

# ***BROECKINELLA HENSONI* N. SP., A NEW LARGER BENTHIC FORAMINIFERA FROM THE UPPER MAASTRICHTIAN OF IRAN AND A REVISION OF THE GENUS *BROECKINELLA* HENSON, 1948**

**Felix Schlagintweit<sup>1\*</sup> & Koorosh Rashidi<sup>2</sup>**

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**Abstract** A new larger benthic foraminifera is described as *Broeckinella hensoni* from the upper Maastrichtian Tarbur Formation of SW Iran (Zagros Zone). In comparison to the type species of the genus, *Broeckinella arabica* Henson, which also occurs in the Tarbur Formation, the new species has distinctly larger dimensions (e.g., size and thickness of test, chamber height). The first record of a microspheric specimen of *B. arabica* shows previously unrecorded annular chambers in the final test stage. Therefore, the generic diagnosis is herein emended. In the Tarbur Formation, both *B. hensoni* n. sp. and *B. arabica* occur in foraminiferal-algal wackestones. However, *B. arabica* occurs in a wider range of microfacies, including packstones and grainstones. It is assumed that *Broeckinella* originated in the Upper Cretaceous with *Broeckinella neumannae* Gendrot. The upper Albian *Broeckinella aragonensis* Peybernès is herein transferred to the porcellaneous genus *Peneroplis* Montfort.

**Keywords:** Foraminiferida, taxonomy, biostratigraphy, Upper Cretaceous, Arabian Plate

## INTRODUCTION

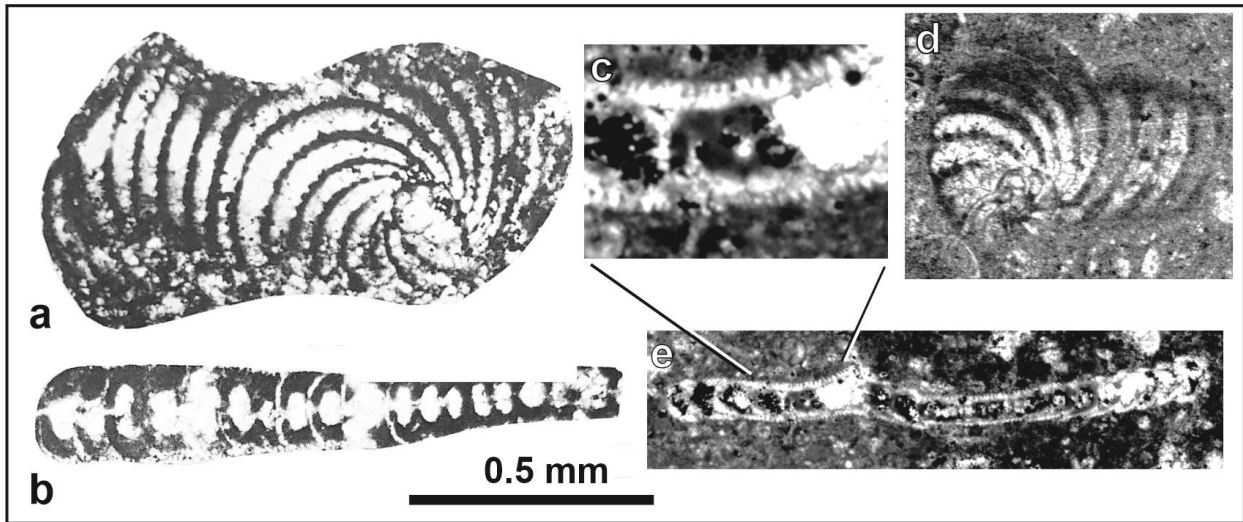
The larger agglutinating benthic foraminifera genus *Broeckinella* was established by Henson (1948) on the basis of an equatorial section (external view of a weathered surface, holotype specimen) from the Maastrichtian Simsima Formation of Dukhan No. 1 well of Qatar associated with *Loftusia* and *Omphalocyclus*. Nonetheless, there followed a long discussion about the type-strata belonging to the Paleocene and not the Maastrichtian (e.g., Drobne and Hottinger, 1971). The common occurrence of *Broeckinella* in the Maastrichtian of the Tarbur Formation of the Iranian Zagros (an equivalent to the Simsima Fm. of Qatar) accords with the original view of Henson (1948) (Schlagintweit and Rashidi, 2016). Henson placed *Broeckinella* (with subepidermal network, flabelliform to reniform chambers and, as now known, agglutinated wall) and *Broeckina* Munier-Chalmas [without subepidermal network, with shallow lateral partitions, annular chambers and porcellaneous wall structure, e.g., Caus et al., 2013] in the same family, the Meandropsinidae. It must be speculated that this misinterpretation of wall structure was due to the lack of thin-section specimens. According to the critical literature review of Cherchi and Schroeder (1978), *Broeckinella* has an initial planispiral stage and a flabelliform test morphology (not becoming annular in the adult part). This statement refers to the single specimen illustrated by Henson, that belongs to the macrospheric generation as clearly demonstrated by Cherchi and Schroeder (1991). Information on the microspheric generation has been lacking. These authors conclude that there is no verified other record of *B. arabica* besides that of its type-locality. The forms described as *B. arabica* by Drobne and Hottinger (1971) from the Thanetian of Slovenia were doubted as belonging to Henson's taxon. In this respect, Cherchi and Schroeder (1975) noted the lack of information about the initial part and missing evidence for the chamber morphology (flabelli-

form or annular). Later, these Thanetian forms were ascribed to a new genus by Sirel and Gündüz (1985): *Vania* with the type-species being *Vania anatolica*. *Vania* differs from *Broeckinella* by its annular chambers in the final part of its adult test. More recently, another allied taxon was established by Sirel (2012) as *Postbroeckinella* (type-species *Postbroeckinella flabelliformis*), also from the Thanetian of Turkey characterized by an initial biserial stage (?) and a flabelliform test. In fact, the Late Cretaceous *Broeckinella arabica* and the two Thanetian taxa *Vania* and *Postbroeckinella* can only be reliably distinguished in sections passing through the initial stage and/or sections of adult specimens displaying either annular or flabelliform chambers (e.g., centered equatorial sections). Bearing in mind that in large-discoidal forms most sections are oblique ones, this makes a correct determination almost impossible when other accompanying taxa are missing, allowing an attribution either to the Late Cretaceous or Thanetian. It is worth noting that forms similar to *Broeckinella* are unknown from Danian-Selandian strata. Last but not least, it should be mentioned that for these taxa the morphological variability and differences between micro- and megalospheric specimens are poorly known.

