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ORIGINAL PAPER

Dissocladella compressa n. sp., a new Dasycladale (green algae) from the Upper Maastrichtian of Iran

K. Rashidi[1] · F. Schlagintweit[2]

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Abstract
The new dasycladalean alga *Dissocladella compressa* is described from the lower part of the Tarbur Formation of SW Iran (Zagros Zone). The medium-sized representative of the genus is characterized by rather large primaries displaying slight vertical compression. It occurs in a foraminiferan-algal packstone associated with larger benthic foraminifera typically *Omphalocyclus macroporus* Lamarck, *Loftusia* sp., *Siderolites* cf. *calcitrapoides* Lamarck, and scattered corals. Associated algae include *Trinocladus tripolitanus* Raineri, *Thyrsoporella longa* Radoičić, *Ovulites delicatula* Elliott, accessory udoteaceans, and corallinaceans.

Keywords Dasycladales · Larger benthic foraminifera · Taxonomy · Systematics

Introduction

The Upper 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.

Microflora of the Tarbur Formation is still rather poorly known and consists almost exclusively of calcareous green algae with a clear dominance of Dasycladales. Some taxa of dasycladalean algae were illustrated in some recently published papers (Abyat et al. 2012, 2015; Afghah 2016; Afghah and Farhoudi 2012; Afghah and Yaghmour 2014; Dehghani et al. 2016; Khosrow Tehrani and Afghah 2004). These determinations, however, are dubious if not incorrect and therefore require further investigations. First results and critical revisions of the microflora of the Tarbur Formation were published recently (Rashidi et al. 2013; Schlagintweit et al. 2016c; Rashidi and Schlagintweit 2018a, 2018b). The present paper deals with the description of a new dasycladale, *Dissocladella compressa* n. sp. Representatives of the genus *Dissocladella* were so far not reported from the Campanian-Maastrichtian interval (see Barattolo 2002, Table 2).

Studied sections

Almost all specimens of *Dissocladella compressa* n. sp. illustrated here are from the type locality, the Rod-Abad section (Fig. 1). More rarely, the new taxon has also observed in the nearby Mandegan section as well as the Naghan section.

Rod-Abad section (type locality)

Type level of the new species of *Dissocladella* is located in the Rod-Abad section (Fig. 2). From the same locality

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✉ F. Schlagintweit

K. Rashidi
kooroshrashidi@yazd.ac.ir

[1] Department of Geology, Yazd University, 89195-741, Yazd, Iran

[2] Munich, Germany

Fig. 1 Location of the Rod-Abad section (star, arrow in **a**; from Consorti and Rashidi 2018, based on Google Maps in **b**)

Elazigina sidereal, a new larger benthic foraminifera (family Rotaliidae) was described recently by Consorti and Rashidi (2018). The section is positioned 6.5 km far to the NE of Mandegan Village, very close to the village of Ab-Malakh (Fig. 1). In the Rod-Abad section, the Tarbur Formation is incompletely exposed (thickness about 70 m) and refers to its basal part. Lithostratigraphically, it represents an equivalent of unit 1 differentiated from the Mandegan section (see below). The lower to middle part of the Rod-Abad section shows four short-term transgressive-regressive pulses expressed by four marly levels that contain rudists in living position. These appear intercalated between massive limestones (Consorti and Rashidi 2018) (Fig. 2). The type level of *Dissocladella compressa* n. sp. is sample TF 3, an algal-foraminiferal packstone (Fig. 3a). The associated larger benthic foraminifers include *Omphalocyclus macroporus* (Lamarck), *Siderolites* cf. *calcitrapoides* Lamarck, *Loftusia* sp., and *Elazigina siderea* Consorti & Rashidi. Some of the larger benthic foraminifera from the Rod-Abad section are illustrated in Fig. 3b–h. The algal association of TF 3 includes *Dissocladella compressa* n. sp., *Trinocladus tripolitanus* Raineri, *Ovulites delicatula* Elliott, and *Thyrsoporella longa* Radoičić. The Greenwich coordinates of the section base are 31°8′32.46″ N and 50°23′51.30″ E.

Mandegan section

In the nearby Mandegan section (see Schlagintweit et al. 2016a; Consorti and Rashidi 2018), the Tarbur Formation attains a thickness of almost 280 m from

