

## ORBITOLINID FORAMINIFERA FROM THE LATE MAASTRICHTIAN OF THE TARBUR FORMATION (ZAGROS ZONE, SW IRAN)

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**Abstract** The orbitolinids *Dictyoconella? minima* Henson, 1948, *Dictyoconus bakhtiari* n. sp., and *Pseudorbitolina* cf. *marthae* Douvillé, 1910, are described from the (late) Maastrichtian of the Tarbur Formation of the Zagros Zone, SW Iran. Due to the presence of marginal foramina and primary radial septules arranged in vertical lines, *D.? minima* is assigned to the subfamily Dictyorbitolininae Schroeder thereby becoming its youngest representative. The belonging of the species to the genus *Dictyoconella* Henson however is challenged, as the type-species *Dictyoconella complanata* in contrast does not display an orbitolinid test architecture. *Dictyoconus bakhtiari* n. sp. represents the highest evolved Cretaceous representative of the genus *Dictyoconus* Blanckenhorn displaying complex marginal zone with several orders of both beams and rafters, a septulate deuterocoenonch and marginal foramina. Therefore, *Dictyoconus bakhtiari* n. sp. is structurally closer to the Paleogene than the Lower Cretaceous representatives of the genus. The convexo-concave specimens described as *Pseudorbitolina* cf. *marthae* Douvillé are identical to forms reported from the Maastrichtian of Iraq and Qatar.

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

### INTRODUCTION

The classical period of orbitolinid foraminifera proliferation with greatest diversity was the late Hauterivian to middle Cenomanian interval (e.g., Douglass, 1960; Schroeder, 1962, 1975; Moullade et al., 1985; Granier et al., 2013). Following the extinction event of larger benthic foraminifera during the late Cenomanian (e.g., Parente et al., 2008), there is no reliable record of orbitolinids in the latest Cenomanian-Turonian interval (e.g., Velić, 2007; Frijia et al., 2015; Arriaga et al., 2016). The radiation of late Cretaceous (post-Cenomanian) orbitolinids started in the Coniacian with distinctly reduced diversity compared to the lower Cretaceous (e.g., Gendrot, 1968; Bilotte, 1974; Caus and Cornella, 1981; Moullade and Viillard, 1973; Fleury, 1970; Luperto Sinni, 1976; Luperto Sinni and Chivelet, 1999). Among the described taxa, there are genera restricted to the late Cretaceous (e.g., *Abrardia*, *Calveziconus*) and species ascribed to genera that were recorded from the late Hauterivian-Albian, assumed to re-appear after gaps of more than one to up to several stages. These are *Orbitolinopsis senonicus* Gendrot, *Falsurgonia parva* Luperto Sinni & Chivelet, and *Paleodictyoconus senonicus* Moullade & Viillard. Maastrichtian orbitolinid foraminifera are rather rarely reported, and represented by species of the genera *Abrardia* Neumann & Damotte, *Pseudorbitolina* Douvillé (see Henson, 1948), *Dictyoconella* Henson, and *Dictyoconus* Blanckenhorn (Loeblich and Tappan, 1987).

In the present paper three orbitolinids are described from the late Maastrichtian of the Tarbur Formation cropping out in the Zagros Zone of southwest Iran: *Dictyoconella? minima* Henson, 1948, *Pseudorbitolina* cf. *marthae* Douvillé, 1910, and *Dictyoconus bakhtiari* n. sp. The description and illustration of these taxa represents a further contribution to the study of the micropalaeontological inventory of the Tarbur Formation. First results of our studies

and critical revisions of the literature have already been published recently (Schlagintweit et al., 2016a, 2016b, 2017 in press; Schlagintweit and Rashidi, 2016).

### GEOLOGICAL SETTING

#### Overview

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). 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 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 paper published in the last decade (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; Pirbaluti and Abyat, 2013; Afghah and Yaghmour, 2014) but several determinations however are incorrect and need revision.

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**STUDIED SECTIONS**

The foraminiferan-bearing samples of the Tarbur Formation studied are from two sections (Fig. 1):  
 a) Mandegan section.

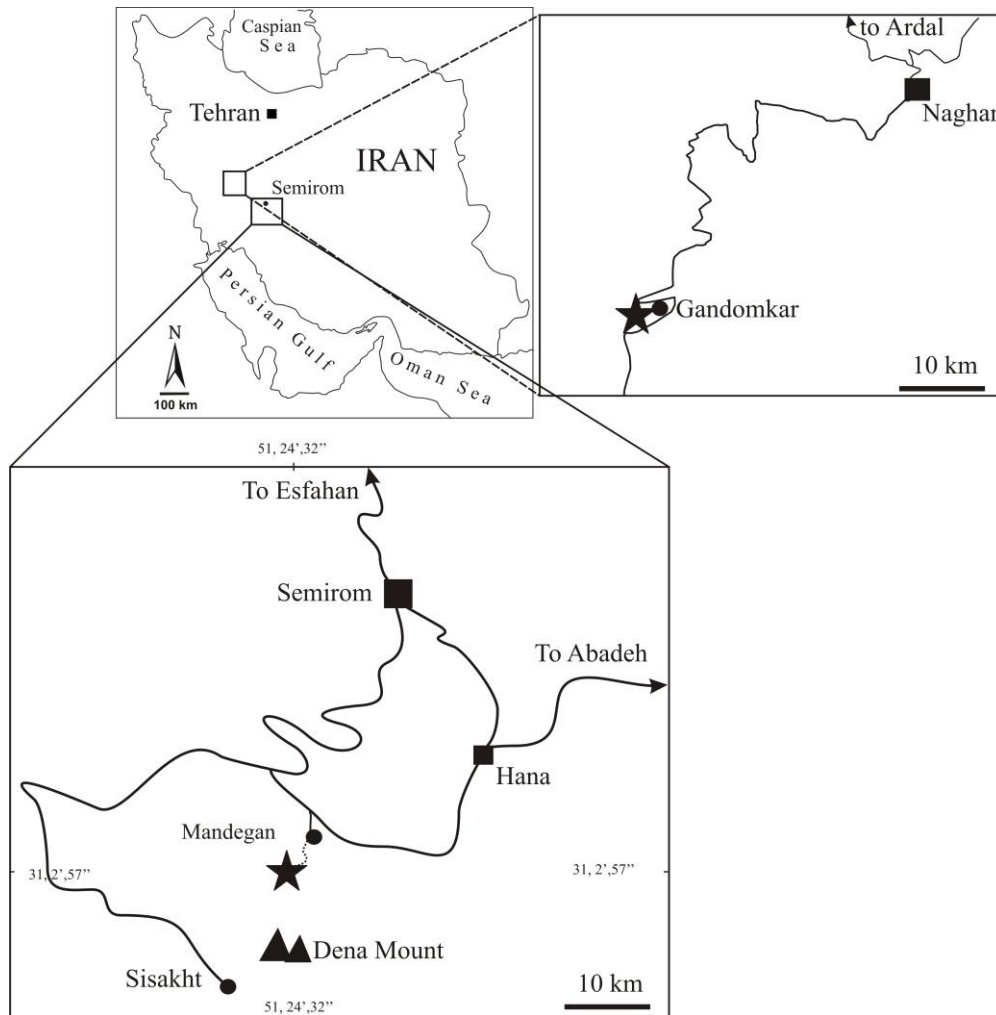
The study area, located in the High Zagros Belt, is situated north of Mount Dena, about 65 km south of the town of Semirom. The section of the Tarbur Formation is exposed about 10 km south of the village of Mandegan, and here named Mandegan section. Here the Tarbur Formation shows a thickness of ~272 m and 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 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., 2016a). Microfacies examples is illustrated in Fig. 3a. The Greenwich coordinates of the section base are N 31°, 25', 8.13" and E 51°, 24', 34.58".

b) Naghan section.

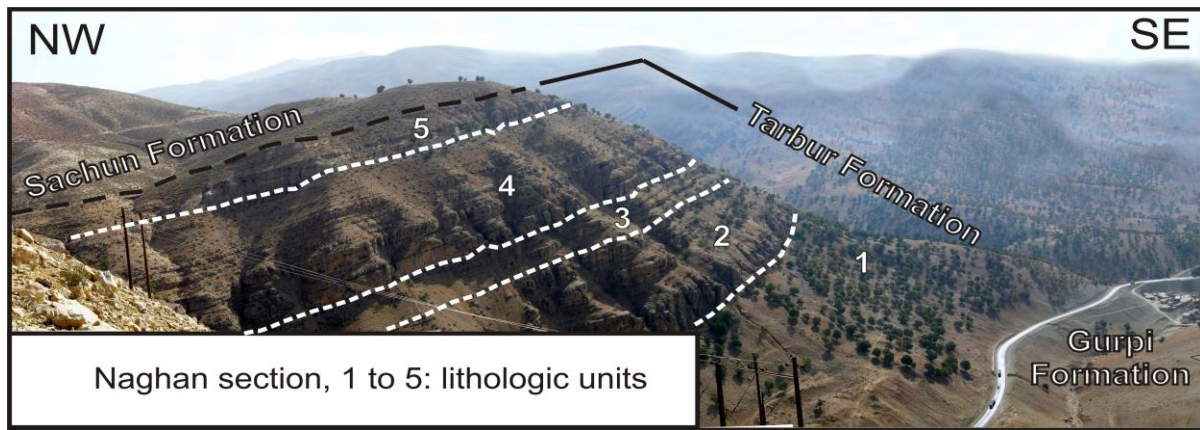
The studied area in the folded Zagros belt is located approximately 50 km south west of Naghan town near the Gandomkar village and is here named Naghan section. At this locality, the Tarbur Formation is underlain by the Gurpi Formation and overlying by the Paleocene Sachun Formation (Figs. 2, 4). Lithologically, 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 limestones, 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 (33m), intercalation of grey shales and cream to grey, medium- to thick-bedded limestones (cacilutites and calcarenite) .



