PERSIELLA PSEUDOLITUUS N. GEN., N. SP., AND *FLABELLOPERFORATA TARBURENSIS* N. GEN., N. SP., TWO NEW LARGER BENTHIC FORAMINIFERA FROM THE UPPER MAASTRICHTIAN OF IRAN

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Abstract Two new larger benthic foraminifera, *Flabelloperforata tarburensis* n. gen., n. sp. (?family Biokovinidae), and *Persiella pseudolituus* n. gen., n. sp. (?family Spirocyclinidae), are described systematically from the upper Maastrichtian of the Tarbur Formation of the Zagros Zone, SW Iran. They occur in diverse foraminiferal wackestone-packstone microfacies, together with other larger benthic foraminifera, rudist debris and dasycladalean algae. *Flabelloperforata* n. gen. is characterized by its flabelliform test, chambers without any structures (no exo- and endoskeleton), and a thin, microgranular-finely agglutinating wall displaying a pseudokeriotheca-like texture. *Persiella* n. gen. is characterized by its planispirally-involute and biumbilicate enrolled test, a finely agglutinating wall with thin imperforate epiderm underlain by a layer displaying pseudokeriotheca-like texture. The exoskeleton is thick, deep and forms a network that in tangential sections displays a rounded pattern. An endoskeleton is absent. Potential ancestral, seemingly more primitive forms of the new Maastrichtian taxa might be *Flabellocyclolina* Gendrot and *Pseudocyclammina* Yokoyama respectively. The new discoveries enrich the diverse associations of (large) benthic foraminifera in the Tarbur Formation of Iran, and give further evidence for a diversification peak (biodiversity hotspot) and provincialism in the Maastrichtian of the Arabian plate with many newcomer genera and species.

Keywords: Loftusioidea, wall structure, systematics, biostratigraphy, diversification, palaeobiogeography, Arabian plate

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 carbonatic 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). Towards the southwest, the Tarbur Formation interfingers with the Gurpi Formation that usually underlies the former in other areas. 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) (Fig. 1). However, the microfaunal content of the Tarbur Formation is still poorly constrained. Some taxa of benthic foraminifera are mentioned and/or illustrated in various recently published papers (Vaziri-Moghadam et al., 2005; Afghah, 2009, 2016; Maghfouri-Moghaddam et al., 2009; Rajabi et al., 2011; Abyat and Lari, 2015; Abyat et al., 2012, 2015; Afghah and Farhoudi, 2012; Pirbaluti and Abyat, 2013; Pirbaluti et al., 2013; Afghah and Yaghmour, 2014). Several determinations however are dubious if not incorrect and therefore require further investigations.

Preliminary results and critical revisions of the micropalaeontology of the Tarbur Formation were published recently and new foraminifers have been described (Schlagintweit and Rashidi, 2016, 2017a, b; Schlagintweit et al., 2016a-d). The present paper represents an additional contribution to this set of studies with the description of two new larger benthic foraminifera, *Flabelloperforata tarburensis* n. gen., n. sp. and *Persiella pseudolituus* n. gen., n. sp. In addition, well preserved specimens of *Neobalkhania bignoti* Cherchi, Radoičić & Schroeder are illustrated for comparison purpose.

STUDIED SECTIONS

The studied foraminiferal-bearing samples studied are from two sections of the Tarbur Formation (Fig. 2):

a) Naghan section

The studied area in the folded Zagros belt is located approximately 50 km south west of Naghan town near Gandomkar village and is here named the Naghan section. At this locality, the Tarbur Formation unconformably rests on the Gurpi Formation and is overlain by the Paleocene Sachun Formation. Lithologically, the Gurpi Formation consists of dark shales, grey calcareous shales with planktonic foraminifera. The Sachun Formation consists of gypsum, red shales, anhydrite and some layer 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 five 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 (calcilutites and calcarenites)
- unit 4 (38 m), thick-bedded to massive, grey to cream-coloured limestones containing broken rudist shells and tests of *Loftusia* (calcarenites, calcilutites to calcirudites)

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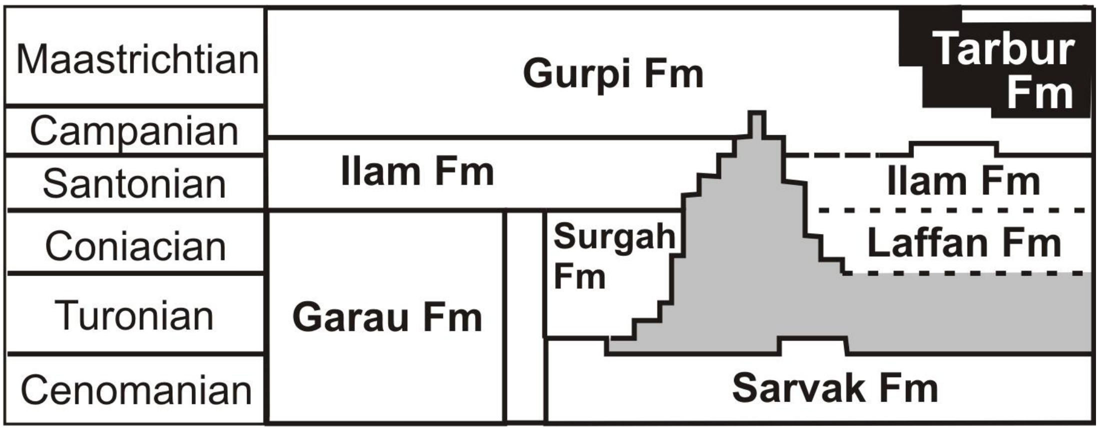

Fig. 1 Lithostratigraphy of Upper Cretaceous strata of the Zagros Zone (redrawn from the Stratigraphic Chart of Iran, Geological Society of Iran, 1995).

Fig. 2 Location of the Naghan and Mandegan sections, the type localities of *Flabelloperforata tarburensis* n. sp., and *Persiella pseudolituus* n. gen., n. sp. (taken from google maps)

- unit 5 (~ 41.6 m), shales interbedded with medium- to thick-bedded yellow limestones containing *Loftusia* fragments.

Persiella pseudolituus n. gen., n. sp. appears in the middle part of unit 2 and disappears in the middle part of unit 4 (see Schlagintweit et al., 2016b, for further details). Within this interval it is rather common and most specimens illustrated in the present paper are from the Naghan section.

Both taxa occur in foraminiferal wackestone-packstone, occasionally associated with dasycladalean algae (Fig. 3). *Persiella pseudolituus* n. gen., n. sp. is accompanied by larger benthic foraminifera such as *Dicyclina* sp, *Dictyoconella*? *minima* Henson, *Zagrosella rigaudii* Schlagintweit & Rashidi, *Lafitteina monody* Marie, *Loftusia* div. sp., *Minouxia*/*Tetraminouxia*, *Neobalkhania bignoti* Cherchi, Radoičić & Schroeder, *Omphalocyclus macroporus* Lamarck, *Dictyoconus bakhtiari* Schlagintweit, Rashidi & Babadipour, *Tarburina zagrosiana* Schlagintweit, Rashidi & Barzani, and other so far still undescribed taxa. The dasycladaleans are represented mainly by the two taxa *Salpingoporella pasmanica* Radoičić and *Pseudocymopolia anadyomenea* (Elliott) (see Schlagintweit et al., 2016d). The Greenwich coordinates of the section base are N 31°47' 52" and E 50° 32' 53 ".

b) 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 was named the Mandegan section (for further details of the location see Schlagintweit et al., 2016a). There the Tarbur Formation with a thickness of ~272 m conformably overlies the Gurpi Formation. 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 subdivided 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 limestone. *Persiella pseudolituus* n. gen., n. sp. has its first appearance in the upper part of unit 1, ranging up almost to the very top of the section (Fig. 4). The microfacies of the samples bearing *Persiella pseudolituus* n. gen., n. sp.

