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Algae (Dasycladales) from the Upper Triassic Nayband Formation (northeast Iran)

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Abstract

Dasycladales are relatively abundant in the bedded limestones of the Bidestan and Howz-e Khan members of the Late Triassic Nayband Formation in central Iran. In a locality south of the town of Naybandan (northwest of Dig-e Rostam), several Rhaetian dasycladacean algae were found in thin sections. The following taxa are described: *Diplopora phanerospora* Pia, *Naybandoporella rhaetica* nov. gen. nov. sp., *Naybandoporella* cf. *rhaetica*. The species *Probolocuspis sarmeikensis* Senowbari-Daryan is replaced and attributed to the genus *Naybandoporella*. The microfacies characteristics of the limestones as well as the associated organisms are mentioned.

Keywords*: Algae, Dasycladales, Naybandoporella, Upper Triassic, Nayband Formation, Iran*

Introduction

The siliciclastic carbonate deposits of the Nayband Formation (Norian-Rhaetian) are outcropping in numerous localities in central Iran. This formation represents a widespread geological unit reaching thickness of locally up to 3000 m at the type locality and consists of up to five lithological members (Brönnimann *et al.*, 1971, Fürsich *et al.*, 2005). Within two of them (Bidestan and Kowz-e Khan members) invertebrate reefs or reefal carbonates are imbedded. The youngest reef-bearing member (Kowz-e Khan member) is represented by mainly carbonate beds with reef structures dominated by corals and sponges. The sponge fauna of the Nayband formation and few other fossils were described by Senowbari-Daryan (2005a, b) and Rashidi & Senowbari-Daryan (2011, further references therein).

Red algae occur in the reef structures imbedded within the Nayband formation and some of them were described from a locality north of Esfahan by Senowbari-Daryan *et al.* (2008). Green algae (dasycladales) were found only sporadically in reef carbonates, but instead they occur abundantly in some bedded limestones of the Bidestan and Kowz-e Khan members. Some dasycladales of the Nayband Formation have already been described by Fenninger (1969), Senowbari-Daryan & Hamedani (2000), and Senowbari-Daryan *et al.* (2011).

Dasycladales are abundant in some thin sections coming from carbonate beds of the Howz-e Khan member at the type locality of the Nayband Formation. The samples of investigated thin sections were collected 1996 from the well bedded carbonates between the localities 1 and 3 in Senowbari-Daryan *et al.* (2011: fig. 1). The locality can be reached only by foot or motorcycle.

Some of the taxa, illustrated only (without description) in this study were already described in detail by Senowbari-Daryan *et al.* (2011).

Depository: The documented thin sections are deposited in the Department of Palaeoenvironment, University of Erlangen-Nürnberg, labelled with "BSD/Iran/Algae".

Systematic Palaeontology

Division Chlorophycophyta Papenfuss, 1955
Class Chlorophyceae Kützing, 1843
Order Dasycladales Pascher, 1931
Family ?Triploporellaceae (Pia, 1920)
Genus *Naybandoporella* nov. gen.

Derivatio nominis: Named after the majestic Mt. Nayband (Iran and Kuh-e Nayband), located northwest of the type locality of the Nayband Formation.

Diagnosis: Cylindrical and straight thallus with possibly euspondyl (aspondyl?) arrangement of the laterals. The laterals are narrowing to the periphery of the thallus (trichophore). Around the axial stem is smooth, caused by a thin and perforated calcareous sheath. The thickness of the thallus is about the diameter of the axial stem.

Type species: *Naybandoporella rhaetica* nov. sp.

Further species: *Naybandoporella sarmeikensis* (=

Probolocupsis sarmeikensis Senowbari-Daryan 2014).

Remarks: *Naybandoporella* is similar to the genus *Probolocuspis* Brönnimann, Zaninetti, Moshtaghian & Huber (1971), whose diagnosis was emended by Senowbari-Daryan & Majidifard (2003: 108). The preservation of both genera is usually very poor and therefore the characteristics of the algae are not well recognisable. *Probolocuspis* differs, howewer, from *Naybandoporella* by the arrangement of individual laterals and the not calcified spaces between them causing the disintegration of the laterals into single "tooth-like bifide" or "trifide" (Brönnimann et al. 1971, compare Senowbari-Daryan & Majidifard 2003: text-figs. 5-6, pl. 20, fig. 6). In addition, *Naybandoporella* differs from *Probolocuspis* by the thin wall around the axial cavity.

