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New solenoporaceans from Upper Triassic (?Norian-Rhaetian) reef limestones in central Iran

Baba Senowbari-Daryan[1], Hossein Torabi[2] and Koorosh Rashidi[3]

[1] GeoZentrum Nordbayern, University of Erlagnen-Nürnberg, Loewenichstr. 28, D-91064 Erlangen, Germany; (basendar@pal.uni-erlangen.de)

[2] Department of Erath Sciences, University of Esfahan, Esfahan, Iran

[3] University of Payame-e Noor, Ardakan, Iran

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ABSTRACT

Two reef-building red algae of the family Solenoporaceae – Solenopora rectangulata n. sp. and Parachaetetes dizluensis *n. sp. – are described from a ?Norian-Rhaetian section of the Nayband Formation exposed south of the town of Bagherabad, northeast of Esfahan, central Iran. These algae build reef structures or patches up to 17 m thick, either on their own or in association with other reef-building organisms including sponges, corals, etc. Such solenoporacean reef structures have not been described before, either from Iran or elsewhere in the world. Morphologically, both algae are easily distinguished by the different sizes of their thalli and particularly by their branching pattern.*

Keywords: algae, *Solenopora*, *Parachaetetes*, Triassic, reef, Iran

1. INTRODUCTION

Upper Triassic (Norian-Rhaetian) deposits of the Nayband Formation are distributed over a large area in central and eastern Iran (SEYED-EMAMI, 1971, 2003). The type locality of the Nayband Formation crops out at the southern area of the Kuh-e Nayband (Nayband Mount), approximately 220 km south of the town of Tabas in northeastern Iran where it reaches a thickness of about 3000 m (FÜRSICH et al., 2005).

Reefs occur interbedded within the Nayband Formation and are usually biostromes, but small bioherms also occur (generally less than 50 m thick and less than 100 m laterally). The reefs are mainly sponge-coral or coral-sponge dominated. Other organisms are of minor importance (SENOWBARI-DARYAN, 1996, 2005a, 2005b).

Various groups of calcareous algae occur within the carbonate facies of the Nayband Formation. Solenoporaceans are usually found in reef facies while dasycladales occur mainly in bedded carbonates (SENOWBARI-DARYAN & HAMEDANI, 1999, 2000). Until now, in Iran and elsewhere in the world, solenoporaceans have only been found as minor components of reefs or reef-like structures and never as the main reef-building organism.

In an outcrop section through the Nayband Formation northeast of Esfahan (Figs. 1–2), as well as sponges and corals, two erect and multi-branched species of solenoporacean red algae are the main reef builders to have acted as bafflers to current-borne sediment grains. The two species can be distinguished in the field by the different size of their thalli (Pl. 2, Figs. a–b). The first species (Pl. 2, Fig. b: small arrows) is described as *Solenopora rectangulata* n. sp. and has smaller and multi-branched thalli, the branching angle being up to 90º and giving the appearance of a fir-tree (Pl. 3, Figs. a–b**).** The second species (Pl. 2, Fig. b: large arrows) has large and finger-like multi-branched thalli and is described as *Parachaetetes dizluensis* n. sp.

Holo- and paratypes of both species are deposited in the Forschungsinstitut Senckenberg, Frankfurt am Main. (Inventary – Nr. MB. 21123-21130; one rock piece and 7 thin sections).

2. LOCALITY AND SECTION

The outcrop of the Nayband Formation with the reef structures and solenoporaceans described in this paper is about 60 km northeast of Esfahan, south of the road from Esfahan to Ardestan (Fig. 1). The locality can be reached by car from Esfahan

Figure 1: Geographic position of the locality south of the town of Dizlu, northeast of Esfahan (modified from SENOWBARI-DARYAN & HAMEDANI, 2000).

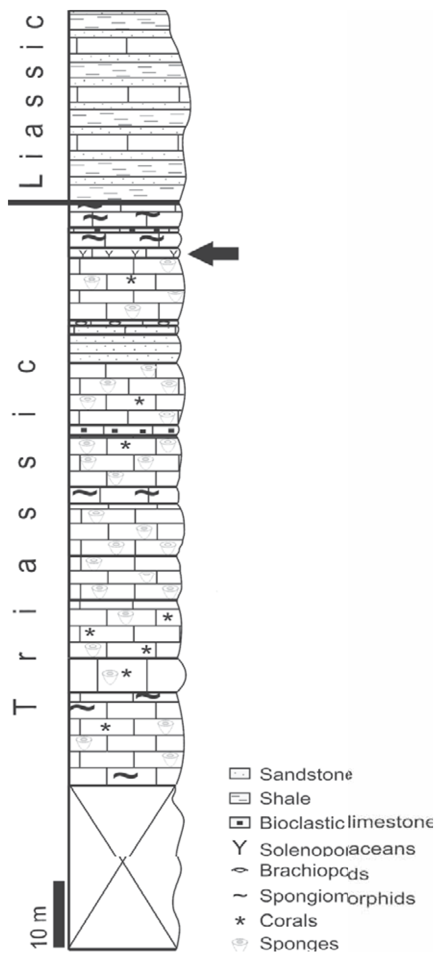


Figure 2: Columnar section of the Nayband Formation and overlying Lower Jurassic rocks through ridge '2' shown in Pl. 1, Fig. 2. The basal 26 m of the Nayband Formation is not exposed. It starts with sponge-dominated, thick bedded to massive limestones. Arrow indicates the solenoporacean horizon.

by taking the small side-road on the right after the town of Komschetsche. The locality is 7 km from the turn-off, at the base of the escarpment, on the left side of the road.

The stratigraphic section (Fig. 2) is well exposed in ridge "2" shown in Pl. 1, Figs. a–c. The Triassic Nayband Formation (about 130 m thick), forms the lower part of the section, and is overlain by Lower Jurassic beds and *Orbitolina*-bearing Cretaceous limestone (Barremian), the latter forming the main part of the escarpment (Pl. 1, Fig. 1). The lowermost part of the Nayband Formation, about 26 m thick, is concealed by a talus of reef boulders containing mainly small hypercalcified sponges and tabular spongiomorphids. Coral-bearing boulders are not abundant. The exposed Nayband Formation succession starts with about 5.5 m of sponge-coral-dominated reef limestone passing up into about 9 m of coral-sponge-dominated, bedded, reefal limestone. This unit is overlain by 7.5 m of bedded reefal limestone in which the dominant organisms are small sphinctozoan sponges. This in turn is overlain by a limestone bed 2.7 m thick containing mainly tabular spongiomorphids which passes up into thick-bedded and sponge-dominated reefal limestone about 8 m thick. Bioclastic Limestone, 1.5 m thick, overlies the spongimorphid bed. This unit is overlain by bedded, sponge-dominated, reefal limestone about 21 m thick which passes up into a 6 m thick sequence of shaley sandstone beds which become calcareous in the upper part. The sandstone beds are overlain by a 1 m thick bed containing small brachiopods, and this passes up into about 10 m of sponge-dominated, reef limestone. That is overlain by about a 1.5 m thick, solenoporacean-dominated bed with some sponges and then a 2.5 m thick unit of spongiomorphid beds. These last fossiliferous beds containing the spongimorphids are overlain by about 30 m of Lower Jurassic deposits comprising interbedded shales and sandstone without macrofossils.

The lower part of the Nayband Formation in ridge "1" (see Pl. 1, Figs. a–b) is not well exposed. The upper part of the section, however, does crop out and at the base of a sandstone unit the solenoporacean reefal build-ups reach a thickness of about 17 m.

3. SYSTEMATIC PALAEONTOLOGY

Phylum Rhodophycophyta PAPPENFUSS, 1946
Class Rhodophyceae RUPRECHT, 1851
Family Solenoporaceae PIA, 1920
Genus *Solenopora* DYBOWSKI, 1878

Remarks: According to RIDING (2004) the type species of *Solenopora (S. spongioides)* from the Ordovician is not a red alga but a chaetetid sponge. Therefore a careful revision of all species described as *Solenopora* is needed and a new generic name for the true algal solenoporaceans should be proposed. Meanwhile, the current generic name *Solenopora* is used here to describe the solenoporacean species from Iran.

The following terms: main stem, branches of first, second and third orders were used to describe the thallus of *S. rectangulata* in detail. These terms are shown in a thallus illustrated in Fig. 3.