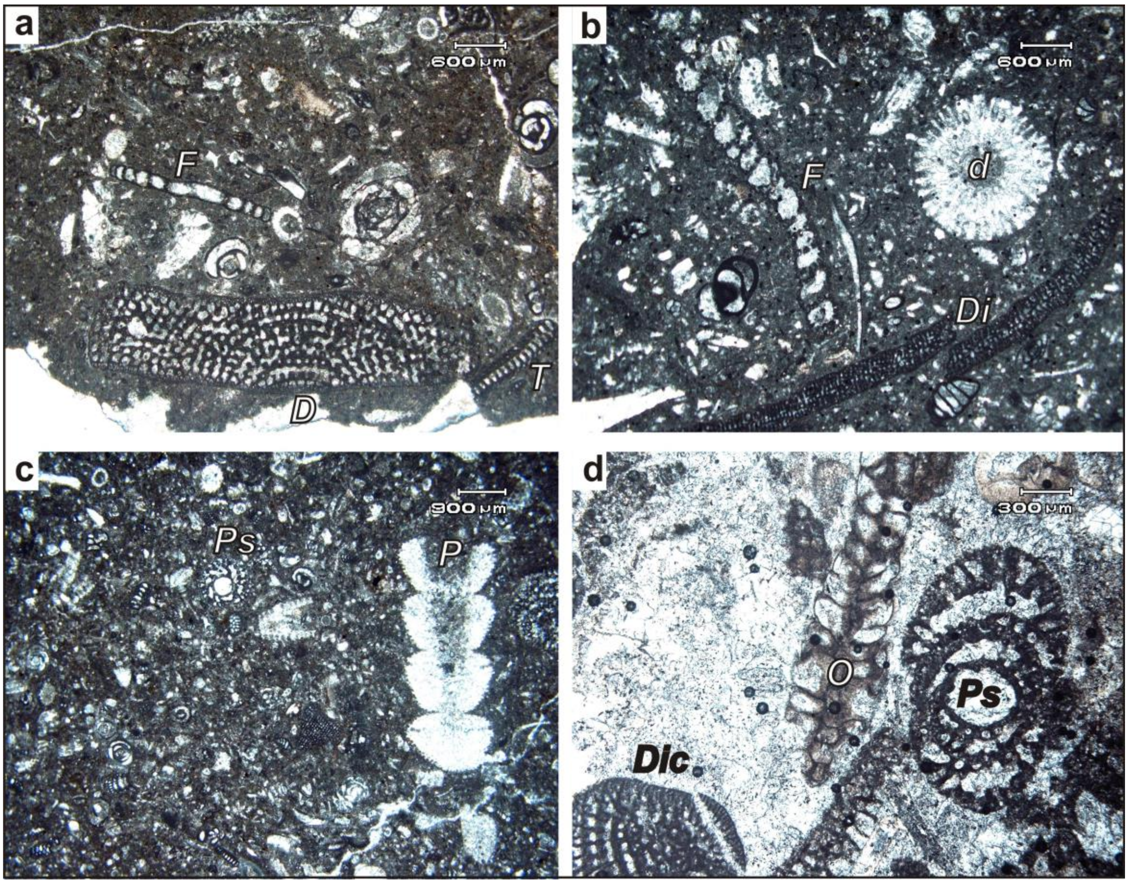

Fig. 3 Typical microfacies of samples with *Flabelloperforata tarburensis* n. gen., n. sp (*F* in **a–b**), and *Persiella pseudolituus* n. gen., n. sp. (*Ps* in **c–d**), from the upper Maastrichtian Tarbur Formation of the Naghan section, Zagros Zone, SW Iran. **a–b** Wackestones/packstones with benthic foraminifera, among many porcelaneous and agglutinating taxa such as *Dicyclina* sp. (*Di*), *Tarburina zagrosiana* Schlagintweit, Rashidi & Barani (*T*), *Dictyoconus bakhtiari* Schlagintweit, Rashidi & Babadipour (*D*) and remains of dasycladalean algae (d in **b**). **c** Wackestone with small and larger benthic foraminifera and oblique longitudinal section of the dasycladale *Pseudocymopolia* cf. *anadyomenea* (Elliott) (*P*). **d** Grainstone/packstone with *Omphalocyclus macroporus* Lamarck (*O*), *Dictyoconella*? *minima* Henson (*Dic*), and slightly oblique axial section of *Persiella pseudolituus* n. gen., n. sp. (*Ps*). Thin-sections: 2NG 81-4 (**a**), 2NG 120 (**b**), 2NG 166 (**c**), 2NG 177 (**d**).

is the same as for the Naghan section. The Greenwich coordinates of the Mandegan section base are N 31º, 25', 8.13'' and E 51º, 24', 34.58''.

MATERIAL AND DEPOSITORY

The specimens of the new taxon described and illustrated in the present contribution are from various thin-sections stored at the Ardakan Payame Noor University, Iran, in the Rashidi collection, under the original sample numbers with the prefixes NG and 2NG for the Naghan section. The thin-section with the holotype of *Persiella pseudolituus* n. gen., n. sp. is stored at the Bayerische Staatssammlung für Paläontologie und historische Geology, Munich, under the official number SNSB-BSPG 2016 V 16. This thin-section is part of 20 thin-sections from the Tarbur Formation stored in the framework of the orbitolinid study of the authors (Schlagintweit et al., 2016b).

SYSTEMATICS

The high-rank classification follows Pawlowski et al. (2013). For the low-rank classification see Kaminski (2014), and Albrich et al. (2015). For a glossary of terms, see Hottinger (2006).

Phylum Foraminifera d'Orbigny, 1826
Class Globothalamana Pawlowski et al., 2013
Order Loftusiida Kaminski & Mikhalevich, 2004
?Suborder Biokovinina Kaminski, 2004

Remarks: The suborder Biokovinina was defined by Kaminski (2004, p. 250) as follows: "Test free or attached, may be coiled in the early stage, later uncoiled or branched. Wall finely agglutinated, traversed by pores, or with a coarsely perforate or canaliculate inner layer and an outer imperforate layer". *Flabelloperforata* n. gen. displays the wall structure of the Biokovinoidea. The unbranched forms assigned to this suborder are classically planispirally coiled forms that may uncoil in the adult stage. In *Flabelloperforata* n. gen. the initially coiling chambers are flaring becoming flabelliform, unknown so far from the Biokovinina and lower rank categories accounting for only a tentative assignment to this group.

?Superfamily Biokovinoidea Gušić, 1977
?Family Biokovinidae Gušić, 1977
Genus *Flabelloperforata* n. gen.

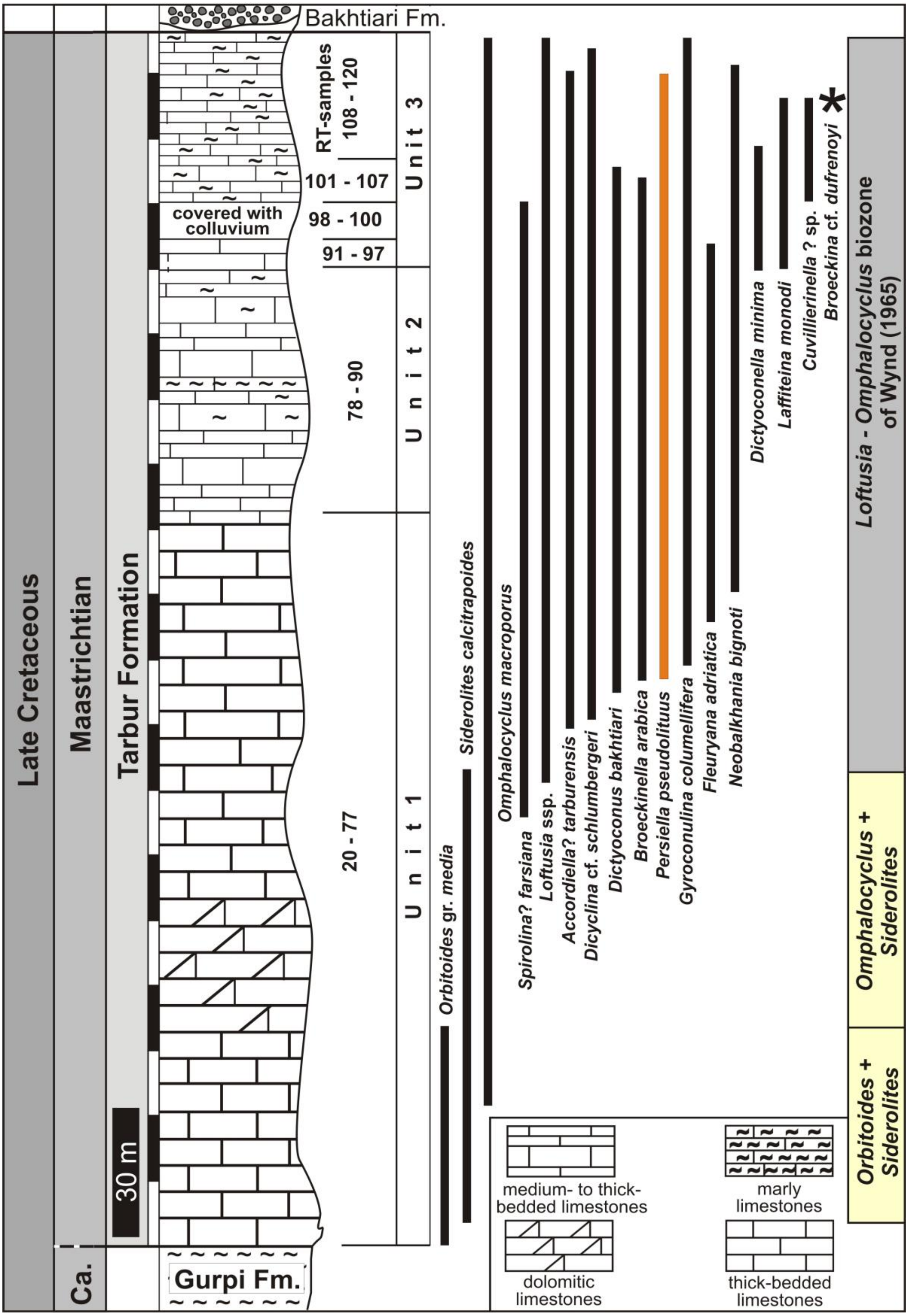

Fig. 4 Vertical distribution of *Persiella pseudolituus* n. gen., n. sp. and some other larger benthic foraminifera in the Tarbur Formation of the Mandegan section.