**Fig. 1** Location map of the two studied sections.



**Fig. 2** Field view of the Naghan section located approximately 50 km south west of Naghan town near the Gandomkar village.

- 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.

Microfacies examples are illustrated in Fig. 3b-f. The vertical distribution of the described taxa and some index forms of larger benthic foraminifera in the Tarbur Formation of the Naghan section is shown in Figure 4. 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 (from the Mandegan section) 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 and 2NG (second series of thin-sections) 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. For glossary, report to Hottinger (2006). Note: orientation of structures (e.g., pillars) with respect to chamber (floor versus ceiling or roof) in direction of growth (see Hottinger and Drobne, 1980, p. 205).

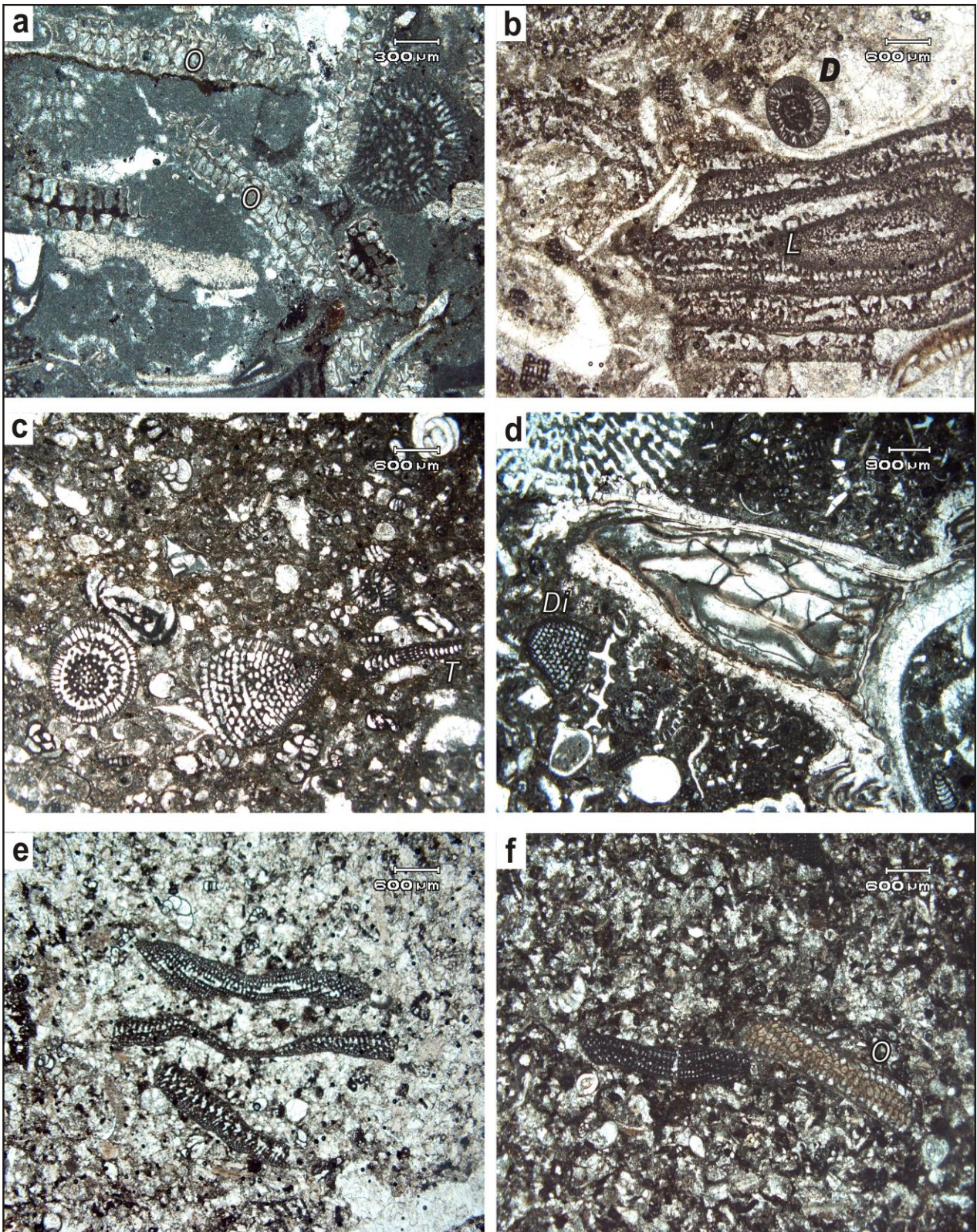
Phylum Foraminifera d' Orbnig, 1826  
 Class Globothalamea Pawlowski et al., 2013  
 Order Loftusiida Kaminski and Mikhalevich, 2004  
 Suborder Loftusiina Kaminski and Mikhalevich, 2004  
 Superfamily Orbitolinoidea Martin, 1890  
 Family Orbitolinidae Martin, 1890  
 Subfamily Dictyorbitolininae Schroeder, 1990 (in Schroeder et al., 1990)

**Remarks:** The subfamily Dictyorbitolininae are defined as follows: "The genera assigned to this subfamily are characterized by the presence of marginal foramina, situated at the periphery of the central zone forming a circular row. These apertures are arranged along vertical lines from the apex to the base. The primary septules show the same arrangement as the apertures (Schroeder, in Schroeder et al., 1990, p. 196, translated). Schroeder attributed three genera to this subfamily: *Dictyorbitolina* Cherchi & Schroeder, *Paracoskinolina* Moullade, and *Praedictyorbitolina* Schroeder (see also Kaminski, 2014). Taking into account the stratigraphic ranges of these genera, the Dictyorbitolininae are so far reported from the Late Hauterivian to Albian. The youngest representative is *Paracoskinolina sunnilandensis* (Maync) from the Albian of the Gulf Coast Area of the United States of America (Maync, 1955a). It should be mentioned here that Mikhalevich (2013, p. 505), referring to the above mentioned paper of Schroeder et al. (1990), distinguished two subfamilies, the Praedictyorbitolininae (including *Praedictyorbitolinina*, and *Paracoskinolina*) and the Dictyorbitolininae (including *Dictyorbitolinina*). Also in the classification provided by Kaminski (2004 and 2014), one finds the Praedictyorbitolininae. Such a subdivision or subfamily names however have not been introduced by Schroeder et al. (1990) (for Dictyorbitolininae see also Schroeder et al., 1999).

Genus *Dictyoconella* Henson, 1948

Type-species *Dictyoconella complanata* Henson, 1948

**Remarks:** In 1948 Henson published a monography of Jurassic to Paleogene larger benthic foraminifera of south-western Asia including the description of fourteen new genera. Among these, Henson established the new genus *Dictyoconella* with two species, the type-species *D. complanata* from the Maastrichtian of Qatar, and *D. minima* from strata with an age of "most probably Upper Cenomanian or Turonian" of Qatar....and "a single specimen, possibly of this species,...in Maastrichtian limestones" of Iraq (op. cit., p. 26). Both species assigned to the family Orbitolinidae were poorly illustrated. According to Henson, both possess a subepidermal polygonal pattern, and *D. minima* main partitions (= primary beams) that are lacking in *D. complanata*. The test of *D. complanata* is distinctly compressed with subparallel opposite



**Fig. 3** Microfacies of some characteristic samples from the Mandegan (a) and Naghan sections (b–f). **a** Packstone with benthic foraminifera *Omphalocyclus macroporus* (Lamarck) (*O*), and oblique transverse section of *Dictyoconella? minima* Henson on the right. Thin-section Rt 105. **b** Grainstone/packstone with debris of rudist shells, and larger benthic foraminifera *Loftusia* sp. (*L*), and transverse section of *Dictyoconella? minima* Henson (*D*). Thin-section 2NG 17. **c** Wackestone/packstone with benthic foraminifera among two specimens of *Dictyoconus bakhtiari* n. sp. (see also Fig. 10c, e). **d** Floatstone with corals, rudists, and tangential section of *Dictyoconus bakhtiari* n. sp. (*Di*). Thin-section 2NG 87-2. **e–f** Packstone with *Pseudorbitolina* cf. *marthae* Douvillé, and *Omphalocyclus macroporus* (Lamarck) (*O*) in **f**. Thin-sections 2NG 47 and NG 47-1.

