***Carnets Geol.* 25 (14)**

E-ISSN 1634-0744
DOI: 10.2110/carnets.2025.2514

Gusicella SCHLAGINTWEIT & RASHIDI, 2021 (type species *Dictyoconella minima* HENSON, 1948), Upper Cretaceous Larger Benthic Foraminifer and its species

Felix SCHLAGINTWEIT [1]
Vicent VICEDO [2]
Koorosh RASHIDI [3]
Gianluca FRIJIA [4]
Lorenzo CONSORTI [5]

Abstract: Based on new material from the middle to upper Cenomanian Natih Formation (members A and B) from Oman, the little-known species *Gusicella minima* (HENSON), originally described from the Mishrif Formation of Qatar (Dukhan wells) is redescribed. Late Maastrichtian specimens from the Tarbur Formation of SW Iran previously assigned to the Cenomanian species display a more complex marginal zone and are therefore introduced as *Gusicella complexa* SCHLAGINTWEIT & RASHIDI sp. nov. Representatives of *Gusicella* have so far only been reported from the Arabian Plate, showing its endemic character. There is no record of the genus so far from the Turonian to early Maastrichtian interval.

Keywords:

- Late Cretaceous;
- Larger Benthic Foraminifera;
- Orbitolinidae;
- systematics;
- biostratigraphy

Citation: SCHLAGINTWEIT F., VICEDO V., RASHIDI K., FRIJIA G. & CONSORTI L. (2025).- *Gusicella* SCHLAGINTWEIT & RASHIDI, 2021 (type species *Dictyoconella minima* HENSON, 1948), Upper Cretaceous Larger Benthic Foraminifer and its species.- *Carnets Geol.*, Madrid, vol. 25, no. 14, p. 283-305. DOI: 10.2110/carnets.2025.2514

Résumé : Gusicella *SCHLAGINTWEIT & RASHIDI, 2021 (espèce-type* Dictyoconella minima *HENSON, 1948), Grand Foraminifère Benthique du Crétacé supérieur et ses représentants.-* À partir d'un nouvel échantillonnage de la Formation Natih (membres A et B), Cénomanien moyen à supérieur, en Oman, l'espèce peu connue *Gusicella minima* (HENSON), initialement décrite dans la Formation Mishrif au Qatar (forages pétroliers de Dukhan), est redécrite. Des spécimens du Maastrichtien terminal provenant de la Formation Tarbur, dans le sud-ouest de l'Iran, précédemment attribués à l'espèce cénomanienne, présentent une zone marginale plus complexe et sont donc décrits ici sous le nom de *Gusicella complexa* SCHLAGINTWEIT & RASHIDI sp. nov. Les représentants du genre *Gusicella* n'ont jusqu'à présent été signalés que sur la plaque arabique, ce qui témoigne de son caractère endémique. Aucun signalement de ce genre n'existe pour l'intervalle allant du Turonien au Maastrichtien inférieur.

---

[1] *Lerchenauerstr. 167, D-80935 München (Germany)*
felix.schlagintweit@gmx.de

[2] *Museu de Ciències Naturals de Barcelona (Paleontologia), Passeig Picasso s/n, 08003 Barcelona (Spain)*
vicent.vicedo@gmail.com

[3] *Department of Geology, Yazd University, 89195-741 Yazd (Iran)*
koo.rashidi@gmail.com

[4] Dipartimento di Fisica e Scienze della Terra, Università di Ferrara, via Saragat 1, 44121 Ferrara *(Italy)*
frjglc@unife.it

[5] *Istituto di Scienze Marine (CNR-ISMAR), Area Science Park, Q2 Building, Basovizza, Trieste (Italy)*
lorenzo.consorti.es@gmail.com

[Editor: Bruno R.C. GRANIER; language editor: Zev BROOK]

Mots-clefs :

- Crétacé supérieur ;
- Grands Foraminifères Benthiques ;
- Orbitolinidae ;
- systématique ;
- biostratigraphie

1. Introduction

In his monograph on Mesozoic and Cenozoic Larger Benthic Foraminifera (LBF) from the area of the Middle East and south-western Asia, Henson (1948) erected the genus *Dictyconella* for more or less 'compressed-conical' dictyoconids including *D. complanata* (type species) and *D. minima*. The latter was described based on a few specimens from Cenomanian strata of Qatar. Both species are, however, structurally completely different, *e.g.*, aligned main partitions in the latter versus alternating structural elements in the former, and together cannot belong either to the same genus nor the same subfamily (Dictyoconinae versus Dictyorbitolininae) (Schlagintweit & Rashidi, 2021; Schlagintweit, 2022). Therefore, the new genus *Gusicella* was erected by Schlagintweit and Rashidi (2021) with the type species *Dictyoconella minima*, resulting in the new combination *Gusicella minima*. Alas, it now turns out that the illustrations of *G. minima* that were then displayed do not correspond to the species but to a more complex species of the genus. In the mentioned work, specimens showing principally equivalent features (compressed test, aligned partitions) from the upper Maastrichtian Tarbur Formation of SW Iran were considered to belong to the Cenomanian *G. minima*, thus exhibiting a long stratigraphic range and surviving the Cenomanian/Turonian boundary extinction event (*e.g.*, Parente *et al.*, 2008). This observation echoes a remark by Henson (1948, p. 26) that "a single specimen, possibly of this species [*Dictyoconella minima*], was observed at Dohuk, Northern Iraq, in Maastrichtian limestones with *Orbitoides media* d'Arch. and *Omphalocyclus macropora* (Lmk.)." New material from the Cenomanian of Oman that is in conformity with Henson's taxon '*Dictyoconella minima*' clearly shows, however, that it displays a more primitive character, namely a less complex marginal zone, than the Maastrichtian species. The present contribution provides a redescription of the poorly known Cenomanian *Gusicella minima* from the Cenomanian Natih Formation of Oman and the establishment of a new species for the upper Maastrichtian form from the Iranian Tarbur Formation as *G. complexa* sp. nov.

2. Geographic and geological setting

2.1 Cenomanian Natih Formation, Oman

The Natih Formation, of late Albian to middle Turonian age (Philip *et al.*, 1995; Wohlwend *et al.*, 2016; Bromhead *et al.*, 2022), is part of a large Tethys carbonate platform system developed during the Permian-Turonian interval in the Arabian Peninsula. The studied material from Oman was collected from the Natih Formation in three locations.

Wadi Tanuf (GPS: 23°03'11"N, 57°28'02"E) and **Wadi Nakhr** (GPS: 23°09'08"N, 57°12'08"E) are located in the southern part of Jabal Akhdar mountain in northern Oman, approximately 150 kilometers from the capital, Muscat (Fig. 1). The studied material comes from the Natih A informal member which has been dated as late Cenomanian to middle Turonian (Meister & Piuz, 2015; Wohlwend *et al.*, 2016; Bromhead *et al.*, 2022). However, the specimens of *Gusicella minima* were found in the lower part of the Natih A of late Cenomanian age according to biostratigraphic and C-isotope stratigraphic data (Meister & Piuz, 2015; Wohlwend *et al.*, 2016; Cardelli, 2024). In the bioclastic packstones, *G. minima* is associated with *Pararotalia boixae* Piuz & Meister, *Pseudorhipidionina casertana* (De Castro), *Decastroia* sp., and *Qataria dukhani* Henson (?*Pastrikella*) sp.

It is worth mentioning that the sections of the Natih Formation exposed in Wadi Mu'Aydin and Wadi Nakhr were previously also studied by Buchem *et al.* (1996, Fig. 1).

Wadi Mu'Aydin, Oman Mountains (GPS: 22°57'16"N, 57°40'04"E) is located about 115 kilometers southwest of Muscat (Fig. 1). For the lithostratigraphic log of the Wadi Mu'Aydin section, see Piuz and Vicedo (2020, Fig. 2). The microfacies corresponds in most respects principally to the samples obtained from Wadi Tanuf and Wadi Nakhr. The associated taxa include *Rotorbinella mesogeensis* Tronchetti, *Decastroia oblonga* Vicedo & Piuz, *Qataria dukhani* Henson, *Edomia reicheli* Henson, *Everticyclammina hensoni* Redmond, *Pastrikella* sp., *Cuneolina* sp., Involutinida indet., and *Nummoloculinodonta akhdarensis* Piuz & Vicedo. The facies also contains other fossils such as rudists from the Radiolitidae group (*e.g.*, *Eoradiolites*? sp.) and questionable bryozoans. The samples with *Gusicella minima* are from the Natih A and B members of middle to late Cenomanian age.

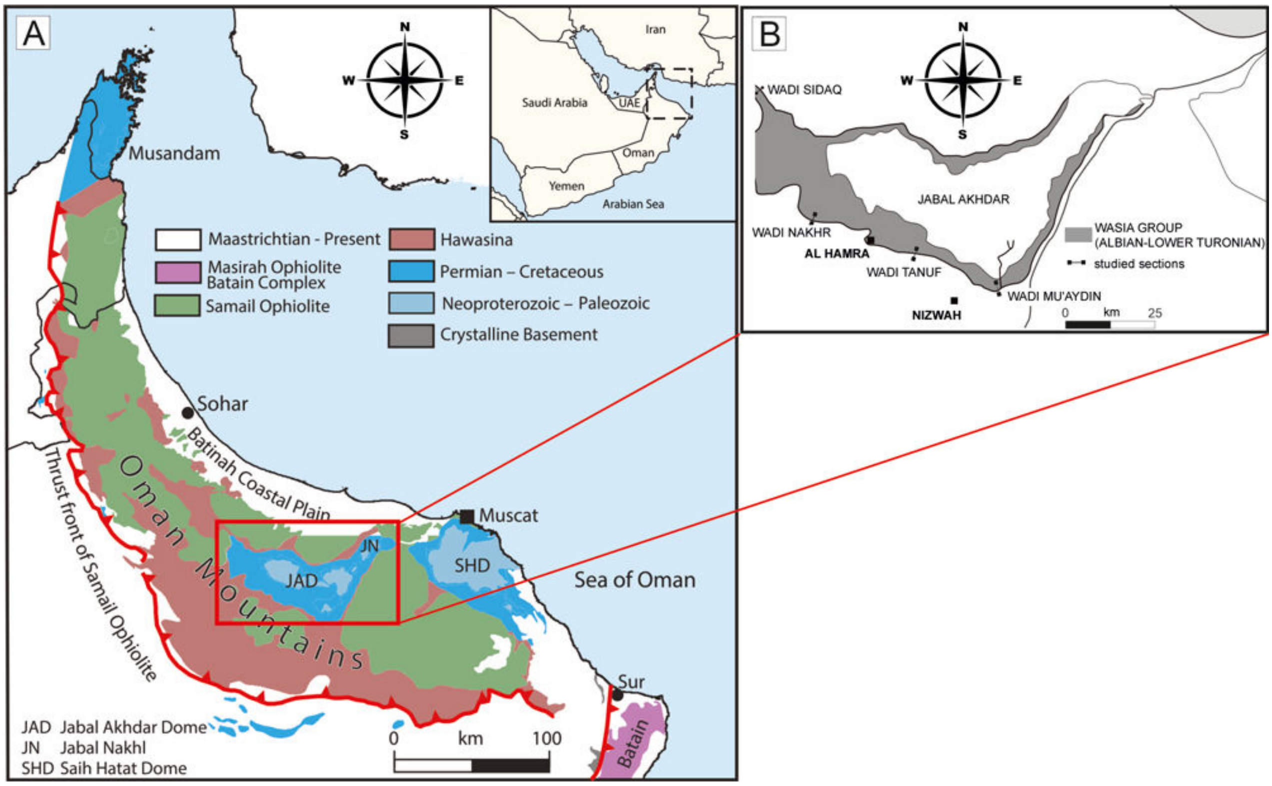


Figure 1: (A) Geological overview map of the Oman Mountains and the Fanja map area after Forbes *et al.* (2010) and Callegari *et al.* (2022). (B) Close-up map of the Jabal Akhdar dome with the sampled locations of *Gusicella minima* (Henson).