Senowbari-Daryan (2014) described a dasycladalean alga from the Norian-Rhaetian reef carbonates of Argolis Peninsula, Greece as *Probolocuspis sarmeikensis*, which is replaced and attributed to *Naybandoporella* in this paper.

Naybandoporella rhaetica nov. sp.
(Pl. 1, Fig. 1-17, Pl. 3, Fig., 5, 9)

2005 Dasycladacean alga gen. et sp. indet.- Fürsich *et al.*, pl. 10, figs. 6, 9.

2011 Dasycladacean alga gen. et sp. indet.- Senowbari-Daryan et al., p. 513, fig. 11B, I.

Derivation nominis: Named from the Rhaetian stage, corresponding the stratigraphic age of the alga.

Holotype: The cross section in Pl. 1, Fig. 3 is designated as holotype. Almost all specimens are cut in cross sections and the oblique to longitudinal sections don't show the relevant characteristics of the alga (e. g. euspondyl or aspondyl?).

Locus typicus: Bedded Nayband Formation, about 10 km south of the town of Naybandan (locality situated between the localities 1 and 3 presented in Senowbari-Daryan *et al.*, 2011).

Stratum typicum: Rhaetian, Howz-e Kahn member of the Nayband formation.

Diagnosis: Cylindrical and straight thallus with possibly euspondyl (aspondyl?) arrangement of the laterals. The laterals are narrowing to the periphery of the thallus (trichophore). The individual laterals don't exit like spines on the thallus surface as in *N.* cf. *rhaetica*. Around the axial stem is smooth, caused by clearly recognisable thin and perforated wall around it. The thickness of the thallus wall is about the diameter of the axial stem.

Material: Numerous specimens in six thin sections.

Description: Unfortunately almost all specimens of this alga are cut in cross sections. Some sections, which are cut longitudinal or oblique don't show more characteristics of the alga as the cross sections. The majority of the thalli isn't well preserved and usually shows a micritic coating ("micritic envelope"). The thallus reaches a diameter (D) between 1.6 mm and 2.2 mm, the diameter of the central axis (d) is between 0.6 mm and 1.4 mm. Characteristic for the alga are the narrow and long laterals, decreasing toward the distal end (trichophore). The arrangement of the laterals could not be surely ascertained, but the specimens illustrated in Pl. 1, Fig. 12 and in Pl. 3, Fig. 9 shows the laterals arranged in rows (euspondyl). A further characteristic of the alga is the thin wall around the axial cavity, which is perforated by the passages of the laterals. Specimens cut in longitudinal or oblique sections show the oblique arrangement of the laterals to the axial cavity (Pl. 1, Figs. 12-13, 15).

The specimen cut in cross section and designated as holotype (Pl. 1, Fig. 3) is exhibiting - at least in half part - clearly the thin wall around the axial cavity and the trichophore laterals.

Remarks: Senowbari-Daryan *et al.* (2011) illustrated two broken and not well preserved specimens of this alga as "Dasycladales gen. et sp. indet 2". The authors compared this alga with the genus *Physoporella*, whose representatives are known from Permian and Middle Triassic, particularly with the Norian-Rhaetian species *Ph. jomaensis* Flügel & Mu (1982) from Tibet, and with *Ph. zamparelliae* Parente & Climaco (1999) from southern Italy, but they noted that "most probably the Iranian species is a new taxon". The numerous and well preserved specimens in the investigated thin sections confirm this assumption.

Naybandoporella cf. *rhaetica*
(Pl. 2, Figs. 1-12)

2011 *Clypeina*? sp.- Senowbari-Daryan *et al.*, fig. 11K.

Material: Numerous specimens in thin sections.

Description: Cylindrical and straight thallus with possibly euspondyl (aspondyl?) arrangement of the laterals. The laterals seem to be narrowing to the periphery of the thallus (trichophore). The protruded extensions of laterals appear spine-like on the thallus surface. Around the axial stem is smooth caused by not well developed thin sheath.

The thallus is usually recrystallised.