Type species: *Flabelloperforata tarburensis* n. sp.
Origin of the name: The name refers to the flabelliform test morphology and the tiny pores within the wall.
Horizon and locality: Late Maastrichtian limestones of the Tarbur Formation of the Mandegan and Naghan sections (Fig. 2).
Diagnosis: Test free, flattened (to undulating), flabelliform, with rounded periphery. Initial part with spirally coiled chambers continuously increasing in size as added, then rapidly increasing in breadth, becoming flabelliform (but never cyclic). Chambers without any structures (no exo- and endoskeleton). The chamber sutures are distinctly depressed. Wall and septa equal in thickness. Solid septa are pierced by numerous (multiple) foramina, arranged in several parallel rows. Wall thin, dark-microgranular-like with close-set simple unbranching parapores (pseudo-keriotheca-like); thin epiderm present, may be decorticated.
Remarks and comparisons: First of all, we have to state that no section of the Iranian specimens demonstrates a cyclic (annular) chamber arrangement. The genus *Flabellocyclolina* (type-species *F. laevigata*), established by Gendrot (1964) from the Coniacian-Santonian of southern France shares some similarities (test morphology, no internal structures) with *Flabelloperforata* n. gen. The foraminal type of the former is multiple with only one row of openings. Instead, the specimens from the upper Maastrichtian of Iran display foramina arranged in several parallel rows. Another difference is the wall structure, simple, microgranular, heterogeneous, without pores in *Flabellocyclolina* and pseudo-keriotheca-like in *Flabelloperforata* n. gen. More precisely, Gendrot (1964, p. 530, translated) stated: “Under normal light as well as under crossed Nichols, the wall shows a dark, heterogeneous aspect, but without any discernible grain”. With respect to *Flabelloperforata* n. gen., *Flabellocyclolina* can be considered a more primitive form, and its potential ancestor.
A possible section of *Flabelloperforata tarburensis* was illustrated by Afghah (2009, pl. 1, Fig. 4) from the Tarbur Formation as *Vania anatolica* Sirel erroneously concluding an early Paleogene age (see discussion in Schlagintweit et al., 2016a). *Vania* is different from *Flabelloperforata* n. gen. above all by its well developed subepidermal network of beams and rafters (exoskeleton) and its finely agglutinating imperforate wall. Other sections of *Vania anatolica* by Afghah (2016, Fig. 5h) belong to the cyclic *Neobalkhania bignoti* Cherchi, Radoičić & Schroeder (Fig. 5). Like *Vania*, *Neobalkhania* possesses an exoskeleton (see Cherchi et al., 1991) and an agglutinating imperforate wall, different from *Flabelloperforata*. It is worth mentioning that in the Tarbur Formation, both *Flabelloperforata tarburensis* and *N. bignoti* can co-occur. Summarizing, the test morphology combined with the lacking of any internal chamber structures (exo-/endoskeleton) and the pseudo-keriotheca-like wall structures differentiate *Flabelloperforata* n. gen. from all other genera.

Flabelloperforata tarburensis n.sp.
?2009 *Vania anatolica* Sirel – Afghah, pl. 1, Fig. 4.
Figs. 3a–b pars, 6–7.

Origin of the name: The species name refers to the late Cretaceous Tarbur Formation of the Zagros Zone, SW Iran.
Holotype: Oblique section illustrated in Figure 6A, thin-section NG 85-2.
Paratypes: Specimens in Fig. 6b–d, f.
Description: Test large, flattened (to undulating) and flabelliform, with rounded periphery. Initial part with chambers (7–8) continuously increasing in size as added, then rapidly increasing in breadth, becoming flabelliform (but never cyclic). The latter part consists of up to 15 chambers. Chambers without any structures (no exo- and endoskeleton). The chamber sutures are distinctly depressed. Wall and septa equal in thickness. The solid septa are pierced by numerous (multiple) and tiny foramina arranged in several parallel rows (?2 to 3) (e.g. Figs. 6i, k, m). Wall thin, dark-microgranular-like to finely agglutinated with close-set simple pseudo-keriotheca-like pores (Fig. 7b); thin epiderm present, may be decorticated.

Dimensions (in mm):
test diameter = up to 14.5 (incomplete)
test thickness = up to 0.4
thickness septum = 0.02–0.06
diameter foramina = 0.01–0.03
diameter pseudo-keriotheca-like pores = 0.005–0.08

Remarks: See further remarks for the genus as the compared forms are monospecific.

Suborder Loftusiina Kaminski & Mikhalevich, 2004
Superfamily Loftusoidea Brady, 1884
?Family Spirocyclinidae (Munier-Chalmas, 1887) Maync, 1950
Remarks: The suprageneric position of *Persiella* remains unclear referring to its type of exoskeleton and wall structure. On the one hand, the coarse subepidermal network represents a typical feature of many spirocyclinids (see Albrich et al. 2015 for discussion) included in the superfamily Loftusoidea Brady. On the other hand, the canaliculated inner layer brings *Persiella* close to the superfamily Biokovinoidea Gušić. It is worth mentioning that the relevance of structural features, and wall structure, for the diagnosis of the families (and subfamilies) of the Loftusoidea is treated controversially. This leads to different generic composition of families and subfamilies (see Loeblich and Tappan, 1987; Kaminski, 2014; Albrich et al., 2015). Due to the morphological and structural affinities with *Pseudocyclammina* Yokoyama, and the coarse subepidermal network, *Persiella* n. gen. is tentatively assigned to the family Spirocyclinidae of the order Loftusoidea.

Genus *Persiella* n. gen.
Type species: *Persiella pseudolituus* n.sp.
Origin of the name: Referring to Persia.
Horizon and locality: Late Maastrichtian limestones of the Tarbur Formation of the Naghan section (Fig. 2).
Diagnosis: Test free, planispirally-involute or rarely streptospirally enrolled in the early stage, and biumbilicate, may become uncoiled in the late growth stage with few chambers. The protoconch is rather large, subspherical to elliptical, and connected to the second chamber

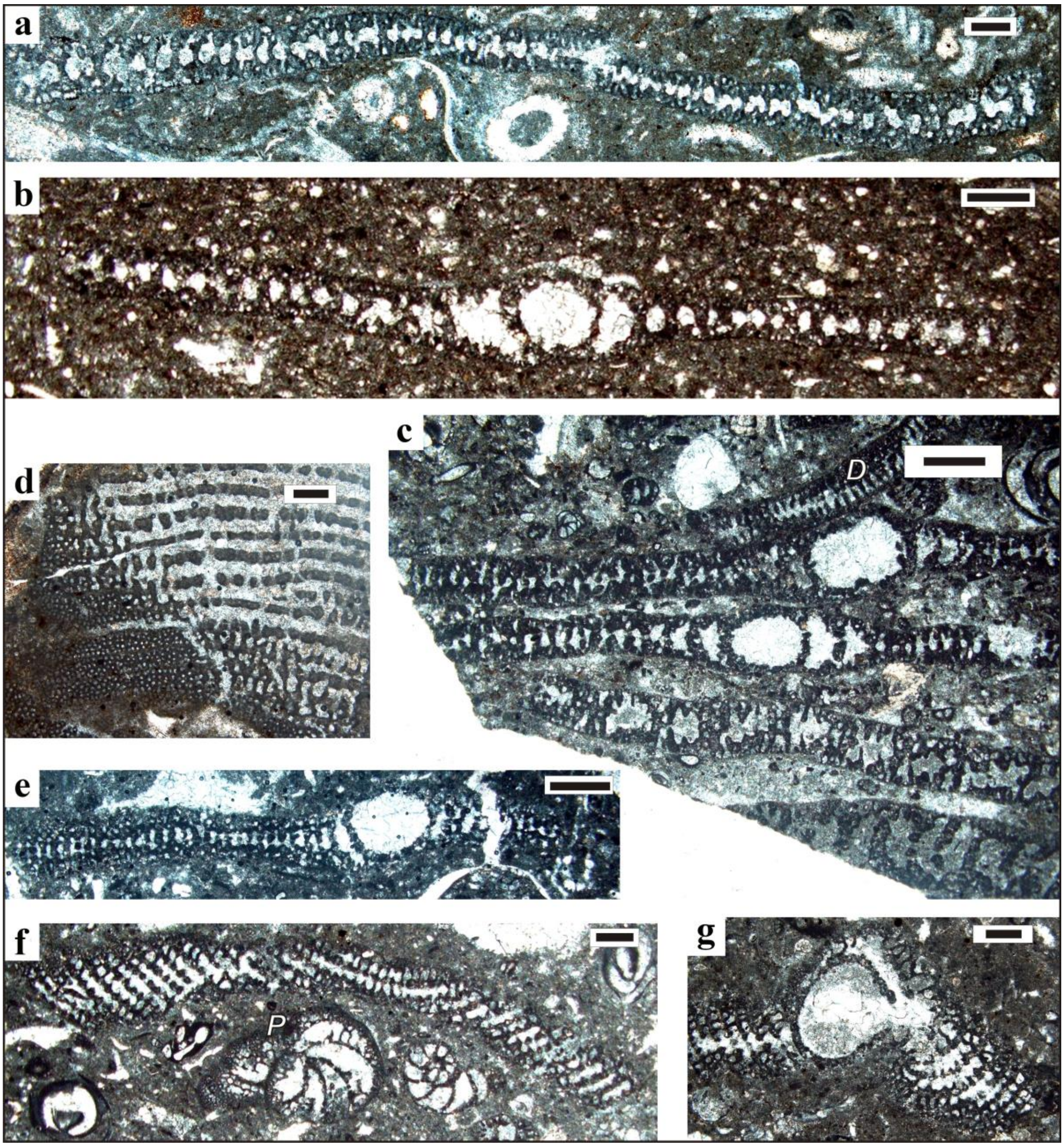

Fig. 5 *Neobalkhania bignoti* Cherchi, Radoičić & Schroeder from the upper Maastrichtian of the Tarbur Formation of the Mandegan (**a**), and Naghan sections (all others). **a** Subaxial section of a large specimen (diameter ~7 mm). **b** Axial section of a megalospheric specimen. **c** Four specimens in (sub)axial sections, and *Dicyclina* sp. (*D*). **d** Tangential section showing subepidermal network with coarse primary partitions (right below) and finer secondary partitions (left below). **e** Oblique axial section of a megalospheric specimen. **f** Fragmentary equatorial section, *P* = *Persiacyclammina maastrichtiana* Schlagintweit & Rashidi. **g** Oblique section of a megalospheric specimen showing large embryo with opening to the second annular chamber. Scale bars: **a–b, d, f–g** = 0.3 mm; C, E = 0.6 mm. Thin-sections: Rt 113 (**a**), 2NG 109 (**b**), 2NG 128 (**c**), 2NG 201-1 (**d**), 2NG 120 (**e**), 2NG 81 (**f–g**).