2.2 Late Maastrichtian Tarbur Formation, SW Iran

The material of *Gusicella complexa* Schlagintweit & Rashidi sp. nov. comes from two sections: the Mandegan and Naghan sections. Various new LBF taxa have already been described from these sections; some references for further reading are provided here (Schlagintweit *et al.*, 2016a, 2016b; Schlagintweit & Rashidi, 2016, 2021).

The Naghan section is located in the folded Zagros belt of southwestern Iran, approximately 50 km southwest of Naghan town near Gandomkar village. The geographical coordinates of the Naghan section base are 31°47'52"N 50°32'53"E. The Mandegan section is situated in the High Zagros Belt, north of Mount Dena, about 65 km south of the town of Semirom (31°25'8.13"N, 51°24' 34.58"E). In both sections, *G. complexa* has a rather wide vertical distribution associated with a variety of LBF such as *Loftusia*, *Omphalocyclus*, *Gyroconulina columellifera* Schroeder & Darmoian, *Dicyclina schlumbergeri* Munier-Chalmas, *Minouxia* sp., rotaliids, *Palaeoelphidium multiscissuratum* (Smout), *Pseudorbitolina schroederi* Luger, and *Dictyoconus bakhtiari* Schlagintweit *et al. Gusicella complexa* occurs preferentially in the lower part of the Tarbur Formation which, evolving from a shallowing-upwards sequence from basinal facies of the Gurpi Formation, reflects an outer platform (ramp) setting.

3. Repository of the material studied

Gusicella minima: The material figured in this paper from Wadi Mu'Aydin, Oman is housed in the micropaleontological collections of the 'Museu de Ciències Naturals de Barcelona' (MGB numbers) with each specimen having a separate number. The material from Wadi Tanuf (illustrated specimens) and Wadi Nakhr is stored in the University collection of Ferrara. The numbers indicated in the plates refer to the thin-section number.

Gusicella complexa: All the specimens illustrated here refer to Schlagintweit and Rashidi (2021). The holotype of the new species is deposited at the Geosciences Museum of Mashhad (in the Geological Survey of North-Iran East territory) labelled Gmm1404-1 referring to the original sample number 2Ng 168.

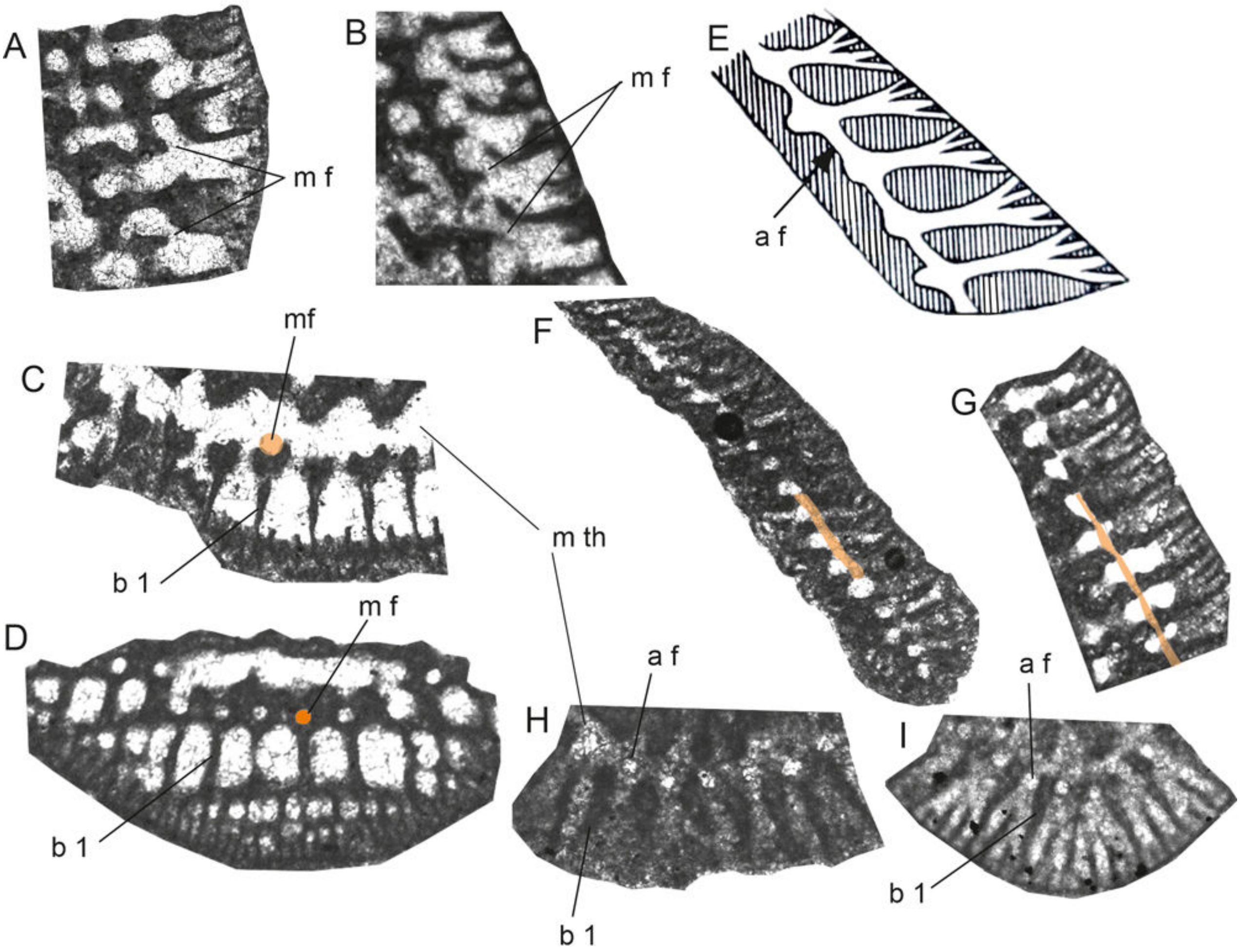


Figure 2: Marginal foramina of the Dictyoconinae SCHUBERT (A-D) compared to so-called tubular foramina *sensu* HENSON (1948) of the Dictyorbitolininae SCHROEDER (E-I) (intentionally without scale). (A-B) Marginal foramina in axial sections from *Dictyoconus bakhtiari* SCHLAGINTWEIT *et al.* (upper Maastrichtian Iran) and *Dictyoconus* sp. cf. *D. egyptiensis* (CHAPMAN) (Eocene of Iran). (C) Slightly oblique transverse section with row of marginal foramina located at the end of the forked main partitions (from *Dictyoconus bakhtiari* SCHLAGINTWEIT *et al.*, upper Maastrichtian, Iran). (D) Oblique section (same as C). (E) Schematic drawing of *Pseudorbitolina* with aligned foramina (modified from HENSON, 1948, Fig. 16A). (F) Axial section of *Pseudorbitolina schroederi* LUGER (upper Maastrichtian, Iran). (G) Axial section of *Gusicella complexa* sp. nov. (upper Maastrichtian, Iran). (H-I) Transverse sections of *Gusicella minima* (HENSON) (upper Cenomanian, Oman) and *Gusicella complexa* sp. nov. (upper Maastrichtian, Iran) showing aligned foramina arranged in a row at the end of the marginal chamberlets between the distal ends of the radial main partitions. Fig. 2.I = excerpt from Pl. 6, fig. O. Abbreviations: a f = aligned foramina, b 1 = beam (radial main partition), m f = marginal foramina, m th = marginal trough.

4. Systematics

Phylum Foraminifera ORBIGNY, 1826
Class Globothalamea PAWŁOWSKI *et al.*, 2013
Order Loftusiida KAMINSKI & MIKHALEVICH *in* KAMINSKI, 2004
Suborder Loftusiina KAMINSKI & MIKHALEVICH *in* KAMINSKI, 2004
Superfamily Orbitolinoidea MARTIN, 1890
Family Orbitolinidae MARTIN, 1890
Subfamily Dictyorbitolininae SCHROEDER *in* SCHROEDER *et al.*, 1990

Remarks: Dicytorbitolininids typically include high-conical Orbitolinidae displaying foramina arranged in a ring at the outer margin of the central zone towards the marginal zone, with an alignment paralleling the vertical main partitions (beams) (SCHROEDER *in* SCHROEDER *et al.*, 1990, p. 196) (Fig. 2.E-I). The aligned beams are usually well constrained in tangential sections, whereas the peculiar arrangement of the foramina is often less clear, requiring well-oriented sections (axial and perpendicular to the cone axis). They are arranged perpendicular to the septum ("verticaux par rapport au plancher"), in continuity paralleling the cone mantel line (*e.g.*, HOTTINGER, 2006, Fig. 80.E) and were named marginal apertures ("ouvertures marginales") by SCHROEDER *in* SCHROEDER *et al.* (1990, p. 196) (Fig. 2.G). They differ from the marginal apertures (foramina) of the Paleogene taxa which are arranged obliquely to the septum (*i.e.*, "about 45° with the mantel line of the cone") (HOTTINGER & DROBNE, 1980) (Fig. 2.A-B). While the 'marginal apertures' of the Dictyorbitolininae are in vertical continuity from chamber to chamber, they alternate regularly from one chamber to the next in the Paleogene forms (Hottinger & Drobne, 1980). In addition, they are laterally displaced to each other, not in linear continuity, but also form a 'single circular row' as discerned in transverse sections (Hottinger & Drobne, 1980, p. 211). Because of these fundamental structural differences, the term marginal foramina (with oblique-radial orientation) should be restricted to the Dictyoconinae (see also Hottinger, 2006, p. 22). For the Dictyorbitolininae, it is instead proposed to call these 'aligned' apertures or foramina. In the description of *Pseudorbitolina marthae* (= *P. schroederi* Luger, see Schlagintweit, 2022), Henson (1948, p. 104, Fig. 16) used the name tubular apertures. Both types are positioned within a ring-shaped space named the marginal trough by Davies (1930) or annular passage by Hottinger (2006, p. 8). In both cases (Dictyorbitolininae and Dictyoconinae), the septa (or beams?) are bent downwards (towards direction of the apex) at the transition of the marginal zone to the marginal trough (Fig. 2.A, .G). While marginal foramina appear at the end of the forked radial main partition (Fig. 2.C-D), the aligned foramina occupy a position at the tapering end of the chamberlets (between two main partitions, b 1 in Fig. 2.I) (Fig. 2.H-I).

With respect to the vertical structural elements (exoskeletal beams and endoskeleton pillars), Dictyorbitolininae include both taxa where all elements are aligned (genus *Paracoskinolina* Moullade, 1965) while in others just the beams are aligned with pillars alternating between the chambers (*e.g.*, genera *Dictyorbitolinina* Cherchi & Schroeder, 1976, *Praedictyorbitolinina* Schroeder *in* Schroeder *et al.*, 1990). This means that neither the structure of the embryo nor the disposition of the pillars represent a differentiating criterion as the former can be either simple or complex, and the latter either aligned or alternating from one chamber to the next.