***Solenopora rectangulata* n. sp.**

(Figs. 3–5; Pl. 2, Figs. a–b; Pl. 3, Figs. a–b; Pl. 4, Figs. a–c; Pl. 5, Figs. a–e; Pl. 6, Figs. a–e)

Derivatio nominis: *Rect* (Lat.) = rect, *angulus* (Lat.) = angle. Named for the rectangular branching pattern

Holotype: The individual thallus illustrated in Pl. 4, Fig. b/H is designated as the holotype (magnification from Pl. 4, Fig. a, and compare Fig. 4).

Paratypes: All specimens are illustrated in Pl. 3, Figs. a–b; Pl. 4, Figs. a–c; Pl. 5, Figs. a–e; Pl. 6, Figs. a–e.

Locus typicus: see Fig. 1.

Stratum typicum: Upper Triassic, most probably Rhaetian.

Diagnosis: Erect, slender and multi-branched, antler- or fir-tree-like thallus. Several branches may radiate outward from the same level on the main stem and when viewed from above the angle between the branches varies from 30 to 90 degrees. The net-like appearance of the thalli in side view can be recognized in the field and in thin-section, and results from lateral branches (i.e. branches from the side branches) tending to grow parallel to the main stem. Orientation of cells in the main stem and in the branches is different. No recognizable cross partitions.

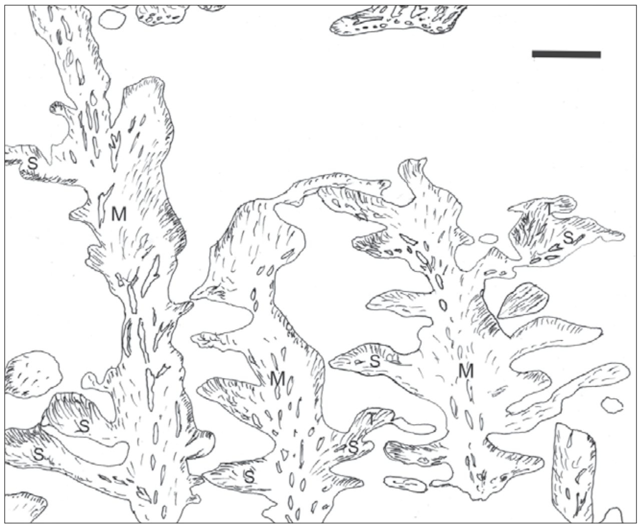


Figure 4: *Solenopora rectangulata* n. sp. Drawn from Pl. 4, Fig. b, this sketch shows the branching pattern of the alga and the large micrite-filled cavities within the axial part of the thallus, interpreted as borings or the result of diagenesis. Legend: **M**) main stem, **S**) branches of first order, **T**) branches of second order. Scale: 2 mm.

Material: In numerous rock samples and in thin-sections numbered 2/1, 2/2, 5, 6, 10, 11, 12, 13, 14/1, 14/2, and 16

Description: Colonies of erect and slender thalli of this gregarious species reach lengths of up to 10 cm with lateral extensions of 30 cm and more. Usually this species occurs alone (Pl. 3, Figs. a–b), but may also occur together with *Parachatetes dizluensis* n. sp. (Pl. 2, Figs. a–b). This alga builds communities occupying surfaces of several square metres. Even in the field this alga is easily distinguished from the

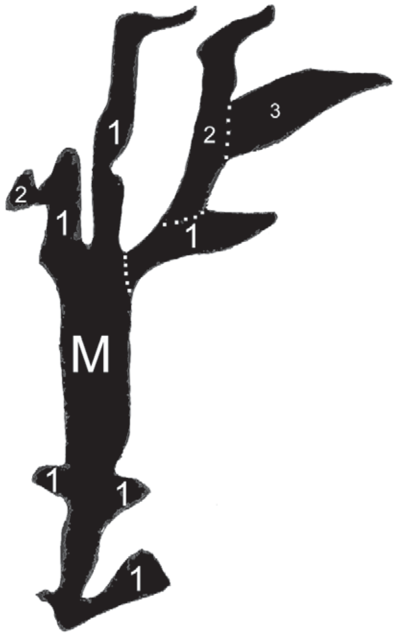


Figure 3: Terms, used to described the thallus (drawn from Plate 3, Fig. B: rectagle) of *Solenopora rectangulata* n. sp. in detail. Legend: **M**) main stem, **1**) branches of first order, **2**) branches of second order, **3**) branches of third order.

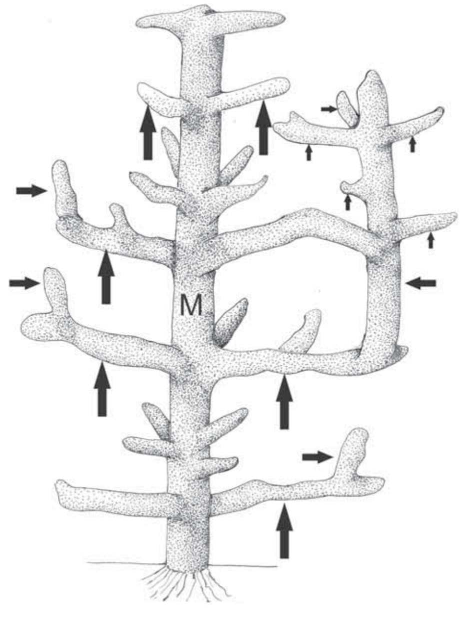


Figure 5: Reconstruction of *Solenopora rectangulata* n. sp. showing the branching pattern of the thalli approaching an angle of 90 degrees. Legend: **M**) main stem, **large arrows** – branches of first order, **small arrows** – branches of second order, **smallest arrows** – branches of third order. Schematic, not to scale.

PLATE 1

a Field overview of the locality. The top of the siliciclastic Nayband Formation at the base of the section is marked with a dark line. It extends laterally for approximately 1000 m and is overlain by Lower Jurassic deposits. The upper part of the escarpment is formed of *Orbitolina*-bearing limestones of Cretaceous (Barremian) age. Numbers 1 and 2 indicate the two ridges of reefal carbonates with solenoporaceans described in this paper.

b Closer view of the two ridges, shown in fig. a above. The white line shows the route of the sampled section illustrated in Fig. 2.

c Side view (from the north) of ridges 1 and 2 shown in figs. a–b above. Outcrops of the Nayband Formation in siliciclastic facies are shown in the foreground.