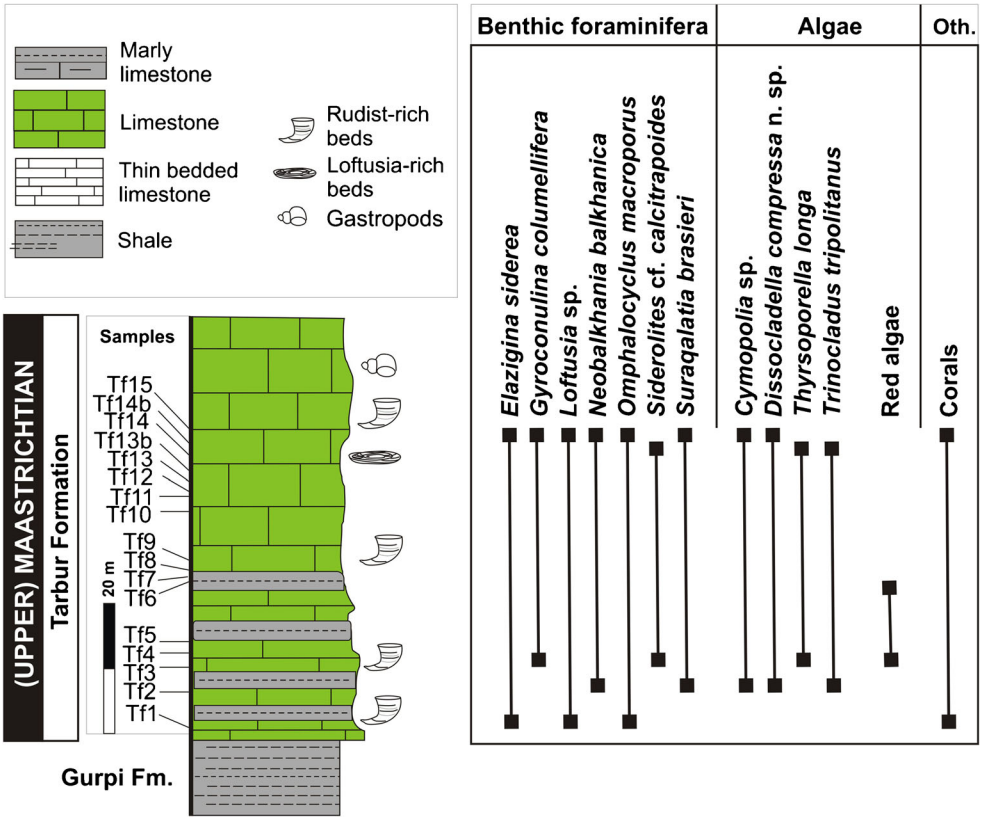

Fig. 2 Vertical distribution of *Dissocladella compressa* n. sp. and selected larger benthic foraminifera in the (late) Maastrichtian of the Tarbur Formation of the Rod-Abad section section

the base (towards the underlying Gurpi Formation) to the top (towards the overlying Pliocene Bakhtiari Formation). Here, *Dissocladella compressa* n. sp. is much less frequent than its type locality. The Greenwich coordinates of the section base are N 31°, 2′, 58.13″ and E 51°, 24′, 34.58″.

Naghan section

The Naghan section is located approximately 50 km south west of Naghan town near the Gandomkar Village (see Rashidi and Schlagintweit 2018a). At this locality, the Tarbur Formation is underlain by the Gurpi Formation and overlying by the Paleocene Sachun Formation. The thickness of the Tarbur Formation at the Naghan section is about ~274 m. Here, *Dissocladella compressa* n. sp. is much less frequent than its type locality. The Greenwich coordinates of the section base are 31°47′52″ N and 50°32′53″ E.

Material and depository

All specimens from *Dissocladella compressa* n. sp. are from thin sections stored at the Ardakan Payame Noor University, Iran, in the Rashidi collection, under the original sample numbers with the prefixes F, FT, and TF. The numbers correspond to the same sampling levels (F 3 = FT 3) (Fig. 2). From the most prolific sample FT 3, several thin sections have been prepared labeled FT 3-1 to FT 3-11.

Systematic micropalaeontology

Phylum CHLOROPHYTA
Class DASYCLADOPHYCEAE
Oder DASYCLADALES Pascher 1931
Family DASYCLADACEAE Kützing, 1843
Genus *Dissocladella* Pia in Rao and Pia 1936 emend. BASSOULLET et al., 1978
Dissocladella compressa n.sp.

Figs. 3pars (a), 4(a–i), 5(a–h), and 6(a–i)

Origin of the name The species name refers to the shape of the primaries, being vertically slightly compressed.

Holotype Slightly oblique transverse section illustrated in Fig. 6h on the left side, thin section TF 4-1.

Type locality Rod-Abad section (Figs. 1 and 2).

Type level Mud or grain-supported limestones (wackestones, packstones) with larger benthic foraminifera (e.g., typically association of *Omphalocyclus macroporus* Lamarck and subordinate *Loftusia* sp.) of the Tarbur Formation.

Description Medium-sized representative of the genus with well calcified cylindrical thallus and main axis on average 42% of the diameter. The inner surface is straight and clearly delineated. Primary laterals numerous, differentiated into a thin proximal stalk, and a main part, subsphaerical to quadrangular-rounded in transverse sections. Due to a slight vertical compression, the primaries are ovoidal in longitudinal