Genus *Gusicella*
Schlagintweit & Rashidi, 2021

Remarks: The genera *Dictyoconella* and *Gusicella* were already discussed in Schlagintweit *et al.* (2016a), Schlagintweit (2020), and Schlagintweit and Rashidi (2021).

The already noted similarities to *Carinoconus* Cherchi & Schroeder, 1982, are discussed in more details in the subchapter Comparisons for *Gusicella minima*.

In addition, some additional remarks are provided regarding the often dense, micritic central zone of *Gusicella*, the embryo, and the arrangement of the pillars. The patchy micritic parts within the central zone of *Gusicella* are referred to as 'thickened shell material' (Loeblich & Tappan, 1987, for *Pfenderina*), 'axial fillings', 'secondary deposits' (Hottinger, 2006, for fusulinids and pfenderinids), or 'masse presque opaque' (Schroeder, 1985). In 1948 (p. 26), Henson already noted that in *Dictyconella minima* "the interseptal structures are sporadic and poorly defined in the central shield" (= central zone). In this context, Henson (*ibid.*) was obviously referring to the presence of secondarily infilled shell material. In orbitolinids they were reported, for example, from *Carinoconus* (Schroeder, 1985). These fillings, when extensively present, mask the inner structure namely the individual pillars of the central zone that appear then as a fused almost homogeneous mass. Being present in both *Gusicella minima* and *G. complexa*, it can be regarded as a characteristic feature of the genus. This feature was so far only reported from very few Cretaceous orbitolinids and is seemingly lacking in Paleogene forms (*e.g.*, Hottinger & Drobne, 1980).

Concerning the embryo of *Gusicella*, no details are known from *G. minima*. Some axial sections of *G. complexa* might point to a tiny subdivision of short partitions (= complex embryo) (Pl. 5, figs. E, G). These elements might also belong to the septa of undivided neanic chambers arranged in a tight whorl around the embryo. Better preserved material is needed for a final conclusion. In any case, the Dictyorbitolininae includes both genera with a complex embryo such as *Dictyorbitolina* Cherchi & Schroeder, 1976, or more common simple embryo (*e.g.*, *Paracoskinolina* Moullade, 1965, or *Praedictyorbitolinina* Schroeder *in* Schroeder *et al.*, 1990). For *Gusicella*, it is thought to be simple (see remarks for the genus below). With respect to the coiling mode of the initial part, Henson (1948, p. 25) stated that it is "planispiral" (…) "lying approximately in the axial plane through the longer diameter of the base". This observation is, in our opinion, also confirmed by the isolated specimen illustrated by Hewaidy and Al-Hitmi (1993, Pl. 5, figs. 1-2) (Fig. 3.A-B), the holotype of Henson (Fig. 3.C), as well as some axial sections in the plane of compression (*e.g.*, Fig. 3.F) or perpendicular to it (Pl. 1, figs. C, J).

The last aspect of discussion refers to the arrangement of the pillars of the central zone. In cylindroconical forms such as *Paracoskinolina maynci* (Chevalier) or *Paracoskinolina arcuata* (Arnaud-Vanneau), the aligned arrangement of the pillars between subsequent chambers is evident (*e.g.*, Arnaud-Vanneau, 1980). In more flat, conical forms, however, the response to the high rate of increasing chamber diameter can mask some structural features, such as the alignment of pillars. Apart from that, there is, in addition, the presence of a central micritic mass that masks the structure.

Type species. *Dictyoconella minima* Henson, 1948. Holotype P.35838 in Henson (1948), stored at the Natural History Museum, London as IPC reference M/3441 i NHM P35838 (see https://marinespecies.org/foraminifera/aphia.php?p=image&pic=171946&tid=911119).

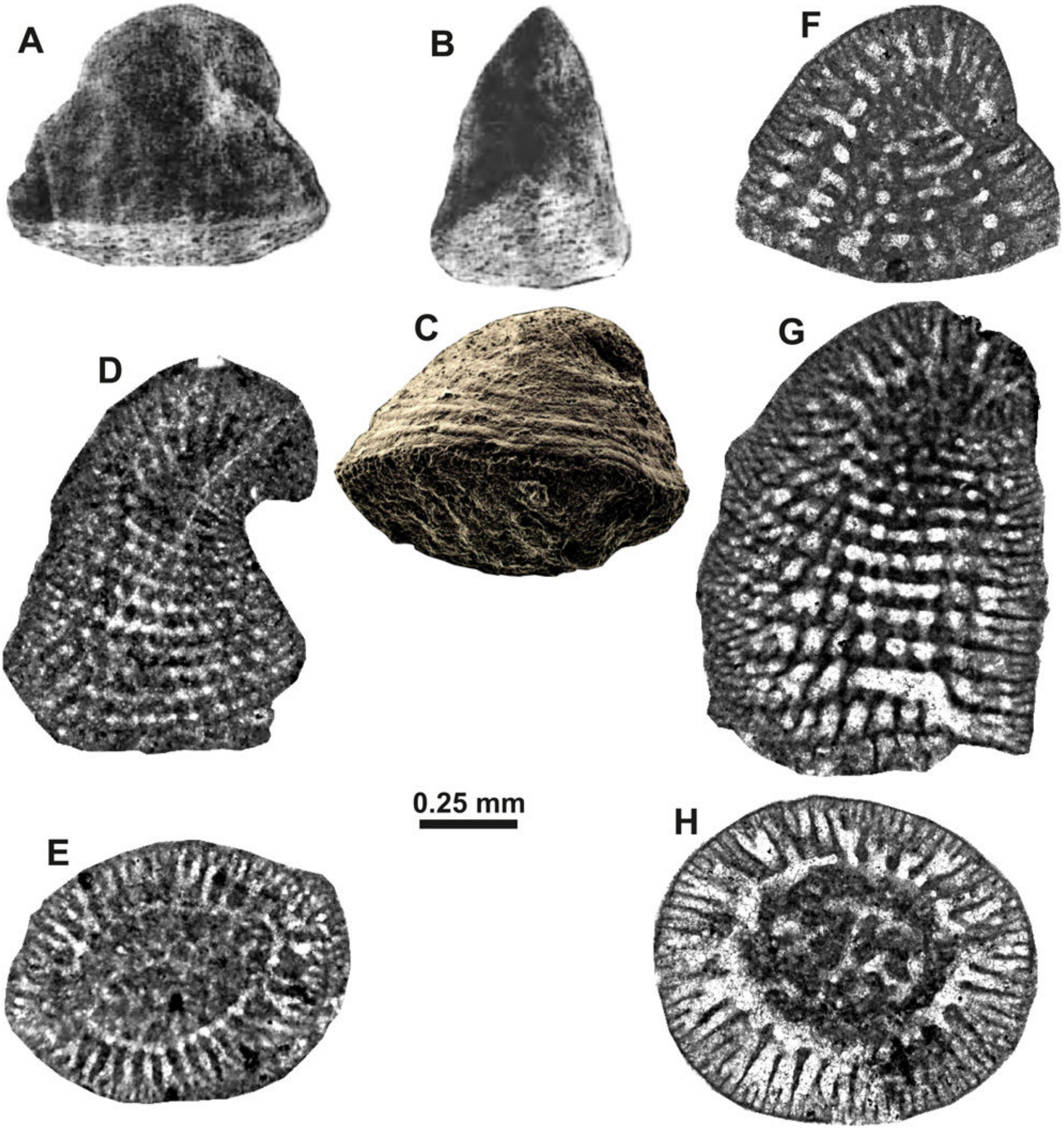


Figure 3: Comparison and confrontation of *Gusicella minima* (Henson) from the Cenomanian of Qatar (**A-C**), the middle to upper Cenomanian Natih Formation of Oman (**C-D**), and *Gusicella complexa* Schlagintweit & Rashidi sp. nov. (**E-G**) from the upper Maastrichtian Tarbur Formation of Iran. (**A-B**) Lateral external views parallel to the plane of test compression. (**C**) Lateral view of A perpendicular to the plane of compression. (**D, G**) Tangential sections showing aligned arrangement of pillars. (**E, H**) Slightly oblique transverse sections. (**F**) Axial section. Fig. 3.A and 3.B from Hewaidy and Al-Hitmi (1993, Pl. 5, figs. 1-2), Fig. 3.C with courtesy of Mike Simmons and permission by NHM, London, Fig. 3.D from Pl. 4, fig. B; Fig. 3.E from Pl. 4, fig. I; Fig. 3.F from Pl. 5, fig. G; Fig. 3.H from Pl. 5, fig. A.

Gusicella minima (Henson, 1948)

(Fig. 2.H-I ; Pls. 1 - 4)

1948 *Dictyoconella minima* n. sp. - Henson, p. 25; Pl. 11, figs. 3, 8-10.

1993 *Dictyoconella minima* Henson - Hewaidy & Al-Hitmi, p. 479; Pl. 5, figs. 1-3.

1998 *Dictyoconella minima* Henson - Whittaker *et al.*; Pl. 4, fig. 3; Pl. 5, figs. 1-2; Pl. 48, figs. 1-4.

non **2020** *Dictyoconella minima* - Mohammed *et al.*; Figs. 7j, 10f.

non **2021** *Gusicella minima* (Henson) - Schlagintweit & Rashidi, p.10; Figs. 2c-d, 7-9 (= *Gusicella complexa* sp. nov.).

non **2022** *Gusicella minima* (Henson) - Schlagintweit, p. 436; Figs. 2H, N-M, 4A-B, D, F-G, 5A-B (= *Gusicella complexa* sp. nov.).

Description: Finely agglutinated shell of medium to high-conical morphology; wall thin (epiderm) and non-canaliculate. Early stage planispiral, offset from the apex. . The embryonic apparatus could not be characterized due to the lack of well-centered sections. In one axial section (Pl. 1, fig. A), a structure interpretable as a first chamber or proloculus of ~30-40 µm is observed, suggesting a possible macrospheric specimen. The preservation of this specimen does not allow ruling out that this structure represents a dissolution artifact of the test rather than the embryonic first chamber.

In the adult stage, the chamber arrangement is uniserial and laterally compressed. As a result, transverse sections of the cone are typically ellipsoidal in shape, with slightly angular peripheries (Pl. 2, fig. N, R). Axial sections perpendicular to the plane of compression result in a measured lower test diameter (*e.g.*, Pl. 1, fig. C). Due to the slight lateral compression of the cone, some slightly oblique transverse sections may give the impression of a circular morphology (*e.g.,* Pl. 2, fig. K). Adult test with up to 25 chambers subdivided into marginal and central zones. There are 7 to 9 chambers per 0.5 mm axial length. The marginal zone consists of one rafter and one to three intercalary beams forming a subepidermal network. The beams are radially stretching towards the center, slightly thickening distally with a rounded end. The length of the beams is roughly three times that of the intercalary beams. Central zone with pillars that appear aligned between successive chambers rather than with strict alternating disposition. As the pillars are thickened at the base and top, they have a knobby appearance in axial sections (*e.g.*, Pl. 1, fig. E). Often, the central zone contains secondary deposits (or opaque micritic masses) thereby laterally fusing neighboured pillars and resulting in a dense micritic zone (Pl. 1, figs. D, O). Marginal zone and central zone are separated by a narrow marginal interspace (marginal trough *sensu* Davies, 1930). Here, foramina are arranged in a concentric row located between the ends of two beams. Beams and foramina are aligned between successive chambers (*e.g.*, Fig. 3.C, .F ; Pl. 1, figs. E-F; Pl. 3, fig. I). Dimorphism not identified.

