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PERSIACYCLAMMINA MAASTRICHTIANA N. GEN., N. SP., A NEW LARGER BENTHIC FORAMINIFER FROM THE MAASTRICHTIAN OF IRAN

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Abstract A new larger benthic foraminifera, *Persiacyclammina maastrichtiana* n. gen., n. sp., is described from the Late Maastrichtian of the Tarbur Formation of the Zagros Zone, SW Iran. The predominantly planispiral-involute taxon, with ammobaculitoid (uncoiled) final part, is characterized by a wall made of a thin imperforate outer layer (epidermis), a fine subepidermal alveolar middle layer and a coarser inner network formed by beams and rafters. Pseudotriangular shaped vertical partitions (septula) extend into the chamber interior downward to the chamber floor where they alternate with intercameral foramina at the margin of the cribrate perforated central area. The new taxon occurs in diverse foraminiferal wackestone-packstone microfacies, together with larger benthic foraminifera (*Dicyclina*, *Dictyoconus*, *Loftusia*, *Neobalkhania*, *Omphalocyclus*, *Tarburina*, *Zagrosella*), rudist debris and dasycladalean algae (*Pseudocymopolia*, *Salpingoporella*).

Keywords: Loftusioidea, exoskeleton, endoskeleton, septulum, 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 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). 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, 2017; Schlagintweit et al., 2016a-d).

The present paper represents an additional contribution to this set of studies with the description of a new larger agglutinated benthic foraminifera, *Persiacyclammina maastrichtiana* n. gen., n. sp. It is worth mentioning that, according to our knowledge, this taxon has so far never been illustrated before in the literature.

STUDIED SECTIONS

The studied foraminiferal-bearing samples studied are from two sections of the Tarbur Formation (Fig. 1):
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 (Fig. 1). 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)
- unit 5 (~ 41.6 m), shales interbedded with medium- to thick-bedded yellow limestones containing *Loftusia* fragments.

Persiacyclammina maastrichtiana n. gen., n. sp. appears in the middle part of unit 2 and disappears in the middle part of unit 4 (see Schlagintweit and Rashidi, 2017, for further details). Within this interval it is rather common and all specimens illustrated in the present paper are from the Naghan section. It occurs in foraminiferal wackestone-packstone, occasionally associated with dasycladalean algae (Fig. 2a). *Persiacyclammina maas-*

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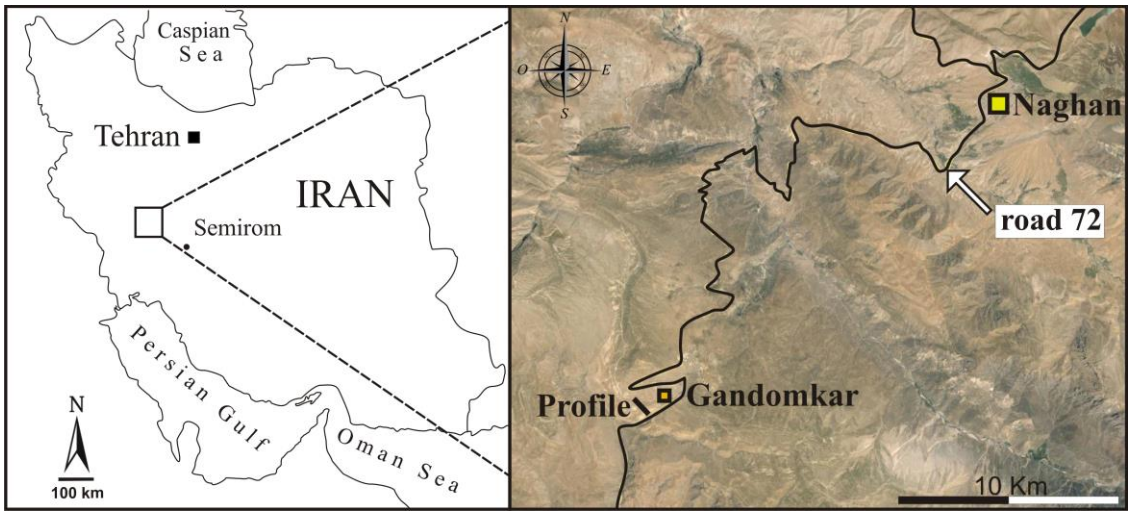

Fig. 1 Location of the Naghan section, the type locality of *Persiacyclammina maastrichtiana* n. gen., n. sp.

trichtiana 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 & Barani, and other so far undescribed taxa (Fig. 2). 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 (see also Schlagintweit et al., 2016a, c). The microfacies of the samples bearing *Persiacyclammina maastrichtiana* n. gen., n. sp. is the same as for the Naghan section. For unknown reasons, it is much less common than in 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.

