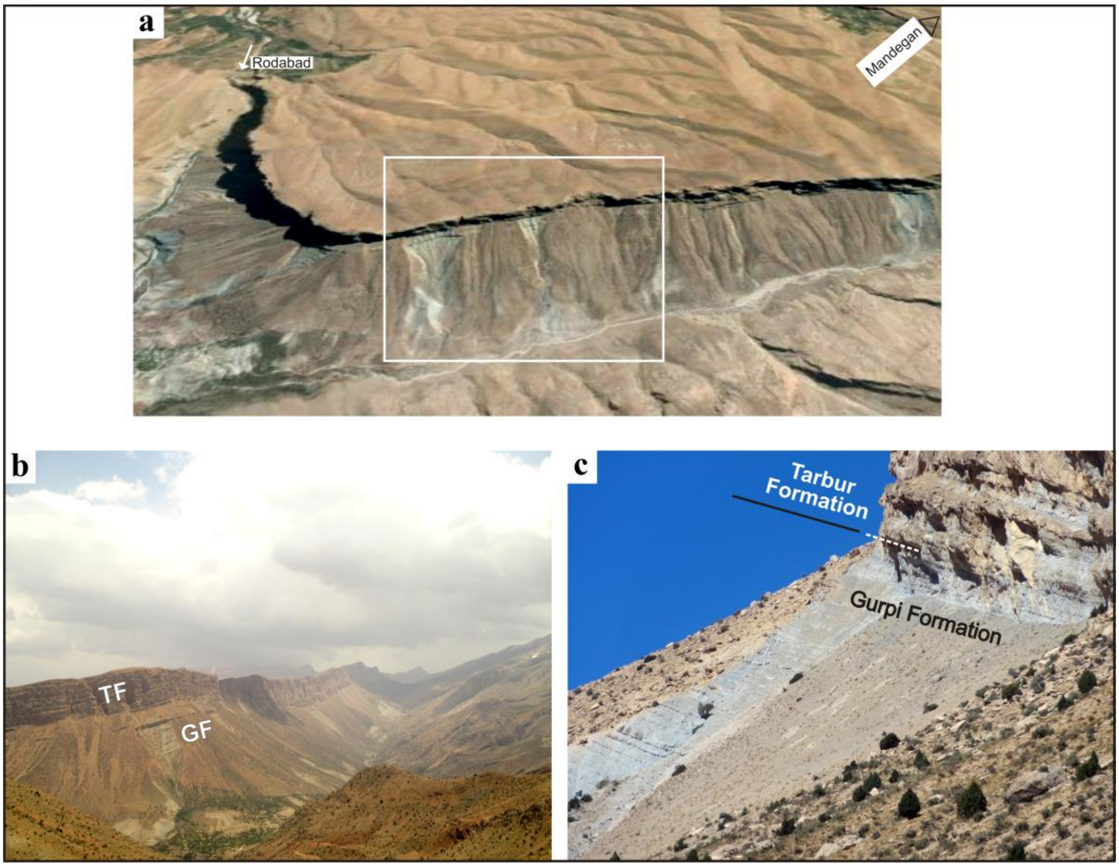

Fig. 3 a-b: Satellite (**A**, from google maps) and field views (**b**) of the Gurpi (GF) and Tarbur formations (TF) in the Mandegan area. The distance from left to right in A is ~4.7 km. Figure **c**: Conform boundary of Gurpi and Tarbur formations at the Mandegan section.

Details on the nepionic stage unknown. Spiral sutures clearly marked by test constrictions. Peripheral lumen of the chambers undivided (no exoskeletal elements). Chamber height decreasing towards the centre of the test. Adaxial area wide, distinctly convex, pierced by numerous cribrate foramina and with numerous, discrete endoskeletal pillars. Wall homogeneous very finely agglutinating, occasionally with thin dark outer layer (detectable in the best preserved specimens). Dimorphism has not been evidenced.

Dimensions (mm): (Data for *Accordiella conica* in brackets)
Test diameter (D): 0.8-1.4 mm (0.6-1.0 mm)
Test height (H): 0.7-1.4 mm (0.8-1.2 mm)
Ratio D/H: 0.8-1.2 (mostly ~1.1)
Apical angle: 60-90 degrees; mostly ~80 degrees (about 80 degrees)
Number of whorls: 5-10 (8-12)
Number of whorls per last 0.5 mm (measured along the cone mantel line = cml, see Hottinger & Drobne, 1980, fig. 3): 2 to 4
Thickness of pillars (central part): 0.025-0.04 mm.

Comparisons: The type-species *Accordiella conica* Farinacci, 1962 (upper Cretaceous of Italy) differs from *A.*? *tarburensis* by its broad axial region with an endoskeleton consisting of numerous, fine horizontal plates that are interconnected by vertical pillars or buttresses (Farinacci, 1962; Torre, 1966; Loeblich and Tappan, 1987, p. 151) (see Fig. 8). In the original description, the central part of *Accordiella* was described as possessing a labyrinthic structure (Farinacci, 1962, p. 7). Torre (1966, fig. 1) presented a schematic drawing of its central zone showing the presence of four horizontal plates per whorl. Stratigraphy of *A. conica* is middle Coniacian to lowermost middle Campanian (Frijia et al., 2015). For the occurrences of the species in the Mediterranean area see the compilation in Radrizzani et al. (1987, tab.1). Compared to *A.*? *tarburensis*, the central part of *A. conica* is densely occupied by narrowly spaced irregular endoskeletal elements (Fig. 8). According to Torre (1965), there are four chambers per whorl in *A. conica* contrasting Farinacci (1962) describing the species as triserially coiled throughout. In fact, four chambers are discernible in some specimens illustrated by Farinacci (1962, pl. 2, fig. 6, and ?some specimens in pls. 4-5). So the more complicated central part of *A. conica* compared to *A.*? *tarburensis* might by an effect of more chambers per whorl in the former. Generally, the shape of the pillars of both taxa is different. In *A. conica* these are irregularly thickening, undulating, and merging whereas in *A.*? *tarburensis* they are straight, cylindrical, with a slight widening at the base and top. With thickness of ~0.017 mm to ~0.035 mm (own observations), the pillars of *A. conica* are more slender compared to *A.*? *tarburensis*. Due to the lack of horizontal plates in the central zone the generic position of the species *A.*? *tarburensis* is uncertain. An *Accordiella*-type larger benthic foraminifer has been recently described as *Pseudoaccordiella ayaki* Gallardo-Garcia & Serra-Kiel (in Serra-Kiel et al., 2016) from the Late Eocene (Priabonian) of Oman and Yemen (see Fig. 8).