Unfortunately all specimens of this alga are strongly recrystallized, therefore the characteristics of the alga can´t be recognized very well. The diameter of the thallus (D) varies between 1.2 mm and 2.2 mm, the axial cavity (d) between 0.4 mm and 1.1 mm. The thallus and the axial cavity are circular in cross sections. Most characteristic of the alga is the spinose surface of the thallus protruded by the extended laterals. Sections through such "spines" appear as pore plates with a central point (Pl. 2, Figs. 1, 4, 6, 11, Pl. 3, Fig. 2). Each spine reflects a lateral with rounded calcified wall (Pl. 2, Figs. 4, 11). The diameter of the individual spines is about 0.1 mm. The longitudinal section in Pl. 2, Fig. 9 shows the bending arrangement of the laterals into the axial cavity. Based on the indistinct thin sheath around the axial cavity it is smoothly rounded (Pl. 1, Figs. 1-2, 7). Laterals pass through the pores of the thin wall.

Discussion: Because of the recrystallisation of all thalli the ascertainment of the character and arrangement of the laterals is not possible.

A similar section like the cross section of *N.* cf. *rhaetica* is illustrated by Nittel (2006) from the Steinalm limestone (Middle Triassic) of the Northern Calcareous Alps, Austria and determined as bryozoa. Most probably it is a section of the genus *Probolocuspis*, possibly *P. aculeata* described in Nittel (2006), too.

Bodrogi *et al.* (1993) illustrated a similar section like the cross section of *N.* cf. *rhaetica* from the Lower Cretaceous of Hungary, which was named as *Clypeina*.

Senowbari-Daryan (2014) described from the Norian-Rhaetian reef carbonates of the Argolis Peninsula, Greece a dasycladalean alga as ~~a~~ *Probolocuspis sarmeikensis* with mainly recrystallised thalli. This alga and *Naybandoporella* cf. *rhaetica* show the recrystallisation as similar or identical diagenesis. Also the passages of the laterals on the thallus surfaces of both algae appear spinose. Sections through the spinose laterals appear as pore plates as illustrated in Pl. 2, Fig. 4. *Probolocuspis sarmeikensis* differs, however, from *Naybandoporella* cf. *rhaetica* distinctly by the wide axial cavity of 0.25 mm - 0.5 mm diameter in the first species and possibly by the lack of the thin sheath around the axial cavity. *Probolocuspis sarmeikensis* is replaced and attributed to the genus *Naybandoporella* in this paper.

Naybandoporella cf. *rhaetica* differs from *Naybandoporella rhaetica* nov. sp. mainly by the spinose surface of the thallus and by the weakly development of the thin wall around the axial cavity. The dimensions of both algae are almost identical.

Family Diploporaceae (Pia 1920) Deloffre, 1988
Genus *Diplopora* Schafhäutl 1863
Diplopora phanerospora Pia, 1920
(Pl. 3, Fig. 8)

1920 *Diplopora phanerospora* n. sp.- Pia, p. 59, pl. 4, figs. 1-10.
1930 *Diplopora phanerospora* Pia.- Pia, p. 178, text-fig. 1b, l. LXIII (4), figs. 10-12. 10-12.
1952 *Diplopora phanerospora* Pia.- Endo, p. 142, pl. 12, fig. 2.
1967 *Diplopora phanerospora* Pia.- Ott, pl. 12, figs. 1-3.
1980 *Diplopora phanerospora* Pia.- Senowbari-Daryan, p. 64, pl. 13, figs. 6. 8.
2004 *Diplopora phanerospora* Pia.- Flügel, p. 432, pl. 59, fig. 2.
2005 *Diplopora phanerospora* Pia.- Fürsich et al., pl. 10, fig. 7.
2010 *Diplopora phanerospora* Pia.- Flügel, p. 432, pl. 59. fig. 2.

Material: Only one specimen.

Description: The externally annulated thallus of *D. phanerospora* is internally composed of several "chamber-like" segment corresponding to the external annulations (Pl. 3, Fig. 8). The single specimen in the investigated thin sections is about 8 mm long with three complete segments of about 1.5 mm height and a maximum diameter of 2 mm. The reproductive organs (sporangia or gametangia) are visible in three segments and arranged in chain-like circles running parallel to the segment or thallus walls. The thallus wall is thin (about 0.2 mm) and pierced by numerous pores.