SYSTEMATICS

The high-rank classification follows Pawlowski et al. (2013). For the low-rank classification see Kaminski (2014). 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 Loftusiina Kaminski & Mikhalevich, 2004
Superfamily Loftusioidea Brady, 1884
Family Cyclamminidae Marie, 1941
?Subfamily Choffatellinae Maync, 1958

Remarks: *Persiacyclammina* n. gen. fully fits the diagnosis of the superfamily Loftusioidea (= Loftusiacea in Loeblich and Tappan, 1987, p. 97). The Loftusiidae possess an agglutinated wall, with imperforate epidermis and inner alveolar layer, but elongate coiling axis and inner chamber pillars, two characteristics lacking in *Persiacyclammina* n. gen. Therefore, it seems more appropriate to include *Persiacyclammina* n. gen. into the Family Cyclamminidae Marie. The subfamiliar attribution however remains unclear; *Persiacyclammina* n. gen. is tentatively assigned to the subfamily Choffatellinae Maync (see diagnosis in Loeblich and Tappan, 1987, p. 101). It is worth mentioning that the relevance of structural features, and wall structure, for the diagnosis of the families (and subfamilies) of the Loftusioidea is still debated. This leads to different generic composition of families and subfamilies (see Loeblich and Tappan, 1987; Athersuch et al., 1992; Kaminski, 2014; Albrich et al., 2015).

Genus *Persiacyclammina* n. gen., n. sp.

Type species: *Persiacyclammina maastrichtiana* n.sp.

Origin of the name: Combination of Persia and *Cyclammina* Brady, 1879.

Horizon and locality: Late Maastrichtian limestones of the Tarbur Formation of the Naghan section (Fig. 1).

Diagnosis: Test free, subcylindrical to elongate, early stage (sub)planispirally coiled and involute with a few