(?deuteroconch) by multiple openings. There are up to two and a half whorls present, increasing continuously in height; test periphery broadly rounded. Septa strongly oblique and perforated by numerous (cribrate) large openings. Wall dark microgranular to finely agglutinating, with thin imperforate epiderm underlain by a layer of fine, parallel, and unbranching pseudokeriotheca-like pores. Exoskeleton (beams and rafters) thick, deep and rather widely spaced, forming a network; no endoskeleton. In tangential sections, the subepidermal meshwork displays a rounded pattern. Foramen basal to multiple in the juvenile stage, later multiple.

Comparisons: The agglutinating benthic foraminifer *Loftusia* Brady co-occurring with *Persiella* n. gen. in the Tarbur Formation, has large, fusiform, ovoid or globular test, planispirally enrolled with increasing elongate coiling axis. Besides exoskeleton, *Loftusia* also possesses an endoskeleton (Loeblich and Tappan, 1987, p. 110). Worth mentioning that *Persiella* n. gen. has been confounded in the literature with a representative of *Loftusia* (see synonymy and comments for the species). Both, *Paracyclammina* Yabe (Late Jurassic) and *Pseudocyclammina* Yokoyama (Late Jurassic-Late Cretaceous) possess a strongly agglutinated wall with coarse subepidermal net

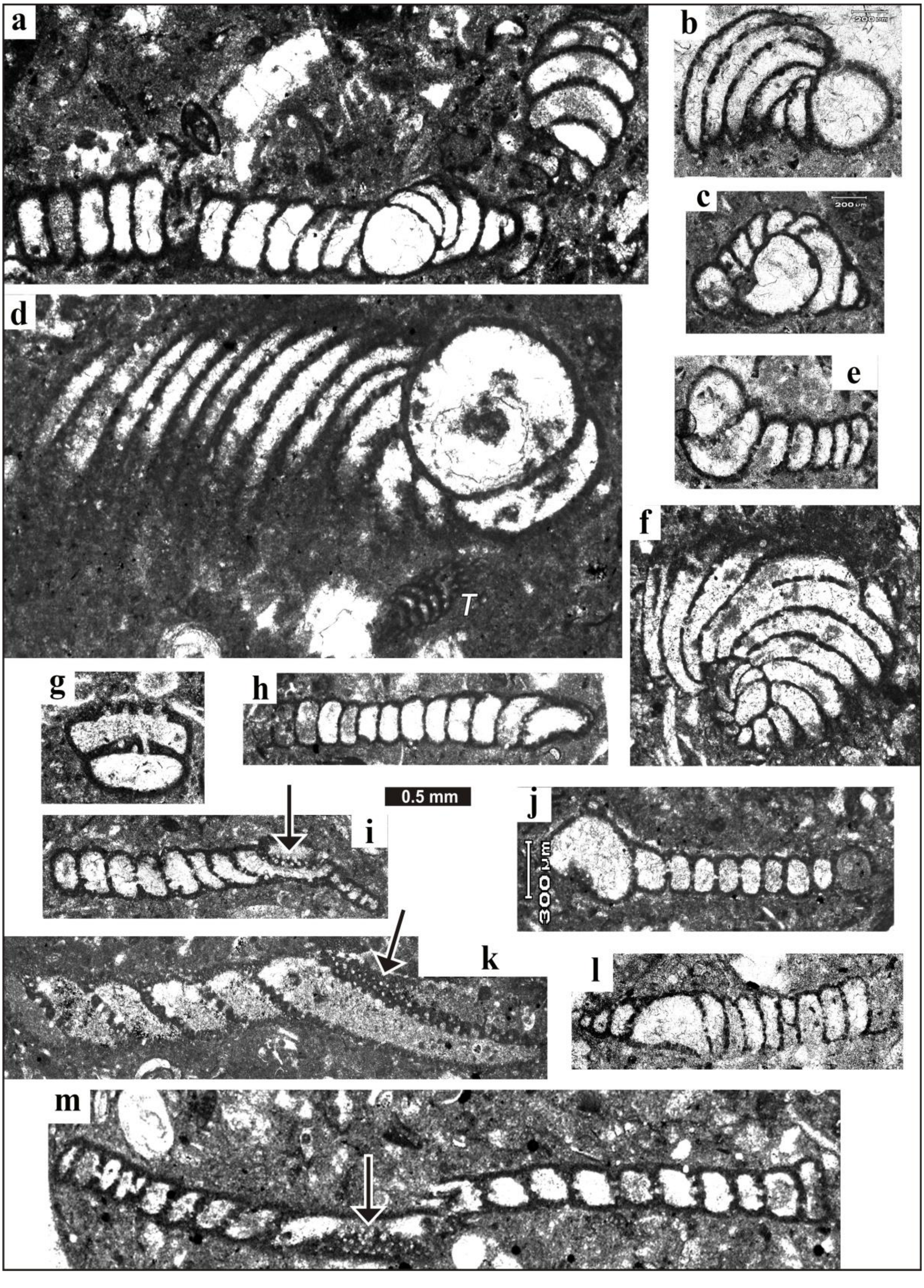

Fig. 6 *Flabelloperforata tarburensis* n. gen., n. sp. from the upper Maastrichtian of the Tarbur Formation of the Naghan section, Zagros Zone, SW Iran. **a–e, g–l**: Oblique sections; holotype specimen in **a**; multiple foramina depicted in **i** and **k** with arrows. **f** Oblique equatorial section. *T*: *Tarburina zagrosiana* Schlagintweit, Rashidi & Barani. **m** Slightly oblique subaxial section. Arrow: multiple foramina. Thin-sections: NG 85-2 (**a**), 2NG 81-2 (**b**), 2NG 85-1 (**c**), 2NG 83 (**d**), 2NG 84-1 (**e, h**), NG 49 (**f**), 2NG 81-4 (**g**), NG 83-2 (**i**), NG 81 (**j**), NG 61 (**k**), 2NG 87-2 (**l**), 2NG 197 (**m**).