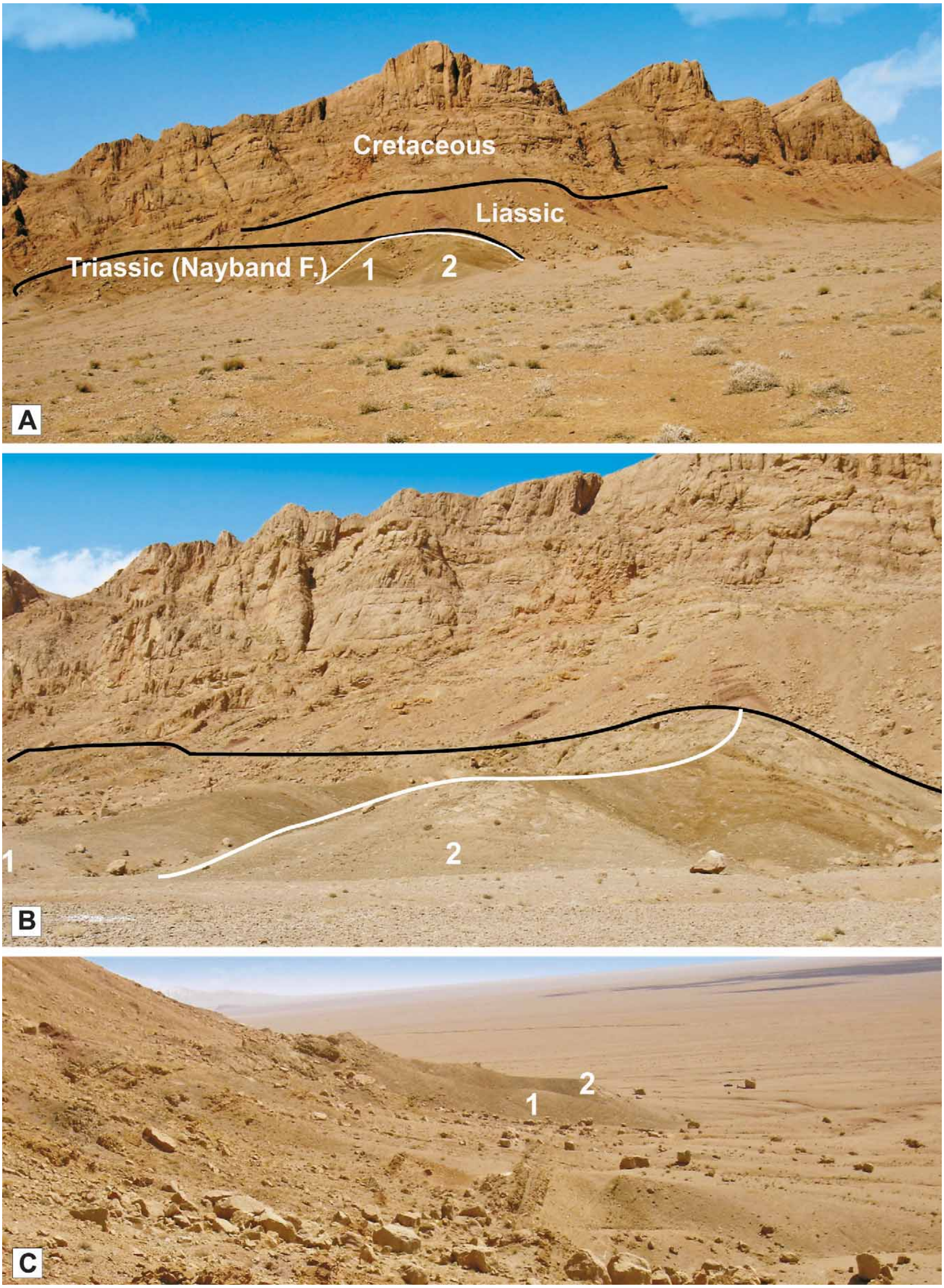

Cretaceous
Liassic
Triassic (Nayband F.)
1
2
A
1
2
B
1
2
C

PLATE 2

a Field photograph shows numerous large, multi-branched thalli of *Parachetetes dizluensis* n. sp. and small, net-like thalli of *Solenopora rectangulata* n. sp.

b Enlargement of part of Fig. a above (marked by the rectangle) showing *Parachaetetes dizluensis* n. sp. with large thalli (large arrows) and *Solenopora rectangulata* n. sp. with small and net-like thalli (small arrows).

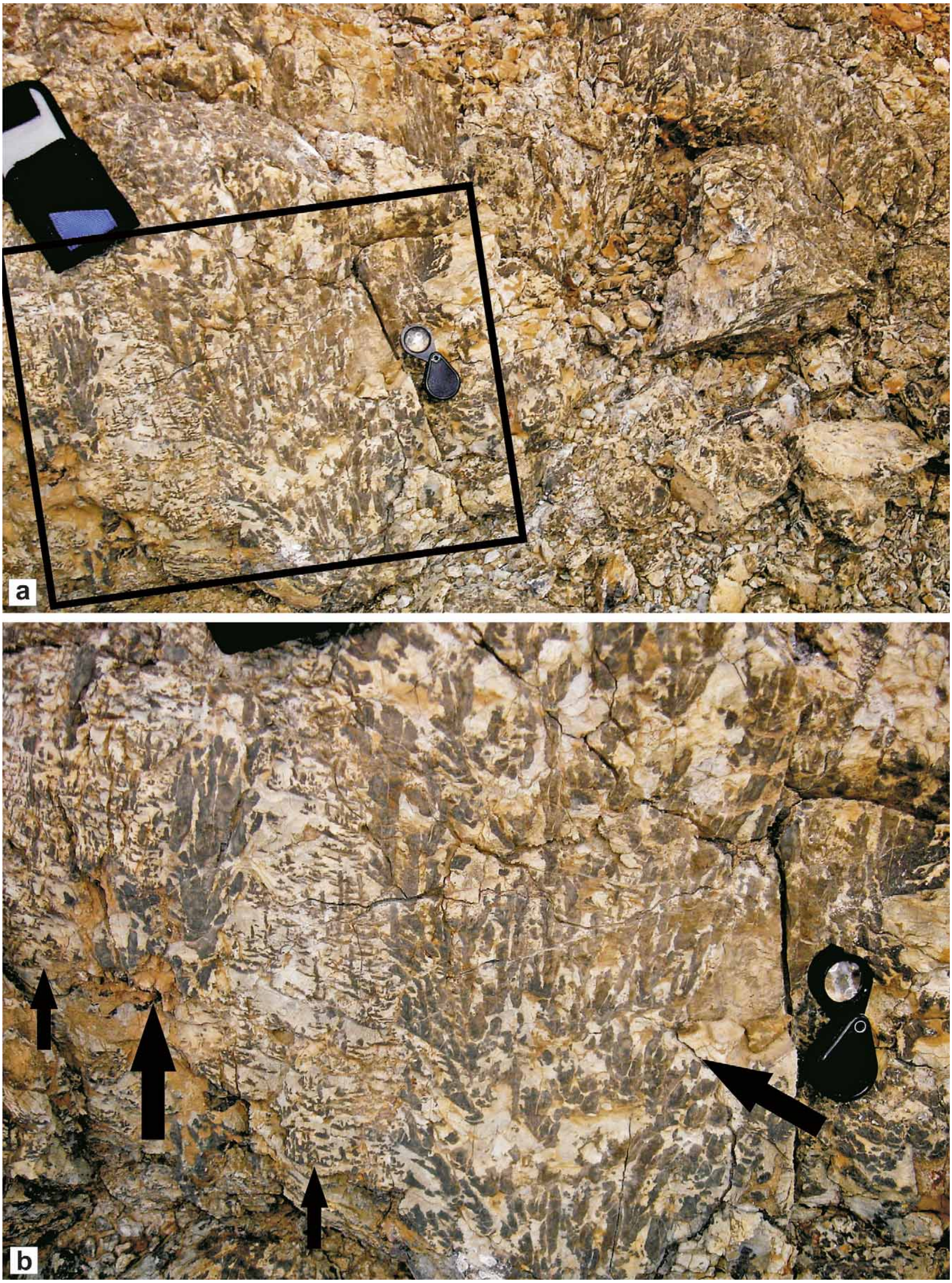

a
b

PLATE 3

a Field photograph shows numerous multi-branched, mostly antler-like thalli of *Solenopora rectangulata* n. sp.. The scale is shown by the lens at the bottom right-hand corner.

b Photograph of a specimen with numerous parallel-growing and antler-like thalli of *Solenopora rectangulata* n. sp. in their in situ position showing the branching nature of the thalli.