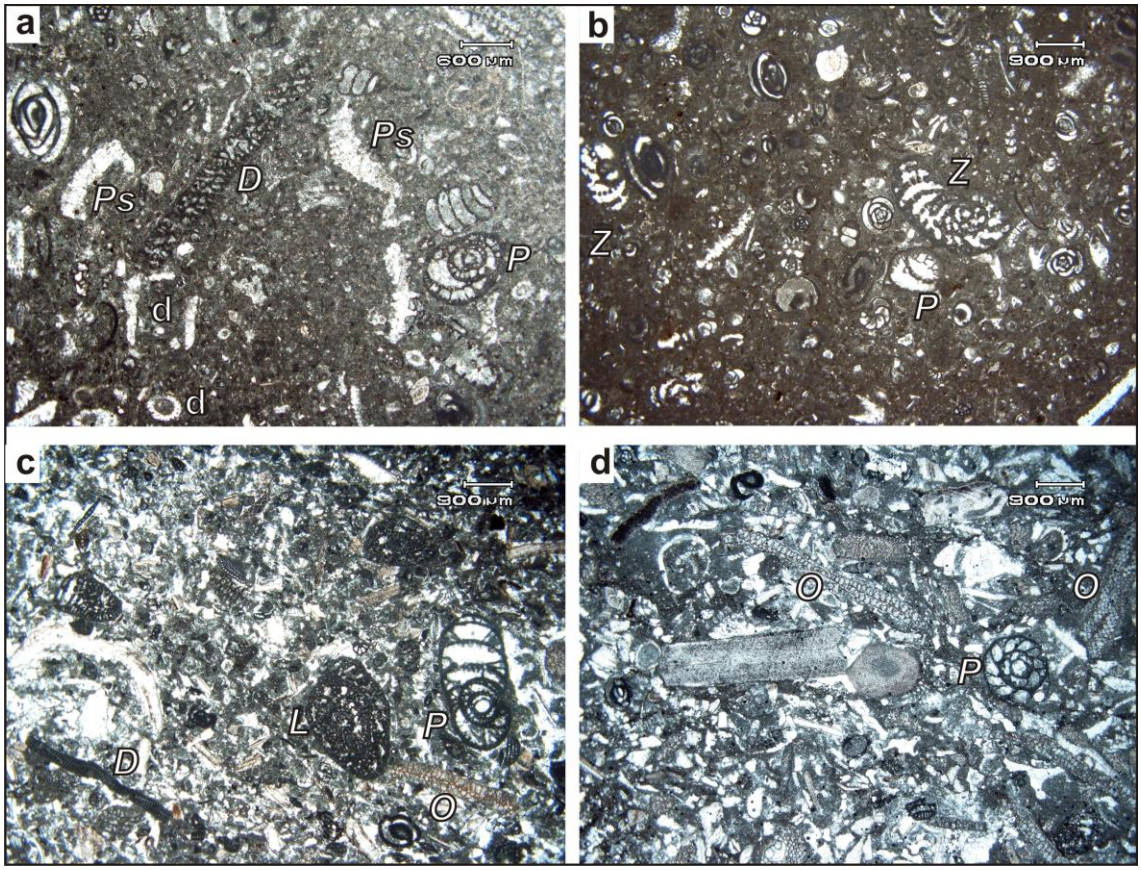

Fig. 2 Typical microfacies of samples with *Persiacyclammina maastrichtiana* n. gen., n. sp. (*P*), from the upper Maastrichtian Tarbur Formation of the Naghan section. **a–b** Wackestones/packstones with benthic foraminifera, among many porcelaneous and agglutinating taxa such as *Dicyclina* sp. (*D*), *Zagrosella rigaudii* Schlagintweit & Rashidi (*Z*), and remains of dasycladalean algae [(d) here: *Pseudocymopolia anadyomenea* (Elliott) (*Ps*) and others in **A]**. **c–d** Wackestones/packstones with debris of rudists, larger benthic foraminifera [*Dicyclina* sp. (*D*), *Loftusia* sp. (*L*), *Omphalocyclus macroporus* Lamarck (*O*)]. Thin-sections: 2NG 81-3 (**a**), 2NG 85-4 (**b**), 2NG 138 (**c**), 2NG 159 (**d**).

whorls of broad and low chambers. Periphery broadly rounded. Adult stage uncoiling and rectilinear with at least up to four chambers, nearly constant in width and rounded to slightly elliptical in transverse section. Wall microgranular with only a few agglutinated grains, with thin imperforate outer layer (epidermis), middle layer of simple, fine alveoles, and increasingly coarser inner (subepidermal) meshwork of beams and rafters. Pseudotriangular shaped radially arranged vertical partitions (subepidermal septula) are related to the latter, and project somewhat into the chamber lumen. They are stretching downward to the chamber floor, but are only barely attached to the chamber roof. At the margin of the perforated central area, they alternate with intercameral foramina. In the early growth stage, foramina are single, basal to areal, rapidly becoming cribrate.

Comparisons: *Loftusia* Brady co-occurring with *Persiacyclammina* 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). The Paleocene to Holocene *Cyclammina* Brady does not uncoil, and displays a prominent and thick subepidermal meshwork; the thickness exceeds that of the chamber lumen (Loeblich and Tappan, 1987, p. 105). Several genera of the Lituolidae de

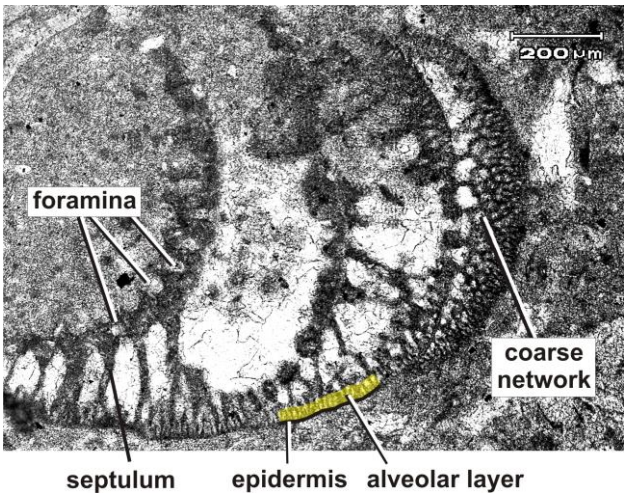

Fig. 3 Wall-structure of *Persiacyclammina maastrichtiana* n. gen., n. sp. from the upper Maastrichtian of SW Iran Thin-section: NG 83-1.

Blainville display test morphologies (elongate, early stage coiled, later uncoiling) similar to *Persiacyclammina* n. gen., *Ammobaculites* Cushman for instance, but these have a simple agglutinated wall, lacking both exo- and endoskeleton. *Pseudocyclammina* Yokoyama (Late Juras-

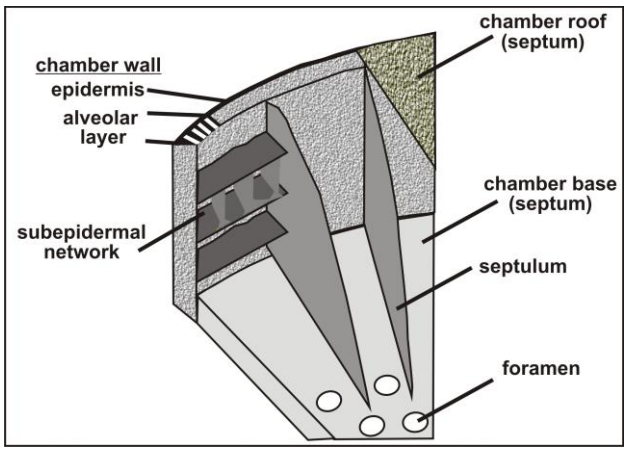

Fig. 4 Schematic drawing of part of one chamber of *Persiacyclammina maastrichtiana* n. gen., n. sp. showing the interpretation and nomenclature of structural elements (without scale).

sic-Late Cretaceous) possesses a strongly agglutinated wall with coarse subepidermal network and lacks the layer of fine and simple alveoles of *Persiacyclammina* n. gen. Also septula are lacking in the former, instead a few irregular pillars may be present, and the chamber shape as well as the foraminal pattern are different (Loeblich and Tappan, 1987, p. 102). The Late Jurassic *Rectocyclammina* Hottinger possesses an agglutinated wall, with imperforate outer layer and subepidermal choffatelloid network (Loeblich and Tappan, 1987, p. 103).