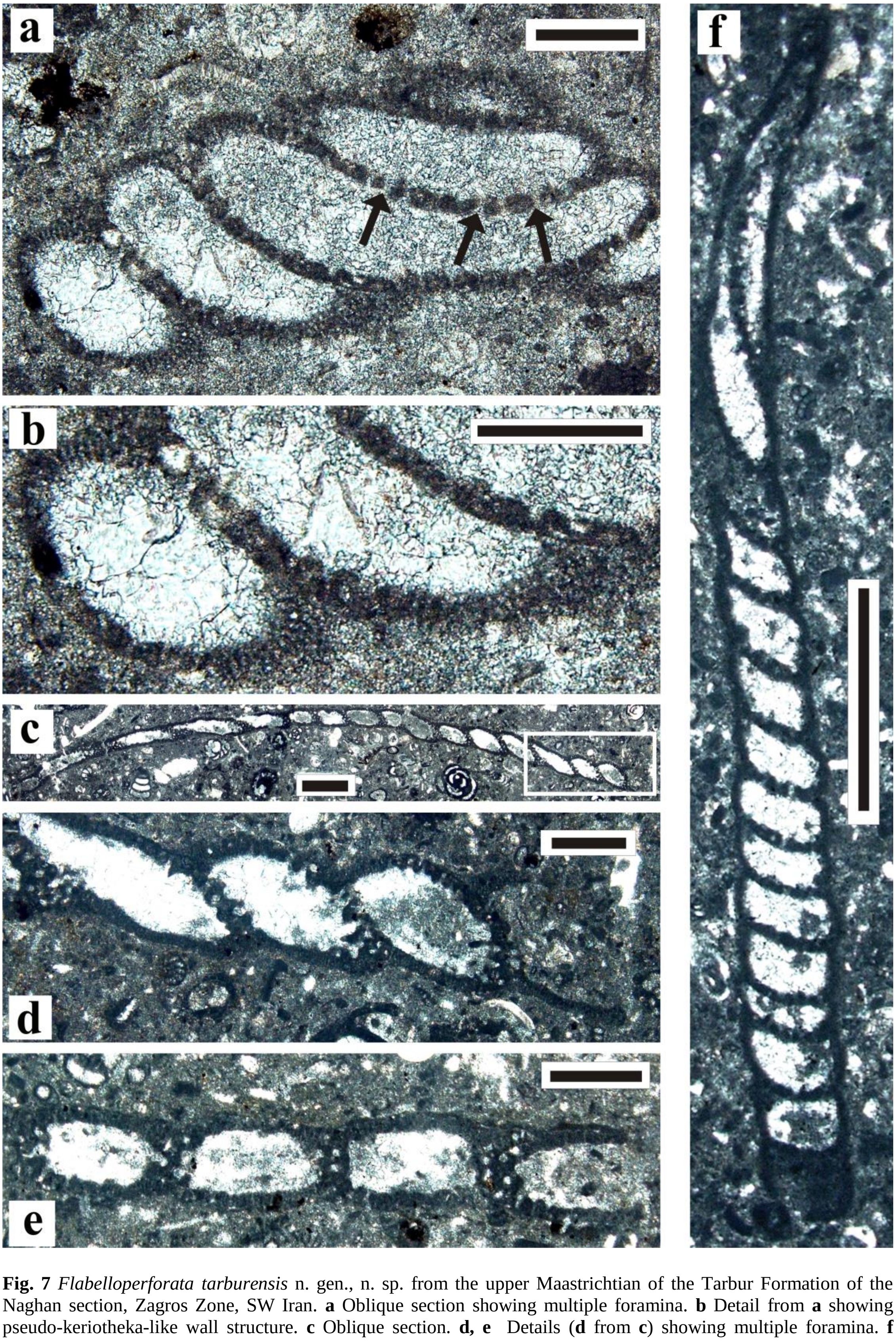

Fig. 7 *Flabelloperforata tarburensis* n. gen., n. sp. from the upper Maastrichtian of the Tarbur Formation of the Naghan section, Zagros Zone, SW Iran. **a** Oblique section showing multiple foramina. **b** Detail from **a** showing pseudo-keriotheka-like wall structure. **c** Oblique section. **d, e** Details (**d** from **c**) showing multiple foramina. **f** Oblique section. Thin-sections: 2NG 8 (**a–b**), 2NG 86 (**c–e**), 2NGN (**f**). Scale bars: **a–b** = 0.2 mm, **c, f** = 1 mm, **d–e** = 0.3 mm.

work and lack the layer of fine and simple alveoles of *Persiella* n. gen. (Fig. 8). From morphological and structural view points, however, *Pseudocyclammina* is very close to *Persiella* n. gen., and could be its potential ancestor as the latter seems to be more advanced. It is worth mentioning that the youngest record of *Pseudocyclammina* is from the late Campanian (Parente, 1994, pl. 1, fig. 5).

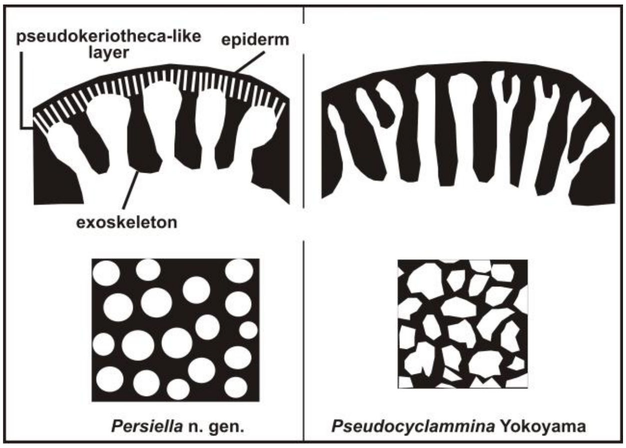

Fig. 8 Schematic drawing showing differences in the wall structure of *Persiella* n. gen. and *Pseudocyclammina* Yokoyama (without scale).

Zagrosella also with a pseudo-kerotheca-like wall structure that has recently been described from the same locality as *Persiella* n. gen. (see Schlagintweit and Rashidi, 2017a) differs from the latter above all by the absence of a subepidermal network (exoskeleton), thick septa with just a few rather large openings, and last but not least the presence of few thin and irregularly distributed pillars. *Persiacyclammina*, also described recently from the Tarbur Formation (Schlagintweit and Rashidi, 2017b) differs from *Persiella* by its morphology (subcylindrical to elongate), wide chamber lumen, foraminal pattern (numerous small and rather close-set openings), and the type of exoskeleton. The latter is delicate and related also to pseudotriangular shaped radially arranged subepidermal septula stretching downward to the chamber floor.

Persiella pseudolituus n. sp.
Figs. 3C–D, pars, 9–12, 13D–F
2013 *Loftusia morgani* – Pirbaluti et al., Fig. 8.10
Origin of the name: The species name refers to seemingly similarities to the species *Pseudocyclammina lituus* Yokoyama.
Holotype: Almost centered axial section illustrated in Figure 12G, thin-section SNSB-BSPG 2016 V 16 (original thin-section Rt 113).
Paratypes: Specimens in figs. 9A–G, 10, 11A–B, F, H, M.
Description: Test free, subglobular (coiled forms) to elongate (uncoiling forms), early stage planispirally (occasionally streptospirally, Fig. 11a) coiled and involute with up to two and a half whorls present. The test periphery is broadly rounded; with slight axial depressions on both sides (biumbonate). The protoconch is rather large, subspherical to elliptical, and connected to the second chamber (?deuteroconch) by multiple openings (Fig. 12j). Chambers increasing continuously in width and only moderately in height, with many as thirteen chambers in the final whorl. In the coiled part, the septa are strongly oblique with five to six chambers in the first, and ten to eleven chambers in the second whorl. Only rarely the adult stage is uncoiling, uniserial and rectilinear with at least up to six chambers (Fig. 9e–f). Here the septa are convex, in direction of growth. Exoskeleton (beams and rafters) coarse, deep, and forming a network that in tangential sections displays a rounded pattern (Fig. 12a–b, f). Foramen basal to multiple in the juvenile stage, later multiple. In some sections it appears as that the foramina are disposed in continuity between successive chambers (Fig. 12 f, i). No endoskeleton present. Wall dark microgranular (?to finely agglutinating), with thin imperforate outer layer (epiderm) underlain by a layer of fine, parallel, and unbranching pseudokeriotheca-like pores.

Dimensions (in mm):
equatorial diameter (uncoiling forms) = up to 2.5
axial diameter (thickness) = up to 1.35
ratio ed/ad (uncoiling forms) = 1.5–1.9 (juvenile specimens ~1.2)
height (uncoiling forms) = up to 3.0
diameter proloculus = up to 0.65 (mostly 0.25–0.45)
thickness septa = 0.075–0.15
diameter foramina = 0.035–0.075
thickness epidermis = ~0.0075
wall thickness (epidermis + fine alveolar layer) = 0.04–0.065
diameter parapores = 0.0075–0.015

Remarks: *Persiella pseudolituus* has been confounded one time with *Loftusia morgani* Cox (see synonymy). *L. morgani* is a large size foraminifer (up to 44.5 mm in length and up to 8 mm in diameter), morphologically different, with endoskeleton, just a name a view differences (e.g., Cox, 1937; Meriç and Görmüş, 2001.). From a morphological aspect and also general appearance in sections, *Persiella pseudolituus* shows similarities with the Late Jurassic to earliest Cretaceous *Pseudocyclammina lituus* (Yokoyama) (Fig. 13). Leaving apart the generic differences, the test of *P. lituus* is more compressed (ratio equatorial diameter/axial diameter about 2), the proloculus is smaller (0.24–0.26 mm), and the number of chambers in the last whorl are less (5–6; all data acc. to Hottinger, 1967, p.63).

STRATIGRAPHY

Persiella pseudolituus n. gen., n. sp. has been observed in the Naghan section and the Mandegan section (see Schlagintweit and Rashidi, 2016, for further details). Based on larger benthic foraminifera [e.g., *Loftusia* ssp., *Siderolites calcitrapoides* Lamarck, *Gyroconulina columellifera* Schroeder & Darmoian, *Omphalocyclus macroporus* (Lamarck)], the Tarbur Formation in the studied sections is upper Maastrichtian in age. *Neobalkhania bignoti*, also found in association with *Persiella pseudolituus*, was originally described by Cherchi et al. (1991) from the upper Maastrichtian of Croatia. Besides, they also noted its occurrence in time-equivalent strata from Greece, leading Cherchi et al. (1991, p. 288) to con-