Remarks: *Diplopora phanerospora* Pia seems to be an index fossil of the Rhaetian stage. Ott (1972) assigned the stratigraphic range of this alga as Upper-Norian-Rhaetian. According to Pia (1920: 59) the stratigraphic age of the first described occurrence of *D. phanerospora* is uncertain.

Ott (1967) and Senowbari-Daryan (1980) described this alga from the Rhaetian of the Northern Calcareous Alps. The specimen of Flügel (2004) is also from the Rhaetian Zlambach beds of Bavarian Alps. *Diplopora phanerospora* Pia is a rare alga in the Upper Triassic of Iran.

Plate 1

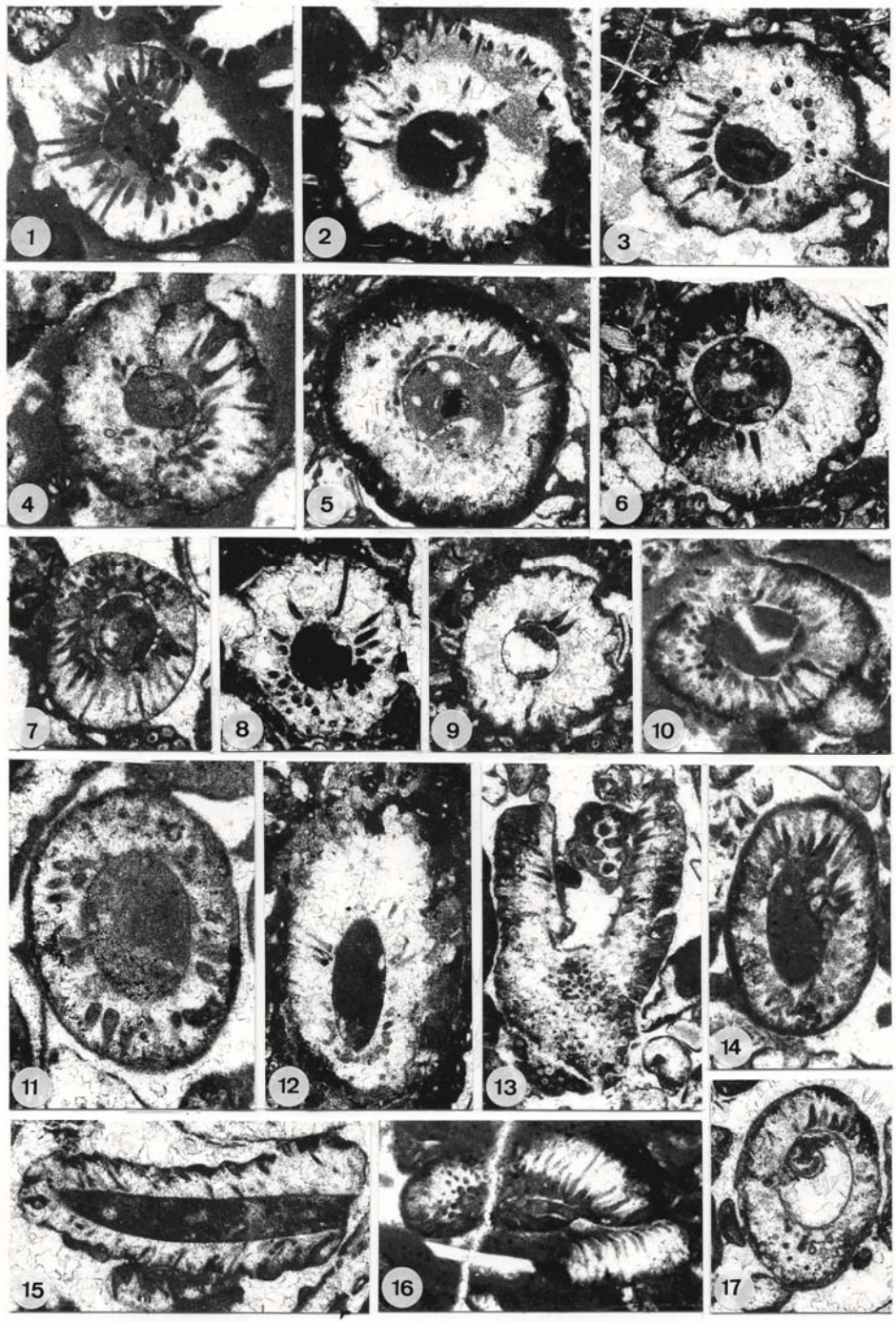

Plate 1. Figs. 1-17: *Naybandoporella rhaetica* nov. gen. nov. sp. from the bedded limestones of the Upper Triassic (Rhaetian) Howz-e Khan member south of the town Naybandan, northeast Iran. Fig. 1: Cross to obliqe section exhibiting the circular axial cavity or central axis (stem) surrounded by a thin and perforated wall. Ho1, x20. Fig. 2: The cross section of a poorly preserved specimen shows only few laterals. Ho1, x20. Fig. 3: Holotype. The cross section exhibits distinctly the thin wall at the base of the laterals around the