Lacking septula, also the terminal, circular aperture in the central part is of *Rectocyclammina* different from *Persiacyclammina* n. gen. *Zagrosella* that has recently been described from the same locality as *Persiacyclammina* n. gen. (see Schlagintweit and Rashidi, 2017) differs from the latter above all by its lacking of a reticulate subepidermal network and septula, the foraminal pattern (cribrate, but just a few rather large openings), thick septa, and the presence of few irregular pillars.

Remarks: The elongate vertical elements (partitions) that project somewhat into the chamber lumen represent a significant characteristic of *Persiacyclammina* n. gen. For instance, elongate beams are present in some representatives of the Choffatellinae, *Amijiella* Loeblich & Tappan and *Bramkapmpella* Redmond (Loeblich and Tappan, 1987). In these taxa, the structural elements are attributed to the exoskeleton as not being connected to the intercameral foraminal pattern contrary to a septulum (see Hottinger, 2006). In *Persiacyclammina* n. gen., however, the disposition of the vertical partitions is related to the arrangement of the intercameral foramina towards the inner margin of the perforated (cribrate) central area, i.e. an alternating disposition of both (e.g., Fig. 3).

Appearing as an extension of the subepidermal alveolar layer (exoskeleton), these are here called "subepidermal septula", thus implying their endoskeletal nature (see Hottinger, 2006, for definition and short discussion). Also the shape and the disposition of these elements in *Persiacyclammina* n. gen. are different.

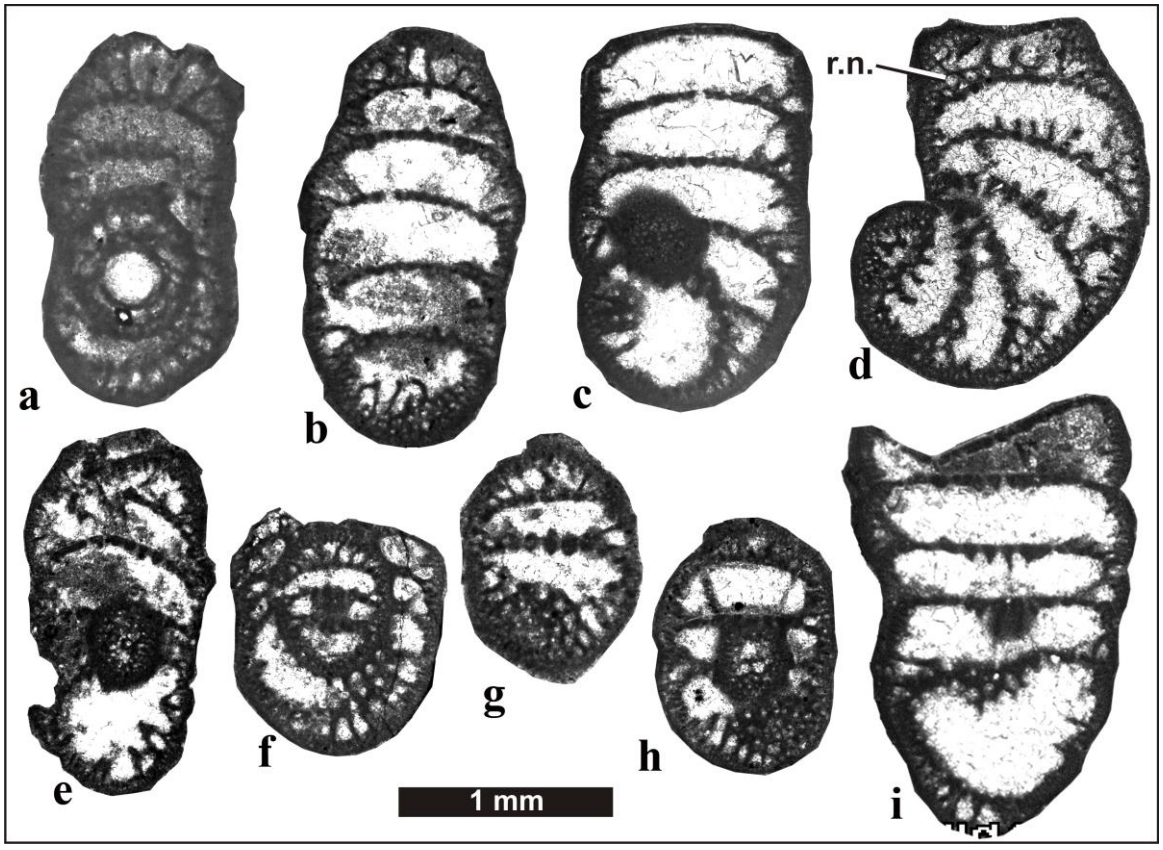

Fig. 5 *Persiacyclammina maastrichtiana* n. gen., n. sp., upper Maastrichtian Tarbur Formation of the Naghan section, Zagros Zone, SW Iran. **a,** centered axial section. **c**–**h**, variously cut oblique sections. **b, i,** tangential sections. Abbreviation: r.n. = reticulate network. Thin-sections: NG 65 (**a**), NG 81 (**b, h**), NG 83-3 (**c**), NG 88 (**d**), 2NG 81 (**e, g**), NG 120 (**f**).