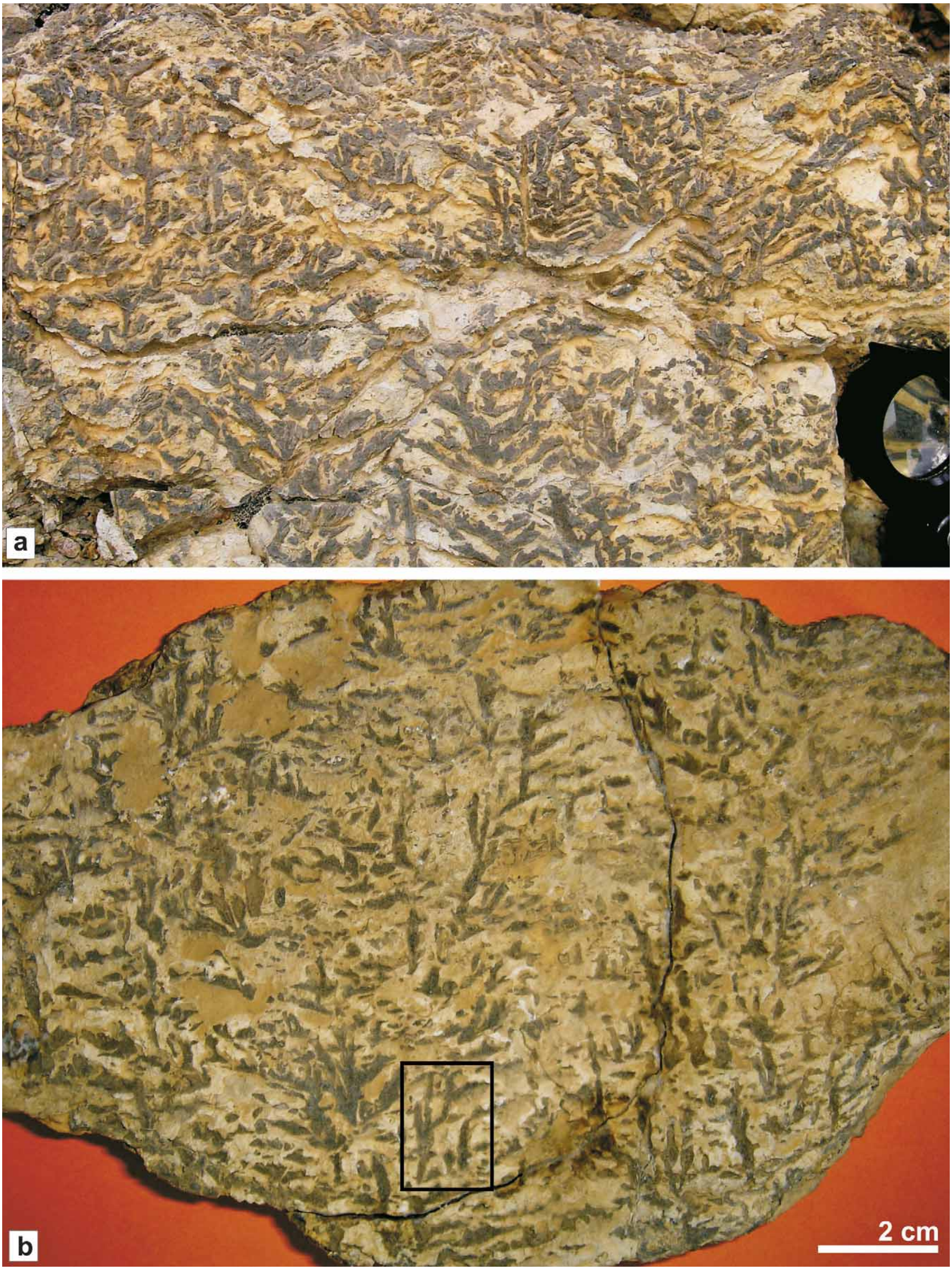

a
b
2 cm

Plate 4

Figs. a-c: *Solenopora rectangulata* n. sp.

a Thin-section photograph showing numerous branched and parallel-growing thalli with the almost constant diameter of the main stems. Several geopetal fabrics (large arrows) indicate the *in situ* position of the thalli. Small arrows indicate the branches of neighbouring thalli growing or fused together. For an enlargement of the holotype (H) and the part shown by the rectangle, see fig. b. Thin-section 6.

b Close-up from fig. a (rectangle) shows three multi-branched thalli. Arrows indicate the branches of neighbouring thalli growing together. Legend: H) holotype M) main stem, F) branches of first order, S) branches of second order.

c Section through a thallus with branches of first and second order. Legend: M) main stem, F) branches of first order, S) branches of second order. Thin section 2.

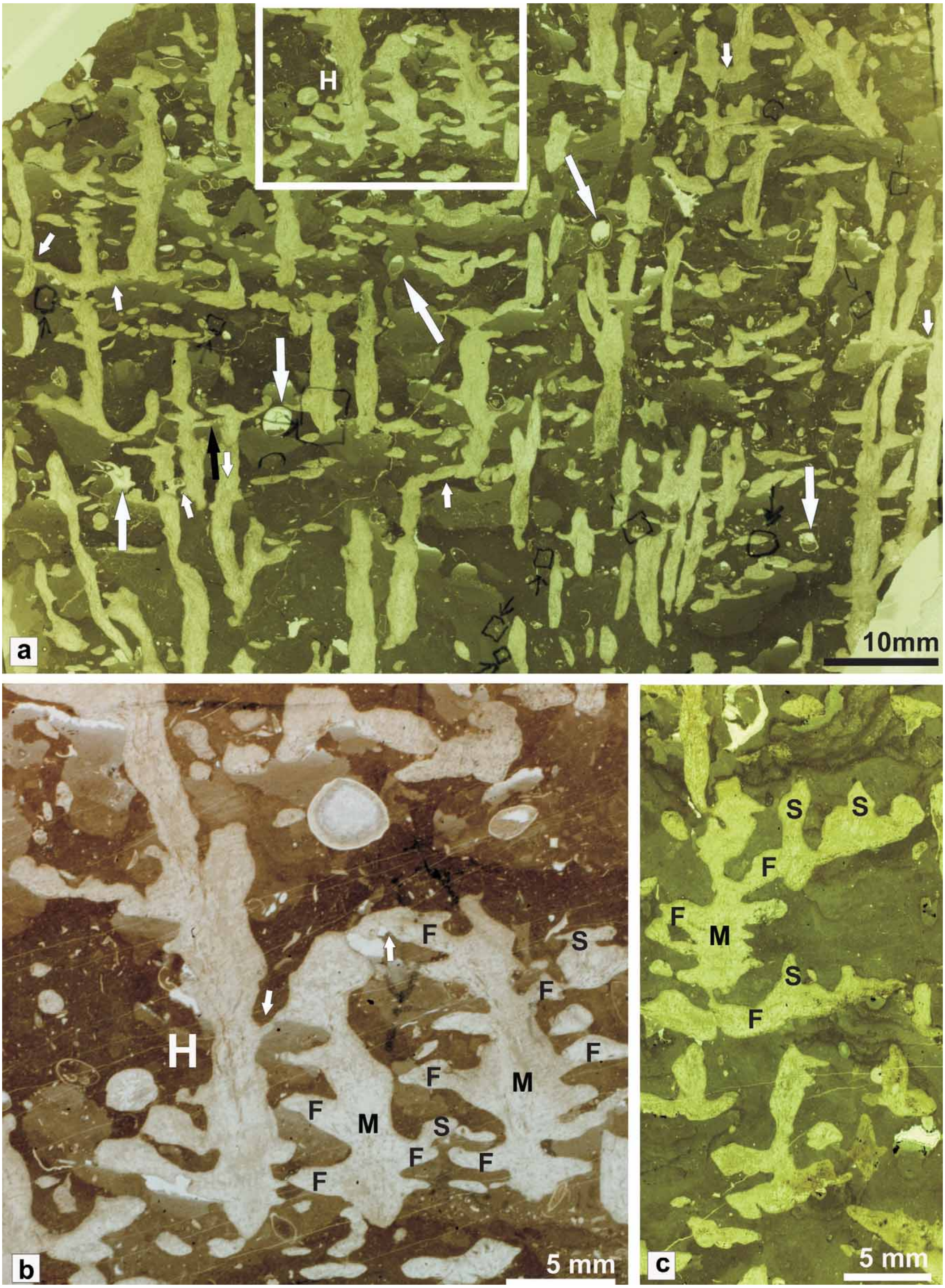

H
a
10mm
H
F
S
F
F
F
M
F
M
S
F
F
F
b
5 mm
S
S
F
F
M
S
F
c
5 mm

Plate 5

Figs. a–e: *Solenopora rectangulata* n. sp.

a Longitudinal section through numerous thalli growing parallel to each other. The branching angle varies from 30 to 90°, mostly from branching points on opposite sides of the main stem. Thin section 16.

b Longitudinal section through a multi-branched, antler-like thallus. Legend: M) main stem, F) branches of first order, S) branches of second order. Thin section 12.

c Longitudinal section through two thalli with branching angles approaching 90°. Numerous micrite-filled tube-like cavities in the axial part of the main stem run more or less parallel to the growth direction. These cavities may be interpreted as "filaments" of the hypothallus in halymedaceans. Because these tubes cut the cells and the concentric layers, they are interpreted as the result of boring by certain organisms or even as the result of diagenesis. The large arrow points to the cells in a lateral branch, bending upward and oriented almost parallel to the main stem. Geopetal fabric in a brachiopod shell indicates the *in situ* growth position of the alga. Thin section 6.

d Section through the branching point of a thallus showing the micrite-filled tubes (partly branched in the growth direction) in the axial part of the main stem and at the base of a branch. Thin section 6.

e Numerous micrite-filled tubes, interpreted as borings or result of diagnesis, are oriented irregularly within a thallus. Thin section 6.