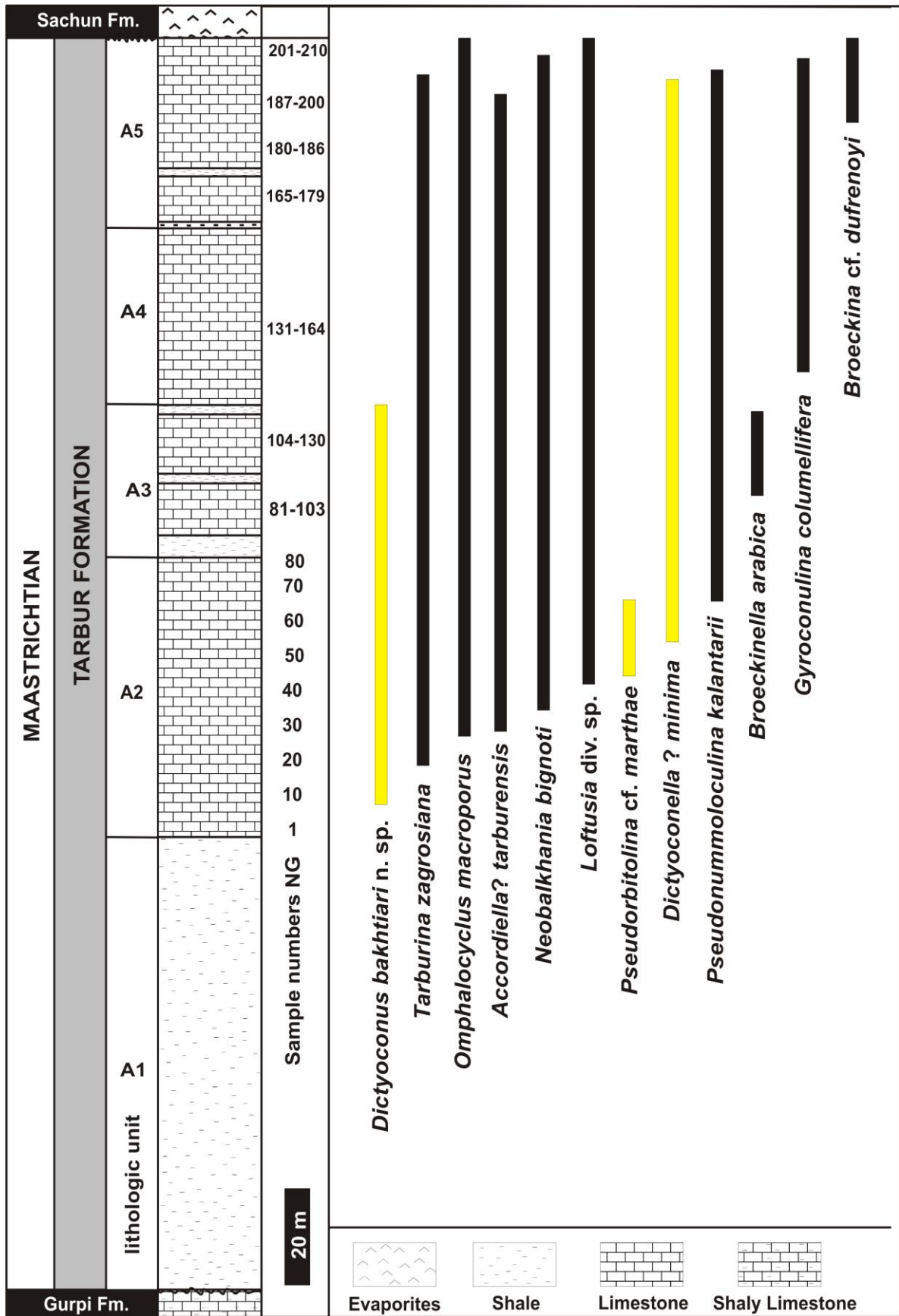


Fig. 4 Vertical distribution of the described taxa and some index forms of larger benthic foraminifera in the Tarbur Formation of the Naghan section.

sides, flabelliform (e.g., like in *cuneolinids*) whereas the one of *D. minima* only slightly may show ellipsoidal transverse sections (Henson, 1948, pl. 11, figs. 8, 10). In addition, Henson supplied morphological details in the description of *D. minima* that are not discernible in the provided illustrations, e.g. the existence of a planispiral initial coil. Douglass (1960, p. 256) stated that “it is likely that the form described by Henson as *Dictyoconella* is merely a variant of the genus *Iraqia*” .... a form where “the partitions are reticulate throughout the central area”. Although almost 80 years have passed since then, both species ascribed to the genus *Dictyoconella* are still very poorly known concerning both systematics and biostratigraphy.

Due to the general morphology and illustrations provided we conclude that from the two only *D. minima* displays the typical morphology and structure of an orbitolinid foraminifera. Therefore both species are here considered as belonging to different genera, one with a flabelliform test (*D. complanata*) and another with an orbitolinid test architecture (*D.? minima*). This interpretation excludes the belonging of *D. minima* to the genus *Dictyoconella*.

*Dictyoconella? minima* Henson, 1948

Figs. 3a–b pars, 5–6

\*1948 *Dictyoconella minima* n. sp. – Henson, p. 25, pl. 11, fig. 3, 8–10.

2008 *Dictyoconella minima* Henson – Boudagher Fadel, pl. 5.7, figs. 1–3 (paratypes).

2016 *Montseciella* sp. – Afghah, fig. 5d (not indicated in the legend of the figure but in the text on page 175; Tarbur Formation of south Zagros Basin).

**Description:** Test medium conical (apical angles 50–90 degrees); both sides and cone base slightly convex. Some transverse sections display an oval outline (Figs. 3b, 5j). The initial part is characterized by a small spire (?trochospiral, ?planspiral) of few chambers and with acute margin; its axis is almost parallel to the test side wall (Fig. 6e, g, l). The embryo is poorly visible and its detailed structure unknown (Fig. 6h–i). The exoskeleton consists of horizontal (rafters) and radial vertical partitions (beams) subdividing the chamber margins. The beams are continuous from one chamber to the next (Fig. 5c, 5e, 5n–m). They extend to a marginal through marking the boundary to the central zone. Their distal ends slightly bend upwards in direction to the apex (Fig. 5k). There are 2 to 3 shorter intercalary beams intercalated between the beams (Fig. 5b, 5o–p). There are two rafters of unequal length per chamberlet in the marginal zone (Fig. 5a). Shallow-tangential sections display a pattern of subrounded alveolar compartments (subepidermal network) (Fig. 5f). The boundary between the marginal and central zones is marked by a marginal through, in close proximity to the marginal foramina (Fig. 5g, 5j, 5p). The latter with oblique axis (Fig. 5k) form a row of circular openings corresponding to the number of beams in transverse sections (Fig. 5o). Indistinct parts of the central zone are filled with opaque micritic masses (fused pillars and/or secondary deposits) masking the original structure (Fig. 5a, 5h, middle part of the cone; Fig. 6b–e). In other parts of the central zone vertical interseptal elements (pillars) alternating between successive chambers are dis-

cernible (see Fig. 5h, youngest chambers; Fig. 6k). The non-marginal foramenal axes in the central zone maybe vertical (as the pillars) but also oblique.

**Dimensions** (in mm; data from Henson, 1948, between brackets):

Test diameter (D): 0.7–1.9 mm (0.7–1.8 mm)

Test height (H): 0.8–1.4 (1.0–1.5 mm)

D/H: 0.8–1.35

Numbers of chambers per 1 mm axial length: 12–16, mostly 15–16 (15)

**Remarks:** Henson (1948, p. 25) noted that the test of *D. minima* is conical but slightly compressed, so that the base shows an elliptical outline. Elliptical (or oval) outline of the test base is rare in orbitolinids. It is reported from the early Albian *Mesorbitolina ovalis* throughout its ontogeny (see Görög and Arnaud-Vanneau, 1996), and the juvenile part of the late Albian *Carinoconus casterasi* (Bilotte, Canérot, Moullade & Peybernès) (see Schroeder, 1985). The acute margin of the initial spire of *D.? minima* however shows affinities to *Carinoconus* (see further remarks below) thus offering an explanation that only transverse sections of the juvenile test part might be ellipsoidal in outline.

Another typical feature of *D.? minima* are the dark, irregular distributed microgranular masses of fused pillars (and/or secondary deposits?) in the central zone. This was also observed by Henson (1948, p. 26), stating that interseptal structures are sporadic and poorly defined in the central part of the test. Among the Orbitolinidae, secondary deposits in the central zone are an extreme exception. An example is the genus *Carinoconus* Cherchi & Schroeder, with the type-species *C. casterasi* from the Late Albian of Spain (Bilotte, Canérot, Moullade & Peybernès) (Cherchi and Schroeder, 1983; Schroeder, 1985; Loeblich and Tappan, 1987). A second species has been described as *Carinoconus iraqiensis* by Bernaus and Masse (2006) from the Cenomanian of Iraq. Marginal foramina and main partitions (beams) arranged in vertical lines in subsequent chambers however are not reported from the genus *Carinoconus*. Without further details on the structure of the embryonic apparatus and the initial part in centered sections however a reliable attribution of *Dictyoconella? minima* to any known (*Carinoconus?*, or new?) orbitolinid genus is not possible for the moment being.

Henson (1948) reported *D.? minima* “most probably” from the late Cenomanian or Turonian of Qatar (Dukhan no. 2 and 3 wells; Wasia Group, see figs. 1–2 in Sugden and Standing, 1975). In addition, Henson (op. cit., p. 26) noted “a single specimen, possibly of this species” from the Maastrichtian of Iraq. For the Dukhan oil field of Qatar, Hewaidy and Al-Hitmi (1994) established a Late Cenomanian “*Dictyoconella minima* total range Zone”. Curiously, Boudagher-Fadel (2008, chart 5.2) indicated the range of *D.? minima* as Late Cenomanian–Santonian.