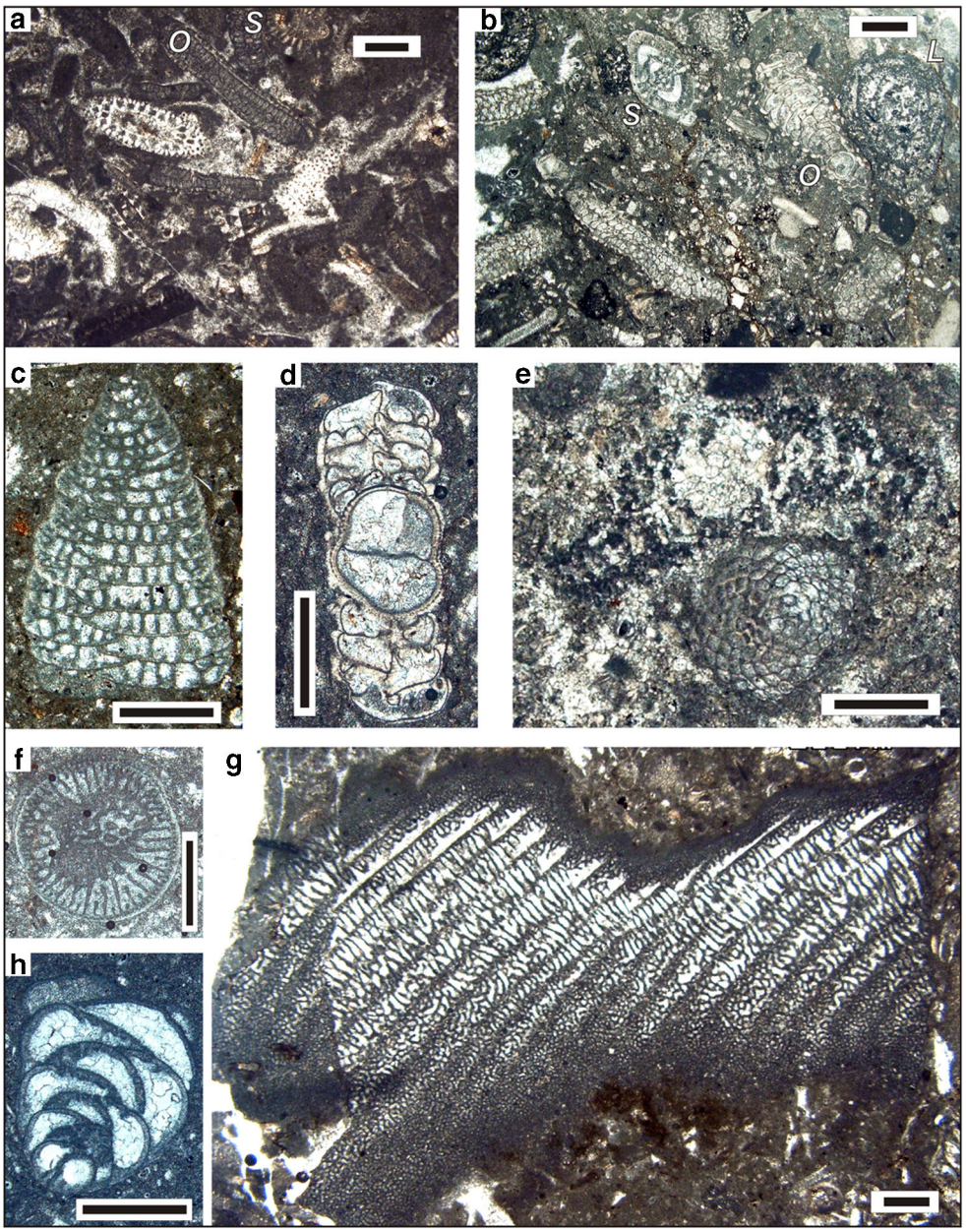

Fig. 3 Microfacies with *Dissocladella compressa* n. sp. (**a**) and some (larger) benthic foraminifera (**b**–**h**) from the (late) Maastrichtian of the Tarbur Formation of the Rod-Abad section, Iran. Foraminiferan packstone with *Loftusia* sp. (*L*), *Omphalocyclus macroporus* (Lamarck) (L), *Siderolites* cf. *calcitrapoides* (Lamarck) (S). *Dissocladella compressa* n. sp. in **b** (**a**, **b**). *Gyroconulina columellifera* Schroeder & Darmoian, subaxial section (**c**), and slightly oblique transverse section (**f**). *Omphalocyclus macroporus* (Lamarck), axial section (**d**). *Neobalkhania bignoti* Cherchi, Radoičić & Schroeder (above), and *Omphalocyclus macroporus* (Lamarck) (below) (**e**). *Suraqalatia brasieri* Görmuş, Lawa & Nuaimy, tangential section (**g**). *Minouxia* sp., oblique section (**h**). Scale bars: 0.6 mm (**a**, **b**), 0.5 mm (**c**–**g**). Thin sections: F 11 (**a**), TF 3-11 (**b**), F 4 (**c**, **d**), TF 5-3 (**e**), FT 11-2 (**f**), FT 5 (**g**), and TF 12 (**h**)

sections. Each primary bears four to five diverging secondaries arising along its distal surface. The latter display a distal swelling thereby touching the neighboring secondaries. In longitudinal sections, the primaries appear slightly shifted between two subsequent verticils, neither clearly alternating nor clearly in line.

Dimensions The main biometric parameters are compiled in Table 1.