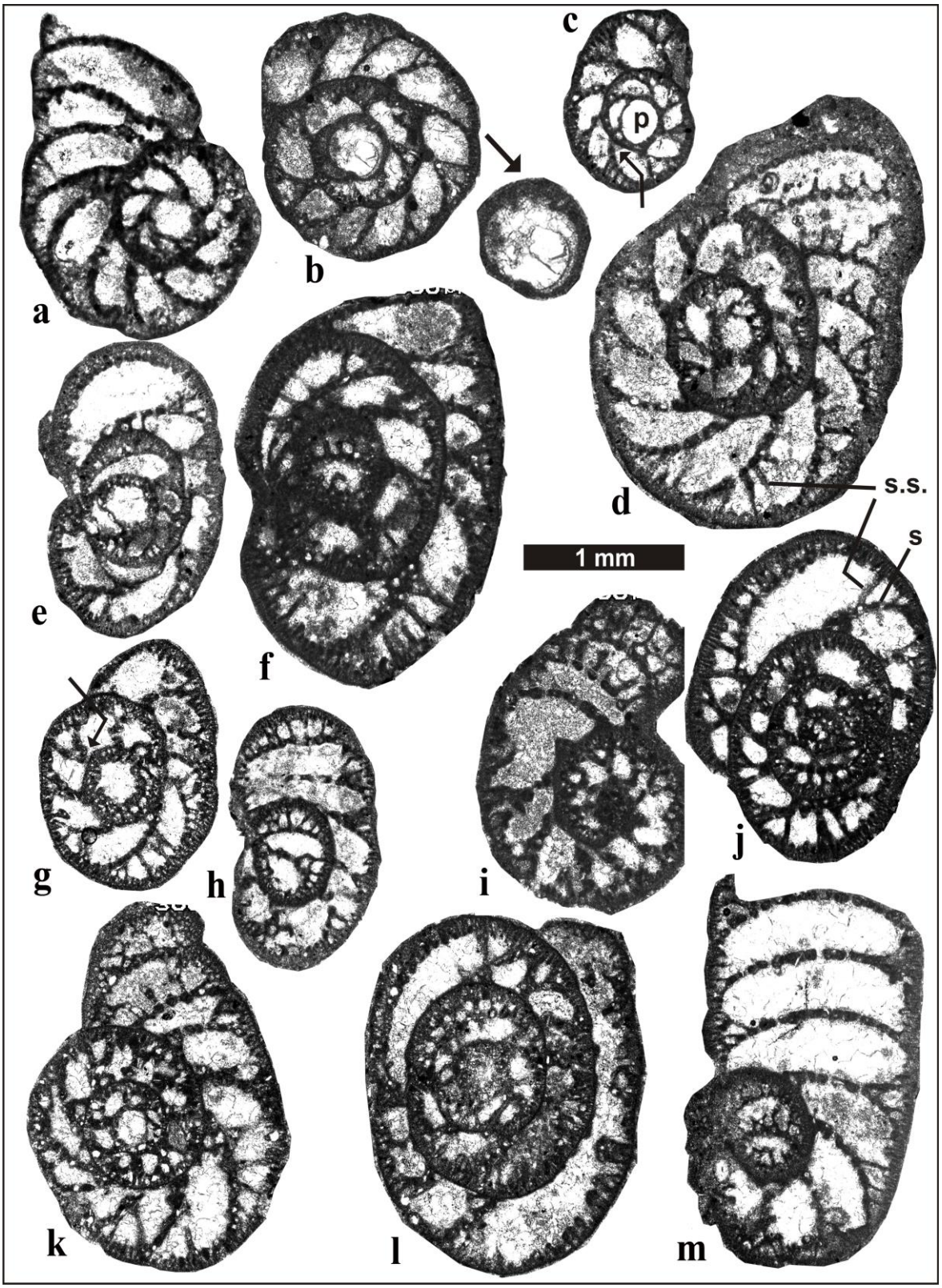

Fig. 6 *Persiacyclammina maastrichtiana* n. gen., n. sp., upper Maastrichtian Tarbur Formation of the Naghan section, Zagros Zone, SW Iran. **a–c**, Almost centered equatorial sections. Arrow: Detail from **b**, showing remnants of an organic membrane inside the proloculus. **d** (holotype specimen)**, g, i, k,** Oblique equatorial sections. **e–f, h, j, l,** Oblique sections. **m,** Oblique section of specimen with four uncoiled chambers (last chamber is broken). Note differing coiling axis of enrolled and uncoiled parts. Arrows in **c** and **g** = single, basal to areal foramina of the early growth stage. Abbreviations: p = proloculus, s = septum, s.s. = subepidermal septulum. Thin-sections: NG 71 (**a**), 2NG 159 (**b**), 2NG 83 (**c**), 2NG 81-1 (**d–e, h**), NG 107 (**f**), NG 144-2 (**g**), NG 52-2 (**i**), NG 113 (**j**), NG 116 (**k**), 2NG 81 (**m**).

Septula (= radial partitions in Henson, 1948, Douglass, 1960, or Schroeder, 1975) are straight or curving (zig-zag shaped) as for instance in the radial zone of the Orbitolinidae (Hottinger, 2006, fig. 71). As in several soritoidean taxa, septula are stretching from the chamber base to the roofs throughout their length (e.g., Henson, 1950, De Castro, 1985, Consorti et al., 2016). In *Persiacyclammina* n. gen. instead, the somehow asymmetric subepidermal septula attain a pseudotriangular shape, obviously only attaching to the previous septum (= chamber floor) but not or only barely attaching to the newly formed septum (= chamber roof) (Fig. 4).

Persiacyclammina maastrichtiana Schlagintweit & Rashidi, n.sp.

Figs. 2 pars, 3–8

Origin of the name: The species name refers to the Late Cretaceous Maastrichtian stage.

Holotype: Very slightly oblique equatorial section illustrated in Figure 5d, thin-section 2NG 81-1.

Paratypes: Specimens in figs. 6a–g, 7, 8a–b.

Description: Test free, subcylindrical to elongate, early stage (sub) planispirally coiled and involute with two to two and a half whorls of broad and low chambers increasing gradually in breadth as added. There are about seven to nine chambers in the first, and nine to twelve chambers in the second whorl. The proloculus is subspherical, and possibly contains an internal microcrystalline membrane (thickness: ~7 µm; ?detached from the inner wall) (Fig. 6B and detail). In the coiled part, the septa are convex, and distinctly curved in direction of enrollment. The test periphery is broadly rounded; with slight axial depressions on both sides (slightly biumbonate). The adult stage is uncoiling, uniserial and