Subfamily Dictyoconinae Moullade, 1965

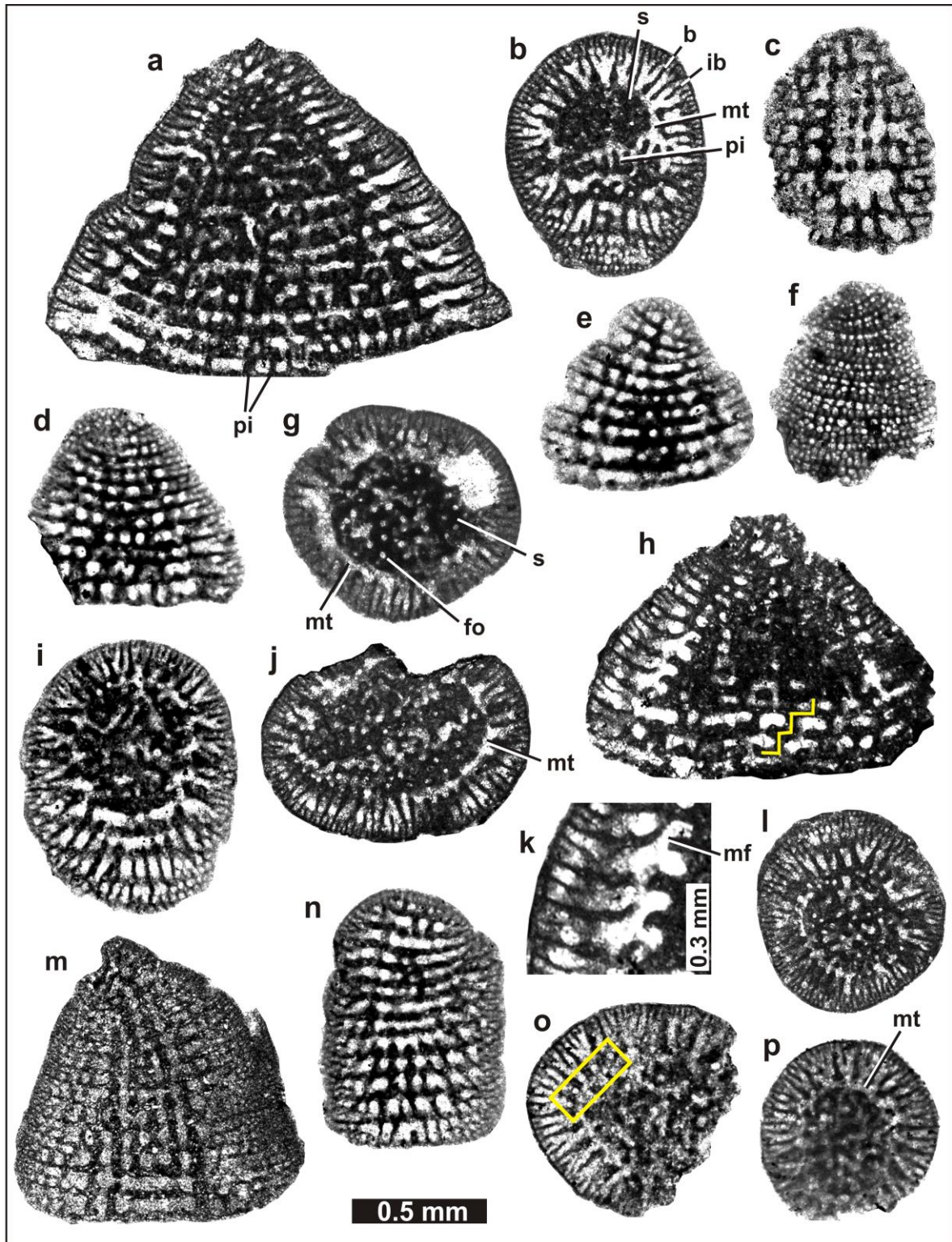
Genus *Dictyoconus* Blanckenhorn, 1900

Type species: *Patellina egyptiensis* Chapman, 1900

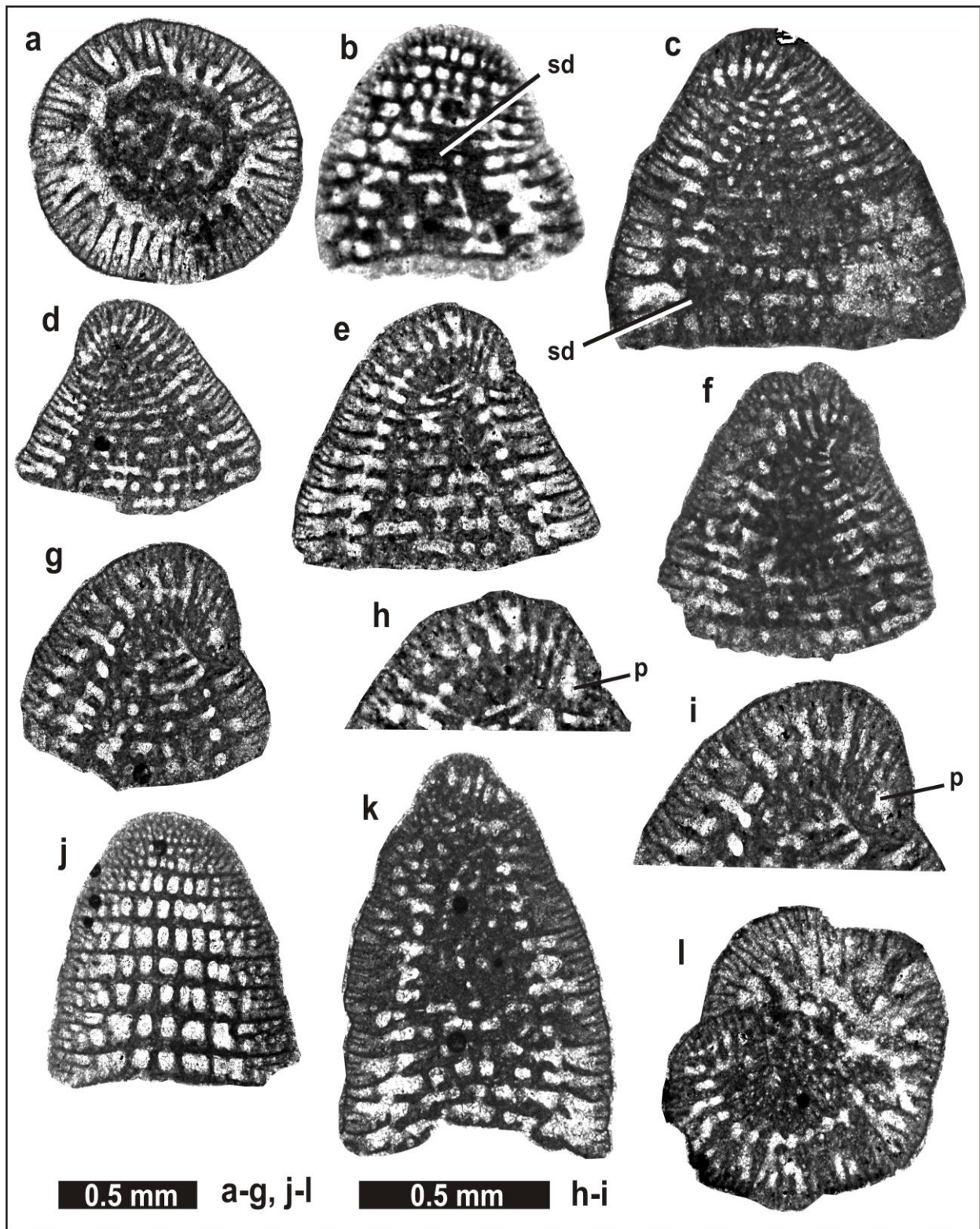
*Dictyoconus bakhtiari* n. sp.

1948 *Dictyoconus* cf. *arietinus* Silvestri – Henson, p. 34, pl. 7, fig. 1, text-fig. 3, Maastrichtian of Qatar.