Comparisons Among the numerous established species of the genus, several have taxonomically been revised (Ott 1965; Dragastan and Trappe 1986; Barattolo and Bigozzi 1996; Barattolo et al. 2008; Granier 2013), while others are controversly discussed (Raineri 1922; Radoičić et al. 2005; Granier et al. 2017). *Dissocladella compressa* n. sp. represents a medium-sized species clearly different from the large-sized forms, the articulated Paleocene type-

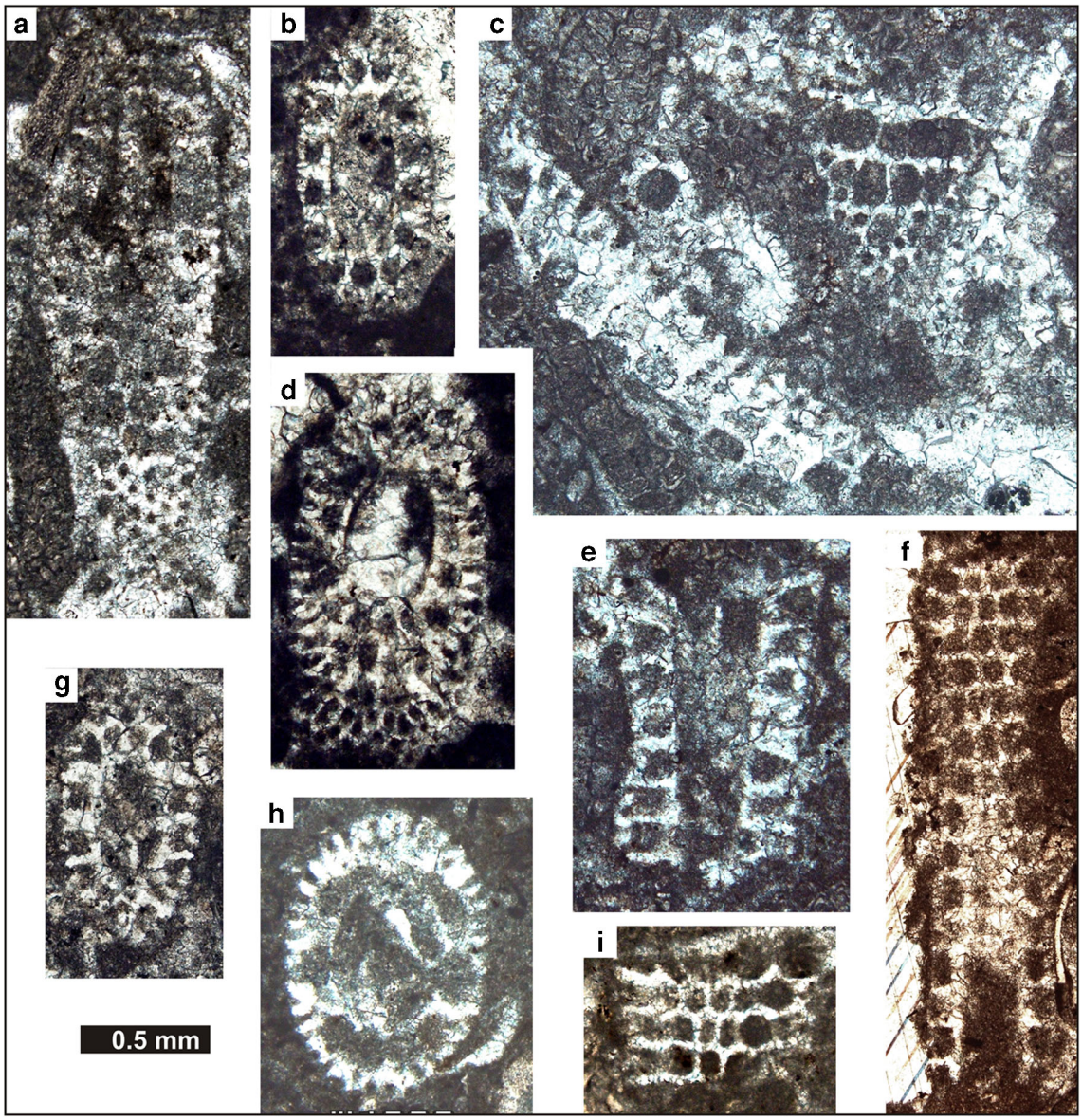

Fig. 4 *Dissocladella compressa* n. sp. from the (late) Maastrichtian of the Tarbur Formation of the Rod-Abad (**a**–**e**, **i**), Mandegan (**f**), and Naghan sections (**h**), Iran. Oblique sections (**a**, **b**, **d**, **g**, **h**). Fragmentary longitudinal section (left) and tangential section showing primaries and secondaries (right) (**c**). Longitudinal section (**e**). Tangential (upper part) to longitudinal section (lower part) (**f**). Tangential section (**i**). Thin sections: TF 3-8 (**a**), TF 3-11 (**b**, **d**, **g**, **i**), TF 3 (**b**), RT 100-2 (**f**), and NG 113 (**h**)

species *D. savitriae* Pia, 1936 (in Rao and Pia 1936), or the Lower Cretaceous *D. urgoniana* Dragastan 1989. It should be mentioned that the latter species shows clustered secondaries, meaning arising from a single point at the surface of the primaries (forming a bunch) as in the genus *Montenegrella* Sokač & Nikler, in Granier and Deloffre 1993 (e.g., Sokač and Nikler 1973; Barattolo 1984; Sokač and Grgasović 2015; Rashidi and Schlagintweit 2018b). Therefore, *D. urgoniana* needs taxonomic revision in our opinion. The widespread Upper Cretaceous *Dissocladella undulata* Raineri is distinctly smaller than *D. compressa*, also with a small number of primaries per verticil (Raineri 1922; Radoičić et al. 2005; Schlagintweit and Wilmsen 2014). The same characteristics differentiate the new Iranian species from other Paleogene forms such as *D. lunata* Segonzac, *D. deserta* Elliott, or *D. gracilis* Radoičić (see Table 1 in Radoičic 1991). Last but not least, the vertical compression of the primary laterals of *D. compressa* represents a unique position feature that is here considered a specific criterion.