Dimensions (in mm; data of Henson, 1948 in parentheses)**:**

Test height = up to 1.5 mm (1.0-1.5 mm)

Diameter at base = 0.75 mm to 1.1 mm (0.8-1.8 mm)

Comparisons: Sections of juvenile specimens of *G. minima* or sections cutting the initial spire obliquely [Pl. 1, fig. C (uppermost part), J and M] display striking similarities to *Carinoconus iraqiensis* Bernaus & Masse, 2007, described from the Cenomanian of Iraq. Bernaus and Masse (2007, p. 4) concluded their generic attribution as follows: "The presence of an initial stage with a sharply angular carina was the only criteria used by Cherchi and Schroeder (1982) for the creation of the new subgenus, now genus, *Carinoconus*. Based on this characteristic, and as no other genus of the family Orbitolinidae has such a distinctive feature, we also assign this new species to the genus *Carinoconus*". Bernaus and Masse (2007) stated that no rafters were observed in *C. iraqiensis*, a view not supported by our observations. Instead, a single rafter per chamber is visible in Pl. 1, figs. 3 (right side), 4 (right side), 5 (right below), and 10 (right) of Bernaus and Masse (2007). This feature provides another point of comparison with *Gusicella minima*. In addition, Bernaus and Masse (2007) noted the presence of two orders of beams and their alignment in successive chambers like in *G. minima*. Possible differences regarding dimensions are not purposeful because the data provided by Bernaus and Masse (2007) are assumed to belong to juvenile forms only. Here we refrain from a direct synonymisation of *Carinoconus iraqiensis* and *Gusicella minima*, the former then having nomenclatural priority, as such a conclusion would be premature without a thorough study of the original material. Due to the possible identity of the two taxa we prefer to treat *Carinoconus iraqiensis* as a species of 'uncertain status', a category used by Loeblich and Tappan (1987). As further consequence of these observations, one might think of the late Albian (?to earliest Cenomanian) *Carinoconus casterasi* (Bilotte *et al.*, 1973) without rafters representing a possible precursor of the more complex *Gusicella minima* (Schlagintweit & Rashidi, 2021), both having the sharp angled carina and a pillared central zone with secondary deposits (masking further details in common). Transverse sections also show foramina arranged in a ring-shaped manner within a marginal trough (Bilotte *et al.*, 1973, Pl. 1, fig. 10, above). Regarding the beams, Schroeder (1985, p. 44) remarked that they are not alternating between subsequent chambers but could be situated one above the other ("peuvent être situées l'une au dessous de l'autre"). *Gusicella* Schlagintweit & Rashidi however appears to differ from *Carinoconus* Cherchi & Schroeder, 1982, because of its inner structure. The (main) beams of *Carinoconus* display a thickened bifurcated distal end (Schroeder, 1985, "l'extrémité de ces cloisonettes et renflée en massue", Pl. 18, figs. 4, 7, above) partly enclosing the outer annular row of foramina (compare Fig. 2.C). In fact, these features are rather delicate and accessible only in selected sections. With the possibility open pending further data and studies that *Gusicella* represents a junior synonym of *Carinoconus*, such a conclusion would result in the lineage *C. casterasi* (late Albian to ?earliest Cenomanian; no rafters), *C. minima* (middle to late Cenomanian; one rafter), and *C. complexa* (late Maastrichtian; two to three rafters). It is worth mentioning that *Carinoconus* was not included within the Dictyorbitolininae by Schroeder *in* Schroeder *et al.* (1990, p. 196).

Finally, juvenile specimens of *Gusicella minima* may also recall juvenile specimens of *Spirocyclina atlasica* Saint-Marc & Rahhali, 1982, from the upper Cenomanian of Morocco. In the rich material from Oman, however, the typical peneropliform compressed adult specimens of *S. atlasica* were not observed.

Stratigraphy: Henson (1948) described '*Dictyoconella*' *minima* "most probably" from the upper Cenomanian or Turonian of Qatar (Dukhan no. 2 and 3 wells; Wasia Group). For the Dukhan oil field of Qatar, Hewaidy and Al-Hitmi (1993) established a late Cenomanian '*Dictyoconella minima* Range Zone'. In Oman, *Gusicella minima* has been identified in Member B and the lower part of

Member A of the well-known Natih Formation. The studied material comes from the localities of Tanuf and Wadi Mu'Aydin, the latter of which can also be considered the regional stratotype section for this formation. At Wadi Mu'Aydin, *G. minima* occurs within a relatively restricted stratigraphic interval, approximately 10 meters thick. In terms of sequence stratigraphy, this *G. minima*-rich interval lies within the third (III) third-order depositional sequence, which has been extensively described and discussed by Buchem *et al.* (1996) and Grélaud *et al.* (2006), among others. This stratigraphic context allows the levels bearing *G. minima* to be dated to the late middle to late Cenomanian (*e.g.*, Bromhead *et al.*, 2022, Fig. 4).

Gusicella complexa
Schlagintweit & Rashidi sp. nov.

(Fig. 3.F-H ; Pls. 5 - 6)

2016a *Dictyoconella*? *minima* Henson - Schlagintweit *et al.*, p. 34; Fig. 3a-b *pars*, 5-6.

2020 *Dictyoconella minima* - Mohammed *et al.*; Figs. 7j, 10f.

2021 *Gusicella minima* (Henson) - Schlagintweit & Rashidi, p. 10; Figs. 2c-d, 7-9.

2022 *Gusicella minima* (Henson) - Schlagintweit, p. 436; Figs. 2H, N-M, 4A-B, D, F-G, 5A-B.

Description: *G. complexa* displays the following specific features:

- test medium conical (apical angle from 50 to 90 degrees) and sometimes laterally slightly compressed (Pl. 5, fig. J; Pl. 6, fig. J) with both sides and base slightly convex;
- acute apex is tilted, marking the early development in a downward turn to the cone base (*e.g.*, Pl. 5, fig. G).

Early stage:

- small spire of few chambers arranged in half a whorl that is closely attaching (almost parallel) to the side test wall (Pl. 5, figs. D-G);
- embryo represented by a single sub-spherical chamber (protoconch) showing short septules? at its upper part facing the cone base (Pl. 5, figs. E-G).

Adult stage:

- marginal zone with one to three rafters (*e.g.*, Pl. 5, fig. E, bottom left) and two to three intercalary beams (*e.g.*, Pl. 6, fig. P). In case of two rafters, the upper one is twice as long as the lower one. In case of three rafters, the middle one is roughly twice as long as the others. At their inner ends, the main beams are moderately thickening. In shallow-tangential sections, the sub-epidermal network displays a pattern of sub-rounded alveolar compartments (Pl. 5, fig. H; Pl. 6, fig. F). The marginal chamberlets are tapering distally;
- outer rim of the marginal trough outlined by the septa slightly bending upwards and forming a 'buttress on marginal ridge' *sensu* Davies (1930) as seen in sub-axial sections (Pl. 5, fig. I bottom; Pl. 6, fig. H left side);
- central zone with pillars [when visible where secondary deposits (= opaque micritic masse) is not present] comparably narrowly spaced (Pl. 5, figs. C-D; Pl. 6, figs. A, H);
- up to 18 chambers in the adult stage, with seven to nine chambers per 0.50 mm axial length;
- dimorphism possible (high-conical megalospheric and low-conical microspheric forms?).

Remarks: The species (as a Maastrichtian form of *G. minima*) has been described in detail by Schlagintweit and Rashidi (2021). However, the new form named herein - *G. complexa* – differs from *G. minima sensu stricto* by its more complex marginal zone regularly including two rafters and two to four intercalary beams. There is a maximum of three rafters in the marginal zone, a longer one in the middle and two shorter rafters of equal length on both sides. As a result of the higher number of rafters, the greater chamber height of *G. complexa* is also worth mentioning. Therefore, there are seven to nine chambers per 0.5 mm axial length in *G. minima*, compared to just six to seven in *G. complexa*. The general high-conical morphology with the angular planispiral initial coil and the dimensional data, however, are shared by both species (Fig. 3). Both fulfill partly the requirements for an orbitolinid lineage characterized by increasing complexity (Schroeder *et al.*, 2002). Ideally, the taxa of such lineages display overlapping ranges, a requirement that however is not applicable in the present case. Instead, there is considerable gap spanning the Turonian to early Maastrichtian time interval without any record of *Gusicella*. Further discoveries will hopefully be forthcoming.

Dimensions (in mm; data of Henson, 1948 in parentheses)**:**

Test diameter (D): 0.7-1.9 mm. Note: specimens with a test diameter > 1.5 mm appear to be microspheric specimens.

Test height (H): 0.8-1.4 (1.0-1.5 mm)

D/H (megalospheric forms): 0.8-1.35

D/H (microspheric forms): around 1.5

Comparisons: The dimensions (height, diameter) of *Gusicella complexa* are in the range reported for *G. minima*, so differences in size cannot be taken as a distinguishing criterion. The main difference corresponds to the more complex marginal zone of *G. complexa* with two to three rafters per chamber (instead of one in *G. minima*) and two to three intercalary beams (instead of one to two in *G. minima*) (Fig. 3). As a consequence of the higher number of rafters in *G. complexa*, the height of adult chambers is also higher than in *G. minima*.

Stratigraphy: *Gusicella complexa* is the orbitolinid with the greatest vertical distribution in the Naghan section of the Tarbur Formation. It preferentially occurs in wackestone/packstones with rudist shell debris as well as in association with *Loftusia* spp., *Omphalocyclus* and several other LBF (Wynd, 1965: *Omphalocyclus-Loftusia* assemblage zone). The occurrences of *Siderolites calci-*

trapoides Lamarck and/or *Canalispina iapygia* Robles-Salcedo *et al.* are in the lower part of several sections of the Tarbur Formation, *e.g.*, in the Mandegan section some meters above the boundary with the underlying Gurpi Formation. This indicates a late Maastrichtian age, since the first occurrence of *C. iapygia* is latest early Maastrichtian (according to Robles Salcedo, 2014; Robles Salcedo *et al.*, 2019). Mohammed *et al.* (2020) reported *Dictyoconella minima* in their "facies-type 9 *Siderolites/Orbitoides* packstone" from the upper part of the Maastrichtian Simsima Formation of the United Arab Emirates, associated with *Loftusia* sp. and *Dictyoconus* sp. Although *Dictyoconus* and *Dictyoconella* were not illustrated, the association clearly recalls the assemblage reported from the upper Maastrichtian Tarbur Formation (Schlagintweit *et al.*, 2016a; Schlagintweit & Rashidi, 2021). However, the illustrated specimen of '*Dictyoconella minima*' (Mohammed *et al.*, 2020, Fig. 7j) does not belong to this species but to an indeterminable orbitolinid. Henson (1948, p. 26) noted "a single specimen, possibly of this species" (= *Dictyoconella minima*) from the Maastrichtian of Iraq.

5. Conclusions

The present contribution provides an enriched description of *Gusicella minima*, one of the little-known 'Henson taxa' reported in his important monograph from 1948. The taxonomic inventory includes two species of the genus *Gusicella*: *G. minima* (Henson) and *G. complexa* Schlagintweit & Rashidi, both restricted palaeogeographically to the Upper Cretaceous margins of Neotethys along the northern rim of the Arabian Plate. As the name implies, the latter is characterized by a more complex marginal zone, which is an important criterion for the distinction of species in different orbitolinid lineages (*e.g.*, *Montseciella* or *Simplorbitolina*). *Gusicella minima* and *G. complexa* are separated by a considerable gap without records that spans the Turonian to early Maastrichtian interval. Both taxa appear at the ends of Global Community Maturation cycles of LBF characterized by high diversities (Hottinger, 1997). Along with *Persiconus sarvaki* Yazdi-Moghadam & Schlagintweit, *Gusicella minima* (Henson) represents the second species of Orbitolinidae recorded from upper Cenomanian strata.