rectilinear with at least up to four chambers, nearly constant in both width and height; rounded to slightly elliptical in transverse section. The apertural face is moderately convex. Wall microgranular with only a few agglutinated grains, a thin imperforate outer layer (epidermis), middle layer of simple (= non-branching), fine alveoles, and increasingly coarser subepidermal meshwork of beams and rafters towards the chamber interior (Fig. 3); septa pierced, massive. In tangential sections, the subepidermal meshwork often displays a rounded pattern. Pseudotriangular shaped radially arranged vertical partitions (subepidermal septula) are related to the subepidermal network. They project somewhat into the chamber lumen, stretching downward to the chamber floor. Obviously, they only attach to the previous septum (= chamber floor) but not or only barely to the newly formed septum (= chamber roof). Transverse sections of the uncoiled part cuts about 24 to 30 septula corresponding to a diameter of 0.85–1.0 mm. The septula appear not aligned but irregularly alternating between subsequent chambers (Fig. 7m). At the margin of the perforated (cribrate) central area, they alternate with intercameral foramina (e.g., Fig. 8e–f, j). In the early growth stage, foramina are single, basal to areal (Fig. 6c, e), later becoming cribrate. It appears as that the foramina in the uncoiled portion are disposed in circles forming a concentric pattern (see Fig. 8f).

Dimensions (in mm):

axial diameter (thickness) = up to 1.4 (mostly ~0.9)
test length (height) = up to 2.5
inner diameter of proloculus: 0.18–0.34 (mostly ~0.25)
thickness septum = 0.04–0.075
chamber height enrolled part (incl. septum) = 0.25–0.35
diameter foramina = 0.025–0.04
thickness epidermis = ~0.01
epidermis + alveolar layer = 0.06–0.1
thickness of septula = ~0.02
length of septula = up to 0.3

STRATIGRAPHY

Persiacyclammina maastrichtiana 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 Maastrichtian in age. *Neobalkhania bignoti*, also found in association with *Persiacyclammina maastrichtiana*, 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 conclude that *N. bignoti* represents "an excellent marker of this time interval" (see also Fleury, 2014, Fig. 3). A late Maastrichtian age for the samples with *Persiacyclammina maastrichtiana* n. gen., n. sp. can be concluded. This conclusion is also in line with the occurrence of *Siderolites calcitrapoides* Lamarck in the lower samples of the Mandegan section, as this taxon has its first appearance in the latest early Maastrichtian (according to Robles Salcedo, 2014).