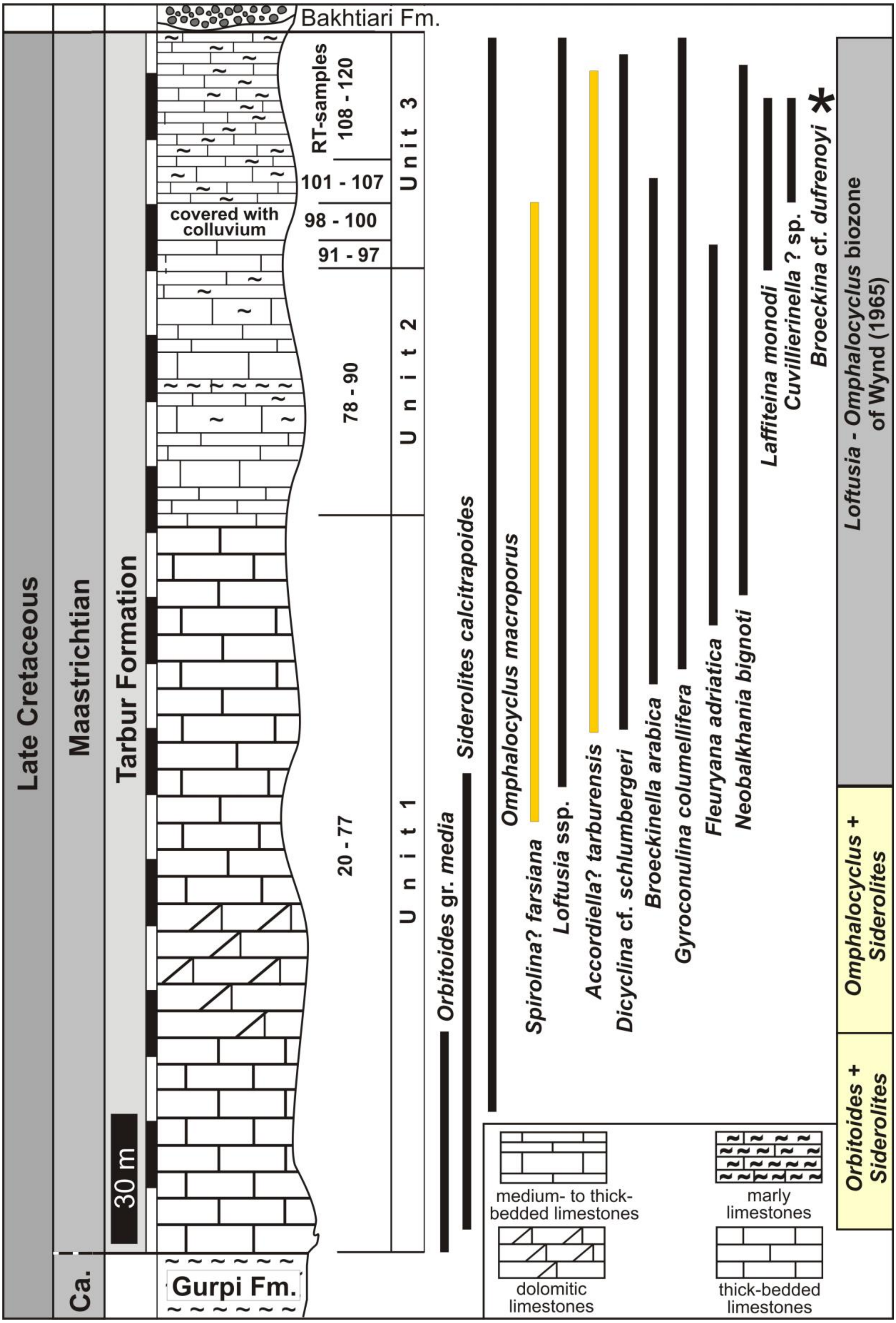

Fig. 4 Vertical distribution of the described taxa and some index forms of larger benthic foraminifera in the Tarbur Formation of the Mandegan section.

Pseudoaccordiella is characterized by a pseudokeriothekal wall texture, a triserial nepionic, and a biserial neanic stage. The structure of the central part of *Pseudoaccordiella* and *Accordiella* is directly comparable. The tests of *Pseudoaccordiella* are larger than *A. conica* and *A.*? *tarburensis* (height up to 2.7 mm, measured from Serra-Kiel et al., 2016, fig. 30.4).

Order Loftusiida Kaminski & Mikhalevich, 2004
Suborder Loftusiina Kaminski & Mikhalevich, 2004
Superfamily Loftusioidea Brady, 1884
? Family Cyclamminidae Marie, 1941
Subfamily Pseudochoffatellinae Loeblich & Tappan, 1985
Genus ***Broeckinella*** Henson, 1948

Remarks: It should be mentioned here that in the definition of the families Cyclamminidae and Spirocyclinidae, Albrich et al. (2015, p. 255) where not following the classification of Kaminski (2014). According to these authors “the genera with polygonal subepidermal patterns should be ascribed to the Family Spirocyclinidae instead of the Cyclamminidae”. In this definition, the genus *Broeckinella* possessing a polygonal subepidermal pattern (e.g., Fig. 9d, left side) should be included in the Spirocyclinidae.

Broeckinella arabica Henson, 1948
Fig. 9a–e
*1948 *Broeckinella arabica* n. gen., n. sp. – Henson, p. 93, pl. 7, fig. 6, text-fig. 13a-c.
1978 *Broeckinella arabica* Henson – Cherchi and Schroeder, p. 514, fig. 1 A-C.
2004 *Dicyclina schlumbergeri* – Khosrow Tehrani and Afghah, pl. 2, fig. 4.
2008 *Dicyclina schlumbergeri* – Khosrow Tehrani et al., pl. 1, fig. 6.

Description: Test compressed, with numerous chambers rapidly increasing in width so that the test becomes slightly flabelliform (Fig. 9a–b). Information on the initial part is not available in our sections (for details see Cherchi and Schroeder, 1978). The wall is very finely agglutinating and the chamber margins are subdivided by exoskeletal elements, both vertical and horizontal resulting in a polygonal meshwork (or pattern) (Fig. 9a, d).

Remarks: *Broeckinella arabica* is the type-species of the genus *Broeckina* described by Henson (1948) from the Maastrichtian? of Qatar. According to the critical literature review of Cherchi and Schroeder (1978) there is obviously no verified other record of this taxon besides its type-locality. In the Tarbur Formation of the Mandegan section, it was rarely observed in samples Rt 64, 68, 78, 85, and 104, referring to the upper most part of unit 1, and persisting into unit 3 (Fig. 4). The material of *Broeckinella arabica* from the Tarbur Formation does not include centered sections. Data on the test dimensions only comprise incomplete sections attaining a maximum size of 2.4 mm. *B. arabica* was figured as *Dicyclina schlumbergeri* from the Maastrichtian of the Tarbur Formation by Khosrow Tehrani and Afghah (2004) and the Maastrichtian of the Amiran Formation (SW Iran, Zagros Zone) where the authors distinguished a *Loftusia-Dicyclina* assemblage zone. On the other side, *Dicyclina* cf. *schlumbergeri* is common in the upper part of the Tarbur Formation (Fig. 4).

Suborder Biokovinina Kaminski, 2004
Superfamily Biokovinoidea Gušić, 1977
Family Charentiidae Loeblich & Tappan, 1985
Genus ***Fleuryana*** De Castro, Drobne & Gušić, 1994
Fleuryana adriatica De Castro, Drobne & Gušić, 1994
Fig. 10
*1994 *Fleuryana adriatica* n. gen., n. sp. – De Castro et al., p. 133, pls. 1–4, figs. 3-5, 7–8.
1998 *Fleuryana adriatica* De Castro, Drobne & Gušić – Caffau et al., fig. 5.2–3.

Remarks: In the original description, information on the suprageneric taxonomy of *Fleuryana* was not provided. In the two classifications of agglutinated taxa provided by Kaminski (2004, 2014), the genus *Fleuryana* is not included. Because of its morphology as well as the finely perforate wall structure, De Castro et al. (1994) discuss in detail similarities and differences to *Montcharmontia* De Castro, a genus included in the family Charentiidae (Loeblich and Tappan, 1987; Kaminski, 2014). We propose to assign *Fleuryana* to this family.

In the Mandegan section, *Fleuryana adriatica* occurs in the upper part of unit 1 persisting into the upper part of unit 2. Originally described from the uppermost Maastrichtian, its first appearance is somewhere in the middle part of the Campanian (Fleury, 2014, fig. 3). This enlarged stratigraphic range should be taken into consideration as in some papers *F. adriatica* is erroneously considered as a late Maastrichtian marker taxon (e.g., Mikuž et al., 2012). The occurrence of *F. adriatica* in the Tarbur Formation is the first record of this taxon in Iran. According to our knowledge it is the easternmost record so far.

Class Tubothalamea Pawlowski et al., 2013
Order Miliolida Delage & Hérouard, 1896
Superfamily **Soritoidea** Ehrenberg, 1839
Family uncertain
Genus ***Broeckina*** Munier-Chalmas, 1882

Remarks: Loeblich & Tappan (1987) included *Broeckina* in the Meandropsinidae Henson. Following the emendation of this family by Hottinger & Caus (2009), *Broeckina* lacking a diaphanous umbo, should be removed from the Meandropsinidae as remarked by Consorti et al. (2016) instead remaining in the superfamily Soritoidea. The family status however is still uncertain.

Broeckina cf. *dufrenoyi* (d’Archiac, 1854)
Fig. 11
*1854 *Cyclolina dufrenoyi* n. sp. – d’ Archiac, p. 205, pl. 2, figs. 1a–d.
1882 *Broeckina dufrenoyi* (d’ Archiac) – Munier-Chalmas, p. 471.
1975 *Broeckina dufrenoyi* (d’ Archiac) – Cherchi and Schroeder, p. 5, pl. 1, figs. 1–6, pl. 2, figs. 1–3, pl. 4, figs. 2, 4–6.

Description: Test flat discoidal, with annular chambers displaying an exoskeleton of radial partitions. Test wall is porcelaneous. Due to the lack of adequate sections, information on the initial part is not available (for details see Cherchi and Schroeder, 1975). The specimens attain diameter of up to 2.6 mm, and a thickness of up to 0.15 mm.