◆

Acknowledgements

Special thanks are extended to the late and much appreciated Prof. Josep Serra-Kiel, as well as to Drs. Carine Grélaud and Philippe Razin, for their logistical support during one of the field seasons in Oman and for generously sharing their extensive knowledge of the geology of Oman. Thanks are also due to Dr. Gerard Lucena, geologist and expert preparator of thin sections at the MCNB. Some remarks provided by an anonymous reviewer and the very detailed review by Hervé Calvez (Lannion) helped to improve the manuscript. The holotype specimen of *Dictyconella minima* was kindly provided by Mike Simmons (London) with courtesy of the Natural History Museum, London. The language review by Zev Brook (San Diego) is gratefully acknowledged

Bibliographic references

Arnaud-Vanneau A. (1980).- L'Urgonien du Vercors septentrional et de la Chartreuse.- *Géologie Alpine*, *Mémoire*, Grenoble, vol. 11 (3 volumes), 874 p.

Bernaus J.M. & Masse P. (2007).- *Carinoconus iraqiensis* (Foraminifera), a new orbitolinid from the Cenomanian Mishrif Formation of the oil fields of southeastern Iraq.- *Micropaleontology*, Flushing - NY, vol. 52, no. 5, p. 471-476.

Bilotte M., Canérot J., Moullade M. & Peybernès B. (1973).- Description et position stratigraphique d'un nouvel Orbitolinidé de l'Albo-Cénomanien Ibérique et Pyrénéen *Paracoskinolina casterasi* n. sp.- *Société de Physique et d'Histoire Naturelle de Genève*, vol. 26, no. 2, p. 183-185.

Bromhead A.F., Buchem, F.S.P. van, Simmons M.D. & Davies R.B. (2022).- Sequence stratigraphy, palaeogeography and petroleum plays of the Cenomanian-Turonian succession of the Arabian Plate: An updated synthesis.- *Journal of Petroleum Geology*, vol. 45, p. 119-162.

Buchem F.S.P. van, Razin P., Homewood P.W., Philip J.M., Eberli G.P., Platel J.-P., Roger J., Eschard R., Desaubliaux G.M.J., Boisseau T., Leduc J.-P., Labourdette R. & Cantaloube S. (1996).- High resolution sequence stratigraphy of the Natih Formation (Cenomanian / Turonian) in Northern Oman: Distribution of source rocks and reservoir facies.- *GeoArabia*, Manama, vol. 1, p. 65-91.

Callegari I., Scharf A., Mattern F. & Scharf K. (2022).- Tectonic transition from thrusting to polyphase non-confining deformation within the Semail Ophiolite along the sinistral, transtensional Issmaiya Fault Zone (Sultanate of Oman).- *Journal of Asian Earth Sciences*, vol. 224, article 105007, 16 p.

Cardelli S. (2024, unpublished).- The impact of the Oceanic Anoxic Event 2 on resilient carbonate platforms: A multidisciplinary approach.- PhD thesis, University of Ferrara, 316 p.

Cherchi A. & Schroeder R. (1976).- *Dictyorbitolina ichnusae* n. gen., n. sp. (Foram.) del Barremiano della Sardegna nord-occidentale.- *Bollettino della Società Paleontologica Italiana*, Milano, vol. 14, no. 1, p. 47-54.

Cherchi A. & Schroeder R. (1982).- Sobre la edad de la transgresión mesocretácica en Asturias.- *Cuadernos de Geología Ibérica*, Madrid, vol. 8, p. 219-233. URL: https://dialnet.unirioja.es/servlet/articulo?codigo=264520&orden=1&info=link

Davies L.M. (1930).- XX.-The genus *Dictyoconus* and its allies: A review of the group, together with a description of three new species from the Lower Eocene beds of northern Baluchistan.- *Transactions of the Royal Society of Edinburgh*, vol. 56, no. 2, p. 485-505.

Forbes G.A., Jansen H.S.M. & Schreurs J. (2010).- Lexicon of Oman - Subsurface Stratigraphy.- *GeoArabia Special Publication*, Manama, vol. 5, 371 p.

Grélaud C., Razin P., Homewood P.W. & Schwab A.M. (2006).- Development of incisions on a periodically emergent carbonate platform (Natih Formation, Late Cretaceous, Oman).- *Journal of Sedimentary Research*, Tulsa - OK, vol. 76, p. 647-669.

Henson F.R.S. (1948).- Larger imperforate Foraminifera of south-western Asia. Families Lituolidae, Orbitolinidae and Meandropsinidae.- *Monograph British Museum (Natural History)*, London, 127 p.

Hewaidy A.G.A. & Al-Hitmi H.A. (1993).- Cretaceous-Early Eocene biostratigraphy of the Dukhan oil field, west Qatar, Arabian Gulf.- *Al-Azhar Bulletin of Science*, Cairo, vol. 4, no. 2, p. 469-494.

Hottinger L. (1997).- Shallow benthic foraminiferal assemblages as signals for depth of their deposition and their limitations.- *Bulletin de la Société Géologique de France*, Paris, vol. 168, no. 4, p. 491-505.

Hottinger L. (2006).- Illustrated glossary of terms used in foraminiferal research.- *Carnets Geol.*, Madrid, vol. 6, no. M02 (CG2006_M02), 126 p. DOI: 10.4267/2042/5832

Hottinger L. & Drobne K. (1980).- Early Tertiary conical imperforate foraminifera.- *Slovenska Akademija Znanosti in Umetnosti, Classis IV Historia Naturalis, Dissertationes*, vol. 22, no. 3, p. 187-276

James G.A. & Wynd J.G. (1965).- Stratigraphic Nomenclature of Iranian Oil Consortium Agreement Area.- *AAPG Bulletin*, Boulder - CO, vol. 49, no. 12, p. 2218-2232.

Kaminski M.K. (2000).- The new and reinstated genera of agglutinated Foraminifera published between 1986 and 1996. *In*: Hart M.B., Kaminski M.A. & Smart, C.W. (eds.), Proceedings of the Fifth International Workshop on Agglutinated Foraminifera.- *Grzybowski Foundation Special Publication*, Varsaw, vol. 7, p. 185-219.

Kaminski M.A. (2004).- The year 2000 classification of the agglutinated Foraminifera. *In*: Bubík M. & Kaminski M.A. (eds.), Proceedings of the Sixth International Workshop on Agglutinated Foraminifera.- *Grzybowski Foundation Special Publication*, Varsaw, vol. 8, p. 237-255.

Kaminski M.A. (2014).- The year 2010 classification of the agglutinated Foraminifera.- *Micropaleontology*, Flushing - NY, vol. 60, no. 1, p. 89-108.

Loeblich A.R. Jr & Tappan H. (1987).- Foraminiferal genera and their classification.- Van Nostrand Reinhold, New York, 2 vol., 970 p. (847 Pls.).

Martin K. (1890).- Untersuchungen über den Bau von *Orbitolina* (*Patellina* auct.) von Borneo.- *Sammlungen des Geologischen Reichs-Museums in Leiden* (ser. 1), vol. 4, p. 209-231.

Meister C. & Piuz A. (2015).- Cretaceous ammonites from the Sultanate of Oman (Adam Foothills).- *GeoArabia*, Manama, vol. 20, p. 19-74.

Mohammed I.Q., Farouk S., Lawa F.A., Alsuwaidi M. & Morad S. (2020).- Upper Cretaceous wedge-top to foredeep architecture in the United Arab Emirates: Insights from the Faiyah Anticline.- *Geological Journal*, vol. 56, p. 2602-2624.

Moullade M. (1965).- Contribution au problème de la classification des Orbitolinidae (Foraminiferida, Lituolacea).- *Comptes Rendus hebdomadaires des Séances de l'Académie des Sciences*, Paris, vol. 260, p. 4031-4034.

Pawłowski J., Holzmann M. & Tyszka J. (2013).- New supraordinal classification of Foraminifera: Molecules meet morphology.- *Marine Micropaleontology*, vol. 100, p. 1-10.

Parente M., Frijia G., Di Lucia M., Jenkyns H.C., Woodfine R.G. & Baroncini F. (2008).- Stepwise extinction of larger foraminifers at the Cenomanian-Turonian boundary: A shallow-water perspective on nutrient fluctuations during Oceanic Anoxic Event 2 (Bonarelli Event).- *Geology*, Boulder - CO, vol. 36, no. 9, p. 715-718.

Philip J., Borgomano J. & Al-Maskiry S. (1995).- Cenomanian-Early Turonian carbonate platform of northern Oman: Stratigraphy and palaeoenvironments.- *Palæogeography*, *Palæoclimatology*, *Palæoecology*, vol. 119, nos. 1-2, p. 77-92.

Piuz A. & Vicedo V. (2020).- New Cenomanian "nummoloculinas" of the Natih Formation of Oman.- *Cretaceous Research*, vol. 107, article 104224, 17 p.

Robles-Salcedo R. (2014).- La Familia Siderolitidae (Macroforaminíferos del Cretácico Superior): Arquitectura de la concha, bioestratigrafía, distribución paleoambiental y palaleobiogeografía.- PhD Thesis, University of Barcelona, 183 p.

Robles-Salcedo R., Vicedo V., Parente M. & Caus E. (2019).- *Canalispina iapygia* gen. et sp. nov.: The last Siderolitidae (Foraminiferida) from the upper Maastrichtian of southern Italy.- *Cretaceous Research*, vol. 98, p. 84-94.

SAINT-MARC P. & RAHHALI I. (1982).- Sur la présence du genre *Spirocyclina* (foraminifère) dans le Cénomanien supérieur du Maroc.- *Revue de Micropaléontologie*, Paris, vol. 25, no. 2, 133-140.

SCHLAGINTWEIT F. (2020).- Maastrichtian larger benthic Foraminifera from the Arabian Plate *sensu lato*: New data from Somalia, Turkey and Iran.- *Acta Palaeontologica Romaniae*, Bucharest, vol. 16, no. 2, p. 69-83.

SCHLAGINTWEIT F. (2022).- Late Cretaceous Orbitolinidae (Larger Benthic Foraminifera): Taxonomy, determination, biostratigraphy and palaeobiogeography.- *Newsletters on Stratigraphy*, Stuttgart, vol. 55, no. 4, p. 427-450.

SCHLAGINTWEIT F. & RASHIDI K. (2016).- Some new and poorly known benthic Foraminifera from late Maastrichtian shallow-water carbonates of the Zagros Zone, SW Iran.- *Acta Palaeontologica Romaniae*, Bucharest, vol. 12, no. 1, 53-70.

SCHLAGINTWEIT F. & RASHIDI K. (2021).- *Dictyoconella* HENSON, 1948, Upper Cretaceous Larger Benthic Foraminifera: A taxonomic revision with the establishment of *Gusicella* gen. nov. (type-species *Dictyoconella minima* HENSON).- *Acta Palaeontologica Romaniae*, Bucharest, vol. 17, no. 2, p. 3-13.

SCHLAGINTWEIT F., RASHIDI K. & BABADIPOUR M. (2016a).- Orbitolinid Foraminifera from the Late Maastrichtian of the Tarbur Formation (Zagros Zone, SW Iran).- *Acta Palaeontologica Romaniae*, Bucharest, vol. 12, no. 2, 29-46.