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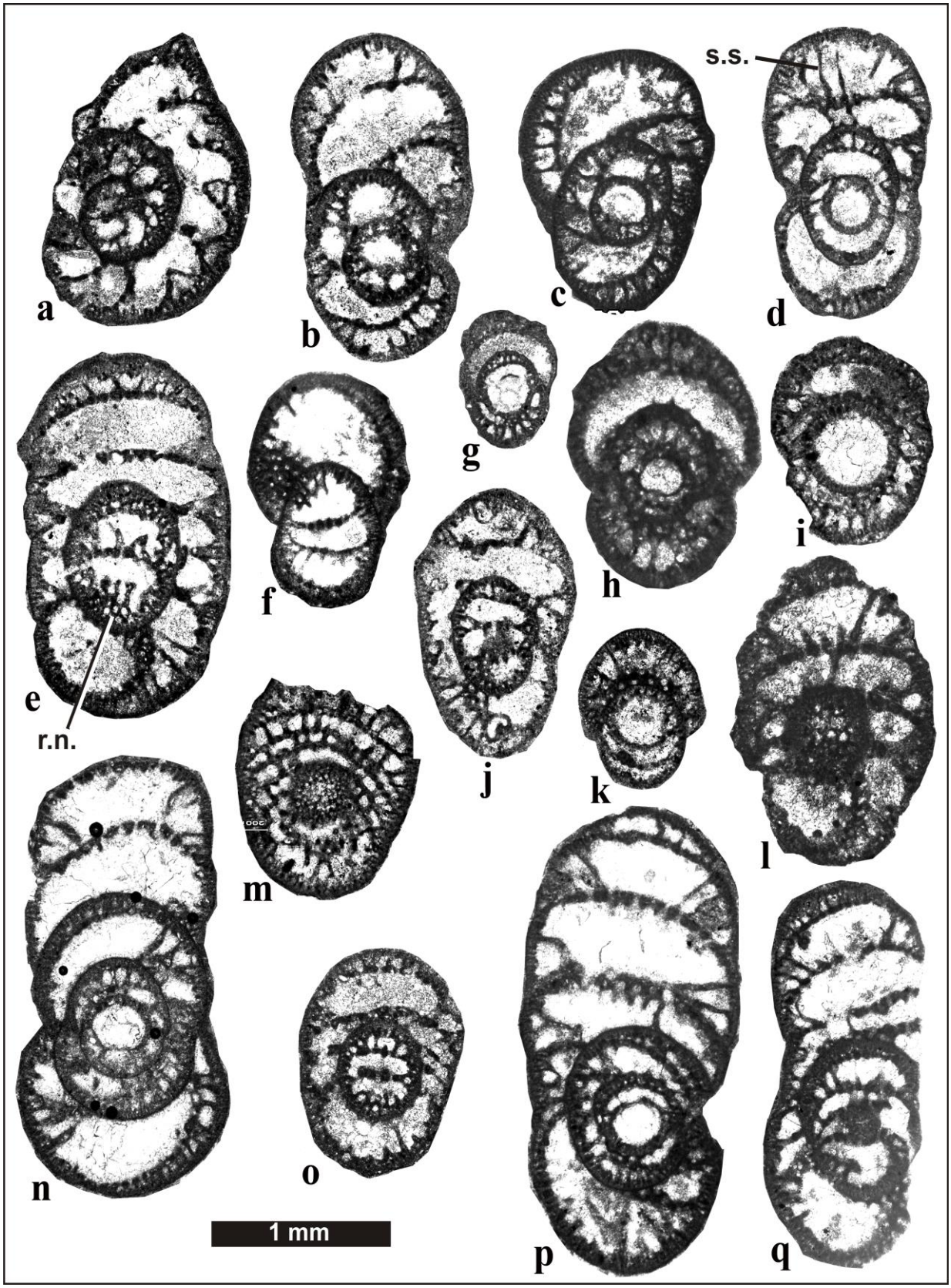

Fig. 7 *Persiacyclammina maastrichtiana* n. gen., n. sp., upper Maastrichtian Tarbur Formation of the Naghan section, Zagros Zone, SW Iran. **a,** Oblique equatorial section. **b–c, m, q,** Oblique sections. **d, j,** Oblique axial sections. **e–f, l, o,** Subaxial sections. **g–i, k,** Axial sections. **n, p,** Longitudinal sections. Abbreviations: r.n. = reticulate network, s.s. = subepidermal septulum. Thin-sections: 2NG 81-4 (**a, f**), 2NG 81-1 (**b**), NG 84 (**c**), 2NG 85-2 (**d**), 2NG 81 (**e**), 2NG 81-2 (**g, q**), 2NG 71 (**h, m**), 2NG 64 (**I**), 2NG 76 (**k**), 2NG 86 (**l**), 2NG 97 (**n**), NG 121 (**o**), 2NG 138 (**p**).