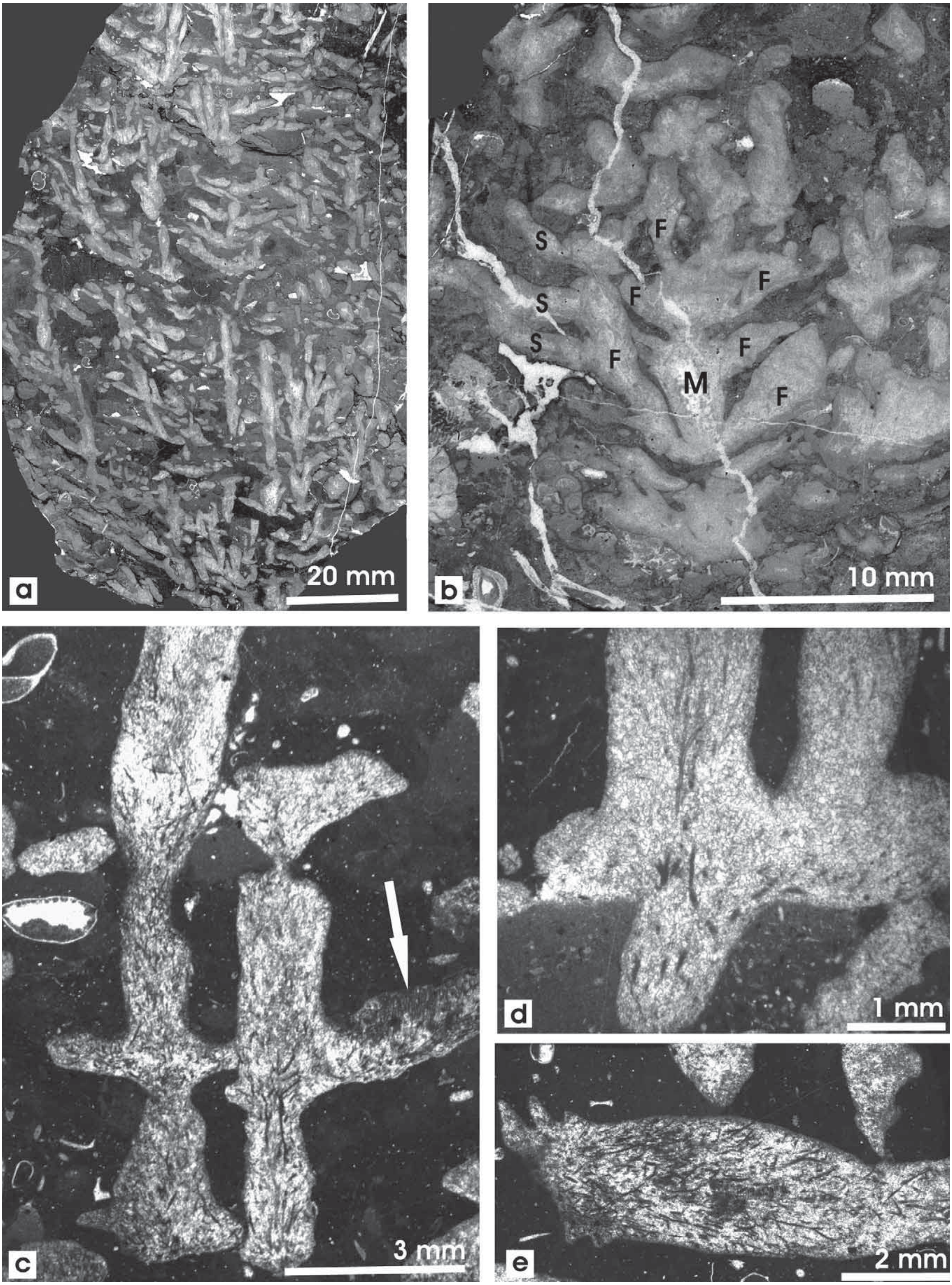

a
20 mm
b
10 mm
S
S
S
F
F
F
F
F
F
M
c
3 mm
d
1 mm
e
2 mm

Plate 6

Figs. a–e: *Solenopora rectangulata* n. sp. Scale in all figs. is 1 mm.

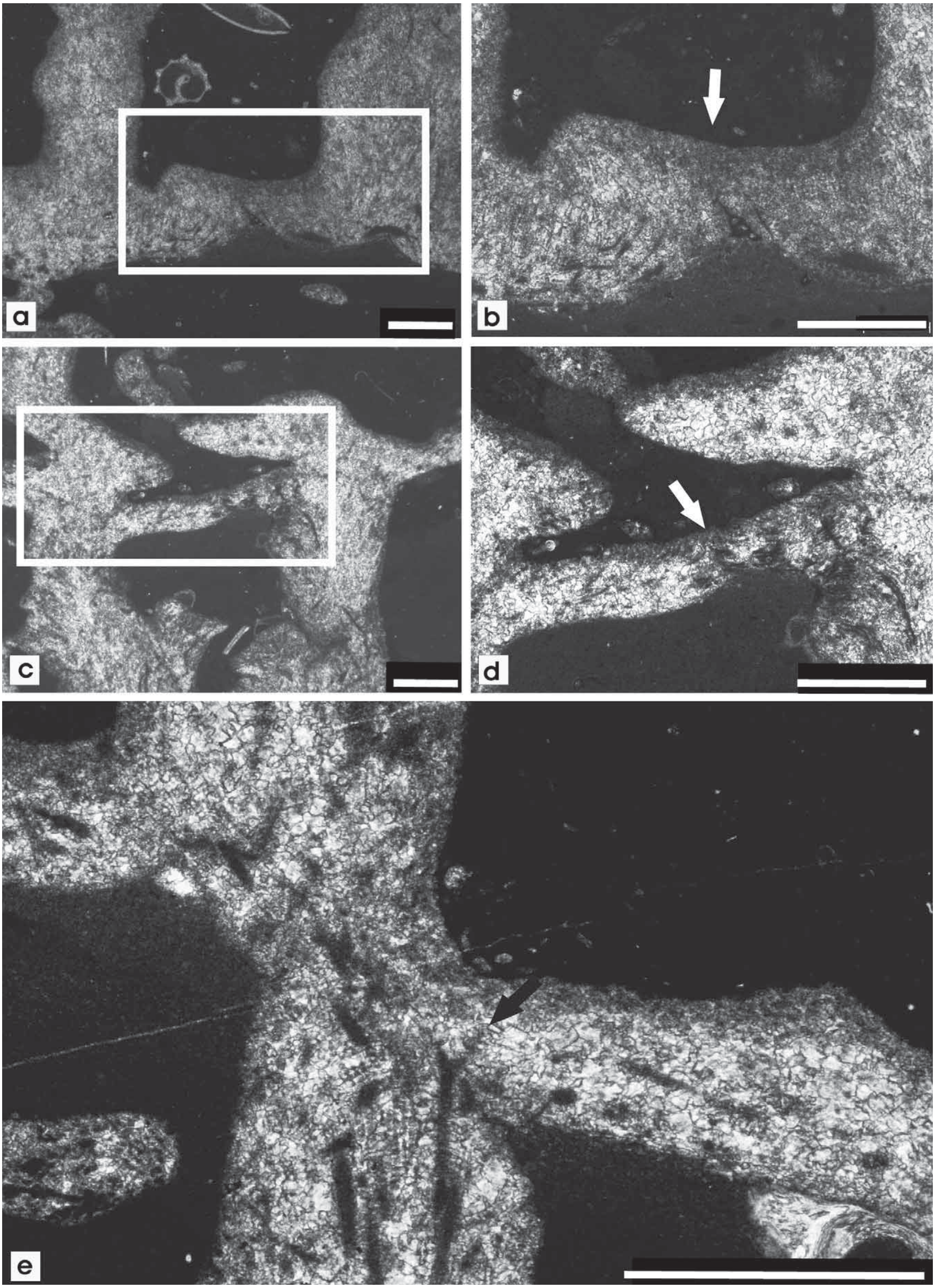
a Section through two main stems with first branches amalgamated together without a recognizable boundary. Micrite filled large tube-like structures are the result of borings or even diagenesis. Thin section 6.

b Close-up from fig. a (rectangle) shows the amalgamated area (arrow) without recognizable boundary.

c View similar to fig. a exhibiting two main stems with first branches amalgamated together without a recognizable boundary. Thin section 6.

d Arrow indicates the amalgamated area of two first-order branches.

e The first-order branches of a thallus (right side in photograph) penetrate into the main stem (left side in photograph) and are amalgamated with the stem without a recognizable boundary. Large micrite filled tube- or hose-like cavities – partly branched (arrow) – that are interpreted as the result of borings or diagenesis due to penetration of the growth bandings, thus destroying them. Thin section 6.


a
b
c
d
e

companion species *P. dizluensis* n. sp. by its small thalli and particularly by the net-like appearance when viewed from the side (Figs. 4–5; Pl. 3, Figs. a–b; Pl. 4, Figs. a–c; Pl. 5, Figs. a–c).