SCHLAGINTWEIT F., RASHIDI K. & BARANI F. (2016b).- First record of *Gyroconulina columellifera* SCHROEDER & DARMOIAN, 1977 (larger benthic Foraminifera) from the Maastrichtian Tarbur Formation of SW Iran (Zagros Fold-Thrust-Belt).- *Geopersia*, Tehran, vol. 6, no. 2, p. 169-185.

SCHROEDER R. (1985).- Sous-genre *Carinoconus* CHERCHI & SCHROEDER, 1983. *In*: SCHROEDER R. & NEUMANN M. (coords.), Les grands Foraminifères du Crétacé moyen de la région méditerranéenne.- *Geobios*, Villeurbanne, mémoire spécial 7, p. 43-44.

SCHROEDER R., CLAVEL B. & CHAROLLAIS J. (1990).- *Praedictyorbitolina carthusiana* n. gen., n. sp., Orbitolinidé (Foraminiferida) de la limite Hauterivien-Barrémien des Alpes occidentales.- *Paläontologische Zeitschrift*, vol. 64, nos. 3-4, p. 193-202.

SCHROEDER R., CLAVEL B., CHERCHI A., BUSNARDO R., CHAROLLAIS J. & DECROUEZ D. (2002).- Lignées phylétiques d'Orbitolinidés dans Hauterivien supérieur - Aptien inférieur du Sud-Ouest de l'Europe et leur importance stratigraphique.- *Revue de Paléobiologie*, Genève, vol. 21, p. 853-863.

WHITTAKER J.E., JONES R.W. & BANNER F.T. (1998).- Key Mesozoic benthic Foraminifera of the Middle East.- The Natural History Museum, London, 237 p.

WOHLWEND S., HART M. & WEISSERT H. (2016).- Chemostratigraphy of the Upper Albian to mid-Turonian Natih Formation (Oman) - how authigenic carbonate changes a global pattern.- *The Depositional Record*, Hoboken - NJ, vol. 2, no. 1, p. 97-117.

WYND J.G. (1965).- Biofacies of the Iranian Oil Consortium Agreement Area.- IOOC Report, no. 1082, 89 p.

Plates

Plate 1: *Gusicella minima* (HENSON) from the middle to upper Cenomanian Natih Formation, Wadi Mu'Aydin, Oman Mountains. All from samples M-47 and M-48 (A-B, D, O) Axial sections in the plane of test compression. Note the dense central zone in (D) and (O). (C, H, J-K, M, P-Q) (Sub)axial sections perpendicular to the plane of test compression (especially the early planispire; *e.g.*, M). (E-G, N, L, R-T) Subaxial sections (unknown orientation towards the plane of compression). (I) Tangential section. Abbreviations: ch lu = chamber lumen, e = embryo, f = foramen, m th = marginal trough, op = opaque micritic mass, pi = pillar, r = rafter, s = septum. Specimen (repository) numbers: A = MGB_59811_LP01.001 B = MGB_59811_LP03.017, C = MGB_59811_LP11.001, D = MGB_59812_LP04.004, E = MGB_59811_LP10.001, F= MGB_59812_LP27.003, G = MGB_59812_LP24.001, H = MGB_59811_LP16.001, I = MGB_59811_LP09.001, J = MGB_59811_LP06.005', K = MGB_59811_LP07.011, L = MGB_59811_LP08.011, M = MGB_59811_LP11.006, N = MGB_59811_LP09.002, O = MGB_59812_LP18.002, P = MGB_59812_LP16.002, Q = MGB_59811_LP10.002, R = MGB_59811_LP14.002, S = MGB_59811_LP03.007, T = MGB_59811_LP03.005. Specimens A-C, E, H-N, and Q-T from sample M-47; specimens D, F-G, O-P from sample M-48.

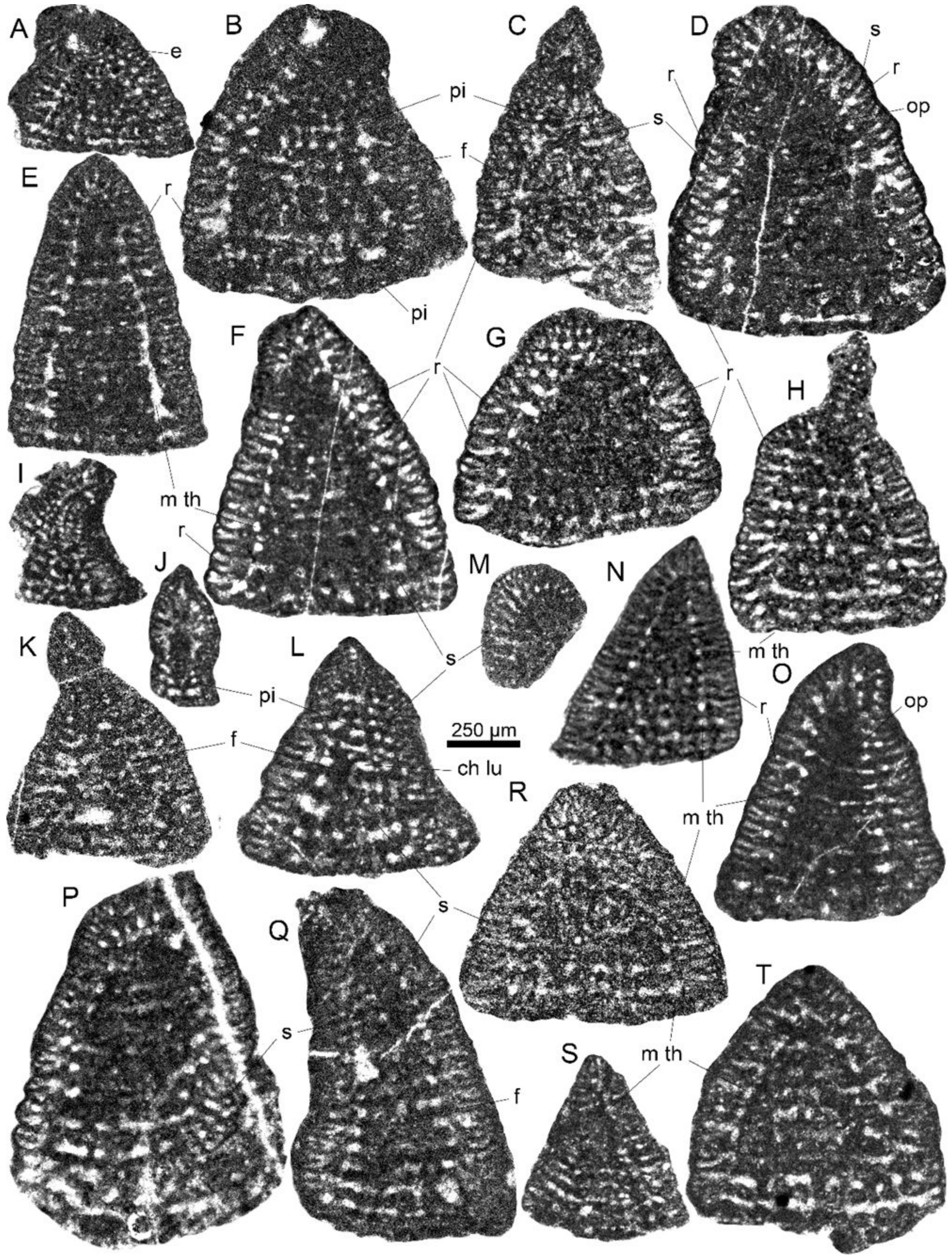

A
e
B
pi
f
pi
C
pi
s
f
D
s
r
op
r
s
E
r
F
r
G
r
H
I
m th
r
J
pi
K
f
L
pi
f
s
ch lu
M
s
250 µm
N
m th
r
O
op
R
m th
P
s
Q
s
s
f
S
m th
T

Plate 2: *Gusicella minima* (HENSON) from the middle to upper Cenomanian Natih Formation, Wadi Mu'Aydin, Oman Mountains. (A-U, W) Partly oblique transverse sections. Note that there are round transverse outlines but compression in various degrees exhibiting subangular margins. In some specimens pillars are well individualized (*e.g.*, O, W) while in others are fused and/or with secondary micritic deposits (*e.g.*, E, N). (M, V) Oblique section. Abbreviations: b = beam, b 2 = secondary (or intercalary) beam, b 3 = third order beam, ch lu = chamber lumen,, f = foramen, m th = marginal trough, pi = pillar, r = rafter, s = septum. Specimen (depository) numbers: A = MGB_59812_LP02.003, B = MGB_59812_LP14.001, C = MGB_59811_LP04.002, D = MGB_59811_LP16.002, E = MGB_59812_LP17.005, F = MGB_59811_LP07.009, G = MGB_59811_LP18.001, H = MGB_59812_LP13.003, I = MGB_59812_LP27.002, J = MGB_59811_LP19.001, K = MGB_59812_LP21.002, L = MGB_59811_LP03.008, M = MGB_59812_LP21.001, N = MGB_59812_LP04.003, O = MGB_59811_LP01.002, P = MGB_59812_LP18.003, Q = MGB_59812_LP19.001, R = MGB_59811_LP01.005, S = MGB_59811_LP19.004, T = MGB_59812_LP30.004, U = MGB_59811_LP18.016, V = MGB_59812_LP30.005, W = MGB_59811_LP08.001_. Specimens A-B, E, H-I, K, M-N, P-Q, T, V from sample M-48; specimens C-D, F-G, J, L, O, R-S, U, and W from sample M-47.