Remarks: *Broeckina gassoensis* from the middle Coniacian of Spain differs from *Broeckina dufrenoyi* by its

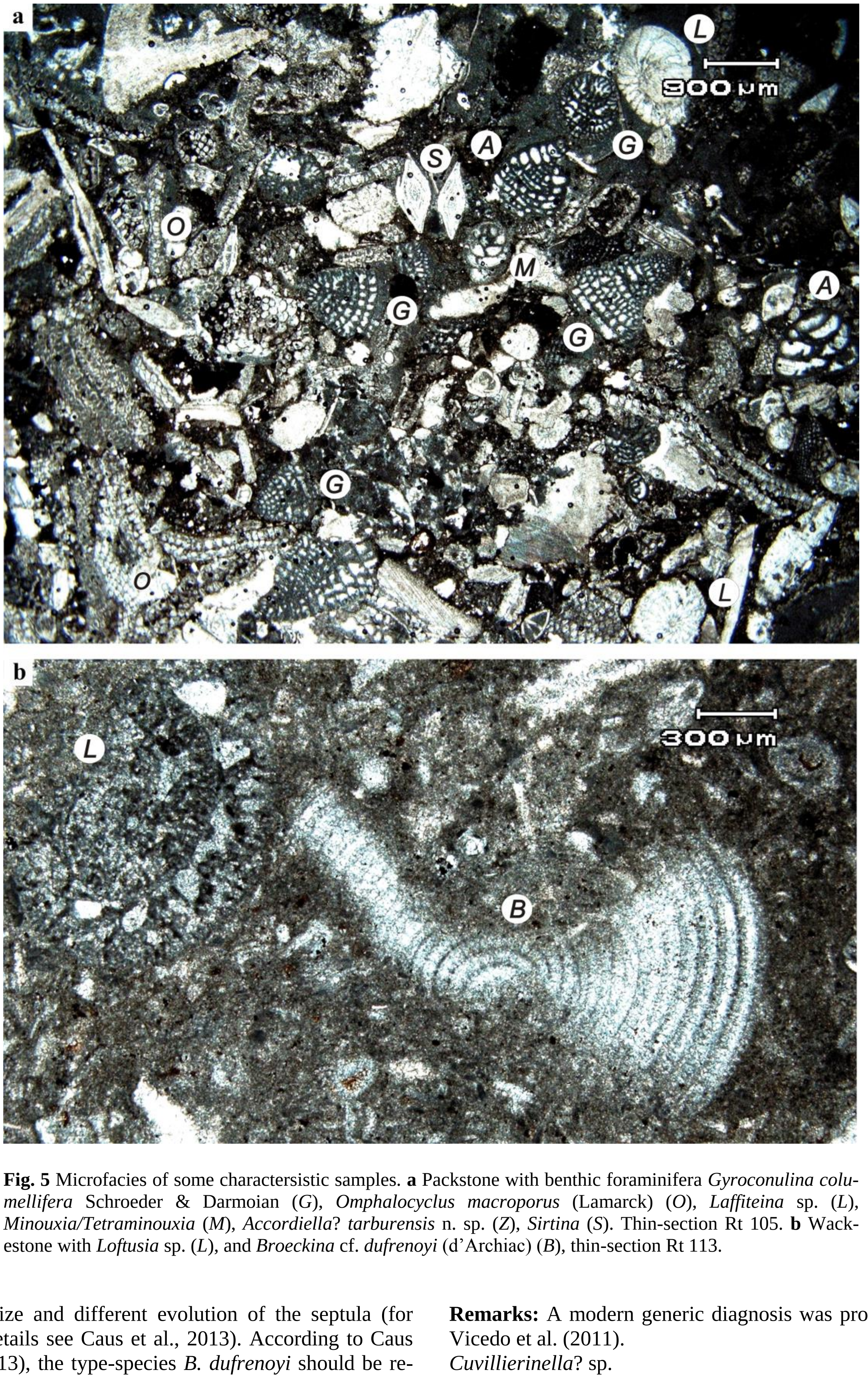

Fig. 5 Microfacies of some charactersistic samples. **a** Packstone with benthic foraminifera *Gyroconulina columellifera* Schroeder & Darmoian (*G*), *Omphalocyclus macroporus* (Lamarck) (*O*), *Laffiteina* sp. (*L*), *Minouxia/Tetraminouxia* (*M*), *Accordiella*? *tarburensis* n. sp. (*Z*), *Sirtina* (*S*). Thin-section Rt 105. **b** Wackestone with *Loftusia* sp. (*L*), and *Broeckina* cf. *dufrenoyi* (d'Archiac) (*B*), thin-section Rt 113.

smaller size and different evolution of the septula (for further details see Caus et al., 2013). According to Caus et al. (2013), the type-species *B. dufrenoyi* should be restricted to the late Santonian–early Campanian. The occurrence of *Broeckina* cf. *dufrenoyi* (d'Archiac, 1854) in the late Masstrichtian of the Tarbur Formation is therefore of special interest. It is recorded from both Mandegan and Naghan sections where it appears in the uppermost part of the sections.

Genus ***Cuvilierinella*** Papetti & Tedeschi, 1965

Remarks: A modern generic diagnosis was provided by Vicedo et al. (2011).

Cuvillierinella? sp.

Fig. 12

Remarks: Rare and very poorly preserved specimens were observed in a comparatively narrow interval of unit 3 of the Mandegan section. The oblique to subaxial section show general similarities to *Cuvillierinella salentina* described by Papetti & Tedeschi (1965) from the Campanian of southern Italy (see also Vicedo, 2011). *Cuvillier-*