Concerning *Broeckinella*, there are three species (besides the type-species *B. arabica*) that have been described: *Broeckinella neumannae* (Santonian of France, Gendrot, 1968), *Broeckinella magna* (Valanginian of Switzerland, Septfontaine, 1978), and *Broeckinella aragonensis* (Late Albian of Spain, Peybernès, 1984). *Broeckinella magna* displays a coarsely agglutinated alveolar wall structure (e.g. holotype specimen in Septfontaine, 1978, pl. 1, fig. 1) but not a delicate subepidermal network as reported from *B. arabica*. Cherchi and Schroeder (1982a) note the resemblance of "*B.*" *magna* to both *Pseudochoffatella* Deloffre and *Balkhania* Momontova and raise doubts about the exact geometric pattern of the foramina (? aligned in a row or cribrose). *Broeckinella aragonensis*

<sup>1</sup> Lerchenauerstr. 167, 80935 München, Germany, \*Corresponding author: felix.schlagintweit@gmx.de

<sup>2</sup> Department of Geology, Yazd University, 89195-741 Yazd, Iran, kooroshrashidi@yazd.ac.ir



**Fig. 1** *Peneroplis aragonensis* (Peybernès) nov. comb. **a** Equatorial section. **b** Broken axial section (both from Peybernès, 1984, pl. 1, fig. 1 and 7, Late Albian of Spanish Pyrenees). **c** Detail from **d** showing fine surface ornamentation (striae). **d** Slightly oblique equatorial section. **e** Subaxial section showing fine striae of surface ornamentation (**c-e** from the Late Albian Barceñaciones Formation, Cantabria, N-Spain, leg M. Najarro).

displays a homogeneous dark wall lacking a subepidermal network (text-fig. 1a-b). Among the three new taxa described by Peybernès (1984) from the upper Albian of Spain, *Fischerina? carinata* displays the same porcellaneous wall structure as "*B.*" *aragonensis*, with a thin but distinct bright outer layer. Cherchi and Schroeder (1982b, pl. 2, figs. 1–7) illustrated the same form from the upper Albian of Asturias, northwestern Spain as "*Soritidae* inc. sed." Supplemented by our own material from the upper Albian of Cantabria (Najarro, 2015, for details) (Fig. 1c–e), *Broeckinella aragonensis* is considered as a representative of *Peneroplis* De Montfort in accordance with the assumed porcellaneous wall texture, its peneroplid test morphology, multiple foramina, and test surface ornamentation (striae) (e.g., Peybernès 1984, pl. 3, fig. 17; see also text-Figure 1a–b). *Peneroplis aragonensis* can be compared with the late Albian-middle Cenomanian *P. parvus* De Castro, 1965 and the early late Cenomanian *P. cairoensis* Chiocchini, 2008. With a maximum test diameter of 4.5 mm (Peybernès, 1984), *P. aragonensis* is much larger than *P. parvus* (De Castro, 1965: up to 0.82 mm) and also *P. cairoensis* (up to 1.2 mm). In addition, the chambers of the latter are less arched than in *P. aragonensis*. It is worth mentioning that another porcellaneous soritid was described by Deloffre and Hamaoui (1969) as *Pseudobroeckinella soumoulouensis* from the Santonian of France.

In summary, with Pre-late Cretaceous of the genus doubtful, *Broeckinella* is herein considered as a foraminiferal genus originating in the Late Cretaceous Global Maturation Cycle of Hottinger (1999), with three species: *B. neumannae* Gendrot, *B. arabica* Henson, and *B. hensoni* n. sp. the later species as described herein the present paper from the Tarbur Formation of Iran.

## GEOLOGICAL OVERVIEW

The Maastrichtian Tarbur Formation represents a shallow-water carbonate succession in SW Iran (Zagros Zone), rich in larger benthic foraminifera and calcareous