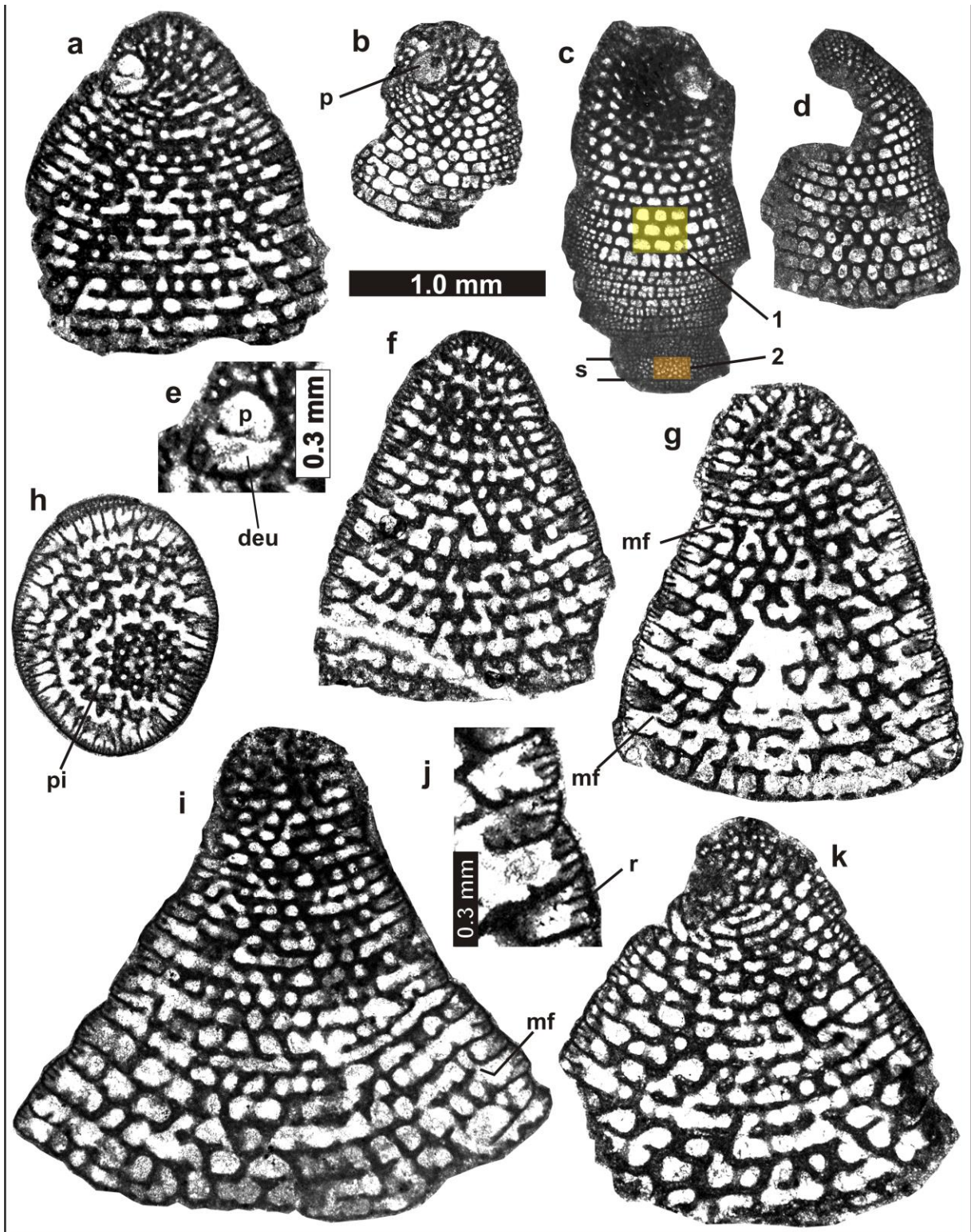
Figs. 3c–d pars, 7–10



**Fig. 5** *Dictyoconella? minima* Henson from the late Maastrichtian of the Tarbur Formation, SW Iran (Naghan section: **a–b, j, l**; Mandegan section: **c–i, k, m–p**). **a** Subaxial section. **b, i, l** Oblique sections. Note oval test outline in **k**. **c–e, m** Deep tangential sections displaying primary septules (beams) continuous from one chamber to the next. **f** Shallow tangential section displaying subepidermal network of beams and rafters. **g, j, l, o–p** Different transverse sections, some slightly oblique. Note five marginal foramina arranged in a radial circle (inside yellow marked rectangle), and oval test outline in **j**. **h** Subaxial section. Note alternation of pillars by stairway-like arrangement of foramina (yellow line) and opaque fused pillars/secondary deposits in the central zone. **k** Detail from **h** showing marginal foramina arranged in vertical lines between successive chambers. **n** Tangential-oblique section. Abbreviations: b = beam, ib = intercalary beam, fo = foramina, mf = marginal foramina, mt = marginal through, pi = pillar, s = septum. Thin-sections: Ng 196 (**a**), Ng 192 (**b**), Rt 108-3 (**c–e, g, n**), Rt 104 (**f**), Rt 96 (**h, k**), Rt 108-6 (**i**), Ng 187 (**j**), Ng 186 (**l**), Rt 107 (**m**), Rt 102-2 (**o**), Rt 104 (**p**).



**Fig. 6** *Dictyoconella? minima* Henson from the late Maastrichtian of the Tarbur Formation, SW Iran (Mandegan section: **b**; Nahghan section: **a, c-k**). **a** Oblique transverse section. **b** Oblique section cutting the marginal (upper part) and central zones (lower part) displaying irregularly distributed fused pillars/secondary deposits. **c, k** Subaxial sections. **d-g** Axial sections showing initial spire. **h-i**. Details (from **e** and **g**) of the initial spire. **j** Tangential section. **l** oblique section passing the initial spire. Abbreviations: p = protoconch, sd = secondary deposits/fused pillars. Thin-sections: 2NG 17 (**a, k**), Rt 100 (**b**), Ng 180-1 (**c**), 2NG 179-1 (**d**), 2NG 168 (**e, h**), 2NG 175 (**f**), 2NG 174 (**g, i**), 2NG 177 (**j**), 2NG 98-2 (**l**).



**Fig. 7** *Dictyoconus bakhtiari* n. sp. from the late Maastrichtian of the Tarbur Formation, Naghan section, SW Iran. **a, e** Axial section of megalospheric specimen. Detail of biconch in **e**. **b** Tangential section passing through the initial spire with embryo. **c** Tangential section passing (from above to below) the initial spire with embryo, the marginal zone with large quadrangular pattern of primary septules (beams) (1, in yellow), and the complex pattern of intercalary beams and rafters (2, orange). **d** Fragmentary tangential section. Note the rounded transverse sections of the chamberlets produced by the primary septules (beams) in the lower middle part of the test. **f-g, j**, Subaxial sections. Detail of the marginal zone (from **g**) showing rafters in **j**. **h** Oblique section. **i, k** Subaxial sections. Abbreviations: b = beam, deu = deuteroconch, mf = marginal foramen, p = protoconch, pi = pillar, r = rafter, s = septum. 1: dense subepidermal network of higher order beams (intercalary beams) and rafters. 2: coarse rectangular subepidermal network of primary rafters and beams. Thin-sections: 2NG32 (**a, e**), Ng 112 (**b-c**), Ng 15 (**d**), 2NG52 (**f**), 2NG53 (**g, j, k**), Ng 73 (**h**), Ng 83-3 (**i**).

**Holotype:** Slightly oblique axial section of a megalospheric specimen illustrated in Fig. 10d, and detail in Fig. 10a. Thin-section 2NG 112.

**Origin of the name:** The species name refers to the Bakhtiaris (Bakhtiyari in Persian), a tribe living in the area of the central Zagros Mountains, southwestern part of Iran.

**Type locality:** Naghan section, SW Iran (Figs. 1–2).

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

**Diagnosis:** Representative of *Dictyoconus* with medium to high conico-convex test in megalospheric ( $d/h$  ratio often around 1), and reflexed conico-convex tests of large diameter ( $d/h > 2$ ) in microspheric forms. Megalospheric forms with eccentrically positioned simple embryonic apparatus formed by a subspherical proloculus and a hemispherical deuterocoenoch occasionally with tiny rudimentary exoskeleton. Marginal zone with two generations of horizontal (rafters) and three orders of vertical partitions (beams) forming a dense and narrowly spaced subepidermal network. Endoskeleton of numerous, narrowly spaced pillars, alternating between successive chambers. Marginal foramina inclined to the cone axis; cribrate foramina in the central zone perpendicular to septa.

**Description:** Test distinctly dimorphic with medium to high conico-convex megalospheric (A form) and low conico-convex microspheric specimens (B form) of large diameter and reflexed sides. The following description essentially refers to A forms, as only two reliably recognizable B forms were observed (Fig. 8g, Fig. 10f). The cone surface is smooth except the laterally slightly protruding initial spire (Fig. 8a). The eccentrically positioned spire (Figs. 7a, 9a) consists of numerous chambers whose exact number is unknown ( $> 10$ ). It starts with a subspherical proloculus followed by a semispherical to kidney-shaped deuterocoenoch partially enclosing the former laterally (Fig. 7a, Fig. 10a–b). The deuterocoenoch occasionally displays the presence of very short, tiny, rudimentary plates (Fig. 10b). Both protoconch and deuterocoenoch are connected by means of a single foramen. The chambers following the spiral stage display convex chambers throughout with convexity increasing during ontogeny. Marginal zone with three, occasionally four horizontal partitions (rafters). In transverse sections, the marginal chamberlets are (sub)rectangular and commonly display three thin vertical partitions (intercalary beams) each. One longer in the middle and two shorter secondaries on the sides. The endoskeleton consists of numerous, narrowly spaced pillars alternating in position between successive chambers. The pillars display round shapes in sections above the chamber floor becoming semicircular to sickle-shaped at the ceiling. In the central zone, foramina are disposed in alternating position between the chambers. Oblique marginal apertures at the transition marginal/central zones.

**Remarks and comparisons:** For all Lower Cretaceous species (Carsey, 1926: *D. walnutensis*; Arnaud-Vanneau, 1980: *D.? vercorii*; Peybernes, 1980: *D. tunesianus*; Schroeder, 1965: *D. pachymarginalis*) we note that these are smaller in dimensions than *D. bakhtiari* and that their embryo is situated close to the slightly inclined apex. In *D. bakhtiari* and also the Paleogene forms, in contrast,