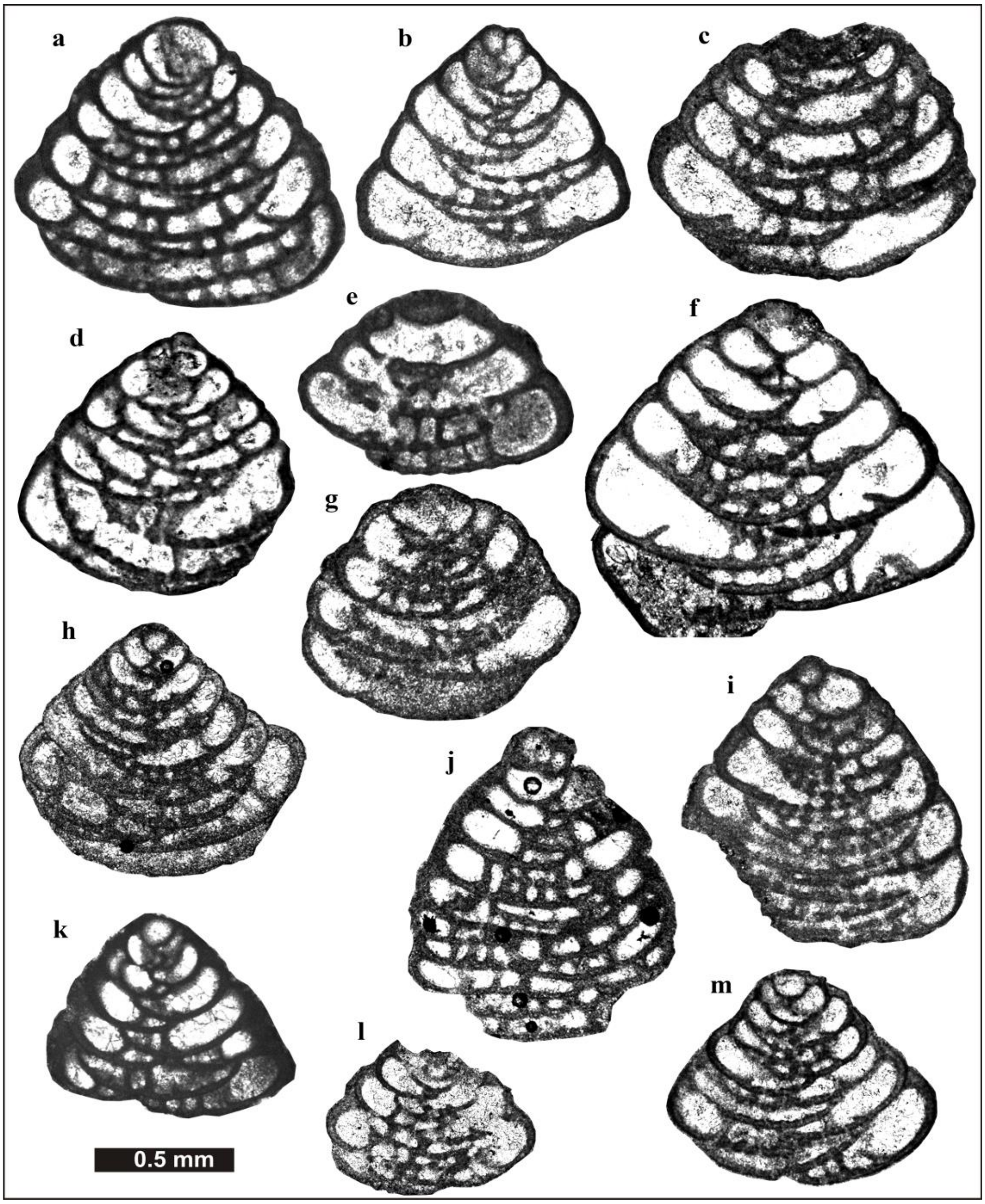

Fig. 6 *Accordiella*? *tarburensis* n. sp., Late Maastrichtian Tarbur Formation of Mandegan section, Zagros Zone, SW Iran. **a**–**d, f, h**–**m** Axial and subaxial sections. **e, g** Oblique sections. Thin-sections: Rt 87 (**a, g**), Rt 67-3 (**b**), Rt 61-1 (**c**), SNSB-BSPG 2016 III-4 (**d**), Rt 89-3 (e), Rt 113-2 (f), Rt 67 (**h**), Rt 70 (**i**), Rt 105 (**j**), Ng 189 (**k**), Rt 82 (**l**), Rt 73 (**m**).

inella is known from the middle Campanian to early Maastrichtian (e.g., Fleury, 2014, fig. 3; Vicedo et.al., 2011), and its occurrence in the late Maastrichtian is debatable.

Genus ***Spirolina*** Lamarck, 1804

Spirolina? *farsiana* n. sp.

Figs. 13–14

Holotype: Fig. 13b, Thin-section Rt 67-2.

Origin of the name: The species name refers to the Fars province of Iran.

Type locality: Mandegan section (Fig. 2).

Type level: Late Maastrichtian of the Tarbur Formation.

Diagnosis: Possible representative of *Spirolina* with two to three planispirally coiled whorls that may also slightly oscillate. Chamber lumen semi-lunate in equatorial and rounded-arched in axial sections. Rectilinear adult part with few chambers. Foramina simple in the planispiral part, becoming most likely cribrate with small projections (teeth?) in the uncoiled part.

Description: Test planispirally coiled in two to three whorls, each with an increasing number of chambers. Early stage most likely involute then biumbonate and semi-involute. Test periphery is rounded. Planes of coiling may slightly oscillate. As discernible in equatorial sections, the sutures are barely if ever discernible at the test surface. There are 8 to 10 chambers in the last en-

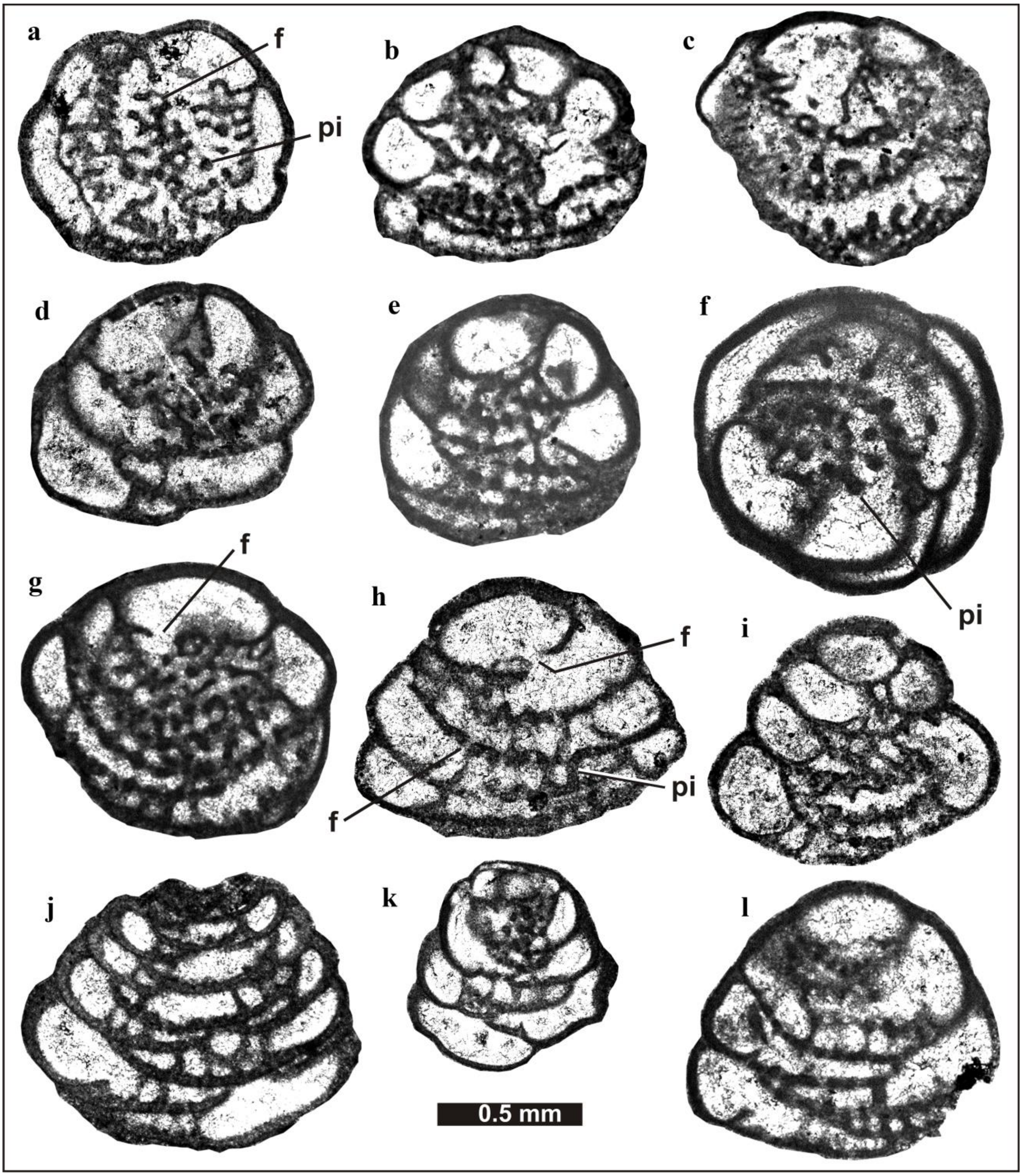

Fig. 7 *Accordiella*? *tarburensis* n. sp., Late Maastrichtian Tarbur Formation of Mandegan section, Zagros Zone, SW Iran. **a**–**f** Oblique transverse sections. **g**–**i, k**–**l** Oblique sections. **j** Broken axial section. Thin-sections: SNSB-BSPG 2016 III-8 (**a**–**c**), Rt 68 (**d–e**), Rt 82 (**f**), Rt 87 (**g**), Rt 71 (**h**), Rt 64 (**i**), Rt 61-1 (**j**), Rt 70 (**k**), Rt 73 (**l**). Abbreviations: f = foramen, pi = pillar.

rolled whorl and then the test becomes uncoiled, rectilinear, more or less cylindrical in the adult part (with up to 7 chambers). In equatorial sections, the outline of the chamber lumen is mostly semi-lunate, and rounded-arched in axial sections. The septa are inclined. The foramina in the planispiral stage are simple, areal, with several tiny protrusions (teeth?) in the uncoiled stage (Fig. 13d, g). The wall is porcelaneous, imperforate. The inner part of the wall always is dark homogeneous, whereas the outer part often displays a light-grey finely grumbly appearance (structural differences enhanced by diagenetic alteration? agglutinated particles?).