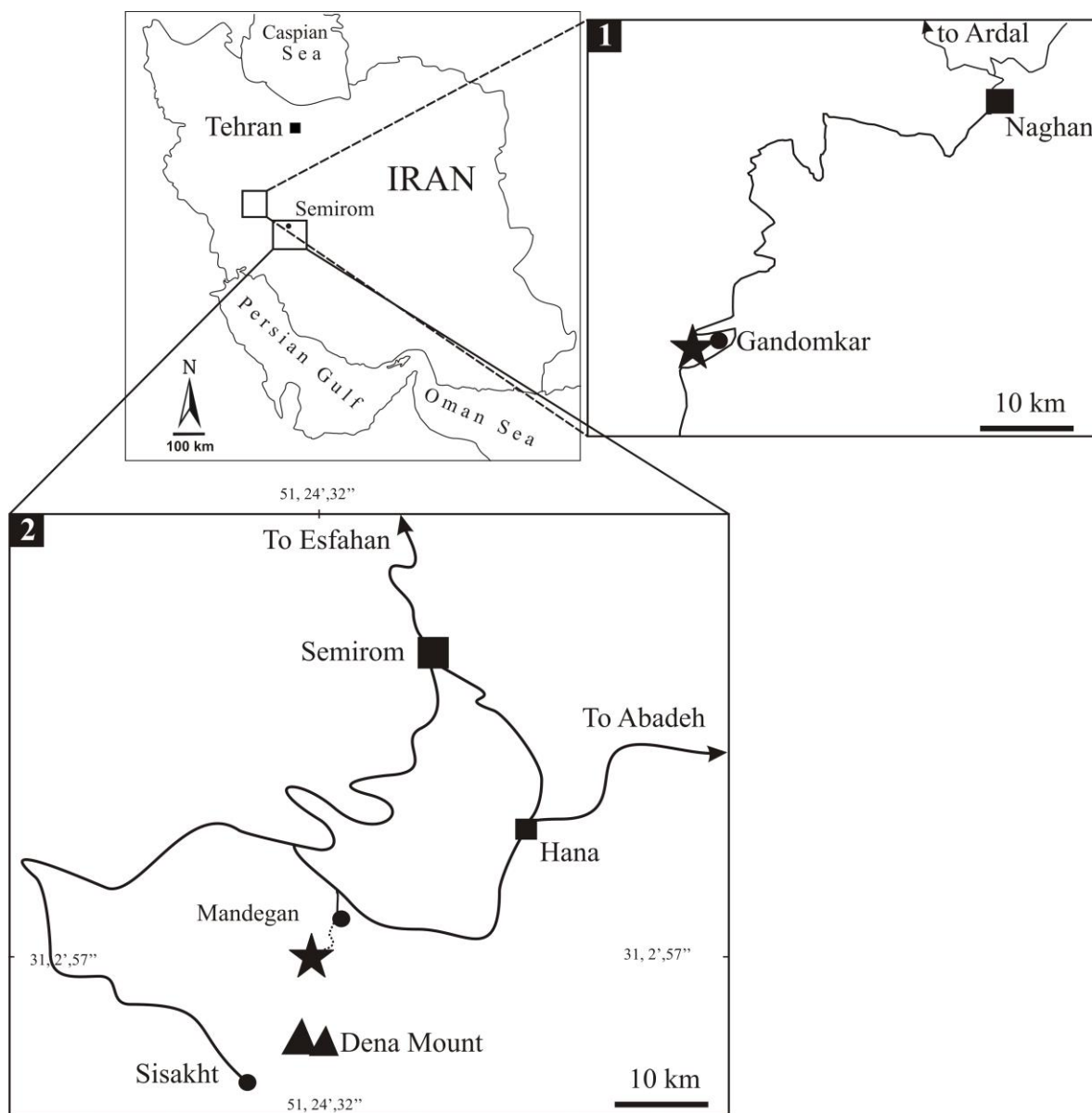
algae (James and Wynd, 1965). Towards the southwest, the Tarbur Formation interfingers with the Gurpi Formation that usually underlies the former. In the stratigraphic chart of Iran provided in 1995 by the Geological Society of Iran, the Tarbur Formation is assigned to the Campanian-Maastrichtian interval. In recent times several new genera of larger benthic foraminifera were described from the upper Maastrichtian of the Tarbur Formation (e.g., Schlagintweit and Rashidi, 2016, 2018; Consorti and Rashidi, 2018; Consorti et al., 2019). Herein *Broeckinella hensoni* n. sp. and *Broeckinella arabica* Henson are described from two localities: the Naghan and Mandegan sections (Fig. 2).

## STUDIED SECTIONS

### Naghan section

The studied section in the folded Zagros belt is located approximately 50 km south west of the town of Naghan, near the village Gandomkar and is herein named the Naghan section. The section occurs on the road from the towns of Naghan and Izeh. At this locality, the Tarbur Formation is underlain by the Gurpi Formation and overlain by the Paleocene Sachun Formation. Lithologically, the Gurpi Formation consists of dark, grey calcareous shale with planktonic foraminifera. The Sachun Formation consists of gypsum, red shales, anhydrite and some layers of carbonates. The thickness of the Tarbur Formation in 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 (from base to top)

- unit 1 (99 m), red to yellow shales
- unit 2 (61 m), medium- to thick-bedded grey limestones with *Loftusia* and rudist debris (calcareonites to calcirudites)
- unit 3 (33 m), intercalation of grey shales and cream to grey, medium- to thick-bedded limestones (calclutites and calcarenite)



**Fig. 2** Location of the Naghan and Mandegan sections in the Zagros Zone, SW Iran.

- 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.

*Broeckinella hensoni* n. sp. is irregularly distributed throughout the whole Tarbur Formation within the Naghan section from base to top. The type-level with the holotype specimen is from the middle/upper part of unit 4 (Fig. 3). The occurrence of *Canalispina iapygia* Robles-Salcedo et al. in unit 3 (see Septfontaine et al., 2019, fig. 2) evidences an upper Maastrichtian age (Robles-Salcedo et al., 2019). The coordinates of the base of the section are N 31° 47' 52" and E 50° 32' 53".

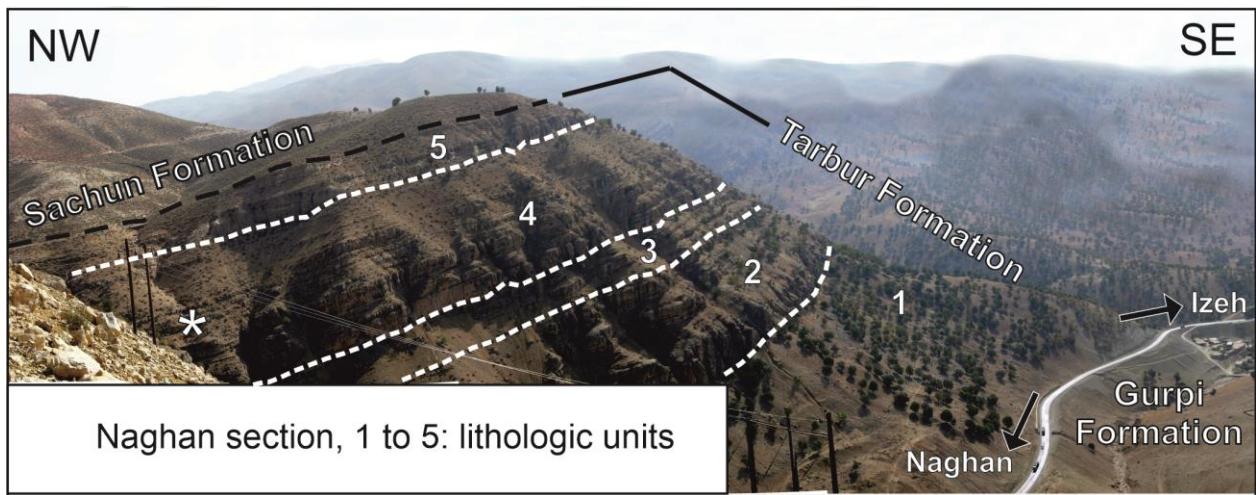
#### Mandegan section

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. Here the Tarbur Formation with a thickness of ~272 m overlies conformably 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 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. The occurrence of *Siderolites calcitrapoides* Lamarck and *Canalispina iapygia* Robles-Salcedo et al. in the lower part of the section evidence an upper Maastrichtian age (Robles-Salcedo et al., 2019). The coordinates of the base of the section are 31° 2' 58.13"N and 51° 24' 34.58"E.