Individual thalli are more or less cylindrical and grow parallel to other individuals; the thallus diameter (diameter of main stem) does not increase during the growth stages (Pl. 4, Fig. a; Pl 5, Fig. b). Branches of the first and second orders (see Fig. 3) diverge from the main stem at varying distances and may radiate from one or all sides (Figs. 4–5; Pl. 3, Figs. a–b; Pl. 4, Figs. a–c; Pl. 5, Figs. a–c). By branching from a number of points on the main stem, the alga has the appearance in side-view of a fir-tree (Fig. 5). Some of the secondary branches taper towards their terminations as shown in Fig. 5. The tendency of secondary branches (i.e. branches from the side branches) to grow parallel to the main stem produces a characteristic net-like appearance when viewed laterally (Pl. 2, Figs. a–b; Pl. 4, Fig. a). Branches of neighbouring thalli may grow or fuse together, with or without recognizable boundaries (Pl. 4, Figs. 4a–b: small arrows; Pl. 6, Figs. a–e).

Individual thalli usually reach a diameter of 2 to 3 mm. The diameter of the main stem remains almost constant and does not increase during the growth stages. Hose- or tube-like, partly branched and micrite-filled cavities were observed in the main stems of several individuals (Fig. 4; Pl. 5, Figs. c–e; Pl. 6, Fig. e). These cavities are oriented more or less parallel or oblique and are usually branched upwards. They could be interpreted as "filaments" of a hypothallus in halymedacean algae. The maximum diameter of these tube-like cavities is 0.07 mm but as they approach the periphery of the thallus they decrease to about 0.02 mm, i.e. approximately the cell diameter of the alga. We interpret these tube-like cavities as secondary products (the result of boring or diagenesis,).

Pronounced recrystallization makes recognition of cell details impossible in most specimens, but in well preserved thalli a weak annual growth banding is recognizable. The larger tube-like cavities pass through the cells and appear to destroy those (Pl. 6, Fig. e).

The holotype (Pl. 4, Fig. b/H) is a multi-branched specimen reaching a height of 22 mm. It exhibits all the characteristics of the alga, in particular its branching pattern and antler- or fir-tree-like appearance. Fig. 5 shows a reconstruction of *S. rectangulata* n. sp..

Discussion: The larger (about 0.07 mm diameter) hose- or tube-like and micrite-filled cavities in the axial region of the main stems of *Solenopora rectangulata* n. sp. and at the base of the branches might be interpreted as borings of micro-organisms, or else as cells of thallus differentiation in this alga, or even as “filaments” of a hypothallus in halymedaceans. If the latter, this feature would justify the assignment of this alga to the halymedaceans.

Several features would support the interpretation of these tube-like cavities as cells or “filaments” of halymedaceans: **a**) the micrite-filled tubes are concentrated in the axial region of the main stem and in the base of the branches and are rare in the peripheral part of the main stem; **b**) the cavities are oriented more or less parallel to the axis of the main stem or its branches; and **c**) branching directions of the tubes are mainly consistent with the growth direction of the thallus.

Alternatively, the following features would support an interpretation of the micrite-filled tube-like cavities as the result of borings or diagenesis: **a**) the micritic cavities cut and appear to have destroyed the concentric structure produced by annular growth banding of the thallus (Pl. 6, Fig. e); **b**) the micritic cavities are without their own walls, **c**) there is no recognizable differentiation between the hypo- and perithallus in the alga.

Table 1: Characteristics of Triassic species of *Solenopora*, including *S. alcicornis* OTT, 1966 (Carnian-Rhaetian), *S. endoi* FLÜGEL, 1975 (Norian-Rhaetian), *S. isoconcentrica* SENOWBARI-DARYAN et al., 2007 (Anisian), *S. karaburunensis* (= *Parachatetes karaburunensis* DÜZBASTILAR, 1976) (Anisian-Ladinian), *S. paraconcentrica* SENOWBARI-DARYAN et al., 2006 (Anisian), *S. simionescui* DRAGASTAN, 1969 (Ladinian), *S. styriaca* FLÜGEL, 1960 (Rhaetian), *S. triasina* VINASSA DE REGNY, 1915 (Norian), *S. undata* SENOWBARI-DARYAN & LINK, 2005 (Norian), *S. vachardi* SENOWBARI-DARYAN et al., 2006 (Anisian), *S. zlambachensis* FLÜGEL, 1962 (Rhaetian). Legend: CD – cell diameter, TCW – thickness of the cell walls, CO – cell outline (in cross section), M – morphology of the thallus. All measurements in µm. Modified from SENOWBARI-DARYAN et al. (2006). *) The original species name *Solenopora concentrica* (SENOWBARI-DARYAN et al., 2006) has been changed to *Solenopora isoconcentrica* by SENOWBARI-DARYAN et al. (2007).

Species	CD	TCW	CO	M
S. alcicornis	15–50	8	Polygonal	Antler-like
S. endoi	20–30	12–15 (–24)	Circular-oval	Nodular, branched
*S. isoconcentrica**	40	10–20	Circular-oval	Hemispherical
S. karaburunensis	52–156	3–10	?	?
S. paraconcentrica	20	10	?	Hemispherical
S. rectangulata n. sp.	20	20	Circular-oval	Fir-tree-like
S. simionescui	30–45	?	Circular-oval	Lobed, fan-like
S. styriaca	30–80	5–10	Circular-oval	Nodular
S. triasina	50–70 (–150)	?	Polygonal	Conical
S. undata	30–80	10–15	Circular-polyg.	Nodular
S. vachardi	20–30	5–8	?	Erect, branched
S. zlambachensis	9–21	?	Polygonal	Nodular-cylindrical

We interpret the micrite-filled large cavities within the thalli as borings of micro-organisms or even as result of diagenesis. These structures are oriented along the weakly calcified direction, which runs parallel to the cell walls, and are not perpendicular to them. This interpretation justifies our assigning this alga to the solenoporaceans.

Remarks: All species of the genus *Solenopora*, known from Triassic deposits are listed with their diagnostic features in Table 1. All of these solenoporacean species have a nodular or club-shaped thallus. Only the antler-like multi-branched species *Solenopora alcicornis* OTT (1966) is comparable with this new species from Iran. The branching pattern (finger-like in *S. alcicornis*, fir-tree-like in *S. rectangulata*) and the small size of the thallus clearly distinguish the Iranian species *S. rectangulata* from the Carnian species *S. alcicornis* OTT.

Genus *Parachaetetes* DENINGER, 1906
Parachaetetes dizluensis n. sp.
(Figs. 6–7; Pl. 2, Figs. a–b; Pl. 7, Figs. a–c; Pl. 8, Figs. a–c)

Derivatio nominis: Named for the small town of Dizlu, to the northwest of the type locality.

Holotype: Multi-branched thallus illustrated in Pl. 7, Fig. a/H (thin section 9).

Paratypes: All specimens illustrated in Pl. 2, Figs. a–b; Pl. 7, Figs. a–c; Pl. 8, Figs. a–c.

Locus typicus: see Fig. 1.

Stratum typicum: Upper Triassic, most probably Rhaetian.

Diagnosis: Erect and finger-like multi-branched thallus with a diameter up to 8 mm (at branching points up to 16 mm). Cells are oriented in the middle part of the thallus parallel to the axis, but toward the periphery of the thallus they diverge at an angle of 30°-90°. Concentric layers about 0.1 mm apart are produced by the thickening of the cell walls at the same height. Other kinds of cross partitions are missing. Cells are round or polygonal with a diameter of 0.04 mm. Reproductive organs were not observed.

Material: Numerous thalli in thin sections 2/0, 3, 4, 8, 9 (holotype), 13, K60.

Description: The erect and large thalli of this alga can easily be mistaken in the field for recrystallized dendroid corals of a similar diameter. This alga grew together with *Solenopora rectangulata* n. sp. in patches several square metres in diameter.

The thallus of this finger-like multi-branched alga reaches heights of up to 20 cm with lateral extensions up to 20 cm long. The thallus of the holotype is at least 9 cm high with lateral extensions of at least 13 cm.

The holotype (Pl. 7, Fig. a/H) is a multi-branched thallus with a length of at least 9 cm and with a diameter of 13 mm at branching points. The diameter of individual branches is usually 8 mm, reaching diameters of up to 16 mm at the branching points.

In cross-section the cells are round to polygonal and have a maximum diameter of 0.04 mm (0.02–0.04 mm). Concentric layers, produced by the thickening of the cell walls, are clearly visible in the axial parts of the thallus but not well developed in the peripheral parts. The concentric layers are a fairly constant 0.1 mm apart. The thickness of the cell walls is about 0.02 mm.