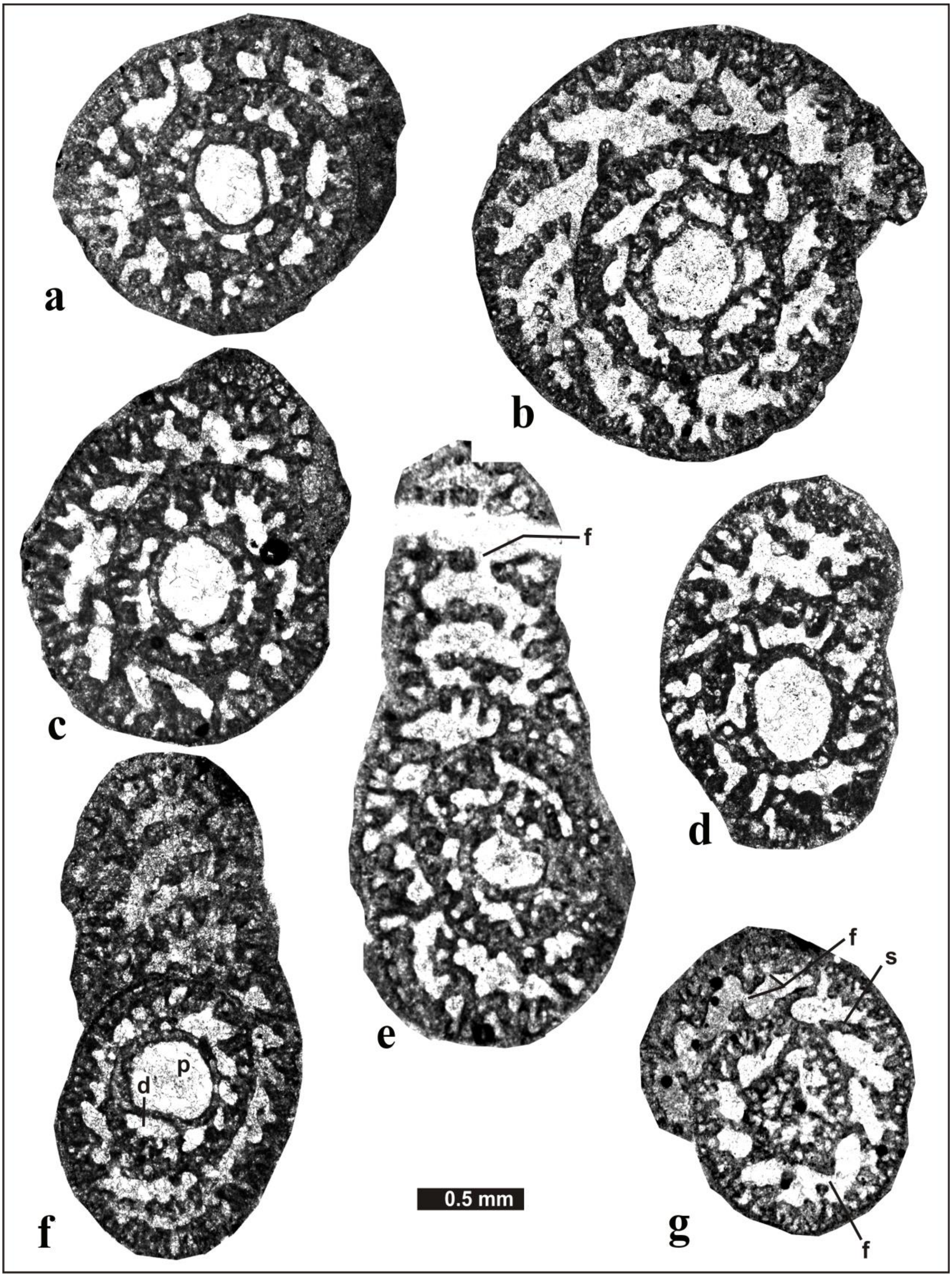

Fig. 9 *Persiella pseudolituus* n. gen., n. sp. from the upper Maastrichtian of the Tarbur Formation of the Mandegan (**a, e, g**) and Naghan sections (**all others**), Zagros Zone, SW Iran. **a–b** Equatorial sections. **c–d, g** Oblique equatorial sections; note tendency to uncoil in the youngest chambers. **e–f** Oblique equatorial sections of uncoiling specimens. Abbreviations: p = proloculus, d = possible deuteroconch, f = foramen, s = septum. Thin-sections: Rt 113 (**a, g**), 2NG 191 (**b**), 2NG 186 (**c**), 2NG 49 (**d**), Rt 87-1 (**e**), NG 196 (**f**).

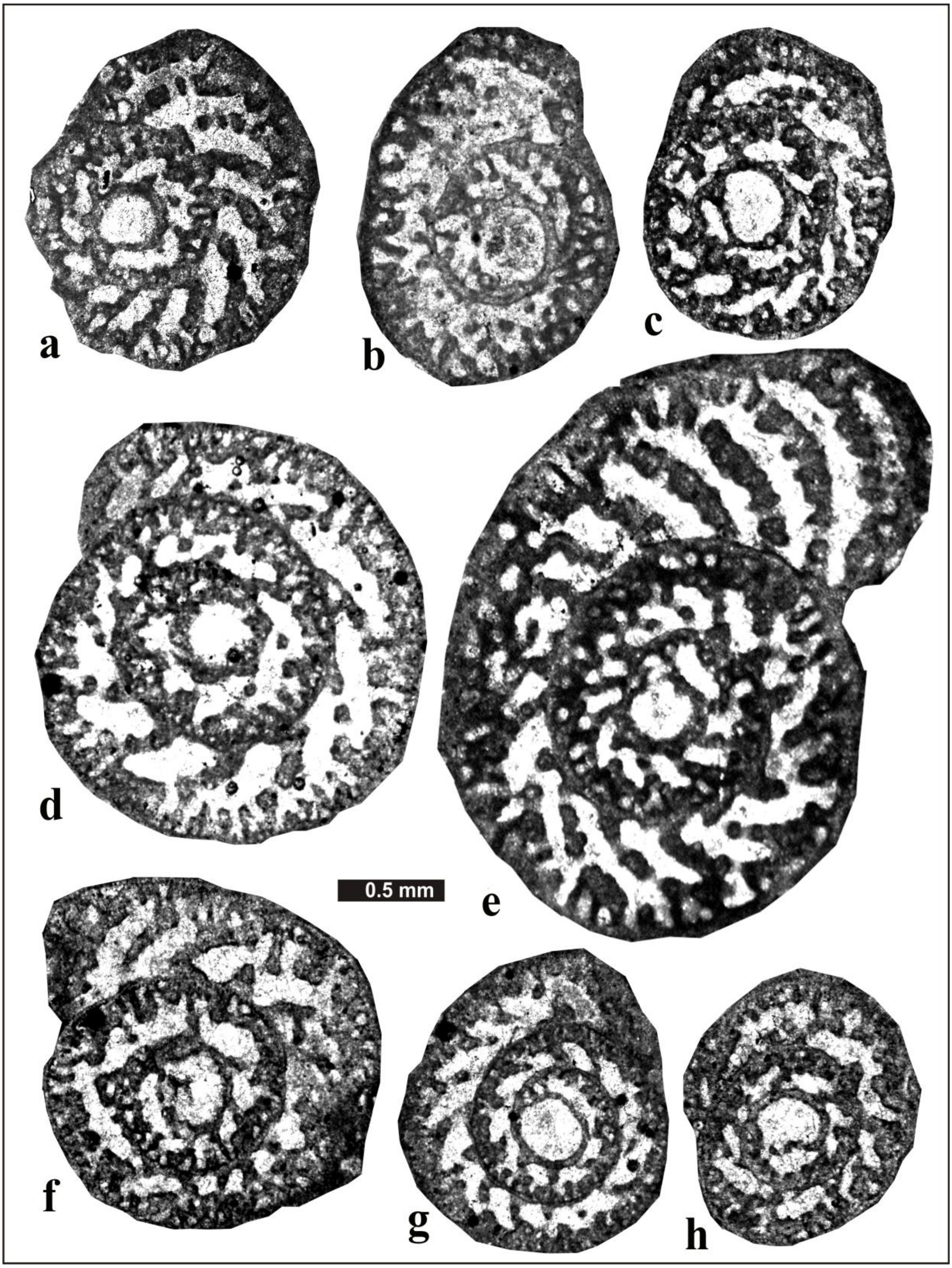

Fig. 10 *Persiella pseudolituus* n. gen., n. sp. from the upper Maastrichtian of the Tarbur Formation of the Naghan (**a**) and Mandegan (**all others**) sections, Zagros Zone, SW Iran. **a–c, h** Oblique equatorial sections. **d, f–g** Equatorial sections. **e** Equatorial section of an uncoiling specimen. Thin-sections: NG 197-2 (**a**), Rt 72 (**b**), Rt 79 (**c**), Rt 113 (**d, f–h**), Rt 98 (**e**).