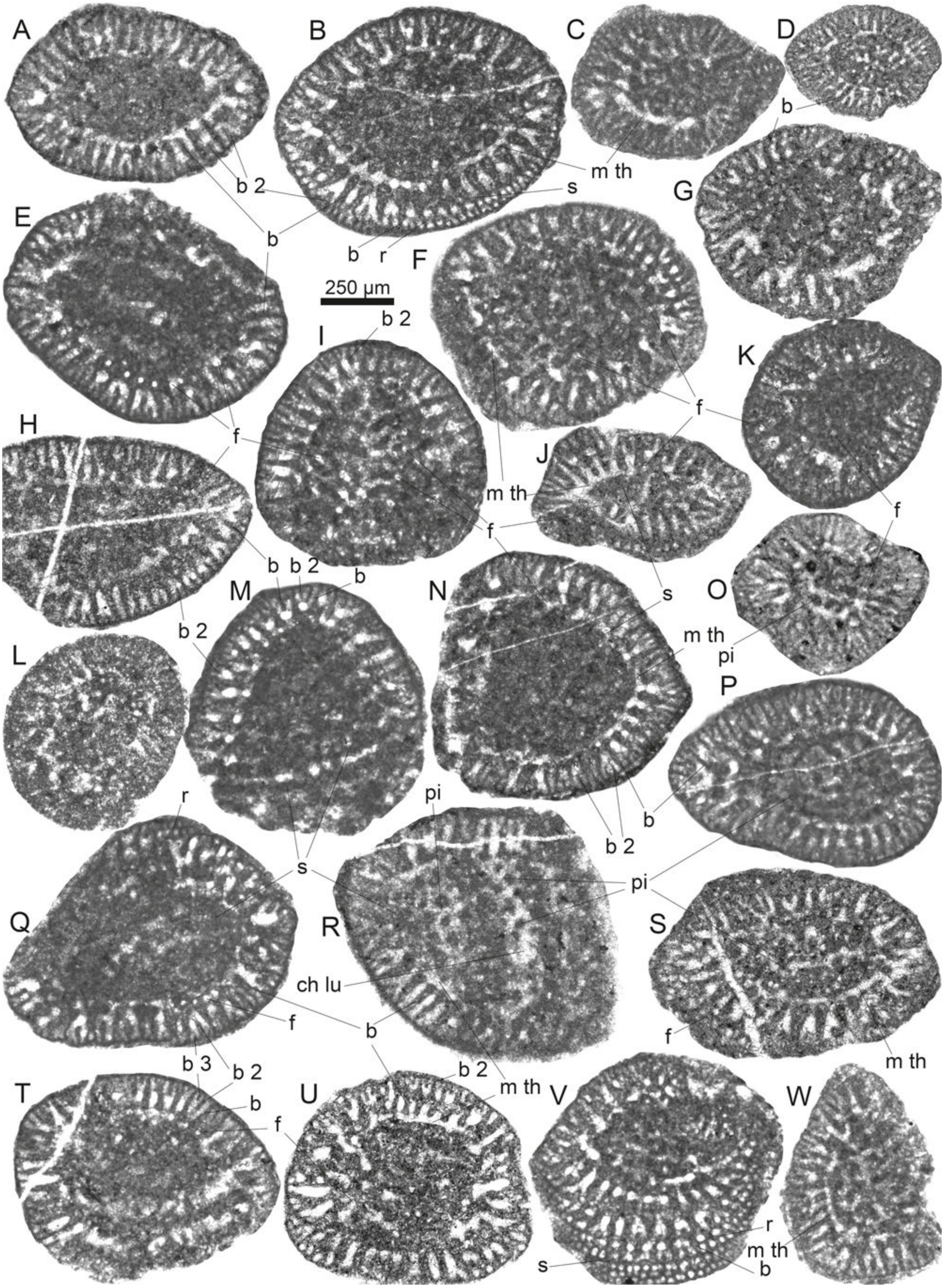

A
B
C
D
b
m th
b 2
s
G
E
b
b
r
F
250 µm
b 2
I
K
H
f
f
m th
J
f
f
b
b 2
b
M
N
s
O
m th
b 2
pi
L
P
b
b 2
r
pi
s
pi
Q
R
S
ch lu
f
b
f
m th
b 3
b 2
b 2
m th
T
b
U
V
W
f
r
m th
s
b

Plate 3: *Gusicella minima* (HENSON) from the middle to upper Cenomanian Natih Formation, Wadi Mu'Aydin, Oman Mountains. (A-S) Tangential, partly oblique sections. Abbreviations: b = beam, b 2 = secondary (or intercalary) beam, b 3 = third order beam, ch lu = chamber lumen, f = foramen, m th = marginal trough, pi = pillar, r = rafter, s = septum. Specimen (depository) numbers: A = MGB_59811_LP02.001, B= MGB_59811_LP06.005, C = MGB_59811_LP14.001, D = MGB_59812_LP02.001, E = MGB_59811_LP08.006, F = MGB_59811_LP18.011, G = MGB_59811_LP16.005, H = MGB_59811_LP16.006, I = MGB_59812_LP11.006, J = MGB_59812_LP23.004, K = MGB_59812_LP29.005, L = MGB_59811_LP18.021, M = MGB_59812_LP16.001, N = MGB_59812_LP16.004, O = MGB_59811_LP03.006, P = MGB_59811_LP11.007, Q = MGB_59811_LP08.008, R = MGB_59811_LP04.001, S = MGB_59812_LP13.001. Specimens A-C, E-H, L, O-R from sample M-47; specimens D, I-K, M-N, and S from sample M-48.

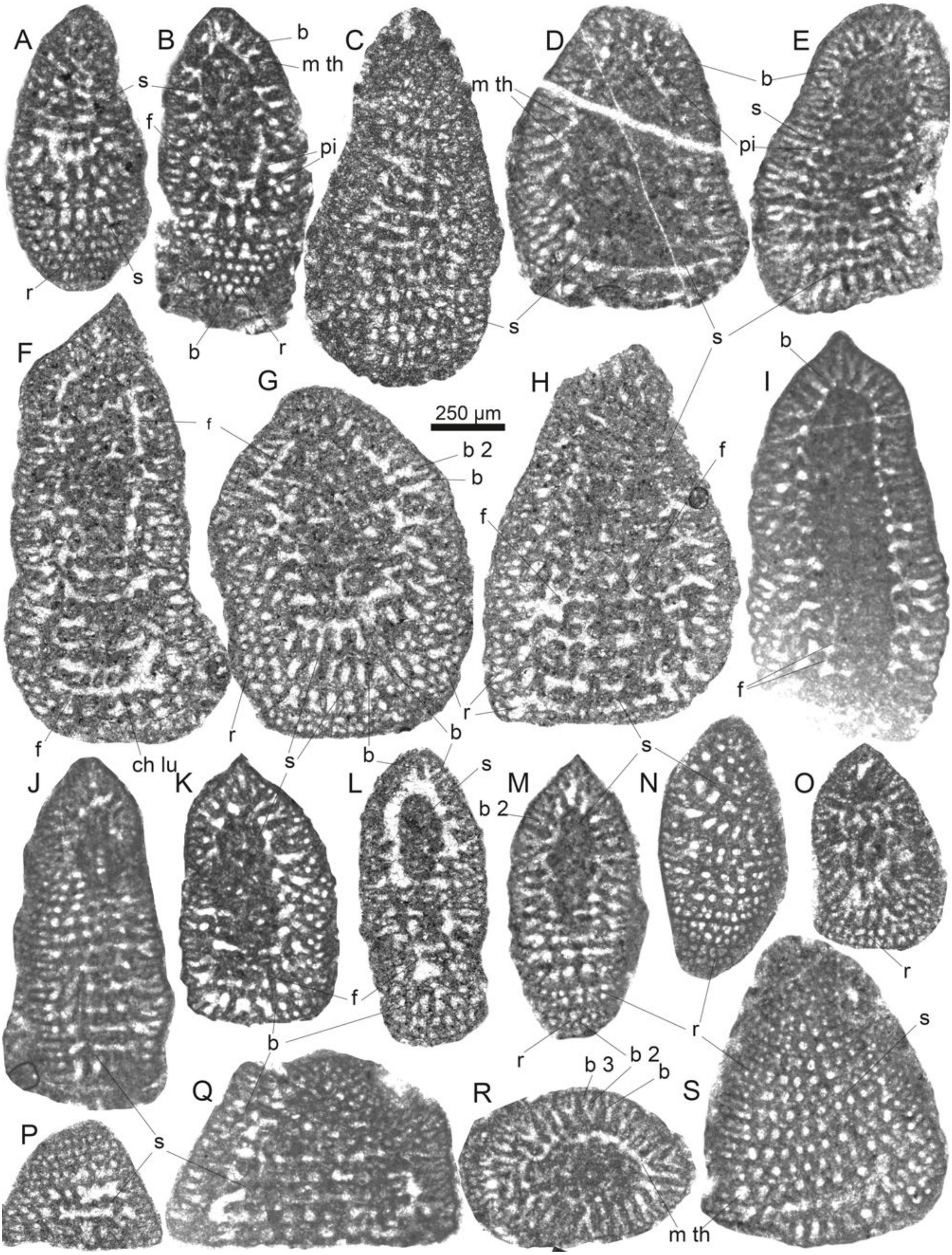

A
B
C
D
E
b
m th
s
f
pi
s
r
b
r
m th
b
pi
s
s
s
F
G
H
I
b
f
250 µm
b 2
b
f
f
f
f
r
r
b
s
r
f
ch lu
J
K
L
M
N
O
b
s
b 2
s
r
f
b
r
r
b 3
b 2
b
s
P
Q
R
S
s
m th

Plate 4: *Gusicella minima* (Henson) from the middle to upper Cenomanian Natih Formation, Wadi Tanuf, Oman Mountains. **A, F** Subaxial sections. **B** Tangential section. **C, E, I** Oblique transverse section. **D, H** Oblique sections. **G** Transverse section. **J** Axial section perpendicular to plane of compression. Note the transverse section of the initial coil. Abbreviations: a f = aligned foramen, b 1 = primary beams, b 2 = second order (or intercalary) beam, ch lu = chamber lumen, m th = marginal trough, pi = pillar, r = rafter, s = septum. Thin-sections: 13 (**A, E-H**), S2 (**B, J**), 14 (**C**), 24 (**D**), 9m (**I**).