axial stem. Ho2, x20. Fig. 4: Cross section exhibiting the thin wall around the axial stem and the laterals. Some laterals seem to be branched at the base (proximal) like Fig. 1. Ho1, x20. Fig. 5: Cross section. Ho6, x20. Fig. 6: Cross section exhibiting similar characteristics of the thallus like Fig. 5. Ho6, x20. Fig. 7-10: Cross sections exhibiting similar characteristics of the thalli. Fig. 7: Ho1, x20; Fig. 8: Ho2, x20; Fig. 9, Ho, x20; Fig. 10: Ho1, x20. Fig. 11: Oblique cross section. Ho3, x20. Fig. 12: Oblique section of a poorly preserved specimen. The row of laterals (at the lower part of the thallus) points to the euspondyl arrangement of the laterals. Ho2, x20. Fig. 13: The longitudinal section of a broken specimen shows the oblique arrangement of the laterals to the central cavity. Ho3, x20. Fig. 14: Oblique section. Ho3, x20. Fig. 15:

Longitudinal section exhibiting numerous laterals arranged obliquely to the axial cavity. Ho3, x20. Fig. 16: The oblique longitudinal section of a poorly preserved specimen exhibits clearly the thin wall around the axial cavity. Ho1, x20. Fig. 17: Similar section like Fig. 14. Ho6, x20.