Recently, another dasycladale also displaying two orders of laterals was described by Rashidi and Schlagintweit (2018b) as *Suppiluliumaella tarburensis* from the Tarbur Formation. This larger taxon (D up to 1.68 mm) shows numerous laterals ($w = 14–20$) inclined to the main axis typical of the genus.

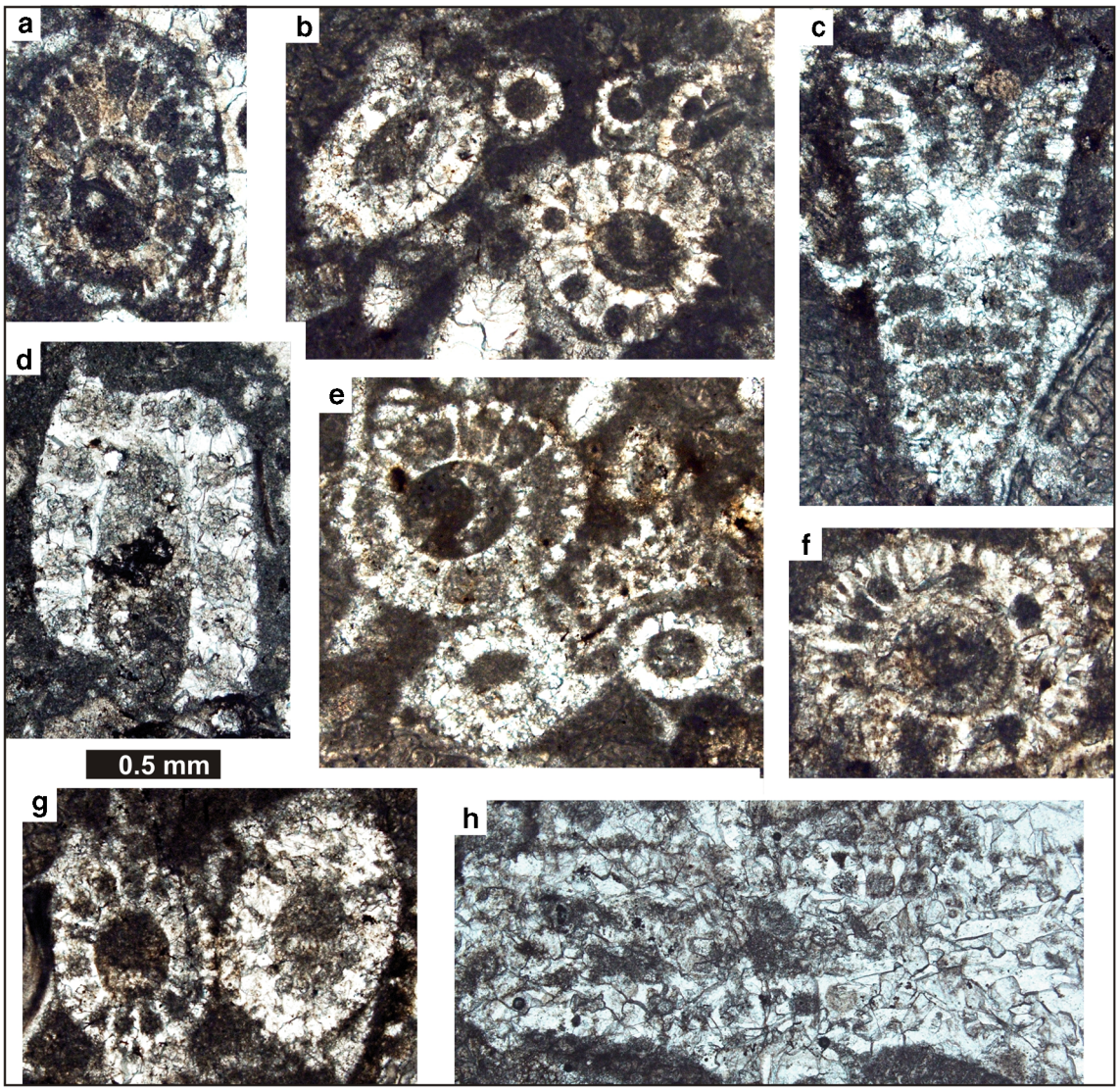

Fig. 5 *Dissocladella compressa* n. sp. from the (late) Maastrichtian of the Tarbur Formation of the Rod-Abad section, Iran. Oblique sections (**a**, **c**, **d**). Oblique and slightly oblique transverse sections (**b**). Oblique transverse sections (**e**–**g**). Longitudinal section (**h**). Thin sections: TF 3-8 (**a**, **c**), TF 3-11 (**b**, **e**–**g**), TF 3-10 (**d**), TF 3 (**h**)

Remarks In the Rod-Abad section *Dissocladella compressa* may be associated with other alga (Fig. 7). Besides accessory corallinaceans, these include dasycladaleans and not further determined udoteacean algae. Among the dasycladales, we observed more frequently an association of *Dissocladella compressa* with *Trinocladus tripolitanus* Raineri (Fig. 7a, b, d), *Thyrsoporella longa* Radoičić (Fig. 7g–l), *Cymopolia*