#### MATERIAL AND METHODS

The seven thin-sections with the new species *Broeckinella hensoni* n. sp. illustrated herein from the Naghan



**Fig. 3** Naghan section, along the road from Naghan to Izeh with the type-level of *Broeckinella hensoni* n. sp. marked by an asterisk (left side).

section (including the holotype) are deposited at the Geosciences Museum of Mashhad (in the Geological Survey of North-Iran East territory). In Table 1 the original sample numbers as designated in the field-campaigns and the corresponding official depository numbers are indicated. The two thin-section Rt 67-1 and Rt 72 (original sample numbers) from the Mandegan section are stored at the Bayerische Staatssammlung für Paläontologie und historische Geology, Munich, under the official number SNSB-BSPG 2016 V 1 to V 20. They are part of 20 thin-sections from the Tarbur Formation stored in the framework of the orbitolinid study of the authors (Schlagintweit et al., 2016).

**Table 1** Numbers of thin-sections (original field numbers) and official depository numbers of the Geosciences Museum of Mashhad (in the Geological Survey of North-Iran East territory).

Number	Original sample number	Depository-inventory number
1	2NGN	Gmm13980F32
2	2NG 38	Gmm13980F33
3	2NG 118	Gmm13980F34
4	2NG 153	Gmm13980F35
5	2NG 166	Gmm13980F36
6	2NG 172	Gmm13980F37
7	NG 197-1	Gmm13980F38

**SYSTEMATIC PALEONTOLOGY**

The higher level classification follows Pawlowski et al. (2013). For other aspects of foraminiferal classification see Kaminski (2014) with modification by Albrich et al. (2015).

- Phylum Foraminifera Orbigny, 1826
- Class Globothalamea Pawlowski et al., 2013
- Order Loftusiida Kaminski & Mikhalevich, 2004
- Suborder Loftusiina Kaminski & Mikhalevich, 2004
- Superfamily Loftusioidea Brady, 1884

Family Spirocyclinidae (Munier-Chalmas, 1887) Maync, 1950

**Remarks:** In the definition of the families Cyclamminidae and Spirocyclinidae, Albrich et al. (2015, p. 255) do not follow 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 should therefore be included in the Spirocyclinidae.

Subfamily Pseudochoffatellinae Loeblich & Tappan, 1985

Genus *Broeckinella* Henson, 1948 emended

**Remarks:** The generic diagnosis of Loeblich and Tappan (1987, p. 104) only referred to the megalospheric form. It needs to be emended with respect to data obtained from a microspheric specimen described here. The diagnosis of Loeblich and Tappan (op. cit.) is emended as follows (added changes in bold letters).....“chambers rapidly increasing in breadth to become arcuate but not completely cyclical, so that the test is successively flabelliform, complanate, and finally reniform **in the macrospheric stage. Microspheric stage with a few annular chambers, so that the test is ovoid to discoidal**”.

*Broeckinella arabica* Henson, 1948

Figs. 4b–d, 5–6.

\*1948 *Broeckinella arabica* n. gen., n. sp. – Henson, p. 93, pl. 7, fig. 6, text-fig. 13a–c.

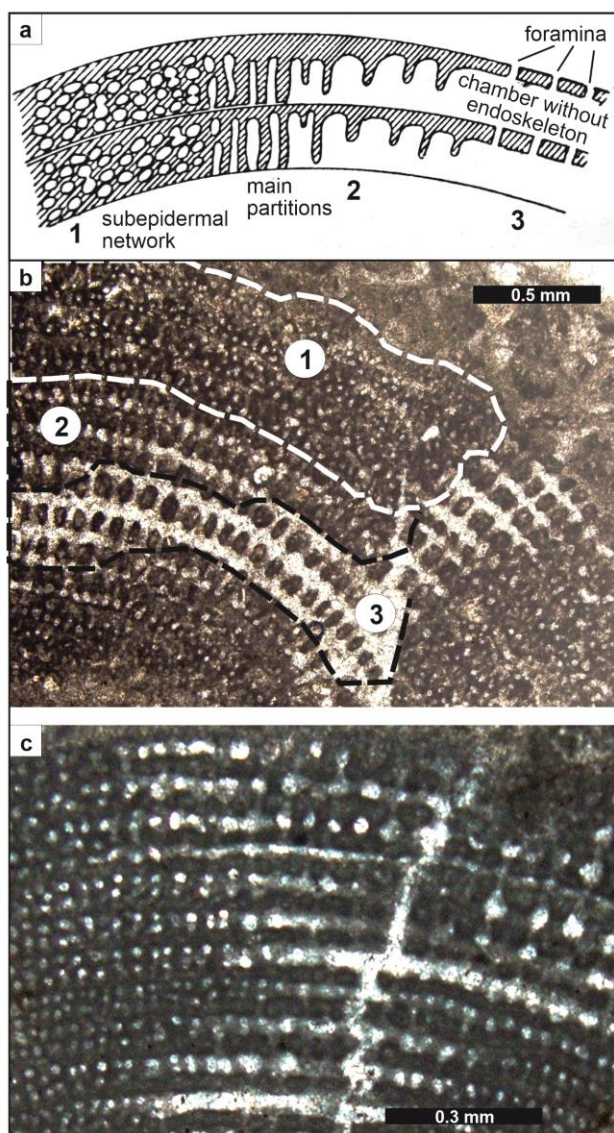
1978 *Broeckinella arabica* Henson – Cherchi and Schroeder, p. 514, fig. 1 A–C.

2004 *Dicyclina schlumbergeri* – Khosrow Tehrani and Afghah, pl. 2, fig. 4.

2008 *Dicyclina schlumbergeri* – Khosrow Tehrani et al., pl. 1, fig. 6.

2016 *Broeckinella arabica* Henson – Schlagintweit and Rashidi, p. 57, fig. 9a–e.