Plate 2

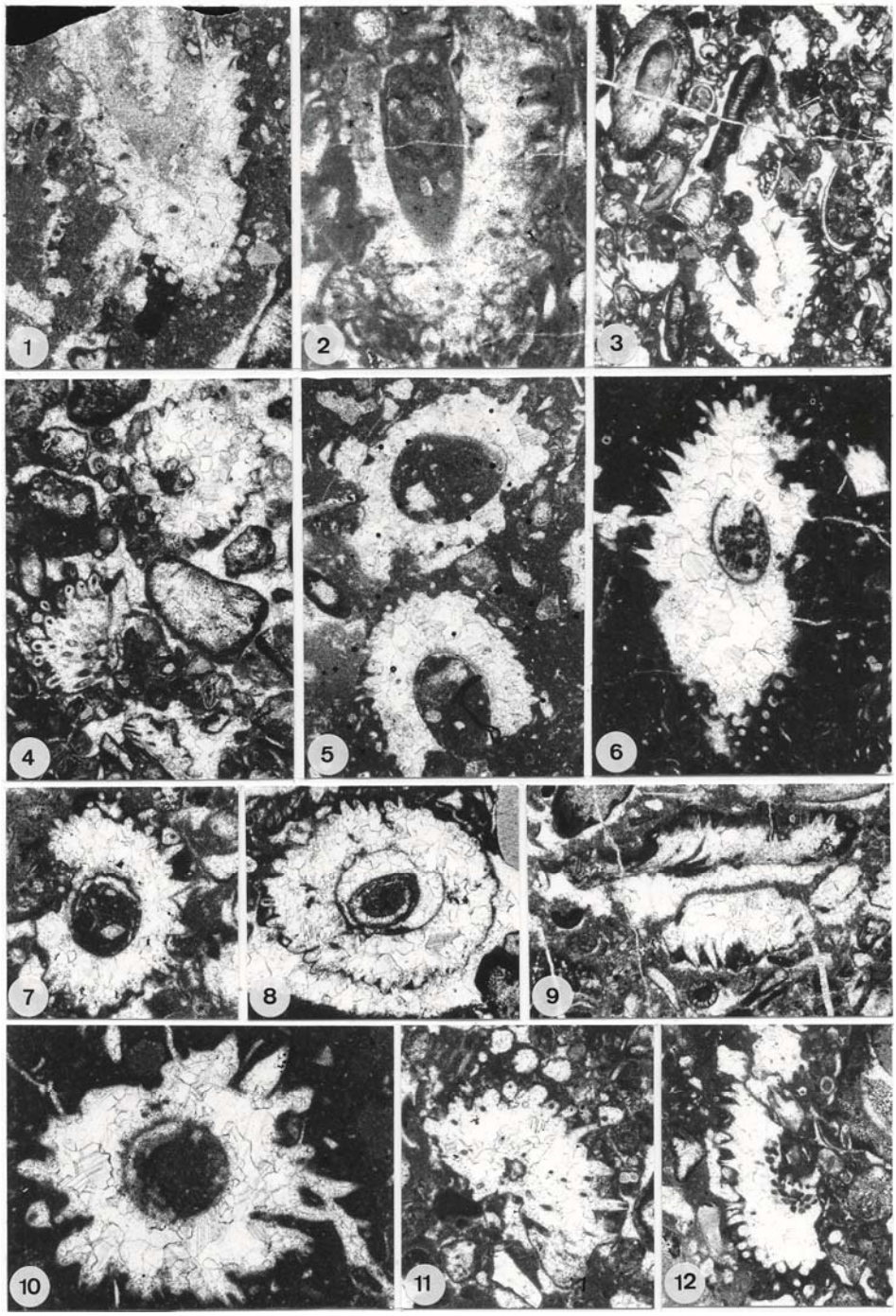

Plate 2. Figs. 1-12: *Naybandoporella* cf. *rhaetica* from the bedded limestones of the Upper Triassic (Rhaetian) Howz-e Khan member south of the town Naybandan, northeast Iran. Fig. 1: Oblique-longitudinal section through a broken and recrytallised specimen exhibiting the ends of the laterals as the base, appearing as small circles. HO6, x20. Fig. 2: The oblique longitudinal section shows the thin and perforated wall around the axial cavity. The ends of the laterals are partly visible. Ho2, x20. Fig. 3: Section through a broken and strongly recrystallised specimen. The ends of the laterals are well visible. Ho6, x10. Fig. 4: Cross section of a specimen with a section plane through the end of laterals appearing as small pore plate in a broken specimen. Ho2, x16. Fig. 5: Sections through two recrystallised specimens. The thin wall around the axial cavity is partly recognisable in one section. Ho2, x20. Fig. 6: Oblique section of a strongly recrystallised

specimen exhibiting the ends of the laterals as spines and as points (below). Ho6, x16. Fig. 7: Cross section. The thin wall around the axial cavity is partly recognisable. HO6, x16. Fig. 8: Similar like Fig. 7. Ho2, x16. Fig. 9: Longitudinal section exhibiting the ends and few distal parts of the laterals. Ho2, x16. Fig. 10: Cross section. Thin section regrettably lost, x16. Fig. 11: Cross section (possibly from the base of the thallus, because of the narrow axial cavity) of a broken specimen exhibiting the end of laterals. Ho6, x16. Fig. 12: Section similar to Fig. 3. Ho2, x16.