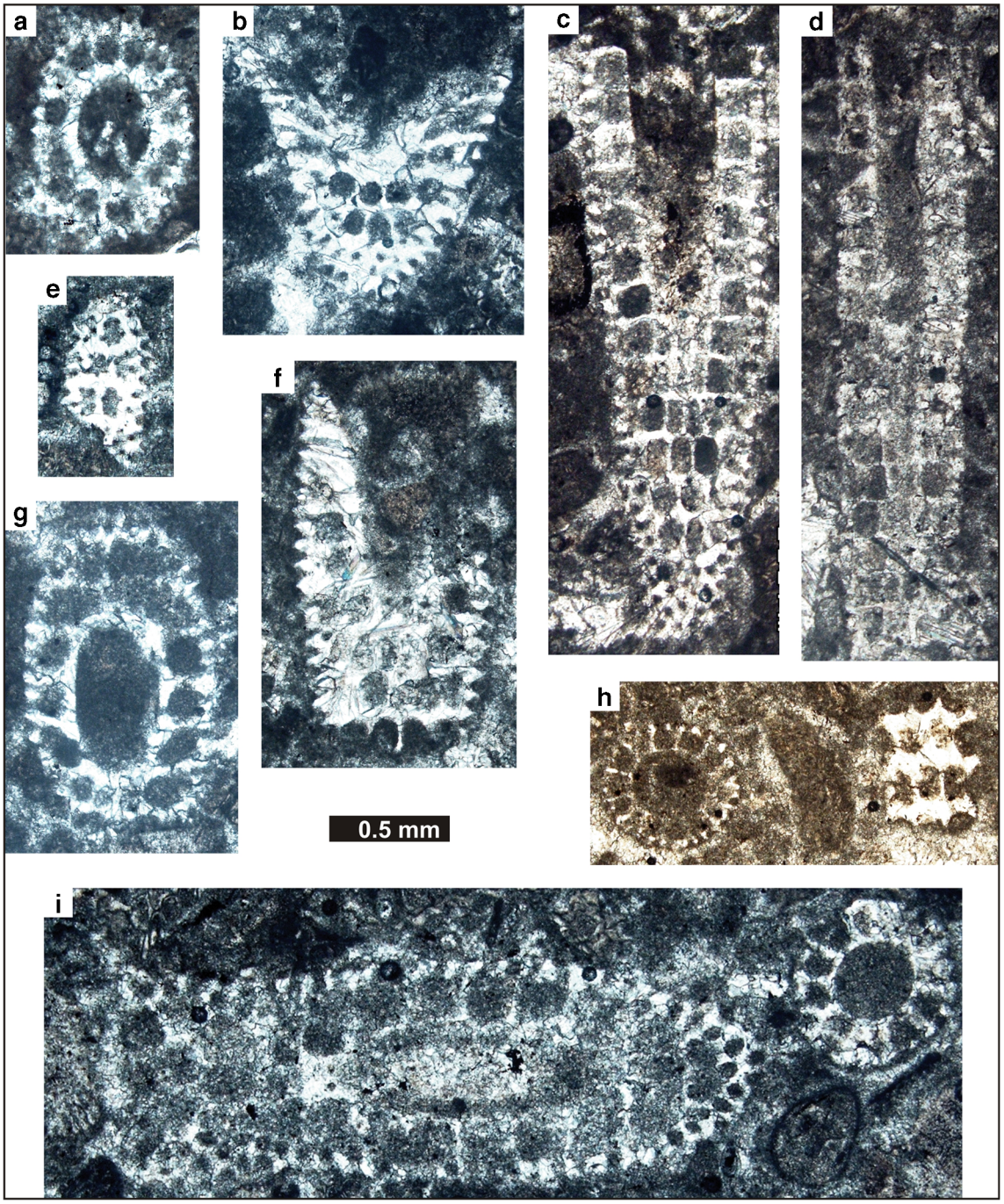

Fig. 6 *Dissocladella compressa* n. sp. from the (late) Maastrichtian of the Tarbur Formation of the Rod-Abad section, Iran. Oblique sections (**a**, **b**, **g**). Longitudinal-tangential sections (**c**–**d**, **f**). Fragmentary tangential section (**e**). Transverse section left (holotype specimen) and tangential section (right) (**h**). Oblique section (left) and slightly oblique transverse section (right) (**i**). Thin sections: TF 5-4 (**a**, **b**, **f**, **g**), TF 5-5 (**c**, **e**, **i**), and TF 4-1 (**h**)

Table 1 Dimensions (in mm; except d/D) of *Dissocladella compressa* n. sp. from the late Maastrichtian of the Tarbur Formation of Iran (in mm, except ratio d/D). *D* outer diameter, *d* inner diameter, *pmax* maximum diameter of primary laterals, *l* length of primary laterals, *p'max* maximum diameter of secondary laterals, *l'max* maximum length of secondary laterals, *h* vertical spacing, *w* number of primary laterals in a vertical