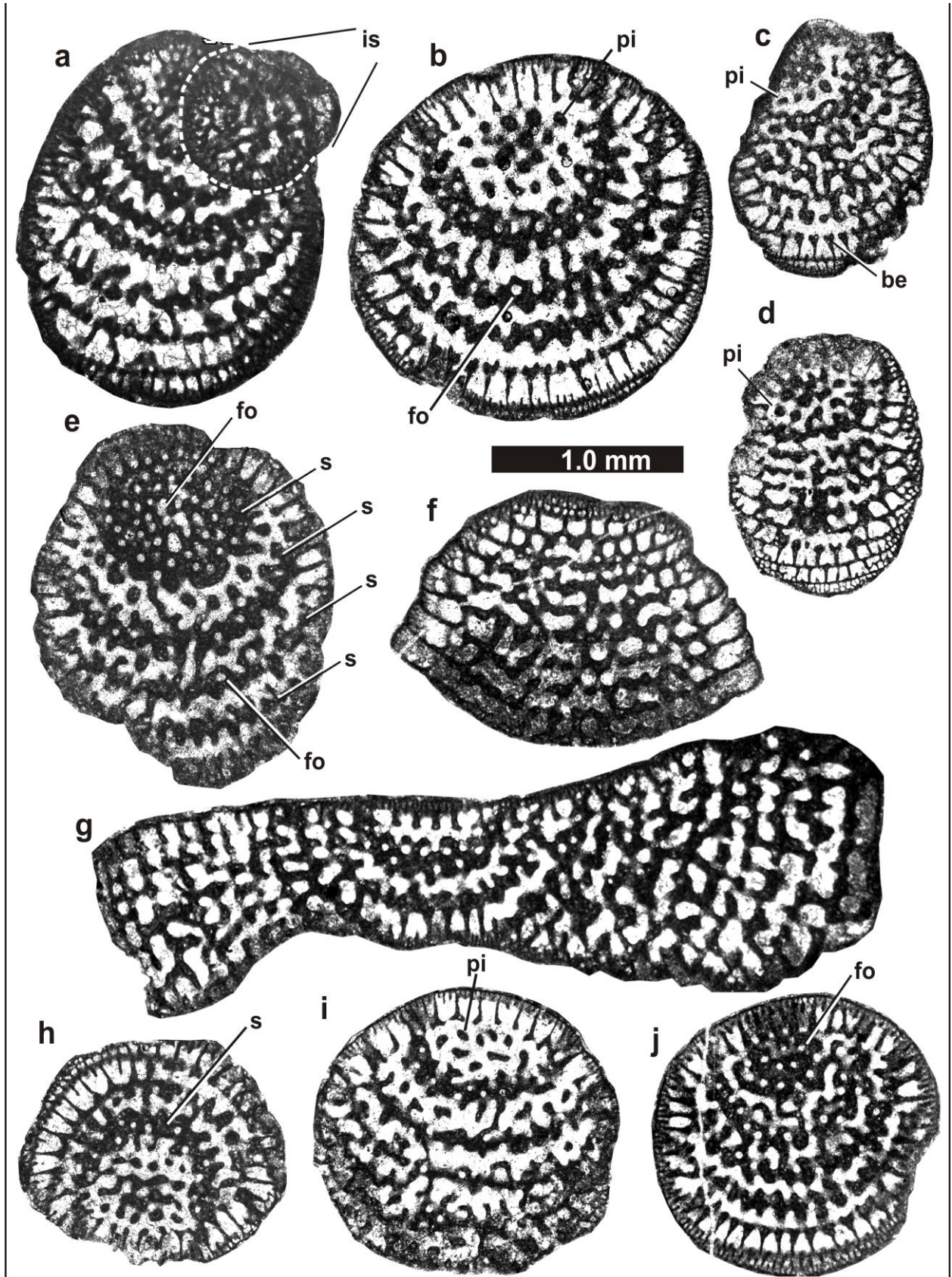
the embryo is situated below the apex at the beginning of a well-developed spire. A deuterocoenoch with exoskeleton is only reported from the Aptian (Bedoulian-Gargasian) *Dictyoconus? pachymarginalis* Schroeder. Considering the complexity of the exoskeleton as generic criterion (e.g., Hottinger and Drobne, 1980; Vecchio and Hottinger, 2007; Vicedo et al., 2014), *Dictyoconus tunesianus* (Peybernes) lacking horizontal partitions (rafters) should be excluded from the genus *Dictyoconus* (Peybernes, 1980). The comparably large-sized *D. walnutensis* just has one rafter and one intercalary beam in the marginal zone (Davies, 1939; Maync, 1955b). The taxonomic revision of the group of Lower Cretaceous *Dictyoconus* species however is beyond the scope of the present paper.

Henson (1948) reported *D. bakhtiari* n. sp. as *Dictyoconus* cf. *arietinus* Silvestri, 1939 (a form described originally from the Eocene of Smalia) from Maastrichtian limestones with *Loftusia* and *Omphalocyclus* from the Maastrichtian of Qatar (Dukhan no. 1 well). The dimensions (height about 1.8 mm, diameter 1.3 mm) correspond to *D. bakhtiari*. Also the number of chambers in the last 1 mm (10 chambers), and the size of the embryo (0.17 mm) indicated by Henson fit well (see Tab. 1). As Henson noted (op. cit., p. 35), the “difference in age and size might justify separation of the Qatar forms under a new name, but I prefer to give a qualified determination until further records are available”. It is worth mentioning here that *Dictyoconus arietinus* represents a junior synonym of *D. egyptiensis* (Cushman) (Hottinger and Drobne, 1980; Serra-Kiel et al., 2016).

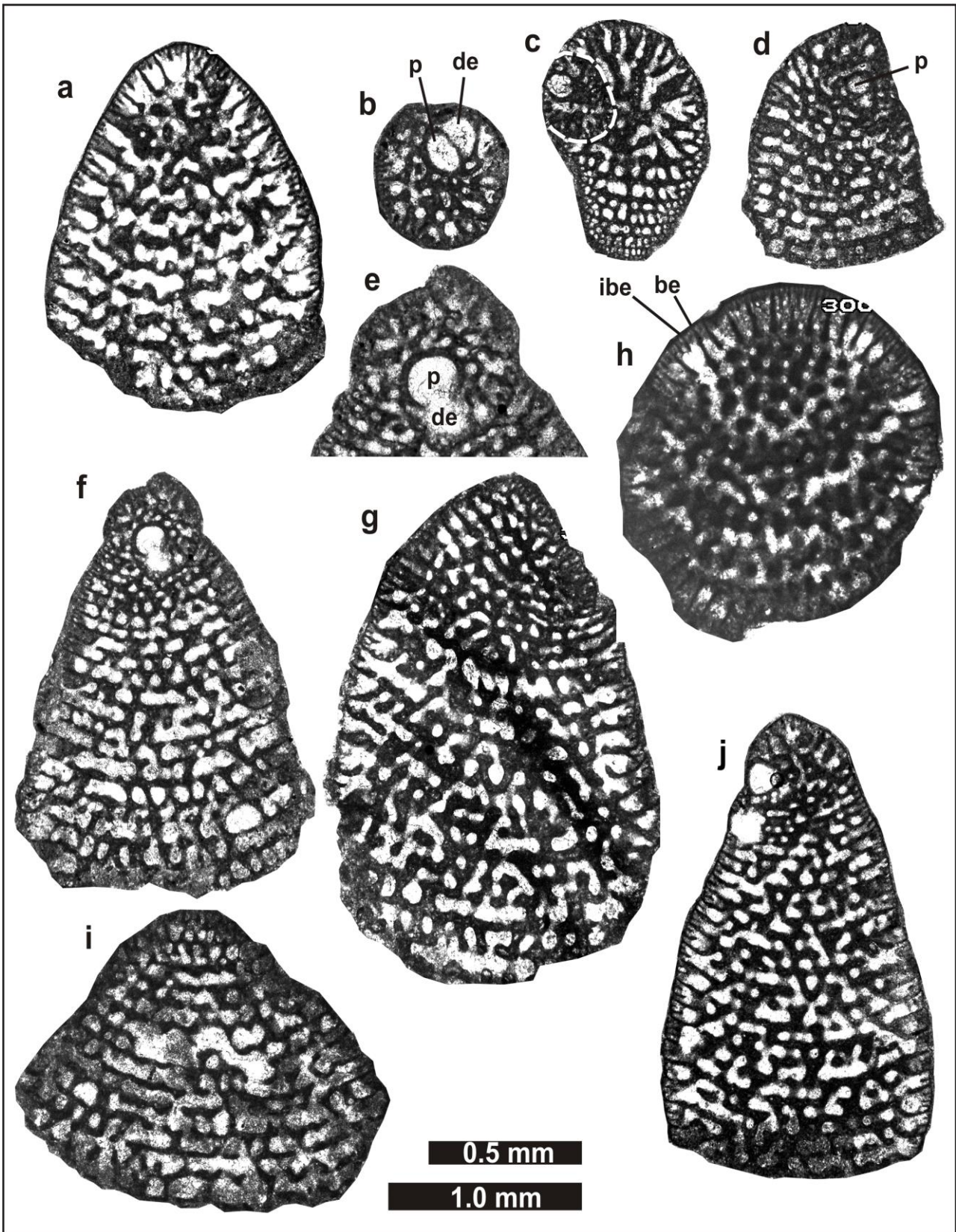
The relationship of the (Lower) Cretaceous representatives of *Dictyoconus* Blanckenhorn to the Paleogene forms is still some matter of debate. Schroeder (1965, p. 978) on the one hand noted the principal same structural features of both, but on the other hand assumed a polyphyletic origin because of the rather long stratigraphic gap between them. Prior to the description of the Maastrichtian *D. bakhtiari*, the reported gap stretched the Late Albian/Cenomanian to Thanetian interval (e.g., Hottinger and Drobne, 1980: *D. turriculus*; Serra-Kiel et al., 1998; Sirel, 2009: *D. baskilensis*). The Eocene *Dictyoconus egyptiensis* (Chapman) and *D. indicus* Davies possess a biconch with simple (non septulate) protoconch and deuterocoenoch with exoskeleton (Douglass, 1960; Hottinger and Drobne, 1980; Hottinger, 2007; Serra-Kiel et al., 2016). The specific distinction between the two may be tricky, and is mainly related to the absence of a pillared deuterocoenoch and a simpler exoskeleton in *D. egyptiensis* (Serra Kiel et al., 2016). Both taxa are larger than *D. bakhtiari*, have less chambers per last mm axial length (e.g., 5–7 in *D. egyptiensis*) and larger size of embryo (e.g., proloculus 0.2–0.35 mm in *D. egyptiensis*; see Hottinger and Drobne, 1980). In any case, with the presence of marginal apertures, rectangular chamberlets in the marginal zone, a complex exoskeleton, and last but not least the rudimentary exoskeleton in the deuterocoenoch, *D. bakhtiari* is closer to the large-sized Paleogene than the Lower Cretaceous representatives.

Genus *Pseudorbitolina* Douvillé, 1910

**Remarks:** The genus *Pseudorbitolina* is monospecific with the type species being *Pseudorbitolina marthae* Douvillé, 1910.