**Emended description:** Test finely agglutinated, compressed, with numerous chambers rapidly increasing in width so that the **megalospheric** test becomes flabelliform. A tiny proloculus (diameter ~0.07-0.1 mm) is followed by about 8-10 planispiral chambers that increase



**Fig. 4** Internal structure of *Broeckinella arabica* Henson. **a** Drawing of a slightly oblique equatorial section (slightly modified from Henson, 1947, fig. 13c; see also Cherchi and Schroeder 1978, fig. 1C). 1 = subepidermal layer (network; exoskeleton), 2 = zone with transverse partitions only, 3 = undivided chamber interior (lacking endoskeleton); septa with foramina. **b** Tangential equatorial section of *Broeckinella arabica* showing the three zones of Henson (1948). Thin-section Rt 85, Mandegan section. **c** Tangential equatorial section showing main partitions aligned between successive chambers (detail from Fig. 6d). Thin-section NG 42-1, Naghan section.

rather rapidly in width (Fig. 6e). The chamber margins are subdivided by exoskeletal elements, both vertical and horizontal resulting in a meshwork (or pattern) of tiny polygonal cells displayed in shallow tangential sections (= zone 1 in Henson 1948; see Fig. 4a) (Figs. 4b, 6a-d). Toward the chamber interior a zone follows where only main partitions are present, aligned between successive chambers (= zone 2 in Henson 1948; see Fig. 4a) (Figs. 4c, 6b, d). The central part is undivided (Figs. 4b, 6c, e). The multiple foramina are arranged in the median plane, not related to the main partitions (that can therefore not be termed septula). The **microspheric** test is ovoid to discoidal due to final annular chambers (Fig. 5b-c). A proloculus is not observable. The planispiral part, contrasting the A-form, consists of numerous (~ 26) chambers. The internal structure is identical to the A-form.

**Remarks:** The material of *B. arabica* from the Tarbur Formation does not include centered sections. Data on the test dimensions therefore only comprise incomplete sections attaining a maximum size of 2.4 mm for megalospheric and up to 4.6 mm for microspheric forms (Tab. 2). *B. arabica* is intermediate in size between the distinctly smaller *B. neumannae* and the larger *B. hensoni* n. sp. (Tab. 3). The description of Henson (1948) was based on a single specimen, a megalospheric form (see Cherchi and Schroeder, 1978). The specimen from the Tarbur Formation illustrated in Fig. 5b is the first record of a microspheric specimen. The differences between the two generations are summarized in Table 2.

*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. *Dicyclina schlumbergeri* is rather common in the Tarbur Formation (see Schlagintweit and Rashidi, 2018). ***Broeckinella hensoni*** Schlagintweit and Rashidi nov. sp. Figs. 5a, 7-8.

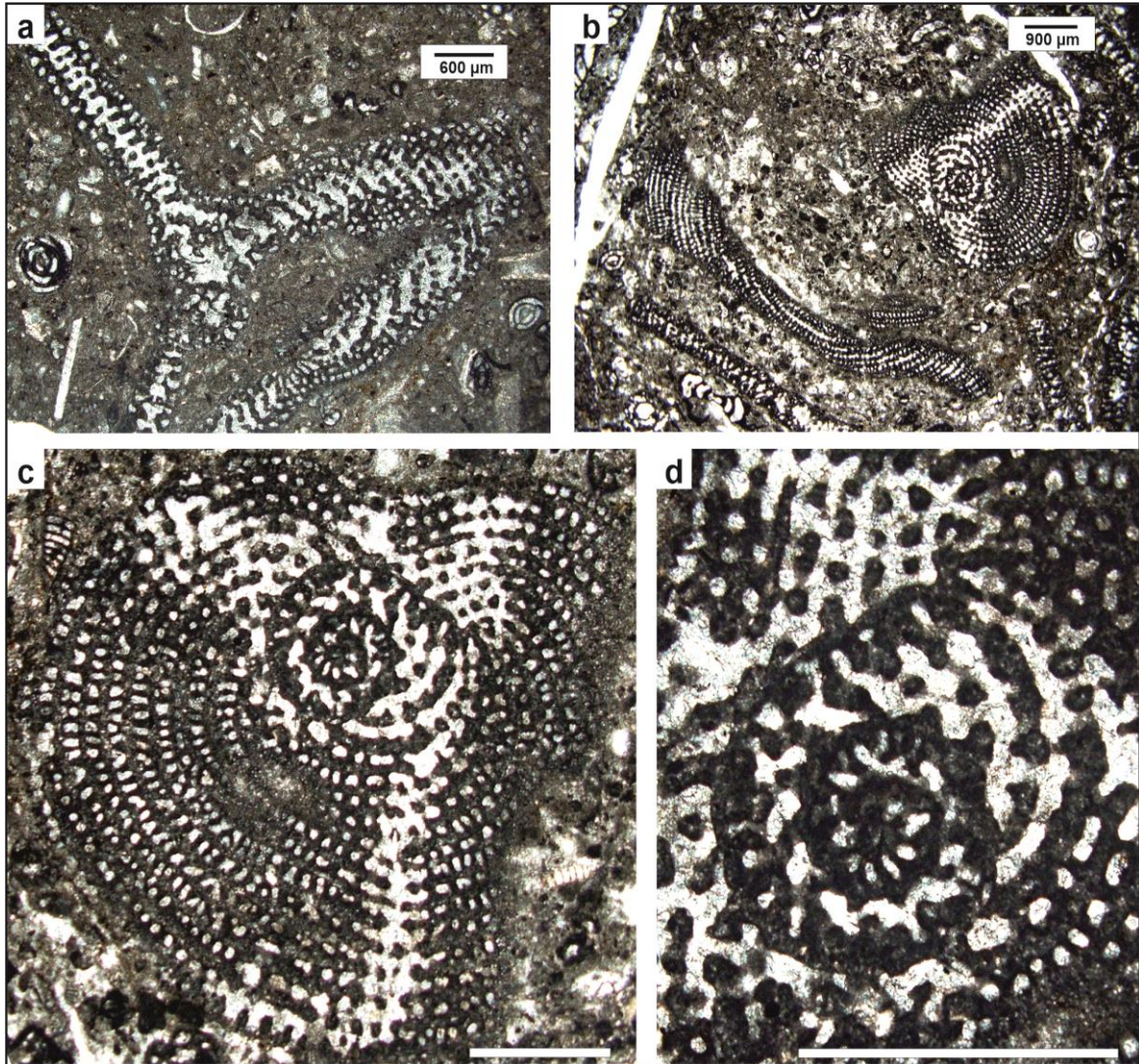
**Holotype:** Equatorial section of an assumed macrospheric specimen showing flabelliform test and illustrated in Fig. 7f, thin-section 2NG N. The diameter of the holotype specimen is ~3.65 mm.