Sample	*D*	*d*	*d/D*	*p*	*l*	*p'*	*l'*	*h*	*w*
NG 113	0.75	0.37	0.5	0.18	0.19	0.08	0.08	–	–
Rt 100-3		–	–	0.16	0.16	–	–	0.16	–
F 4	0.35	0.15	0.43	0.07	0.06	0.045	0.04	–	14
F 4	–	–	–	0.13	–	–	–	0.16	–
FT 11	0.48	0.26	0.54	0.09	0.08	0.06	–	–	16
TF 3	0.79	0.35	0.44	0.11	0.16	0.07	0.14	0.15	–
TF 3	0.84	0.31	0.37	0.12	0.17	–	–	0.16	–
TF 3	0.72	0.33	0.47	0.08	0.12	0.06	0.09	–	15
TF 3	0.55	0.25	0.45	0.1	0.13	–	–	–	–
TF 4-1	0.47	0.21	0.45	0.08	0.1	–	–	–	14
TF 4-1	0.5	0.25	0.5	0.09	0.09	0.06	0.06	–	14
TF 3-8	–	–	–	0.075	0.13	0.06	0.16	–	–
TF 3-8	0.55	0.23	0.41	–	–	–	–	–	17
TF 3-8	0.7	0.31	0.44	0.19	0.14	0.07	0.08	–	–
TF 3-8	–	–	–	0.14	0.18	0.08	0.11	0.17	–
TF 3-10	0.82	0.33	0.4	0.16	0.19	0.06	–	0.18	–
TF 3-11	0.87	0.41	0.47	0.13	0.17	0.05	0.1	–	19
TF 3-11	0.77	0.31	0.4	0.1	0.17	–	–	–	?17–18
TF 3-11	0.61	0.27	0.44	0.09	0.13	0.05	0.08	–	15
TF 3-11	0.63	0.24	0.38	–	–	–	–	–	–
TF 3-11	0.42	0.16	0.38	–	–	–	–	–	–
TF 3-11	0.84	0.37	0.44	0.16	0.17	0.07	0.08	–	17
TF 3-11	0.53	0.2	0.38	0.1	0.1	–	–	–	–
TF 3-11	0.76	0.31	0.42	0.11	0.13	0.08	0.12	–	–
TF 3-11	0.55	0.23	0.42	0.1	0.12	0.07	0.07	–	–
TF 4-1	0.55	0.28	0.51	0.14	0.14	0.08	0.05	–	14
TF 4-11	–	–	–	–	–	–	–	0.17	–
TF 5-4	0.8	0.33	0.42	0.17	0.19	0.08	0.08	–	–
TF 5-4	0.63	0.27	0.42	0.1	0.12	0.08	0.08	–	–
TF 5-4	–	–	–	0.13	–	0.09	0.14	0.18	–
Tf 5-5	0.78	0.35	0.45	0.16	0.14	0.09	0.11	0.17	–
FT 3-11	–	–	–	0.16	–	–	–	0.16	–
Range	0.35–0.87	0.15–0.41	0.37–0.54	0.07–0.19	0.06–0.19	0.045–0.09	0.04–0.14	0.15–0.18	14–19
medium	0.65	0.28	0.42	0.12	0.14	0.07	0.09	0.166	17

sp., and more rarely *Cymopolia tibetica* Morellet & Morellet (Fig. 7c, f). A similar association of *Trinocladus tripolitanus* Raineri with representatives of *Dissocladella* (here: *D. undulata*) and udoteaceans is reported from the Upper Cretaceous of Lybia (Raineri 1922; Radoičić et al. 2005) or the Cenomanian of Spain (Schlagintweit and Wilmsen 2014). As in the Tarbur Formation, the microfacies of this algal association correspond to external platform environments with medium to high energy levels. The occurrence of *Trinocladus tripolitanus* in the late Maastrichtian Tarbur Formation represents the youngest record of the species (see Barattolo 2002, Table 2). *Thyrsoporella longa* was described by Radoičić (1990) from the early Paleocene of Iraq and is here recorded for the first time from the late Maastrichtian (see Barattolo 2002).

Stratigraphy

The occurrence of *Siderolites* cf. *calcitrapoides* Lamarck basal part of the Rod-Abad section is worth mentioning, as this