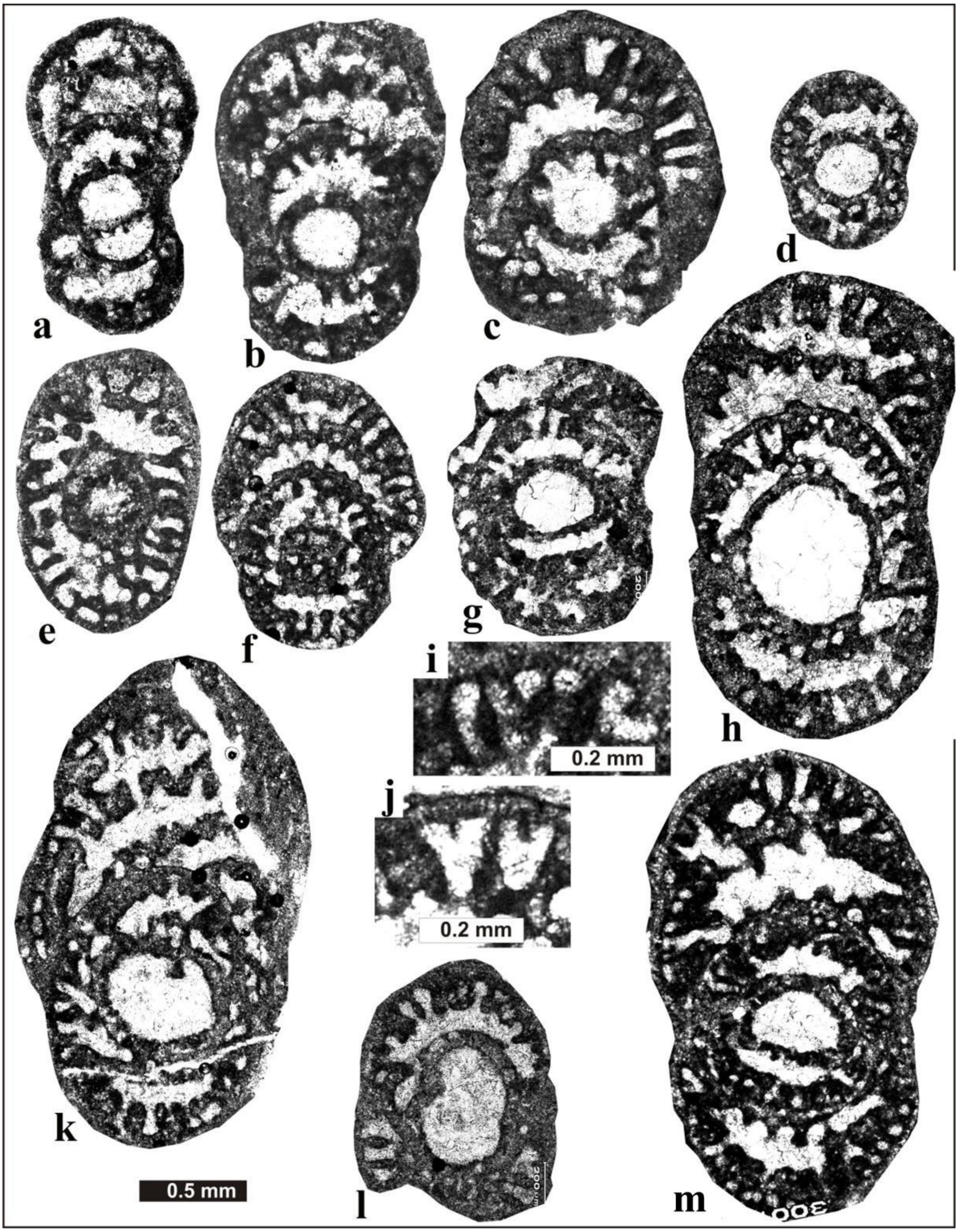

Fig. 11 *Persiella pseudolituus* n. gen., n. sp. from the upper Maastrichtian of the Tarbur Formation of the Naghan section, Zagros Zone, SW Iran. **a-b, d, g-h, m** Axial sections (partly slightly oblique); note initial streptospiral coiling in **a**. **e–f** Subaxial sections. **i–j**: Details from **f** and **h** showing pseudokeriotheka-like wall structure. **k–l** Oblique sections. Thin-sections: 2NG 76 (**a**), 2NG 120-1 (**b**), 2NG 152 (**c**), 2NG 122 (**d**), 2NG 153 (**e**), 2NG 154 (**f, i**), 2NG 127 (**g**), 2 NG 186 (**h, j**), 2NG 152-1 (**k–l**), NG 3-1 (**m**).

clude that *N. bignoti* represents "an excellent marker of this time interval" (see also Fleury, 2014, Fig. 3). An upper Maastrichtian age for the samples containing the two new taxa described herein can be concluded. This conclusion is in line with the occurrence of *Siderolites calcitrapoides* Lamarck in the lower samples of the Mandegan section (Fig. 4), as this taxon has its possible first appearance in the latest early Maastrichtian, or is restricted to the upper Maastrichtian (according to Robles Salcedo et al., 2018).

CONCLUSIVE REMARKS

The new discoveries enrich the diverse associations of large benthic foraminifera (LBF), mainly agglutinating taxa, in the Tarbur Formation of Iran. A rough review of the literature with illustrations on Maastrichtian larger benthic foraminifera clearly let us to conclude that the recently described new taxa are not cosmopolitan forms but are obviously palaeogeographically confined to the Arabian plate, with their exact distributional pattern needing further refinement (Table 1). Such a provincialism/endemism during the Maastrichtian is also expressed by some species of dasycladalean alga like *Pseudocymopolia anadyomenea* (Elliott), *Ovulites delicatula* Elliott, or *Cymopolia eochoristosprica* Elliott (Schlagintweit et al., 2016a; Rashidi and Schlagintweit, 2018). Worth mentioning, that the latter taxon is also reported further to the east, from Tibet. In any case, we may note a strong diversification phase of LBF in the Maastrichtian of the Arabian plate with many newcomer genera and species described in the past (e.g Henson 1948) and only recently. Such patterns of high species diversity including also LBF are named biodiversity hot-spots (see Renema et al. 2008). The development, evolution and changes of such patterns are generally discussed in relationship to plate tectonics affecting for example the presence/absence of suitable habitats, and (palaeo)environmental parameters such as sea water temperature or nutrient levels (e.g. Renema, 2007; Goldbeck and Langer, 2009). In the present case, the reasons for that are a field of open speculations, one might be for example a link to a late Maastrichtian greenhouse warming phase in causal connection to the Deccan volcanism (e.g. Li and Keller, 1998; Robinson et al., 2009). In this context, we observe an extreme increase in test size in many Maastrichtian larger benthic foraminifera (the largest in the whole Mesozoic) with *Loftusia* (test diameter up to 12 cm in *L. elongata*,

Maastrichtian	**Simsima Fm. Qatar**	**Aqra Fm. Iraq**	**Tarbur Fm. Iran**
Accordiella? tarburensis	**?**	**?**	**X 1)**
Broeckinella arabica	**X 2)**	**?**	**X 3)**
Dictyoconella? minima	**X 2)**	**?**	**X 4)**
Dictyoconella complanata	**X 2)**	**?**	**?**
Dictyoconus bahktiari	**X 2) ***	**?**	**X 4)**
Flabelliperforata tarburensis	**?**	**?**	**X 5)**
Gyroconulina columellifera	**?**	**X 6)**	**X 7)**
Persiella pseudolituus	**?**	**?**	**X 5)**
Persiacyclammina	**?**	**?**	**X 8)**
Shuraqalatia brasieri	**?**	**X 9)**	**X 10)**
Tarburina zagrosiana	**?**	**?**	**X 11)**
Zagrosiella rigaudii	**?**	**X 12)**	**X 13)**
Cenomanian	**Equivalent fms**	**Mishrif Fm. Iraq**	**Sarvak Fm. Iran**
Carinoconus iraqiensis	**?**	**X 14)**	**?**
Cycledomia iranica	**?**	**?**	**X**
Dicyclina sampoi	**?**	**X ? 15)**	**X 16)**
Multispirina iranensis	**?**	**X 15)**	**X 17)**
Orbitolinella depressa	**X 2)**	**?**	**X 18)**
Praetaberina bingistani	**X 2)**	**X 15)**	**X 2, 19)**

Table 1. Taxa of larger benthic foraminifera of assumed provincialism (endemism) within the Arabian plate during the Cenomanian and Maastrichtian (known and possible occurrences). The different distributions are due to various investigation states and related publications in the literature. 1: Schlagintweit and Rashidi (2016) 2: Henson (1948), * as Dictyoconus cf. arietinus3) Schlagintweit and Rashidi (2016) 4: Schlagintweit et al. (2016b) 5: this paper 6: Schroeder and Darmoian (1977) 7: Schlagintweit et al. (2016a) 8: Schlagintweit and Rashidi (2017b) 9: Görmuş et al. (2017) 10: own observations and paper in prep. 11: Schlagintweit et al. (2016c) 12: Lawa et al. (2017: figured as Loftusia coxi in Fig. 7G) 13: Schlagintweit and Rashidi (2017b) 14: Bernaus and Masse (2006) 15: Al Naqib (1967) 16: Cherchi and Schroeder (1990) 17: Reichel (1947) 18: Afghah and Fadaei (2015: fig. 8b, legend of fig. 9) 19: Consorti et al. (2016). Note that equivalent assemblages can be expected also in the Simsima Formation of Oman, or Aruma Formation of Saudi Arabia.