**Fig. 8** *Dictyoconus bakhtiari* n. sp. from the late Maastrichtian of the Tarbur Formation, Mandegan section (c) and Naghan section (all others), SW Iran. **a** Oblique section passing the eccentric initial spire. **b-e, h-j** Oblique sections; affecting five chambers in **b**. Note the broadening of the distal end of the beams in **b-d, i, f** Tangential-oblique section. **g** Tangential oblique section of a microspheric specimen. Abbreviations: be = beam, fo = foramen, is = initial spire, pi = pillar, s = septum. Thin-sections: Ng 53-2 (**a**), 2NG 52 (**b**), Rt 62-1 (**c**), Ng 53-1 (**d, h**), Ng 52-1 (**e**), 2NG 32 (**f, j**), Ng 87-2 (**g**), 2NG 53 (**i**).



**Fig. 9** *Dictyoconus bakhtiari* n. sp. from the late Maastrichtian of the Tarbur Formation, Naghan section, SW Iran. **a** Oblique section. **b–c** Oblique sections cutting the initial spire with the embryo. **d, g** Subaxial sections. **e–f, j** Axial sections. **h** Oblique-transverse section. **i** Tangential section. Abbreviations: be = beam, de = deuteroconch, ib = intercalary beam, p = protoconch. Thin-sections: Ng 21 (**a**), Ng 85 (**b**), Ng 53-1 (**c**), Ng 52-2 (**d, h**), 2Ng 87-2 (**e–f**), Ng 53-2 (**g**), Ng 55 (**i**), 2NG 27 (**j**).

*Pseudorbitolina cf. marthae* Douvillé, 1910

Figs. 3e–f, 11

\*1910 *Pseudorbitolina marthae* n. gen., n. sp. – Douvillé, p. 57, text-fig. 1–4.

1948 *Pseudorbitolina marthae* Douvillé – Henson, p. 102, pl. 6, fig. 17, pl. 11, fig. 6 ?, text-fig. 16 (Maastrichtian Simsima Formation of Qatar, see Sugden and Standring, 1975).

1978 *Pseudorbitolina marthae* Douvillé – Neumann, p. 198, figs. 1–3, pls. 1–2 (with synonymy).

1979 *Pseudorbitolina marthae* Douvillé – Radoičić, pl. 8, figs. 1–3.

Non 2008 *Pseudorbitolina cf. marthae* Douvillé – Al-Kubaysi, fig. 2–12 = random section of *Loftusia* sp. (Maastrichtian Aqra Formation of Iraq).

2008 *Pseudorbitolina marthae* Douvillé – Boudagher-Fadel, pl. 5.7, figs. 8, 14 (Maastrichtian of Dukhan no. 1 well, Qatar; original material of Henson, 1947).

Non 2016 *Pseudorbitolina marthae* Douvillé – Al-Kubaysi and Abid, fig. 6-1 to 6-3 = random section of *Loftusia* sp. (Maastrichtian Aqra Formation of Iraq) (see Fig. 12).

**Description:** Test mostly low, more rarely high conico-concave and irregularly curved. The specimens display a rather wide range of apical angle and consequently the ratio test diameter to height. The chambers do not cover the complete basal cone surface but exhibit marginal annuli only (type annular-concentric, e.g., Hottinger, 2008, fig. 37.4), becoming slightly broader during ontogeny. Adult specimens consist of up to 35 chambers (specimen in Fig. 11a). The chambers display a marginal zone with a fine subepidermal network of intercalary beams and rafters (Fig. 11f, lower part). There are up to two rafters; numbers of vertical partitions unknown. As can be seen in tangential sections, the primary beams are radially aligned between successive chambers (Fig. 11e, h). Towards the central part, an undivided zone connects the chamberlets of each chamber. Large foramina (tubular aperture of Henson, 1947) connect these undivided zones of succeeding chambers.

**Dimensions** (in mm):

Test diameter (D): ~1.6 mm to 4.6 mm (Douvillé, 1910: ~2–3 mm)

Test height (H): 0.75–1.2

D/H: 2.0–6.0

Diameter proloculus: 0.1 mm (1 value)

**Remarks:** First of all we have to stress that the available sections are not convenient for a detailed description of the test architecture. In any case, with its annular-concentric chambers more or less throughout the complete ontogeny, *Pseudorbitolina* represents a rather unusual chamber arrangement among the orbitolinids. According to the drawing of Douvillé (1910, fig. 3), the monospecific genus *Pseudorbitolina* shows a subspherical proloculus in apical position displaying a septulated supraembryonic zone at its top (like in *Palorbitolina*, see Schroeder, 1963, fig. 1). The thin-section specimens illustrated by Neumann (1978, pl. 1, fig. 7, pl. 2, fig. 6) in transverse sections instead shows an embryo in apical position consisting of a spherical proloculus and a hemispherical septulated deuteroconch arranged laterally to

the former. In the Maastrichtian material, only one specimen was cut passing the proloculus (Fig. 11a).

In the revision of the species provided by Neumann (1978), the author concludes that it represents a good marker for the Campanian. Obviously there is a stratigraphic discrepancy of the occurrence of *Pseudorbitolina marthae* between the western Europe type region and Iran/Iraq (see synonymy). In the Campanian-Maastrichtian deposits of Turkey, *P. marthae* is restricted to the southeastern part belonging to the Arabian platform (Özer et al., 2009). In the Maastrichtian of the Iraqi Aqra Formation, random sections of *Loftusia* sp. have been confounded with *Pseudorbitolina marthae* Douvillé (see synonymy) (Fig. 12).

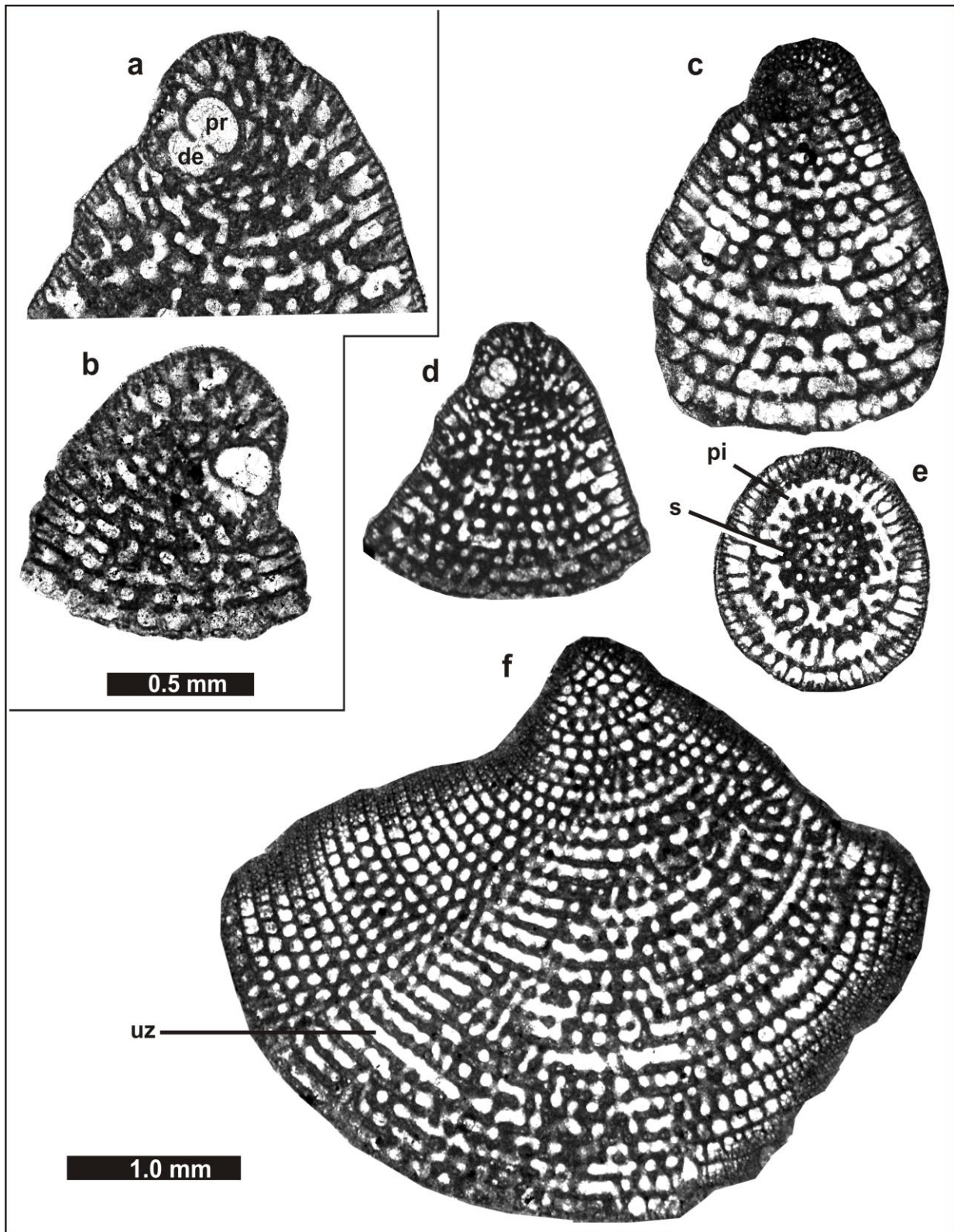
## MICROFACIES AND FAUNAL ASSOCIATIONS OF THE DESCRIBED TAXA

The taxa described and reported in the present paper were observed above all in foraminiferan-dasycladalean wackestones to packstones, referring to a soft substrate and very low water energy in a shallow protected lagoon. In the shallowing-upwards Tarbur Formation, this facies occurs in the upper part and is characterized by a diverse association of benthic foraminifera, among agglutinated conical foraminifera (Orbitolinidae, *Gyroconulina*), large-sized miliolids (*Broeckina*, *Pseudonummoloculina*, *Tarburina*), orbitoidids (*Omphalocyclus*) and representatives of *Loftusia* div. sp.