Thalli are generally recrystallised, particularly in the axial region. Peripheral parts are locally well preserved and may exhibit a thickening of the cell walls (Pl. 7, Fig. c; Pl. 8, Fig. b). This thickening is mainly on one side of the cell wall and the concentric layers are then indistinct or even absent (Fig. 6). In the axial region the cell walls are thickened on both sides

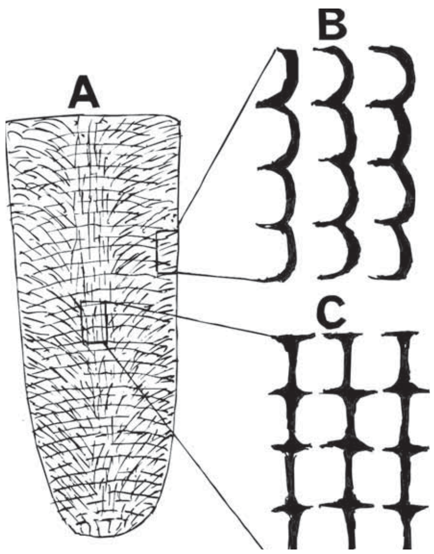


Figure 6: **a**) Sketch showing the "water jet" orientation of cells in a thallus of *Parachaetetes dizluensis* n. sp. **b**) Curved cell walls and thickening on one side at the periphery of the thallus. **c**) Thickening of the cell wall on both sides in the axial region of the thallus causing the concentric layers of the thallus. Schematic, not to scale.

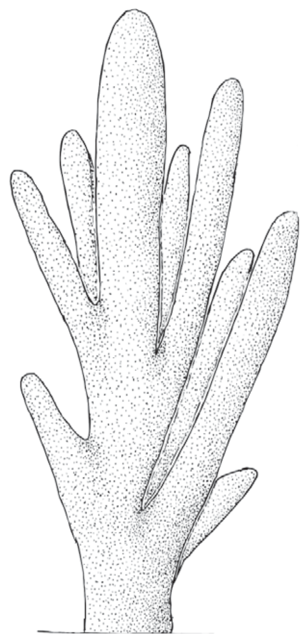


Figure 7: Reconstruction of *Parachaetetes dizluensis* n. sp. showing the finger-like branching pattern of the alga. Schematic, not to scale.

Plate 7

Figs. a–c: *Parachaetetes dizluensis* n. sp.

a Longitudinal section through a colony of numerous thalli showing the finger-like branching pattern of individual thalli. H) Holotype. Thin section 9.

b Enlargement of the axial part of a thallus showing the cells and the thickening of the cell walls at the same level producing the concentric layers. Thin section 2/0.

c Longitudinal section at the edge of a thallus showing the thickening of the cell walls at the same level producing the concentric layers. Thin section 2/0.

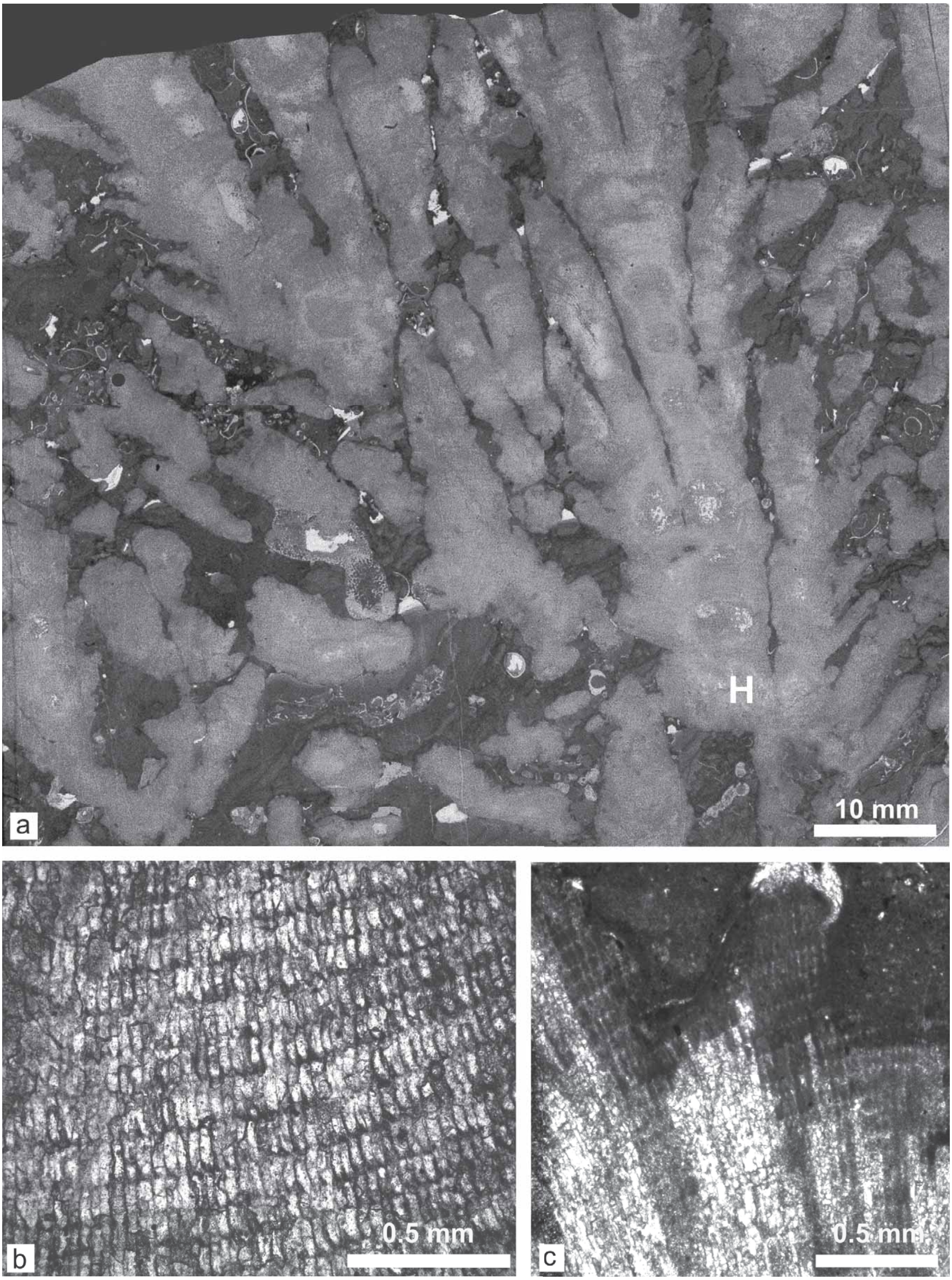

H
10 mm
a
0.5 mm
b
0.5 mm
c

Plate 8

Figs. a–c: *Parachaetetes dizluensis* n. sp.

a Longitudinal section through numerous thalli showing the finger-like branching pattern of individual thalli. Enlargements of the marked rectangles are shown in figs. b and c (rotated approx. 90° clockwise). Thin section K60.

b Enlargement from Fig. 8a (quadrangle 1) showing the wavy cells and the concentric running growth lines in longitudinal section, produced by the thickening of the cell walls. Thin section K60.

c Enlargement from fig. a (quadrangle 2). For explanation see fig. b. Thin section K60.