Plate 3

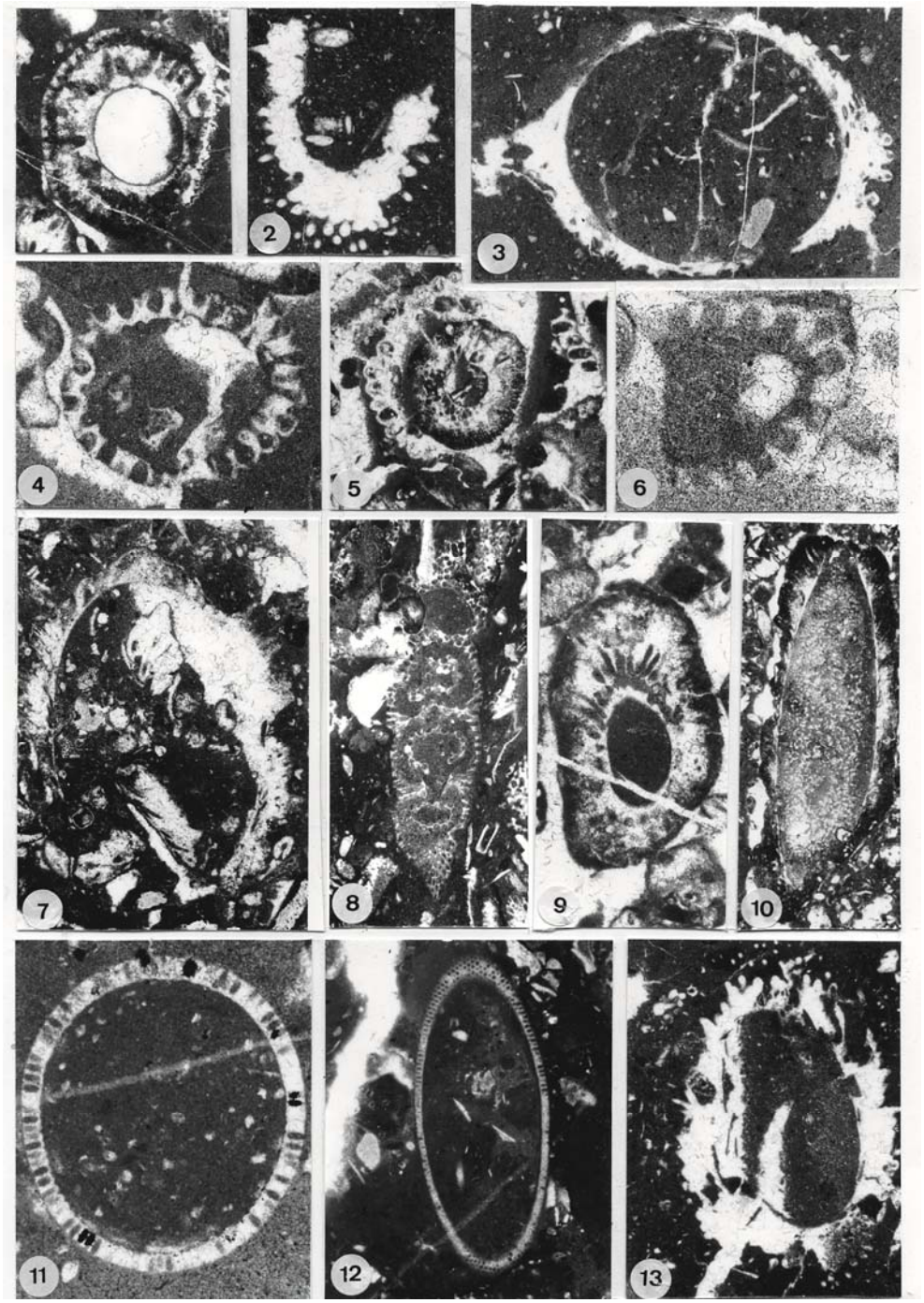

Plate 3. Dasycladalean algae from the bedded limestones of the Upper Triassic (Rhaetian) Howz-e Khan member south of the town Naybandan, northeast Iran. Fig. 1: Dasycladales alga gen. et sp. indet. 1. Cross section exhibiting the laterals, which are distally and proximally multi-branched. Ho1, x20. Fig. 2: *Naybandoporella* cf. *rhaetica*. Oblique-longitudinal section through a recrystallised specimen exhibiting the peaks of the outer laterals appearing as white points. Thin section regrettably lost, x16. Fig. 3: Dasycladales gen. et sp. indet. 2. Oblique cross section exhibiting the wide axial canal and the thin thallus wall of the specimen. The distal ends of some laterals are visible as