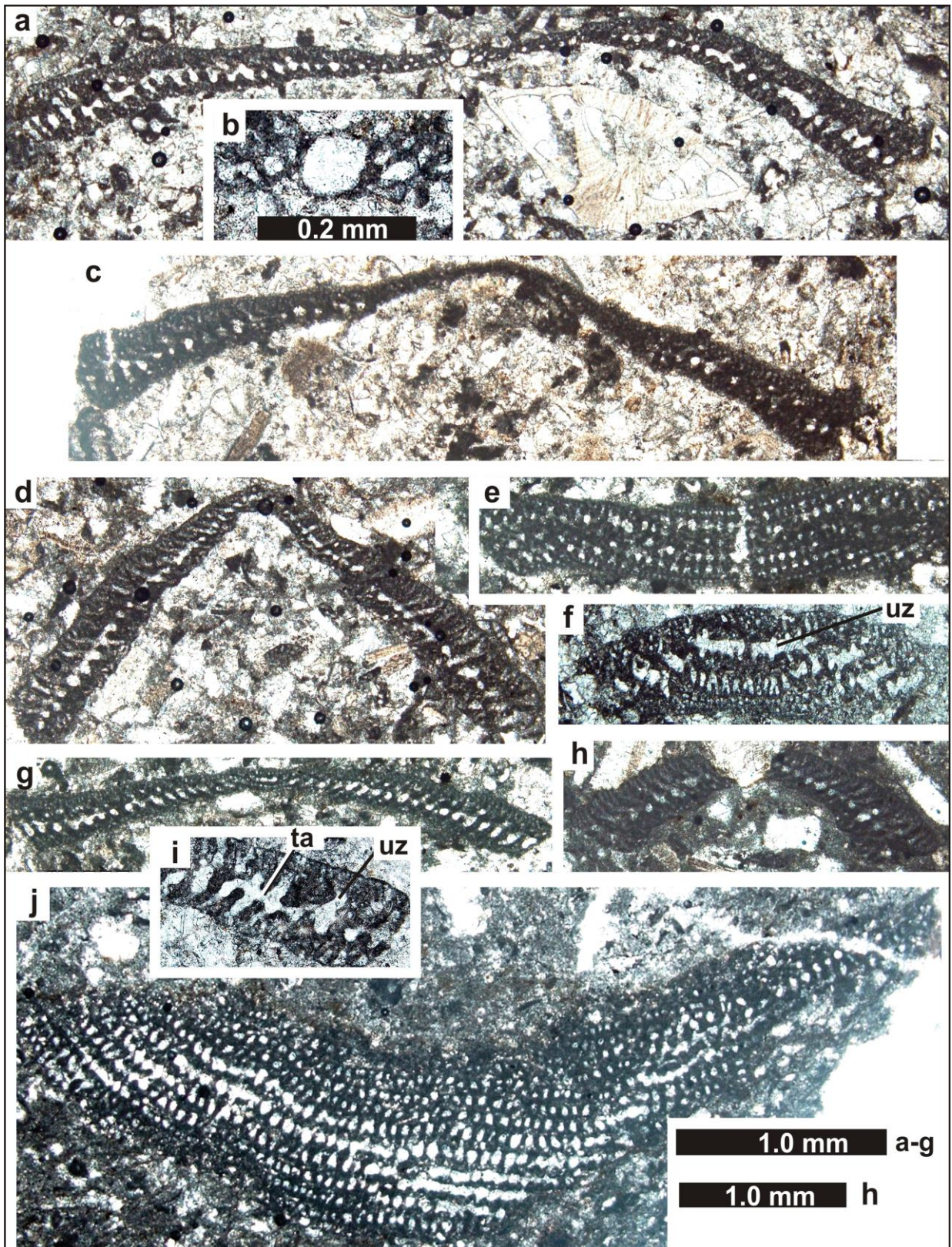
Among the orbitolinids described in the present paper, *Dictyoconella? minima* Henson represents the one with the greatest vertical distribution in the Naghan section (Fig. 4). It preferentially occurs in wackestone/packstones with *Omphalocyclus* and small debris of rudist shells as well as in association with *Loftusia* ssp. (Figs. 3b 12). *Dictyoconus bakhtiari* n. sp. occurs in foraminiferan packstones and in floatstones with debris of rudists and corals (Fig. 3c–d). *Pseudorbitolina cf. marthae* Douvillé was observed typically in poorly diversified argillaceous, high-energy deposits in great abundances and in packstones with *Omphalocyclus* and fine debris of rudist shells (Fig. 3e–f). These correspond to a comparably short interval in the lower part of the Naghan section (Fig. 4).

## STRATIGRAPHY

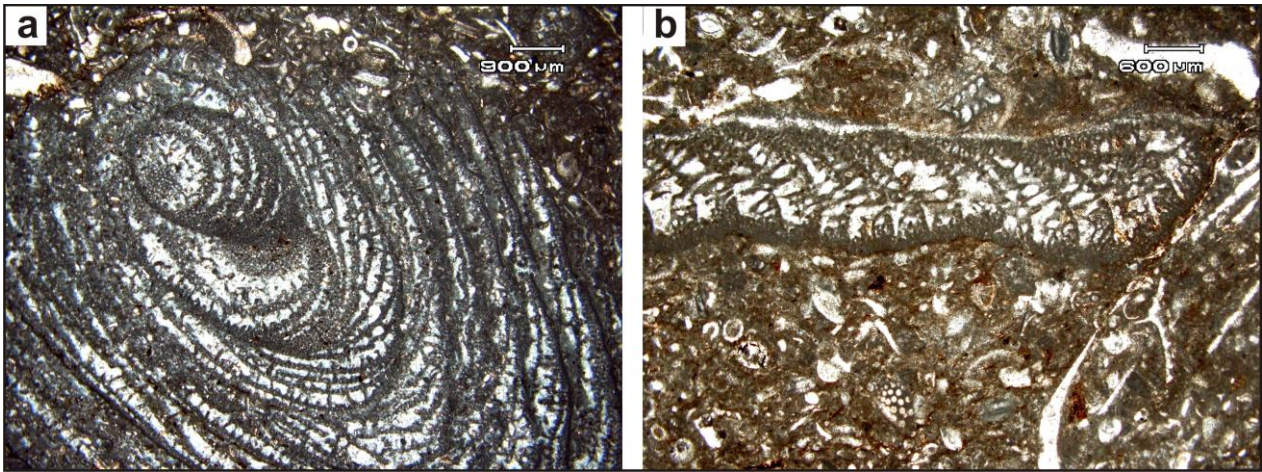
Based on larger benthic foraminifera [e.g., *Loftusia* ssp., *Siderolites calcitrapoides* Lamarck, *Gyroconulina columellifera* Schroeder & Darmoian, *Neobalkhania bignoti* Cherchi, Radoičić & Schroeder, *Omphalocyclus macroporus* (Lamarck)], the studied sections are Maastrichtian in age (Schlagintweit et al., 2016, and in press, with references therein). A Late Maastrichtian age for the upper part of the Tarbur Formation 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), since the first occurrence of this taxon is latest early Maastrichtian (according to Robles Salcedo, 2014). As the early/late Maastrichtian boundary is unclear in the studied sections, we can attribute an overall Maastrichtian age to the samples contain-



**Fig. 10** *Dictyoconus bakhtiari* n. sp. from the late Maastrichtian of the Tarbur Formation, Naghan section, SW Iran. **a, d** Slightly oblique axial section of a megalospheric specimen (holotype!). **b** Centered axial section of a juvenile megalospheric specimen. Note the presence of tiny rudimentary septules in the deutoconch. **c** Oblique axial section, partially passing through the initial spire with protoconch. **e** Oblique transverse section. **f** Tangential-oblique section of microspheric specimen. Abbreviations: de = deutoconch, pr = protoconch, s = septum, pi = pillar, uz = undivided zone (between marginal and central zone). Thin-sections: 2NG 112 (**a, d**), 2NG 69 (**b**), 2NG 87 (**c, e**), 2NG 83 (**f**).



**Fig. 11** *Pseudorbitolina* cf. *marthae* Douvillé from the late Maastrichtian of the Tarbur Formation, Naghan section, SW Iran. **a–b** Axial section. Detail of protoconch in **b**. **c** Subaxial section of a low convexo-concave specimen. **d** Subaxial section of a high convexo-concave specimen. **e, j** Tangential sections showing the vertically aligned arrangement of main septules (beams). **f–g** Oblique sections. Note the undivided chamber zone sensu Neumann (1978). **h** Subaxial section of a juvenile specimen. **i** Detail of a specimen in axial section showing the “undivided zone” sensu Neumann (1978) connected by radial foramina (= tubular aperture sensu Henson, 1948). Abbreviation: tu = tubular aperture, uz = undivided zone. Thin-sections: 2NG 47 (**a–c**), 2NG 43 (**d**), Ng 47-1 (**e, g**), Ng 65-1 (**h**), 2NG 47 (**i**), 2NG 116 (**j**).



**Fig. 12** *Loftusia* sp. from the late Maastrichtian of the Tarbur Formation, Naghan (a) and Mandegan (b) sections, SW Iran. a Oblique section. b Random section. This type of section has been confounded in the literature with *Pseudorbitolina marthae* Douvillé (see synonymy). Thin-sections: 2NG 207 (a), Rt 79-3 (b).

ing the described orbitolinids. *Dictyoconella? minima* reaches almost the top of the Tarbur Formation (Fig. 4) for which a Late Maastrichtian age is deduced.

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