**Table 2** Megalospheric versus microspheric generations of *Broeckinella arabica* Henson (A-form: data from Cherchi and Schroeder, 1978; B-form: this work, specimen shown in figure 5b-d).

generation	megalospheric (A) form	microspheric (B) form
number chambers planispiral part	~10	~26
diameter proloculus	0.07-0.1 mm	not discernible
test diameter	3.1 mm (holotype)	~4.6 mm (~4.2 preserved part)
adult final chambers	flabelliform	annular
test morphology	fan-shaped	ovoidal to discoidal

**Table 3** Summary table of the biometric parameters of *Broeckinella* species. Data from Henson (1948), Gendrot (1968), Cerchi and Schroeder (1978), and this work. \* measured from the original papers.

species	<i>B. arabica</i>	<i>B. neumannae</i>	<i>B. grandis</i> n. sp.
Type-locality	Maastrichtian of Qatar (Henson, 1948)	Santonian of France Gendrot (1968)	Maastrichtian of Iran
Test diameter (mm)	up to 3.1 (A-form) up to 4.6 (B-form)	up to 1.5 mm (A-form)	up to 7.5 (?B-form)
Test thickness (mm)	~0.3	up to 0.22	up to 0.4
Number chambers last mm	8-14 *	6-8 *	5-7
Diameter foramina (mm)	0.02-0.04	0.06	0.05-0.07
Proloculus diameter (mm)	~0.1	0.07-0.09 *	-



**Fig. 5** *Broeckinella hensoni* n. sp. (a) and *Broeckinella arabica* Henson (b–d) from the upper Maastrichtian of the Tarbur Formation, Naghan section. a Foraminiferal wackestone with *Broeckinella hensoni* n. sp., thin-section 2NG 197. b Foraminiferal wackestone with *Broeckinella arabica* Henson, 2NG 128-1. c–d Details from b, showing a microspheric specimen. Scale bars in c and d = 1 mm.

**Etymology:** The species name is dedicated to Francis Roger Spencer Henson (1901-1967) in honour for his fundamental works on larger imperforate foraminifera from the Middle East area. For further information on F.R.S. Henson and his merits see Hughes (2013).

**Type-locality:** Naghan section (Figs. 2–3).

**Type-level:** Late Maastrichtian of the Tarbur Formation.

**Description:** Test finely, agglutinating, large (up to almost 8 mm), flattened with an early evolute planispiral stage followed by a flabelli- to reniform adult growth stage (Fig. 7f). Axial sections display almost constant chamber width (Fig. 7a). Further details on the early stage are limited by the available sections. The adult part consists of up to 50 chambers. There are five to seven chambers in the last mm of the test. Wall finely agglutinated. Exoskeleton consisting of one short horizontal and two orders (short, and longer) of subepidermal vertical (or radial) partitions (beams and rafters) together forming a subepidermal network (Fig. 8e). Due to the shortness of the secondary partitions this network of polygonal cells is only visible in shallow tangential sections. Longer vertical partitions (beams) are aligned between successive chambers, and reach slightly deeper into the chamber lumen. The central part of the chamber lumen is undivided (e.g., Fig. 8e in the lower part; see Henson, 1948: fig.13c). Multiple foramina (one row) arranged in the median plane. Microspheric specimens not reported.

**Dimensions:** See table 3.

**Comparisons:** Amongst the three Late Cretaceous species of the genus, *Broeckinella hensoni* is distinctly larger than *B. arabica* Henson (double the size!) and *B. neu-mannae* Gendrot (five times larger!) (see table 3). With respect to the time-equivalent *B. arabica*, the distinctively lower number of chambers per last mm test length (8 to 14 in *B. arabica* against 5 to 7 in *B. hensoni*), due to a greater chamber height, is notable.