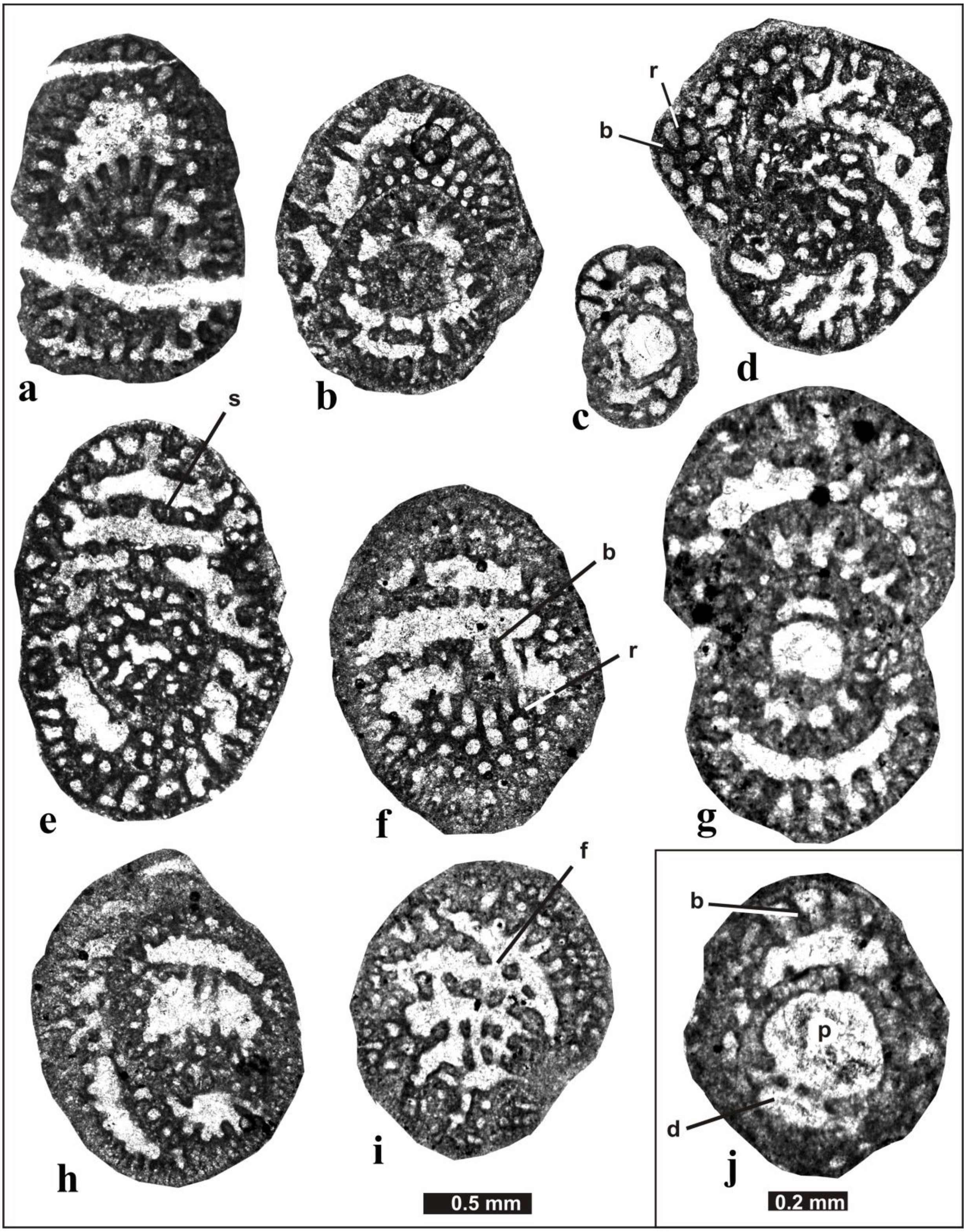

Fig. 12 *Persiella pseudolituus* n. gen., n. sp. from the upper Maastrichtian of the Tarbur Formation of the Mandegan (**a, g, i–j**) and Naghan sections (**all others**), Zagros Zone, SW Iran. **a–e, h–i** Oblique sections; note the rounded outline of the network in **a** and **b**. **f** Tangential section; note the rounded subepidermal network (lower part). **g** Almost centered axial section, holotype specimen. **j** Juvenile specimen showing protoconch connected to the following chamber (?deuteroconch) by numerous openings. Abbreviations: b = beam, p = proloculus, d? = possible deuteroconch, f = foramen, r = rafter, s = septum. Thin-sections: Rt 87 (**a**), NG 198 (**b**), 2NG 120-1 (**c**), 2NG 144 (**d**), 2NG 113 (**e**), 2NG 200-1 (**f**), Rt 113 (SNSB-BSPG 2016 V 16) (**g**), 2NG 200-1 (**h**), Rt 113-1 (**i**), Rt 72 (**j**).

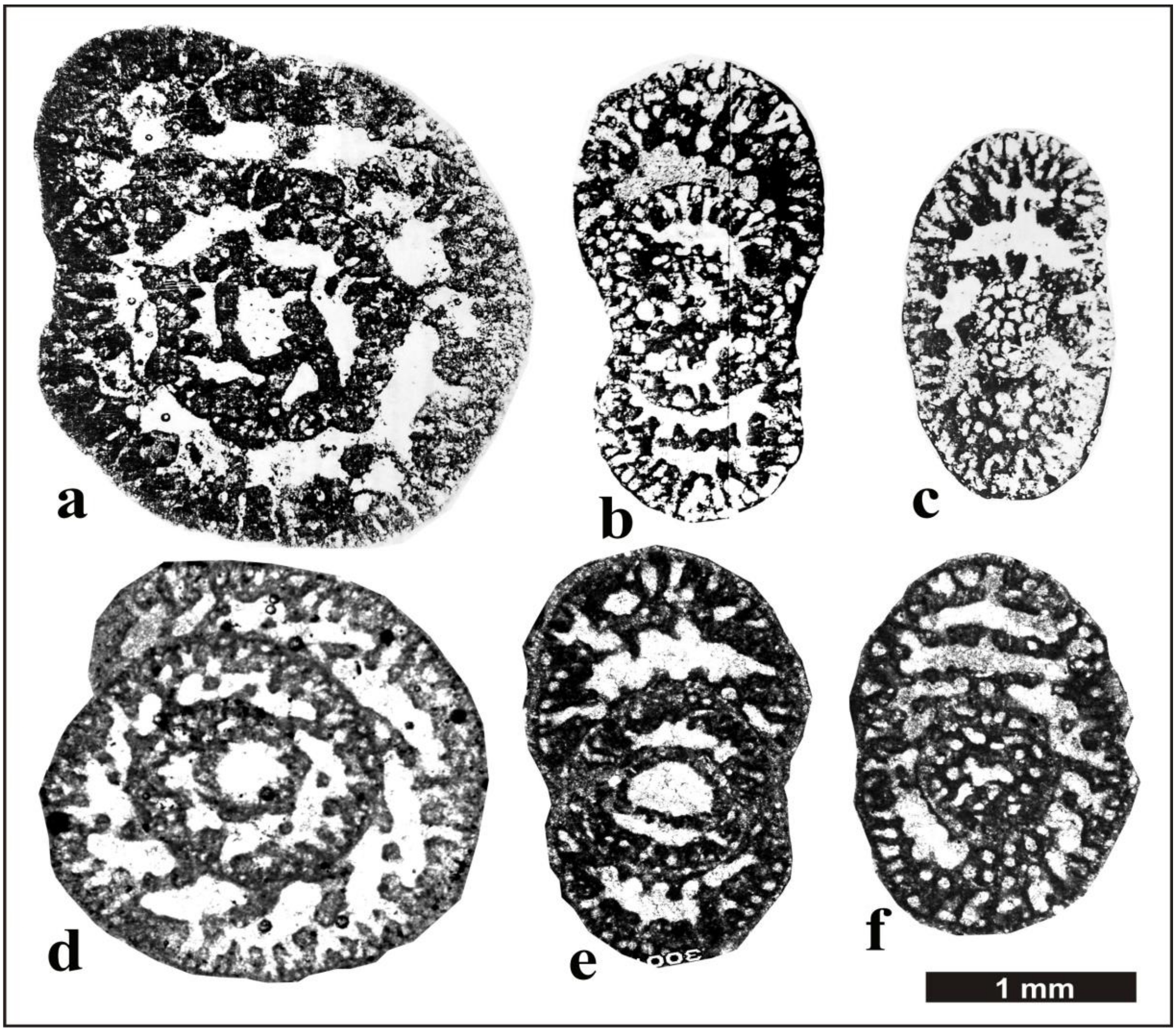

Fig. 13 *Pseudcyclammina lituus* Yokoyama (**a–c**) compared to *Persiella pseudolituus* n. gen., n. sp. (**d–f**). **a, d** Equatorial sections; **b**, **e** axial sections; **c, f** subaxial-tangential sections. From Hottinger (1967): **a** = pl. 10, fig. 11 (late Jurassic of Poland), **b** and **c** = pl. 10, fig. 12 and fig. 13 (topo-type from Tithonian-Berriasian Torinosu limestone, Japan).

see Meriç and Görmüş, 2001) the largest forms in the whole Mesozoic, or the recently described *Suraqalatia* (up to 7 cm, Görmüş et al., 2017). A possible existence of a geographically confined foraminiferal diversity hot-spot in the Central Neotethys during the Maastrichtian, a forerunner of the Paleogene Lockhartia Sea (e.g. Hottinger, 2014, fig. 1.4) might be envisaged but needs further critical revision of literature data and compilations. Such a revision is beyond the scope of the present contribution however. The Adriatic Carbonate Platforms are sufficiently studied (e.g. Luperto Sinni, 1976; Velić, 2007; Chiocchini, 2012, and many others) that the absence of these Late Cretaceous LBF from Iran can be taken as granted. On the other hand, a distribution further to the east, Southern India or Tibet, might be possible. The literature review also allows the conclusion that these taxa on both specific and generic level became eliminated due to the K/Pg boundary event(s). One triggering factor might be the loss of shallow-water habitats displayed by the sedimentary evolution from the Gurpi Formation to the Tarbur Formation. This clearly reflects a shallowing-upward trend with an assumed restricted inner-platform environment in the upper part of the Tarbur Formation and a possible final emersion at its top, possibly the K/Pg boundary (see e.g. discussions in Schlagintweit et al., 2016a, d).

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