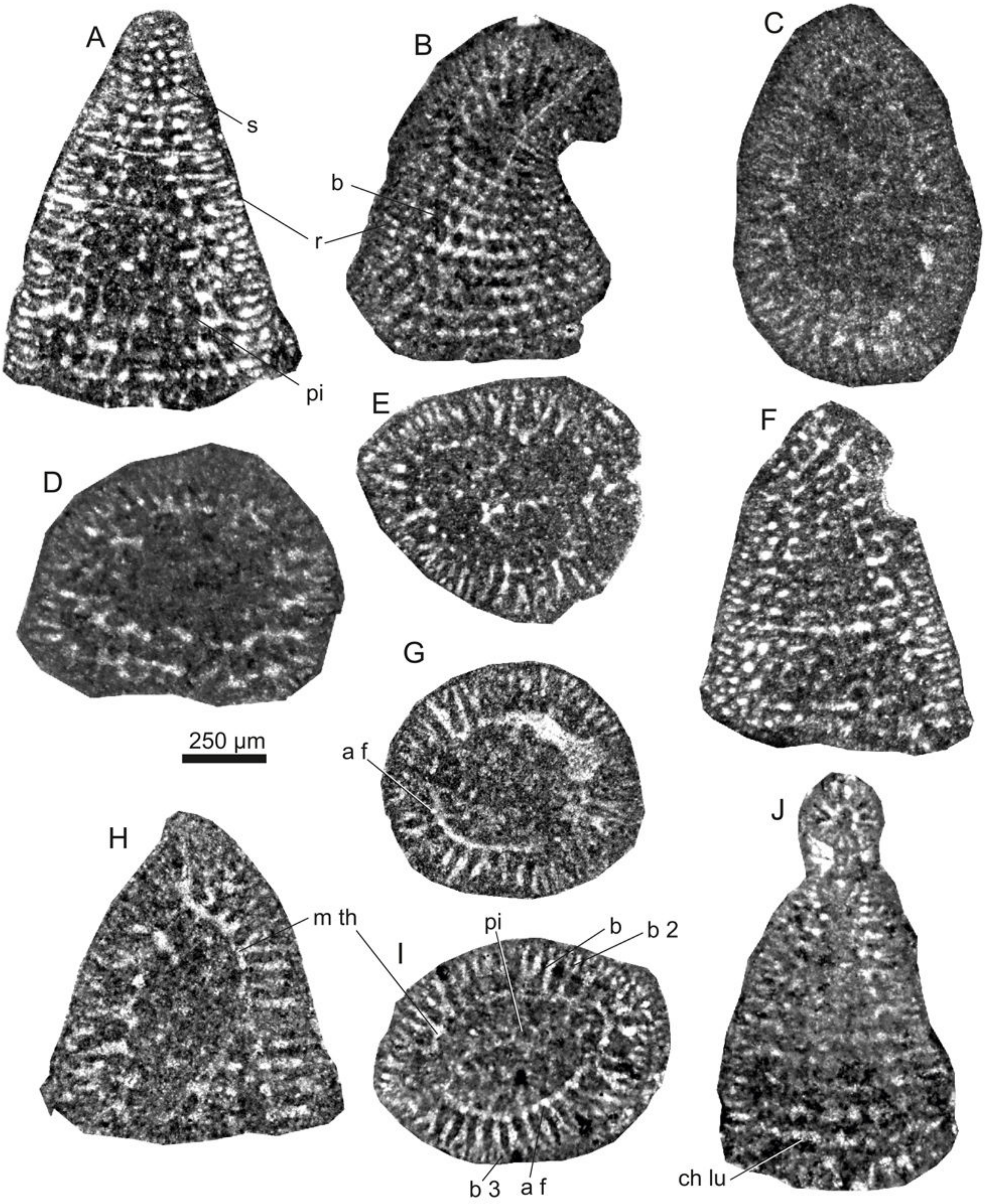

A
s
r
B
b
r
C
pi
D
E
F
250 µm
G
a f
H
m th
I
pi
b
b 2
J
b 3
a f
ch lu

Plate 5: *Gusicella complexa* SCHLAGINTWEIT & RASHIDI sp. nov. from the upper Maastrichtian Tarbur Formation of SW Iran (Mandegan section: **B**; Naghan section: **A, C-J**). **A, J** Oblique transverse sections. **B** Tangential-oblique section cutting the marginal (upper part) and central zones (lower part) displaying irregularly distributed fused pillars/secondary deposits. **C-D, I** Subaxial sections. **E-G** Axial sections showing initial spire and partial embryo; holotype specimen in **E**. **H** Tangential section passing through the subepidermal network and the aligned beams (centre). Abbreviations: a f = aligned foramen, b = beam, b 2 = second order beam, b 3 = third order beam, e = embryo, f = foramen, op = opaque micritic mass,, r = rafter, r 2 second order rafter, r 3 = third order rafter, s = septum, pi = pillar. Thin sections: 2NG 17 (**A, I**), Rt 100 (**B**), Ng 180-1 (**C**), 2NG 179-1 (**D**), 2NG 168 (**E**), 2NG 175 (**F**), 2NG 174 (**G-H**), 2NG 177 (**J**).

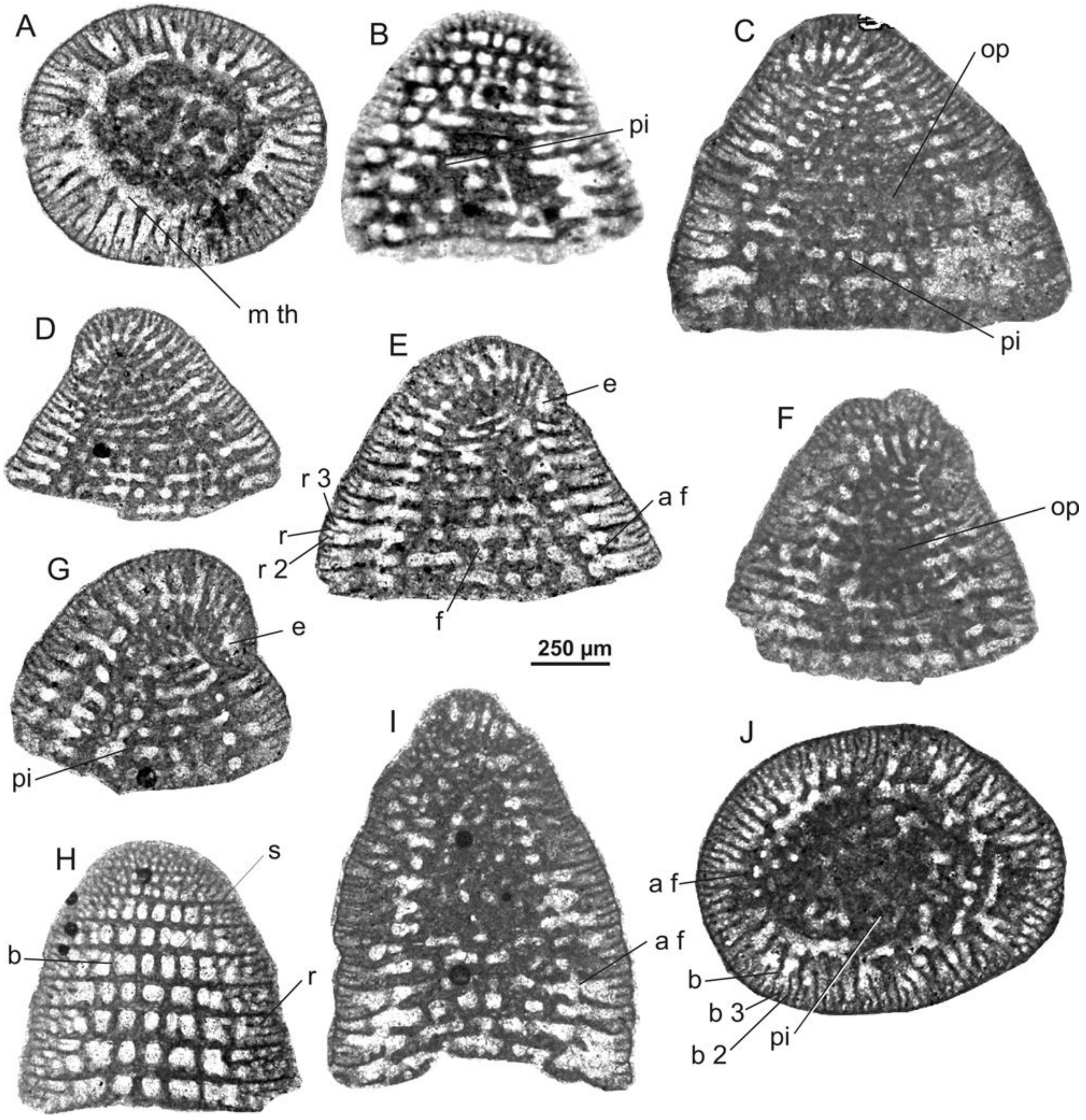
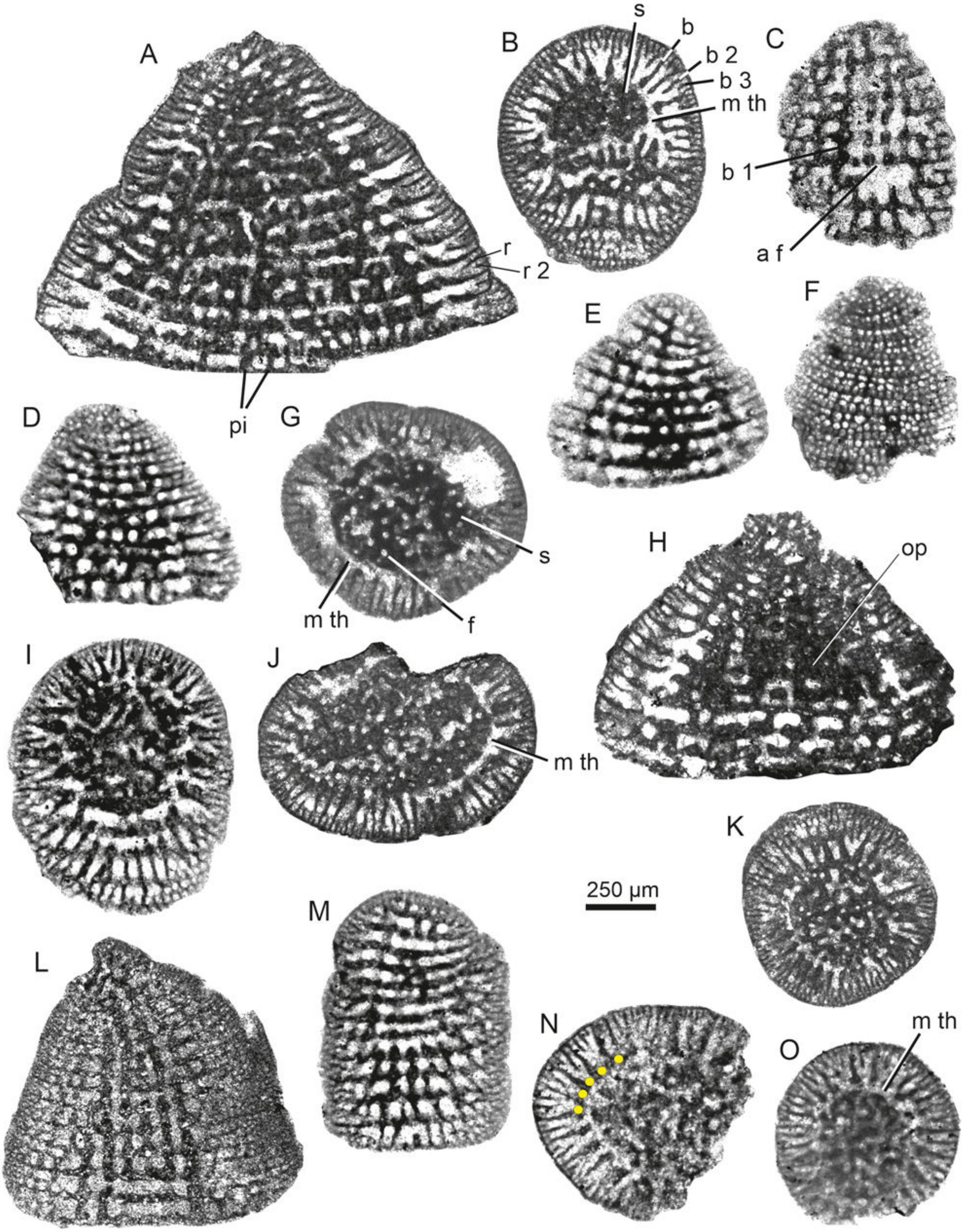

A
m th
B
pi
C
op
pi
D
E
e
r 3
r
r 2
a f
f
F
op
G
e
pi
250 µm
H
s
b
r
I
a f
J
a f
b
b 3
b 2
pi

Plate 6: *Gusicella complexa* SCHLAGINTWEIT & RASHIDI sp. nov. from the upper Maastrichtian Tarbur Formation of SW Iran (Naghan section: **A-B, J, K**; Mandegan section: **C-I, L-O**). **A** Subaxial section. **B, I, K** Oblique sections. **C-E, L-M** Tangential sections displaying beams continuous (aligned) from one chamber to the next. **F** Shallow tangential of the marginal zone section displaying subepidermal network of beams and rafters. **G, J-K, N-O** Different transverse sections, some slightly oblique. Note oval test outline in **J** and five marginal foramina arranged in a tangential row (yellow circles) in **O**. **H** Subaxial section. Note alternation of pillars by stairway-like arrangement of foramina and opaque fused pillars/secondary deposits in the central zone. **M** Tangential-oblique section. Abbreviations: b = beam, b 2 = second order beam, b 3 = third order beam, f = foramen, a f = aligned foramen, m th = marginal through, op = opaque micritic mass, pi = pillar, r = rafter, r 2 = second order rafter, s = septum. Thin sections: Ng 196 (**A**), Ng 192 (**B**), Rt 108-3 (**C-E, G, M**), Rt 104 (**F**), Rt 96 (**H**), Rt 108-6 (**I**), Ng 187 (**J**), Ng 186 (**K**), Rt 107 (**L**), Rt 102-2 (**N**), Rt 104 (**O**).


A
B
s
b
b 2
b 3
m th
C
b 1
a f
r
r 2
pi
D
G
E
F
s
m th
f
H
op
I
J
m th
K
250 µm
L
M
N
O
m th