## ACKNOWLEDGMENTS

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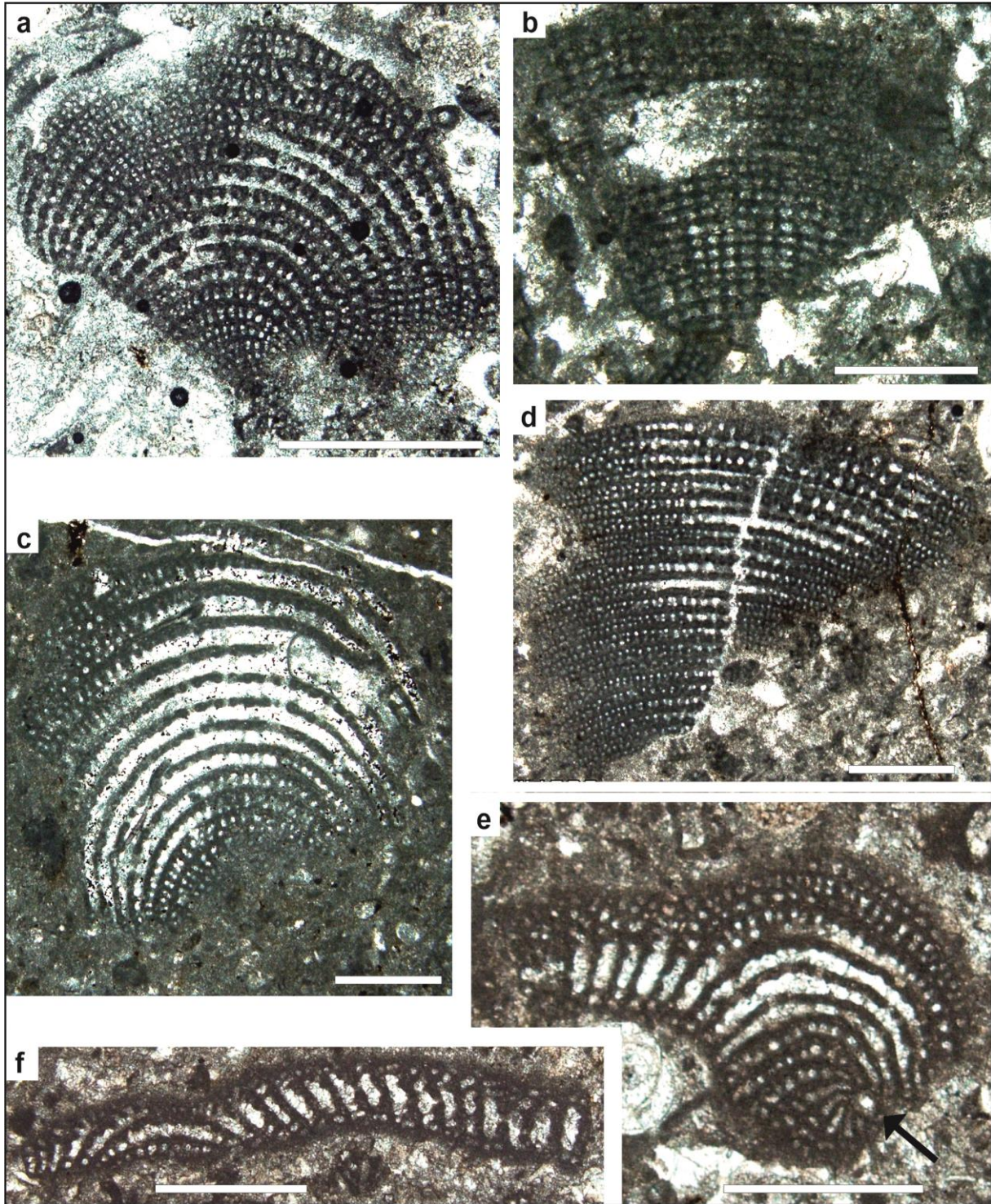
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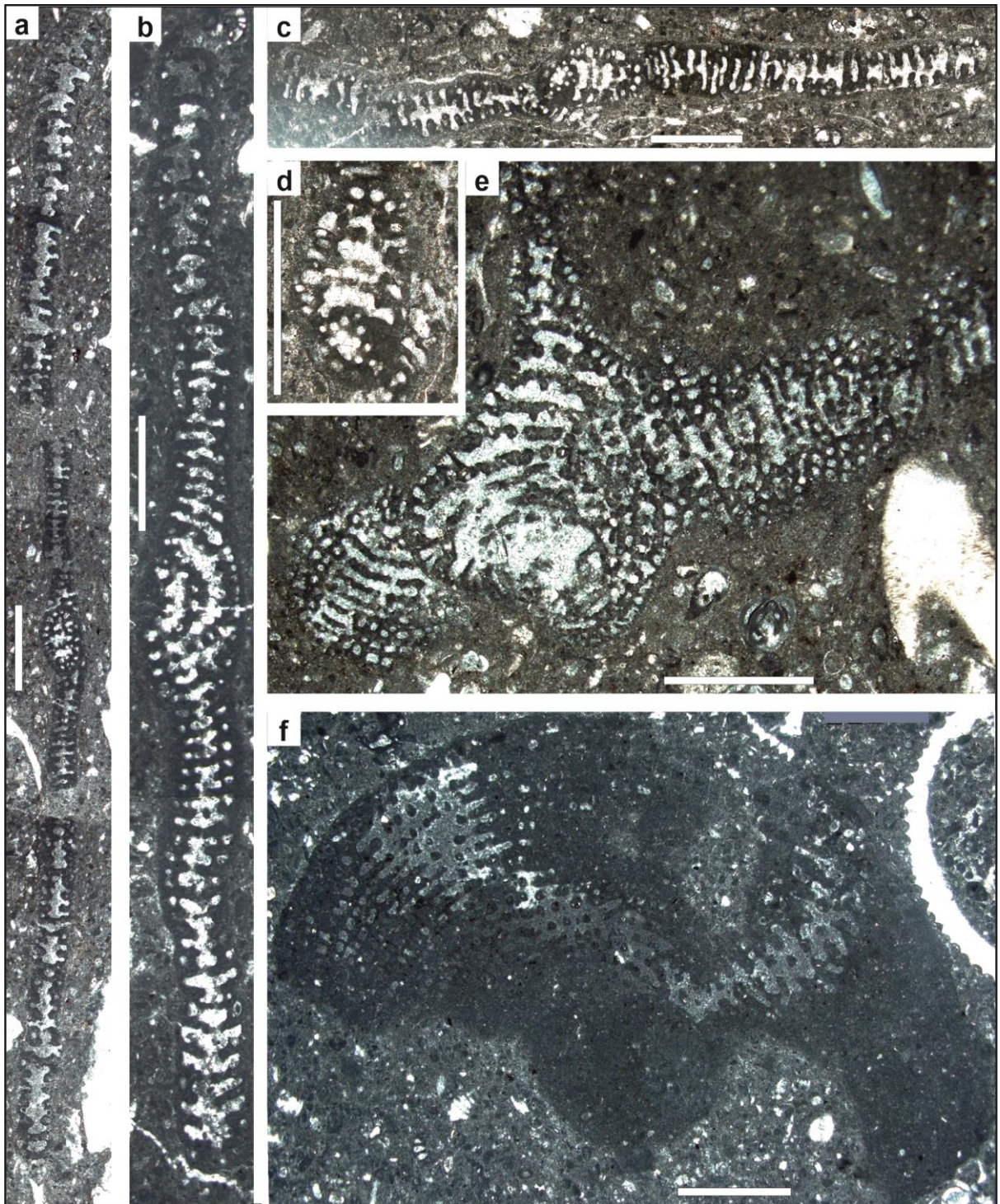
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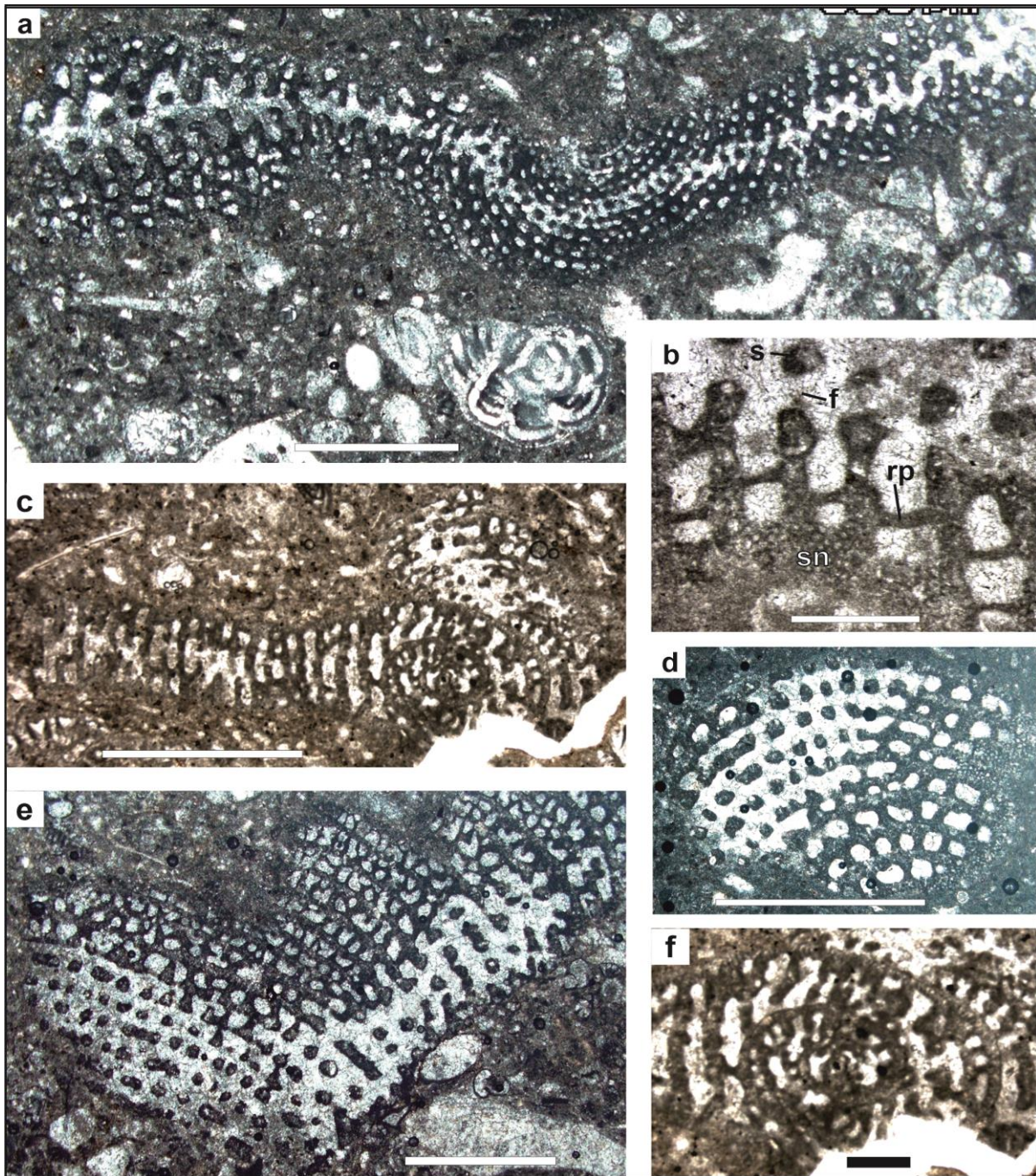
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**Fig. 6** *Broeckinella arabica* Henson, upper Maastrichtian Tarbur Formation of the Mandegan (**a, d**) and Naghan sections (**b–c, e–f**), Zagros Zone, SW Iran. **a, c–d** Oblique equatorial sections, partly fragmentary, in some parts crossing the subepidermal network (e.g., **a** and left side of **d**). Note the undivided central part of the chambers in **c**. **b** Tangential section in the plane with only main partitions aligned between subsequent chambers (= zone 2 in Henson 1948; see Fig. 6a). **e–f** Oblique sections. Note initial planispiral part in the megalospheric specimen in **e** passing the proloculus (arrow). Note also the chambers undivided in the central part in **e**. Thin-sections: Rt 104 (**a**), NG 42-1 (**b**), NG 21 (**c**), Rt 85 (**d**), 2NG 49 (**e**), 2NG 112 (**f**). Scale bars 0.5 mm.