Remarks and comparisons: The genus *Spirolina* has been critically reviewed by Tronchetti and Grosheny (1992) concluding that all Mesozoic representatives are highly doubtful, and that *S. cretacea* Tronchetti & Grosheny from the Santonian of France would be the only Mesozoic *Spirolina* and therefore its oldest record. Note that Loeblich and Tappan (1987) regarded the genus as Eocene to Holocene. *Spirolina cretacea* Tronchetti &

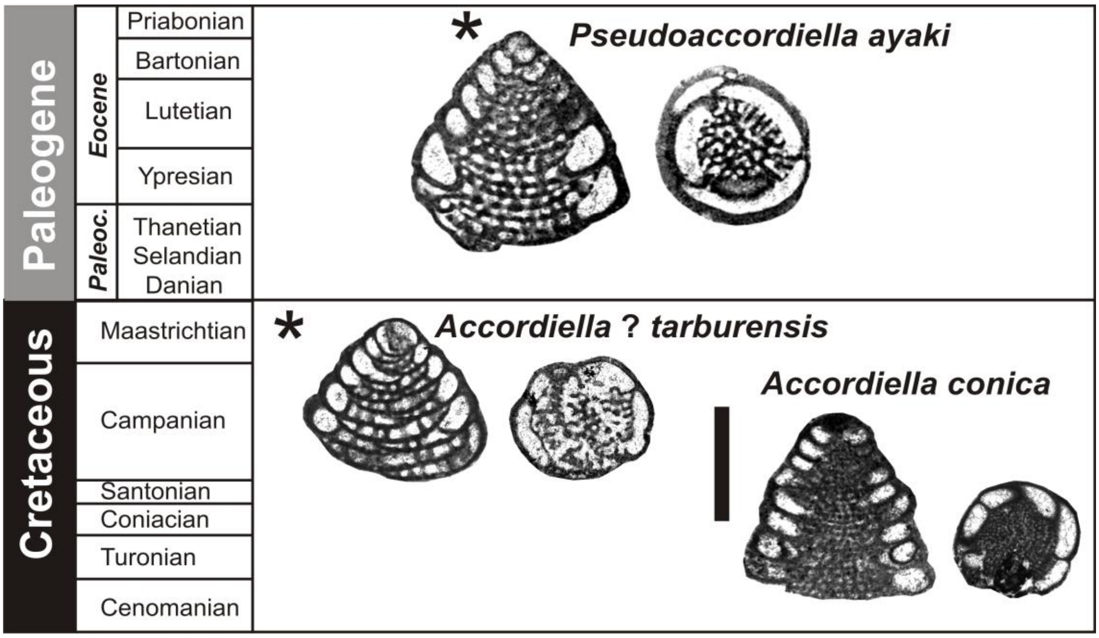

Fig. 8 Stratigraphic distribution and general comparison of *Accordiella conica* Farinacci, *Accordiella*? *tarburensis* n. sp., and *Pseudoaccordiella ayaki* Gallardo-Garcia & Serra-Kiel, (from Serra-Kiel et al., 2016, fig. 30.3 and 30.7).

Grosheny, is different from *Spirolina*? *farsiana* above all due to its chamber shape (more or less pyriform), the well expressed sutures, reduced number of chambers, and the costate surface ornamentation (Tronchetti and Grosheny, 1992, for details). The taxonomic uncertainty of the Maastrichtian taxon from Iran is due to the lack of test ornamentation and especially details on the aperture that is controversely discussed in the literature. According to Loeblich and Tappan (1987), *Spirolina* displays a terminal, rounded aperture, whereas the allied genus *Dendritina* d' Orbigny (both Eocene to Holocene) has a dendritic (or stellate) aperture. A single opening as apertural type for *Spirolina* was recently also remarked by Sirel et al., (2013). Tronchetti and Grosheny (1992, p. 397) on the other hand united forms with either a rounded terminal aperture with numerous small teeth-like projections or forms with ramified, simple or multiple aperture. It is worth mentioning that *S. cretacea* possesses a multiple aperture with small teeth. An equivalent aperture seems to be present also in *S.*? *farsiana*. The presence of a dentritic aperture in *S.*? *farsiana* however cannot be excluded due to the lack of transverse section cutting the foramina in the uncoiled part. The dendritic foramina/aperture in the Paleogene taxon *Paraspirolina gigantea* for example shows very similar projections above the septa in longitudinal section through the uncoiled part (Fleury, 1997, e.g., pl. 1, fig. 23, penultimate chamber!) as observed in *S.*? *farsiana* (Fig. 13d, g).

We note some morphological similarities of *Spirolina*? *farsiana* to the early Paleogene *Kayseriella decastroi* Sirel. This species differs from the former by its thick apertural tooth and peristomal rims (Sirel, 1999). Last but not least, *S.*? *farsiana* displays also affinities to representatives of *Pseudorhapydionina* De Castro (e.g., De Castro, 1985; Consorti et al., 2016), but lacking septula.

Superfamily Miliolacea Ehrenberg, 1839
Family Hauerinidae Schwager, 1876
Subfamily Haueríninae Schwager, 1876
Genus ***Pseudonummoloculina*** Calvez, 1988

Remarks: Calvez (1988) established the genus *Pseudonummoloculina* (type-species *Pseudonummoloculina aurigerica*, Albian of the Pyrenees) for "nummoloculinas" with a notched aperture (= an aperture bordered by a series of notches protruding from the floor and roof of the chambers). The widespread Cenomanian "nummoloculinas" were thereafter regarded as *Pseudonummoloculina* sp. by De Castro (1987) since they show a "wavy margin" simulating a cribrate aperture. Likewise, the restudy of the Mexican material of *Nummoloculina heimi* Bonet by Hottinger et al. (1989) did not substantiate the existence of an aperture with a tooth, in contrast to the emendation provided by Conkin & Conkin (1958), but according to the former, the aperture "*clearly show rows of notches in the distal margin*". Owing to these structural differences, Hottinger et al. (1989: p. 104) introduced the new combination *Pseudonummoloculina heimi* (Bonet) concluding that "*pseudonummoloculinid species exist from Albian to Senonian in at least three neighboring bioprovinces (Caribbean, Pyrenean and western Tethys)*". In a contribution on Lower-Middle Cretaceous foraminifers from deep-sea drilling legs, Arnaud-Vanneau & Sliter (1995) state, "the genus *Pseudonummoloculina* is represented by three species: the type-species *P. aurigerica* Calvez (Albian of Spain), *P. heimi* (Bonet) (Cenomanian of Mexico) and *P. robusta* (Torre) (Coniacian or Santonian of Italy)". Excluded are *Nummoloculina regularis* Philippson (late Cretaceous of Austria, see discussion in Schlagintweit, 2008, for details) and *Nummoloculina irregularis* Decrouez & Radoičić, 1977. The latter possessing an ophthalmidid type of coiling different from *Pseudonummoloculina*.