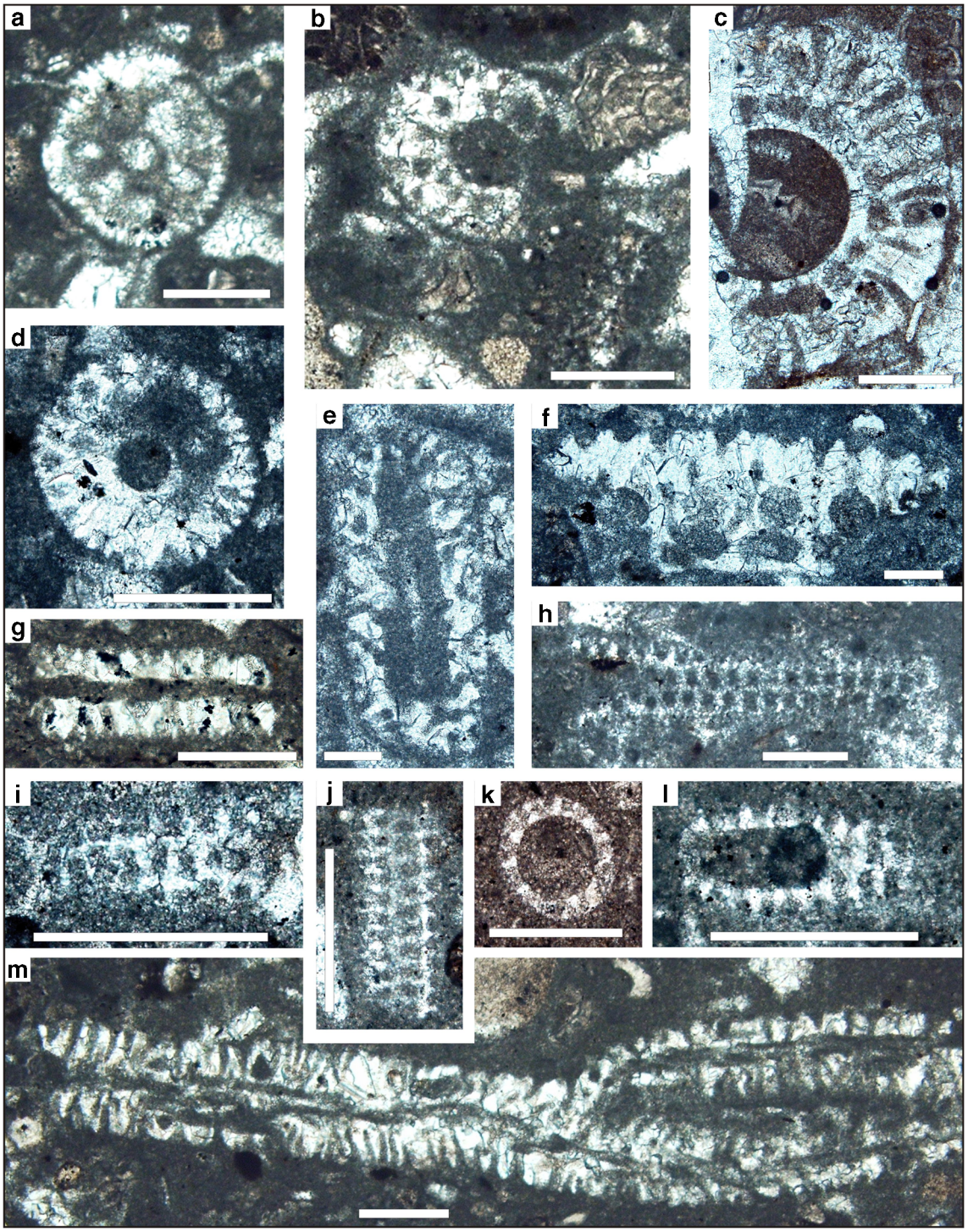

Fig. 7 Calcareous green algae from the (late) Maastrichtian of the Tarbur Formation of the Rod-Abad section, Iran. *Trinocladus tripolitanus* Raineri, transverse sections (**a**, **d**), and oblique section (**b**). *Cymopolia tibetica* Morellet & Morellet, transverse section (**c**), and fragment (**f**). Udoteacean alga, oblique section (**e**). *Thyrsoporella longa* Radoičić, longitudinal section (**g**), diverse tangential sections (**h**–**j**), and slightly oblique transverse section (**k**). Udoteacean alga showing low-angle branching on the right side (**m**). Scale bars: 0.3 mm except (**k**) = 0.2 mm. Thin sections: F 10 (**a**, **b**, **m**), TF 3-1 (**c**), TF 3-4 (**d**, **f**), TF 3-6 (**e**), F 11 (**g**), TF 8-1 (**h**), FT 3 (**i**, **j**, **l**), and TF 14 (**k**)

taxon has its possible first appearance in the latest early Maastrichtian, or is completely restricted to the upper Maastrichtian (according to Robles-Salcedo et al. 2018). Other typical Maastrichtian taxa include *Loftusia*, *Gyroconulina*, and *Omphalocyclus* (e.g., Schlagintweit et al. 2016a).

Table 2 Dasycladales inventory of the Tarbur Formation of the Rod-Abad, Mandegan, and Naghan sections

Taxa section	Rod-Abad	Mandegan	Naghan
Clypeina sp.		X	X
Cymopolia eochoristosporica Elliott	X	–	X
Cymopolia tibetica Morellet & Morellet	X	–	–
Dissocladella compressa Rashidi & Schlagintweit	X	X	X
Pseudocymopolia anadyomenea (Elliott)	–	X	X
Salpingoporella pasmanica Radoičić	–	X	X
Suppiluliumaella tarburensis Rashidi & Schlagintweit	–	X	X
Thyrsoporella longa Radoičić	X	–	–
Trinocladus tripolitanus Raineri	X	X	–
Zittelina? *arumaensis* (Okla)		X	X

Conclusive remarks

The description of the new dasycladale *Dissocladella compressa* contributes to the improving knowledge on the microflora of the Tarbur Formation of Iran. It is the first record of the genus from the Maastrichtian. The total range of *Dissocladella* is Upper Triassic (Sokač and Grgasović 1995) to Lutetian (Barattolo 2002). Ongoing studies evidence a greater diversity of larger benthic foraminifera than dasycladaleans. Both may show typical associations. In the case of *Dissocladella compressa*, these are *Omphalocyclus* and *Loftusia* that in the Iranian literature classically define a biozone characteristic for the lower part of the Tarbur Formation (James and Wynd 1965). The late Maastrichtian Rod-Abad section represents another locality lacking Campanian parts of the Tarbur Formation that are so far not proven by hard facts (see Discussion in Schlagintweit et al. (2016a, 2016b, 2016c)).

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