**Fig. 7** *Broeckinella hensoni* n. sp., upper Maastrichtian Tarbur Formation of the Naghan section, Zagros Zone, SW Iran. **a, c** Subaxial sections. Specimen shown in A displays more than 40 chambers in the uncoiled adult part. **d** Detail from **c** showing initial coiled part. **e** Oblique equatorial section. **f** Slightly oblique equatorial section showing flabelliform test morphology (test diameter: ~6.6 mm). Thin-sections: 2NG 153 (**a**), 2NGN (**b, f**), 2NG 38 (**c-d**), NG 197-1 (**e**). Scale bars 1.0 mm.



**Fig. 8** *Broeckinella hensoni* n. sp., upper Maastrichtian Tarbur Formation of the Naghan (a, d–e) and Mandegan (b–c, f) sections, Zagros Zone, SW Iran. **a** Oblique equatorial section. Note porcelaneous test of *Cuvillerinella* sp. below. **b** Detail showing fine subepidermal network (sn, below), followed by zone with radial partitions (rp) only and finally the undivided central chamber part with foramina (f) piercing the septa (s). **c** Oblique section cutting the initial planispiral part. **d–e** Oblique equatorial sections showing zones of different internal structure (see Text-Figure 3). **f** Detail from c showing initial planispirally coiled part with numerous chambers. Note also the fine subepidermal network and main partitions (right side). Thin-sections: 2NG 166 (a), Rt 67-1 (b), RT 72 (c, f), 2NG 118 (d), 2NG 172 (e). Scale bars 1.0 mm for a, c–e, 0.2 mm for b and f.

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