Pseudonumoloculina kalantarii n. sp.
Fig. 15

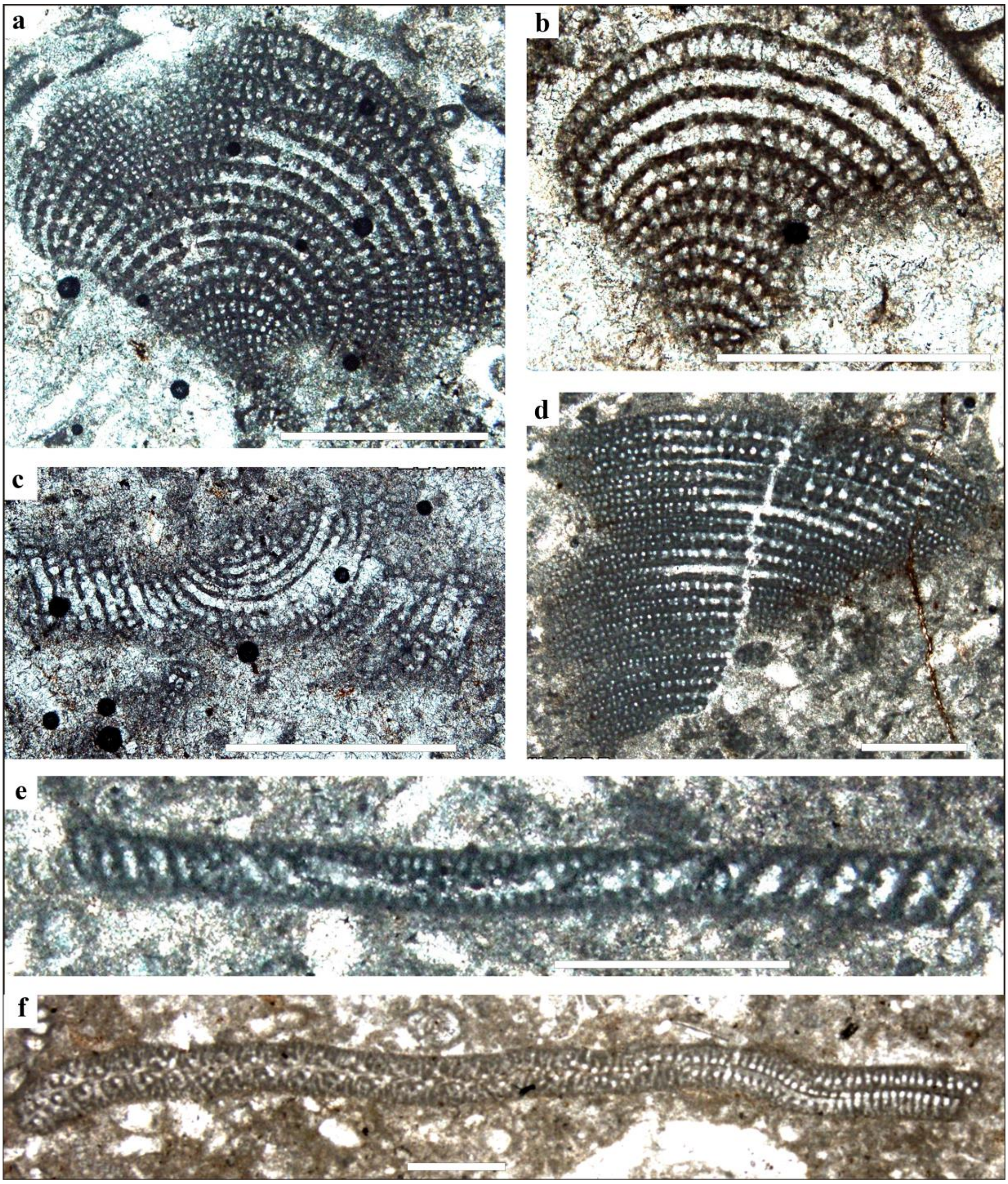

Fig. 9 *Broeckinella arabica* Henson (**a–e**) and *Dicyclina* cf. *schlumbergeri* Munier-Chalmas (**f**), Late Maastrichtian Tarbur Formation of Mandegan section, Zagros Zone, SW Iran. **a**–**d** Oblique equatorial sections, partly fragmentary, in some parts crossing the subepidermal network of beams and rafters (e.g., left side of **d**). **e** Oblique section of *Broeckinella arabica*, comparable to the section erroneously illustrated as "*Dicyclina schlumbergeri*" by Khosrow Tehrani et al., 2008 in pl. 1, fig. 6. **f** *Dicyclina* cf. *schlumbergeri* Munier-Chalmas, subaxial section. Thin-sections: Rt 104 (**a**), Rt 64 (**b**), Rt 78 (**c**), Rt 85 (**d**), Rt 68 (**e**), SNSB-BSPG 2016 III-4 (**f**). Scale bars 0.5 mm.

Holotype: Slightly oblique axial section of a juvenile specimen (showing notched aperture) illustrated in Figure 15k (and detail in Fig. 15n). Thin-section NG 85.

Origin of the name: The species name is dedicated to Amir Kalantari, micropalaeontologist of the National Iranian Oil Company for his contributions to the micropalaeontology of Iran.

Type locality: Naghan section (see Fig. 2)

Type level: Late Maastrichtian of the Tarbur Formation.

Diagnosis: Representative of *Pseudonummoloculina* with egg-shaped, slightly biumbilicate test, and rounded margin. The test is streptospirally coiled initially (3 to 4 whorls) then oscillating to almost planispiral (up to 5 whorls). Chambers elongated along the coiling, low and only gradually increasing in height.

Description: Test ovate, with slight biumbilical depression and broadly rounded periphery. First whorls streptospirally coiled, later planes of coiling become more and more regular to almost planispiral, resulting in an overall sigmoid arrangement when observed in axial sections

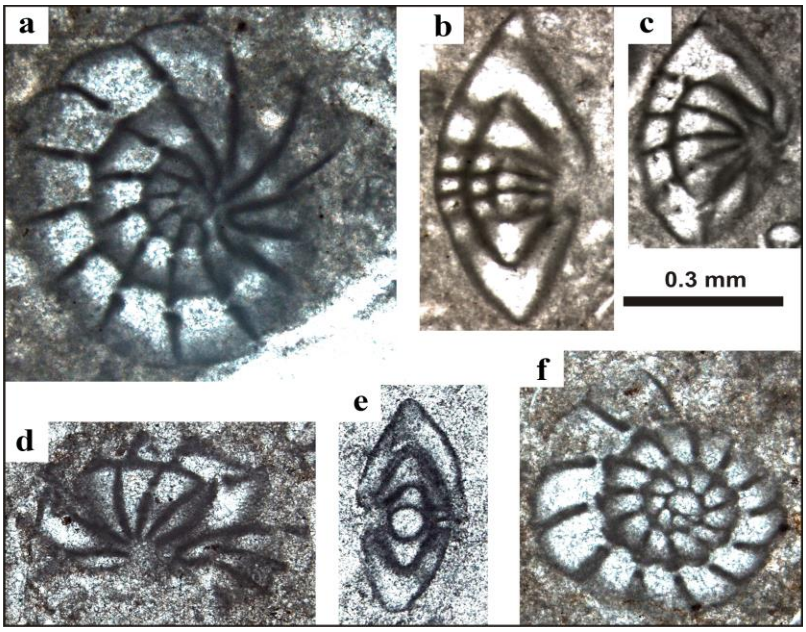

Fig. 10 *Fleuryana adriatica* De Castro, Drobne & Gušić, Late Maastrichtian Tarbur Formation of Mandegan section, Zagros Zone, SW Iran. **a, f** Equatorial sections. **b–c** Oblique sections. **d** Broken oblique section. **e** Axial section. Thin-sections: Rt 87 (**a**), SNSB-BSPG 2016 III-7 (**b–c**), Rt 82 (**d**), Rt 68 (**e**), Rt 70 (**f**).

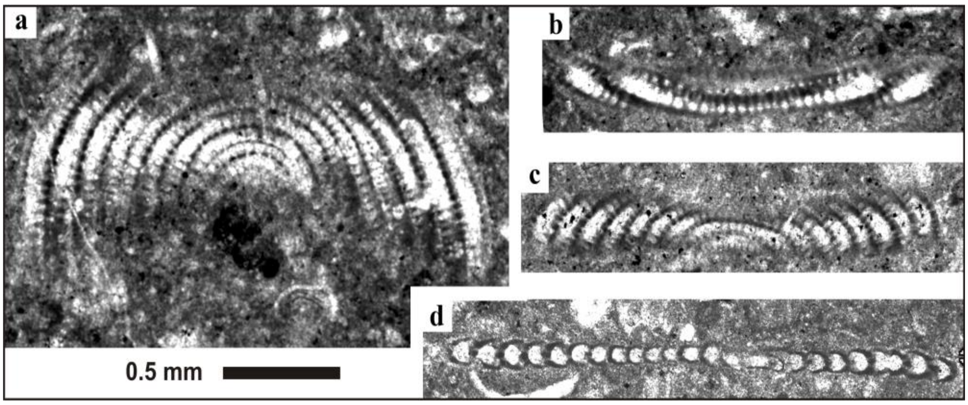

Fig. 11 *Broeckina* cf. *dufrenoyi* (d'Archiac), Late Maastrichtian Tarbur Formation of Mandegan section, Zagros Zone, SW Iran. **a** Fragmentary equatorial section showing septules. **b–c** Oblique sections showing septula. **d** Subaxial section. Thin-sections: SNSB-BSPG 2016 III-16 (**a–b**), SNSB-BSPG 2016 III-17 (**c**), Rt 113-2 (**d**).

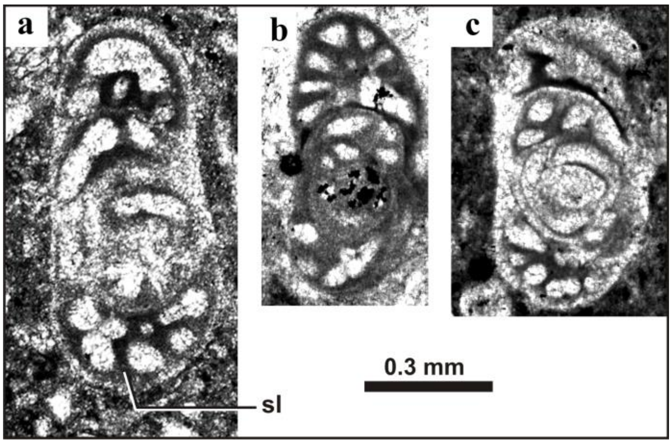

Fig. 12 *Cuvillierinella*? sp., Late Maastrichtian Tarbur Formation of Mandegan section, Zagros Zone, SW Iran. **a** Oblique section close to axial plane. **b–c** Subaxial sections. sl = septulum. Thin-sections: Rt 100 (**a**), SNSB-BSPG 2016 III-10 (**b**), SNSB-BSPG 2016 III-18 (**c**).