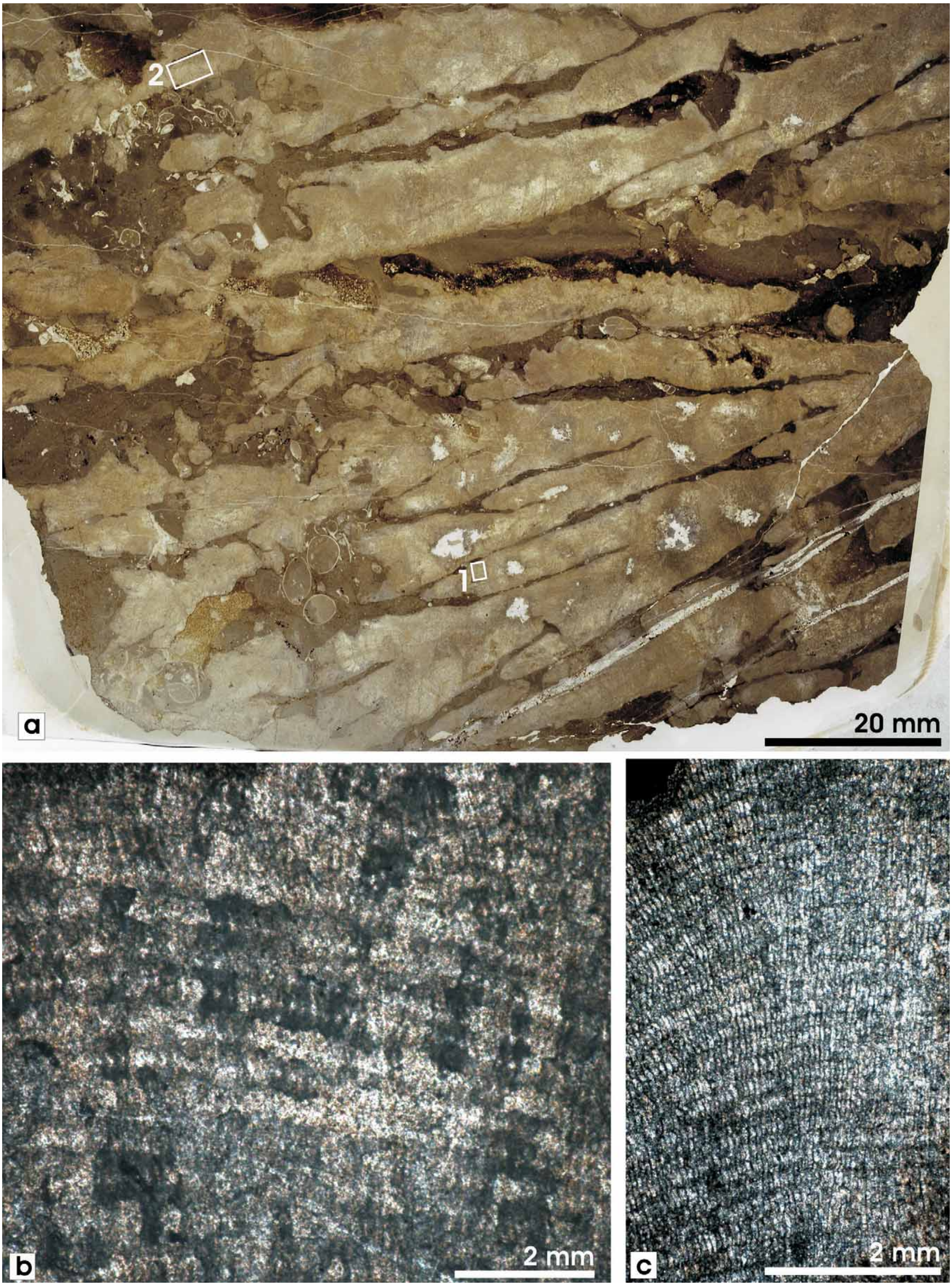

2
1
a
20 mm
b
2 mm
c
2 mm

Table 2: Characteristics of Triassic species of *Parachaetetes*, including *P. cassianus* (= *Solenopora cassiana* FLÜGEL, 1961) (Carnian), *P. clatratus* SENOWBARI-DARYAN & LINK, 2005 (Norian), *P. marii* (= *Lithothamnidium marii* MOISEEV, 1944) (Norian), *P. maslovi* FLÜGEL, 1975 (Norian-Rhaetian), *P. rhaeticus* DRAGASTAN et al., 2000 (Rhaetian), *P. riedeli* SENOWBARI-DARYAN & LINK, 2005 (Norian), *P. tauricus* SENOWBARI-DARYAN & LINK 2005 (Norian). Legend: CD – cell diameter, TCW – thickness of the cell walls, CO – cell outline (in cross section), DCL – distance apart of concentric layers. All measurements are in µm. Modified from SENOWBARI-DARYAN et al. (2006).

Species	CD	TCW	CO	DCL
P. cassianus	50–100	25	Polygonal	40–420
P. clatratus	50–120	60–80	Polygonal-circular	40–350
P. dizluensis n. sp.	20–40	20	Polygonal-circular	100
P. marii	50	5	Polygonal	100
P. maslovi	18–35	6–12	Polygonal-angular	50–300
P. rhaeticcus	12–20	?	Circular	24–40
P. riedeli	30–40	~10	Circular	40–100
P. tauricus	30–50	~10	Circular	60–80

producing the concentric layers. Cell partitions (except the thickenings) are lacking. A schematic reconstruction of the thallus of *P. dizluensis* n. sp. is shown in Fig. 7.

Remarks: The Triassic species of *Parachaetetes* were revised by SENOWBARI-DARYAN & LINK (2005) and according to those authors the following species of *Parachaetetes* can be assigned a Triassic age: *Parachaetetes marii* (= *Lithothamnidium marii* MOISEEV, 1944), *P. maslovi* FLÜGEL, 1975, *P. cassianus* (*Solenopora cassiana* FLÜGEL, 1961), and P. *rhaeticus* DRAGASTAN et al., 2000. Additionally the species *P. clatratus*, *P. riedeli*, and *P. tauricus* were described from Norian reef boulders in the Taurus Mountains of southern Turkey by SENOWBARI-DARYAN & LINK (2005).

Algae with erect and branched thalli – like *P. dizluensis* – are known from other Upper Triassic localities. The growth pattern and multi-branched thallus of *Parachaetetes tauricus* SENOWBARI-DARYAN & LINK (2005) is very similar to *P. dizluensis* n. sp., but it differs from this Iranian species by its smaller thallus diameter, wider spacing (0.6–0.8 mm) of its concentric layers and by its rounded cell outlines. In addition the concentric layers, reflecting the thickening of the cell walls, are much better developed in *P. tauricus* and other species than in this Iranian species. Thickening of one side of the cell walls in *P. dizluensis* was not observed in other species of the genus. Different degrees of thickening of the cell walls in the axial and peripheral regions may reflect the beginning of differentiation of the hypo- and perithallus. Such differentiation was also interpreted by PIA (1939) for the Tertiary species *Parachaetetes asvapatii* and for the Triassic species *Solenopora alcicornis* by OTT (1966). *P. asvapatii*, however, differs from *P. dizluensis* by well thickened cell walls and wider spacing of its concentric layers (see MOUSSAVIAN, 1989, pl. 5, figs. 3-4). Multi-branched pattern of the thallus in *P. dizluensis* and the stratigraphic range are further differences to *P. asvapatti*.

For comparison, the diagnostic features and dimensions of *P. dizluensis* n. sp. and other species of *Parachaetes*, known from Triassic deposits, are listed in Table 2.

4. ORGANISM ASSOCIATIONS AND MICROFACIES

In the sponge-coral dominated reefal parts of the succession, only a few individual thalli of the two species of algae described here occur. In the upper part of the section both algae occur, either alone or together, in algal patches, usually without any other reef builder. Several instances of geopetal fabrics (Pl. 4, Fig. 1; Pl. 7, Fig. 1) indicate the *in situ* growth position of the algae. Spaces between the thalli are filled with micrite, indicating a quiet environment with limited water currents.

In the sediment between the thalli, small foraminifera including different species of *Trocholina* sp., *Seminivoluta* sp., and *Coronipora* sp. occur, along with rare small miliolids (*Galaenella* sp., "*Sigmoilina*" sp., *Ophthalmidium* sp.), brachiopods (including *Gosaukammerella eomesozoicum* (FLÜGEL)), gastropods and ammonites. An epifauna comprising sessile foraminifera and a few worm tubes was noted. The foraminiferal association of the investigated material in this locality differs from other localities of the Nayband Formation and will be published separately. A number of the foraminifera which occur here range up into the Lower Jurassic of the Tethyan realm but the association indicate late Triassic for this section.

Other organisms include hypercalcified sponges (mainly small species), corals and other reef organisms.

Solenoporaceans occur in reefs together with other reef builders in the Upper Triassic Nayband Formation at other localities in central and northeast Iran. However, reefal buildups composed solely or mainly of algae, or where solenoporaceans are so abundant, have not been described before from the Nayband Formation. Moreover, such algal constructions are not known from any other Triassic localities in the world. The multi-kilometre sized *Solenomeris* reefs in the Pyrenean domain (S. France, N. Spain) are not classified as algal reefs. *Solenomeris*, a taxon previously interpreted as a solenoparcean alga, is nowadays assigned to encrusting foraminifera (PERRIN, 1987; PLAZIAT & PERRIN, 1992; MOUSSAVIAN & HÖFLING, 1993). Therefore the solenoporacean reefal structure in Iran seems to be a unique algal construction.

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