spines on the right of the thallus. The thick wall on the right and on the left is an effect of the oblique cross section. Some small and pore-like cavities are arranged parallel to the axial cavity (compare also Fig. 7). Ho2, x16. Figs. 4-6: *Griphoporella curvata* (Gümbel). Fig. 4: Cross section exhibiting the wide axial cavity and the thin wall with numerous laterals. Ho1, x30. Fig. 5: Cross section through a broken specimen. In the Griphoporella is a specimen of *Naybandoporella rhaetica* nov. sp. included. Ho2, x16. Fig. 6: Longitudinal section through a broken specimen. Ho1, x30. Fig. 7: Dasycladales gen. et sp. indet. 2. Oblique cross section of a specimen similar to this illustrated in Fig. 3. Ho2, x16. Fig. 8: *Diplopora phanerospora* Pia. The longitudinal section shows an externally annulated thallus with thin a wall. Several circles of spore chains are visible within the "chambers", corresponding to the external annulations. Ho, x8. Fig. 9: *Naybandoporella rhaetica* nov. sp. Oblique cross section exhibiting the arrangement of the laterals in rows indicating the euspondylity of the thallus. The thin wall around the axial cavity is well visible. Ho3, x20. Fig. 10: Dasycladales gen. et sp. indet. 2. Longitudinal section of the thin-walled thallus. The axial cavity shows a filling (spores of the alga?). Ho6, x10. Figs. 11-12: *Griphoporella lutensis* Senowbari-Daryan, Rashidi & Saberzadeh. Fig. 11: Cross section through the thin-walled thallus. AB, x30. Fig. 12: Oblique section. 96/31/22, x16. Fig. 13: Dasycladales gen. et sp. indet. 2. Oblique-cross section exhibiting the wide axial canal. Numerous wide and narrow pores (borings?) are cut within the thallus wall. The narrow pores are arranged parallel to the axial cavity. The distal ends of some laterals are cut, appearing as point (lowermost and topmost parts of the thallus cross section). 96/48, x12.

Only one specimen was found in the investigated thin sections. The determination of *Diplopora phanerosphora* from Japan by Endo (1952) with a stratigraphic age of Lower Permian is uncertain.

Dasycladales gen. et sp. indet. 1
(Pl. 3, Fig. 1)

Description: The single cross section of this alga with a diameter of about 1.5 mm exhibits a wide axial cavity with a relatively thick thallus wall. The laterals are branched dichotomously (V-shaped) around the central stem (first branching) and later multi-branched (second branching) at the distal end. After the second branching a thin and fine perforated wall arises. Because of insufficient material a detail description is not possible.

Dasycladales gen. et sp. indet. 2
(Pl. 3, Fig. 3, 7, 10, 13)

Description: With a thallus diameter of about 2.5 mm and wide axial cavity of about 2 mm this alga is one of the largest specimens in the investigated thin sections. Because of recrystallization it is not possible to recognize the character of individual laterals. The specimens in Pl. 3, Figs. 3 and 13 show (right in photo) the proximal ends of the laterals as points, which seem to be similar to *Naybandoporella* cf. *rhaetica* (Pl. 3, Fig. 3: right). The thallus wall exhibits some pore-like cavities running parallel to the axial cavity (Pl. 3, Figs. 3, 7, 13). The interpretation of these pores as borings or as remains of the laterals is uncertain.

Microfacies and organism association

The Howz-e Khan member as the youngest member of the Nayband formation (Brönnimann *et al.*, 1971, Fürsich *et al.*, 2005) represents the intercalation of well bedded limestones and shales with mainly coral-dominated reefs or reefal carbonates. The dasycladales-bearing carbonate beds are well medium bedded, dark coloured and about 50 cm in thickness. Investigated samples are classified as packstone to grainstone with abundant, but mostly fragmented dasycladalean algae. Other types of algae (e. g. solenoporaceans) occur very rare in the investigated thin sections. Remarkable is the abundant occurrence of "*Lithocodium*/*Bacinella*" consortium, which etches as bio-eroding the biogenic components (e. g. fragments of corals) and grew around these. Most of the biogenic components, including the dasycladales show a "micritic envelope" indicating a shallow water depositional environment. Some, usually recrystallized aulotortid foraminifers [(*Aulotortus tumidus* (Kristan-Tollmann), *Aulotortus* sp.) are associated organisms with the described green algae.

In addition to the above mentioned taxa the following dasycladaleans and problematic algae were described from the Nayband Formation from the same locality by Senowbari-Daryan (2011): *Chinianella carpatica* (Bystrický), *Griphoporella curvata* (Gümbel) (Pl. 3, Figs. 4-6), *Griphoporella lutensis* Senowbari-Daryan, Rashidi & Saberzadeh (Pl. 3, Figs. 11-12), and *Diplopora* cf. *D. interiecta* Fenninger. Problematic algae: *Thaumatoporella parvovesiculifera* (Raineri), "*Lithocodium aggregatum*" Elliott (= boring sponge *Entobia* Bronn, see Schlagintweit, 2011, Cherchi & Schroeder 2013), *Bacinella irregularis* Radoicic and an incertae sedis fossil as "Problematicum 1".

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