Fig. 13 *Spirolina*? *farsiana* n. sp., Late Maastrichtian Tarbur Formation of Mandegan section, Zagros Zone, SW Iran. **a** Oblique equatorial section of specimen with uncoiled adult part. **b** Slightly oblique equatorial section with few uncoiling chambers; holotype specimen. **c** Subaxial section: Note changing growth direction of enrolled part. **d** Detail of **e** showing foramina with lip-like projections. **e, f** "Axial" section of the uncoiled part. **g–h** Subaxial sections. Note teeth-like projections in **g** (arrow). **i**, fragmentary oblique section. Thin-sections: Rt 67-3 (**a, e–d**), Rt 67-2 (**b, h**), SNSB-BSPG 2016 III-1 (**c, g, i**), SNSB-BSPG 2016 III-8 (**f**).

(Fig. 15h). Septa inclined and rather short delimiting chambers that are greatly elongated along the coiling direction and that only gradually increase in height. Number of chambers per whorl unclear. Wall calcareous imperforate, porcelaneous, possibly with some incorporated (agglutinated) grains (e.g., Fig. 15j, g). Foramina and aperture with numerous short notches, irregular in shape, protruding from the chamber roof and floor (Fig. 15l–n)

Dimensions (in mm):

Equatorial diameter (ed): up to 2 mm
Axial diameter (ad): up to 0.9 mm
Ratio ad/ed: 0.6 to 0.7

Comparisons: The differences to the other species of *Pseudonummoloculina* can be summarized as follows. <u>*Pseudonummoloculina aurigerica* Calvez, 1988 (Albian of Spain)</u>: The planispiral stage of the type-species is reduced with only 1 ½ to 2 ½ whorls compared to up to 5

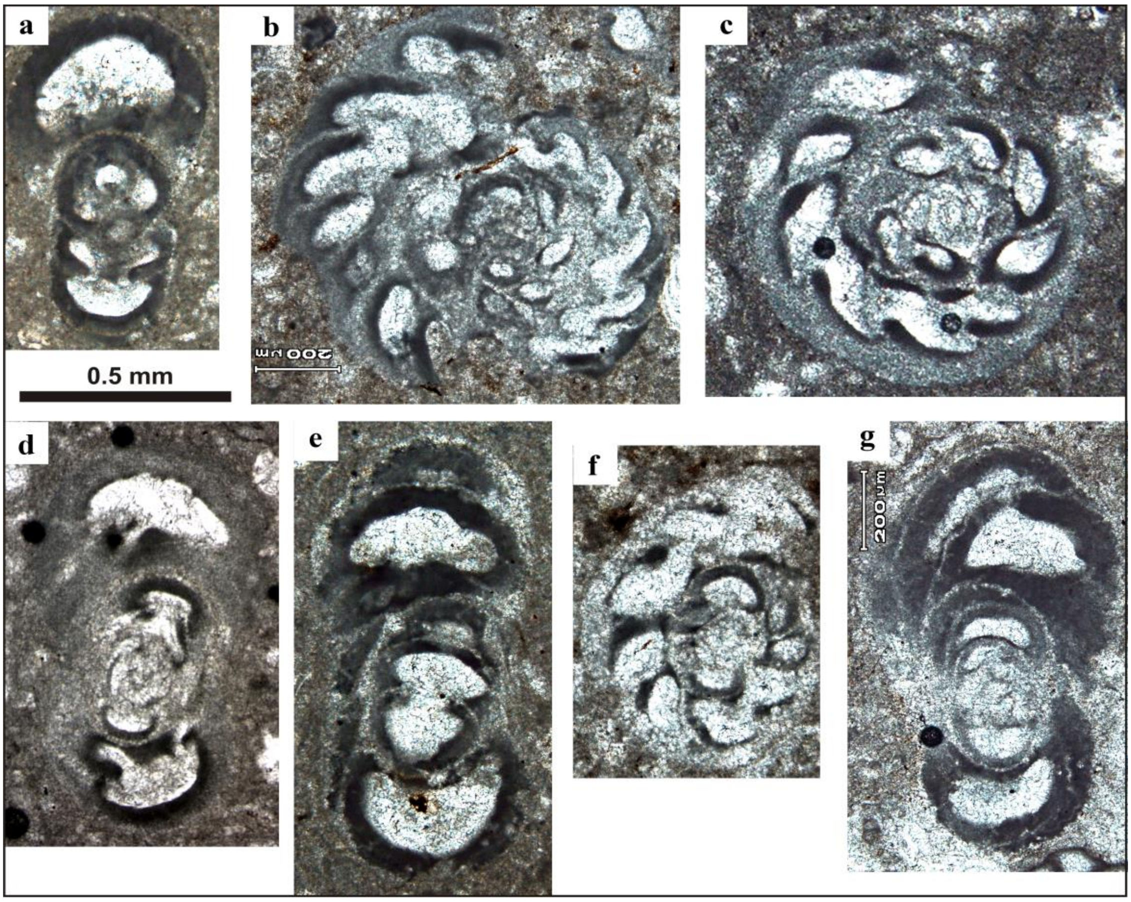

Fig. 14 *Spirolina*? *farsiana* n. sp., Late Maastrichtian Tarbur Formation of Mandegan section, Zagros Zone, SW Iran. **a** Subaxial section. **b–c, f** Equatorial section, partly oblique. **d–e, g** Subaxial, slightly oblique sections. Thin-sections: Rt 67-3 (**a, e**), Rt 70 (**b, f),** Rt 86 (**c**), SNSB-BSPG 2016 III-3 (**d**), Rt 84 (**g**).

in *P. kalantarii*. Also the size is reduced (ed up to 1.3 mm, ad up to 0.73 mm).

Pseudonumoloculina heimi (Bonet, 1956) (Cenomanian of Mexico): With its numerous whorls (up to 5), and size (ed up to 2.16 mm), *P. heimi* is close to *P. kalantarii*. *P. heimi* is different from the former in its compressed discoidal test (ratio ad/ed 2.45 to 3.6, as measured from Conkin and Conkin (1958, fig. 1-25).

Pseudonummoloculina robusta (Torre, 1966) (Coniacian or Santonian of Italy): In *P. robusta*, wall thickness nearly equals the width of the chamber lumen, given rise to the species name. With maximum size of 1.025 mm, *P. robusta* is much smaller than *P. kalantarii*. A further difference is the inclination of the axes of successive chamber within a whorl as discernible in equatorial sections (Torre, 1966, pl. 3, fig. 3) whereas in *P. kalantarii* they are more or less in line.

Pseudonummoloculina sopadensis Drobne, Premru & Ogorelec, 2005, nom. nud. (Thanetian of Slovenia): In a congress abstract, Drobne et al. (2005) introduced the new species *Pseudonummoloculina sopadensis* (with test sizes of up to 1.5 mm) from the Thanetian of Slovenia. So far no valid description and typification were provided and therefore currently the taxon fails to confirm to article 13 of the International Code of Zoological Nomenclature (= nomen nudem). Nonetheless, *P. sopadensis* was included in the list of the shallow benthic zones, respectively SBZ 2 to 3 of Serra-Kiel et al. (1998), noting a forthcoming description. In this connection reference was made to Dieni et al. (1985, pl. 17, fig. 7). One illustration of this taxon can be found in Drobne and Cosovic (2009, fig. 4, *Pseudonummoloculina* n. sp.). A difference of *P. sopadensis* to *P. kalantarii* might be the reduced size, and test morphology indicated as spherical to slightly nautiloid in Drobne et al. (2005).