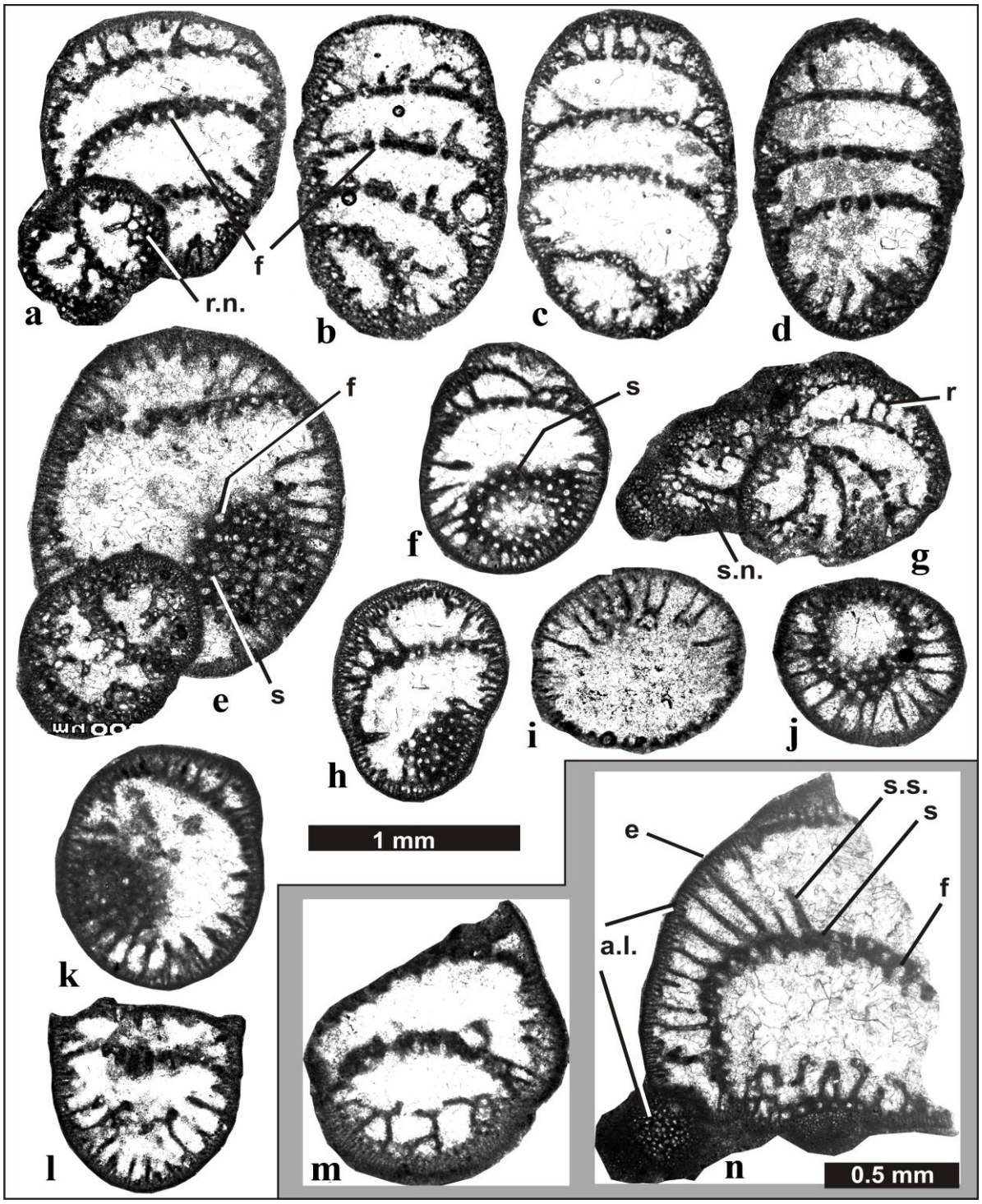

Fig. 8 *Persiacyclammina maastrichtiana* n. gen., n. sp., upper Maastrichtian Tarbur Formation of the Naghan section, Zagros Zone, SW Iran. **a, f–h, l,** Oblique sections. **b–d**, Oblique sections through the uncoiled part. **i–j**, Transverse sections, slightly oblique of the uncoiled part. **k,** subtransverse section. **m–n**, Details of oblique sections showing structural elements. Abbreviations: a.l. = alveolar layer, f = foramen, r = rafter, s = septum, s.s. = subepidermal septulum, r.n. = reticulate network. Thin-sections: 2NG 81-2 (**a**), 2NG 55 (**b**), 2NG 114 (**c**), 2NG 1 (**d**), NG 74 (**e**), 2NG 81-4 (**f, h**), 2NG 81-1 (**g**), 2NG 71 (**i**), NG 83-3 (**j**), NG 81 (**k**), 2NG 18-2 (**l**), 2NG 85-4 (**m**), 2NG 81-3 (**n**).

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