MICROFACIES AND FAUNAL ASSOCATIONS OF THE DESCRIBED TAXA

The taxa described and reported in the present paper were observed in foraminiferan-dasycladalean wackestones to packstones, referring to a soft substrate and very low water energy in a shallow protected lagoon. In the Tarbur Formation this facies is characterized by the association of agglutinated conical foraminifera (Orbitolinidae indet., *Gyroconulina*, *Dictyoconella*), miliolids [among complex taxa such as *Broeckina* cf. *dufrenoyi* (d' Archiac), and *Tarburina zagrosiana* Schlagintweit, Rashidi & Barani], and dasycladalean algae. Except for the lack of alveolinids, and the presence of rudists, this association can palaeoecologically be compared to similar associations of the Paleogene (e.g., Vecchio and Hottinger, 2007, fig. 5), e.g., the so-called "*Spirolina* facies" of the Mediterranean area (e.g., Sartoni and Crescenti, 1962; Radoičić, 1995;

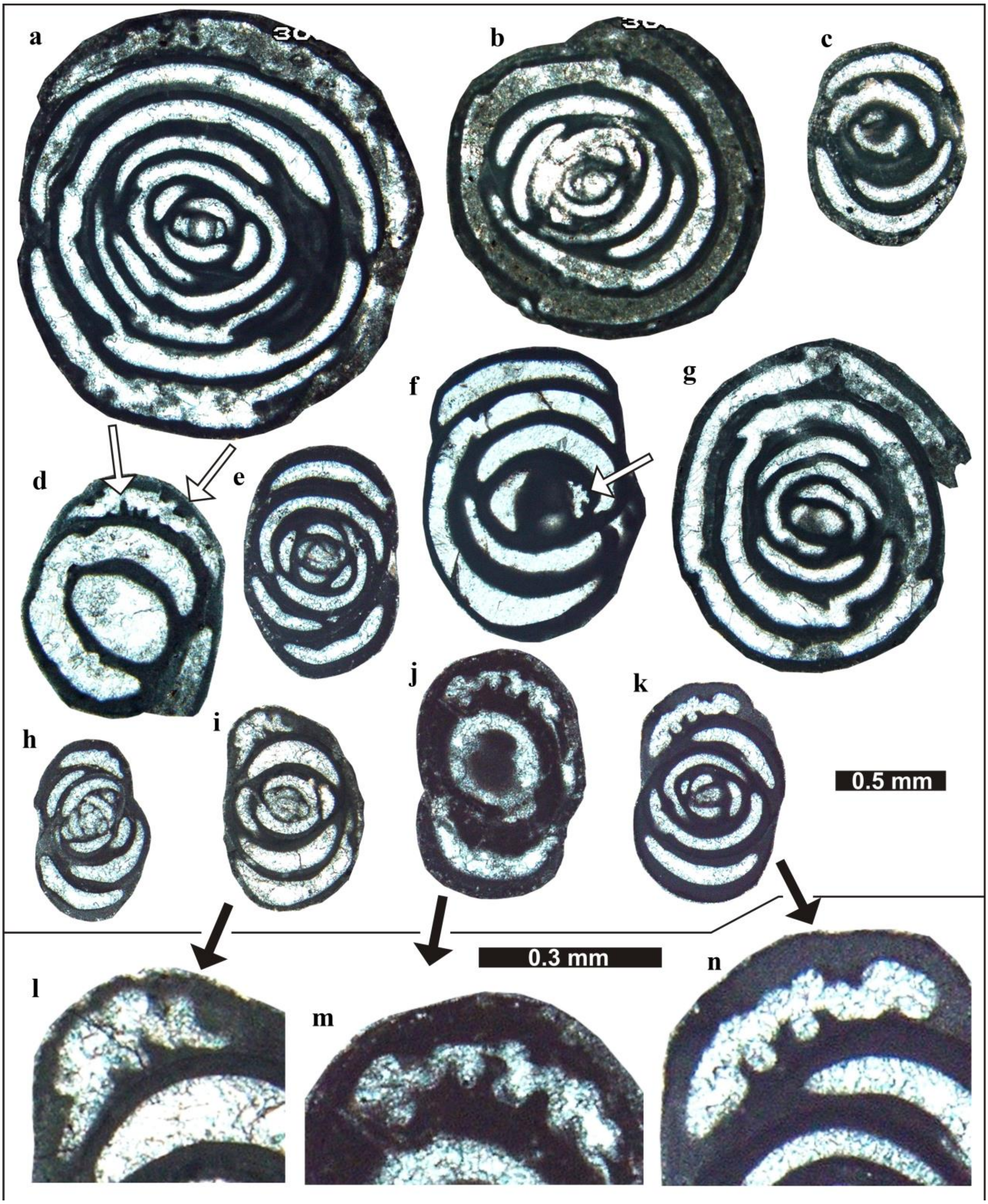

Fig. 15 *Pseudonummoloculina kalantarii* n. sp., Late Maastrichtian Tarbur Formation of Naghan section, Zagros Zone, SW Iran. **a–b** Equatorial sections. **c–d, f–g, j** Oblique sections. **e, h–i, k** Oblique axial to subaxial sections. **l–n** Details from **i–k** showing notched aperture in the last whorls. Holotype specimen in **k** (detail in **n**). Notched apertures are also discernible in **d** and **f** (arrows), and **a**?. Thin-sections: TB 82 (**a**), NG 81 (**b**), NG 83 (**c, h–i, l**), NG 86 (**d**), NG 83-2 (**e–f, j, m**), NG 85 (**g, k, n**).

Fleury, 1997; Barattolo et al., 2000). As a depth trend, the Mandegan section displays a shallowing upwards sedimentary succession with the remarked association occurring in the upper part. Amongst the Dasycladales we note the occurrence of *Pseudocymopolia anadyomenea* (Elliott), *Pseudocymopolia*? sp., *Salpingoporella pasmanica* Radoičić (see Schlagintweit et al., 2016b) and other taxa currently under study. The foraminiferan association is highly diverse and includes (in alphabetical order) besides the taxa illustrated in the present paper: *Antalyna korayi* Farinacci & Köylüoglu, *Cuneolina* sp., *Dicyclina* cf. *schlumbergeri* Munier-Chalmas, *Dictyoconella minima* Henson, *Elazigella*? sp., *Fallotia* aff. *jacquoti* Douvillé, *Gyroconulina columellifera* Schroeder & Darmoian, *Laffiteina monodi* Marie, *Loftusia harrisoni* Cox, *Loftusia coxi* Henson, *Loftusia morgani* Douvillé, *Missis-*

sippina? *binkhorsti* (Reuss), *Nezzazatinella*? cf. *picardi* (Henson), *Neobalkhania bignoti* Cherchi, Radoičić & Schroeder, *Elphidiella*? *cretacea* (Pérébaskine), *Omphalocyclus macroporus* (Lamarck), Orbitolinidae indet., *Tarburina zagrosiana* Schlagintweit, Rashidi & Barani, *Valvulina*? sp. 1 Sirel. It must be stressed, that not all the above listed taxa are co-occurring in the same sample.

STRATIGRAPHY

Based on larger benthic foraminifera [e.g., *Loftusia* ssp., *Siderolites calcitrapoides* Lamarck, *Gyroconulina columellifera* Schroeder & Darmoian, *Omphalocyclus macroporus* (Lamarck)], the studied sections are Maastrichtian in age (Schlagintweit et al., 2016b, and in press, with references therein). We also want to stress the occurrence of the lamellar perforate Maastrichtian taxon *Laffiteina monodi* Marie (e.g., Hottinger, 2014) in the uppermost part of the Mandegan section (samples Rt 90 to Rt 111) (Fig. 16). *Neobalkhania bignoti* was originally described by Cherchi et al. (1991) from the Late Maastrichtian of Croatia. Cherchi et al. (1991, p. 288) also noted its occurrence in time-equivalent strata from Greece, concluding that *N. bignoti* represents “an excellent marker of this time interval” (see also Fleury, 2014, Fig. 3). A Late Maastrichtian age for the upper part of the Tarbur Formation, which contains the new taxa *Accordiella*? *tarburensis*, *Spirolina*? *farsiana*, *Pseudonummoloculina kalantarii* and other foraminifers reported in this paper, can be concluded. This conclusion is also in line with the occurrence of *Siderolites calcitrapoides* Lamarck in the lower samples of the Mandegan section (some meters above the boundary to the underlying Gurpi Formation, see Fig. 4), since the first occurrence of this taxon is latest early Maastrichtian (according to Robles Salcedo, 2014). This implies that the Gurpi Formation ranges into the Maastrichtian at the Mandegan section.

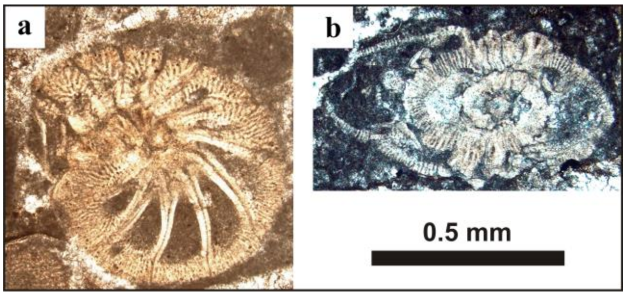

Fig. 16 Lamellar perforate foraminifera *Laffiteina monodi* Marie. **a** Oblique section, thin-section Rt 100-2. **b** Subaxial section, thin-section Rt 90.

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