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UPPER TRIASSIC (NORIAN-RHAETIAN) HYPERCALCIFIED SPONGES FROM THE LUT BLOCK, EAST CENTRAL IRAN

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Abstract. In order to study the hypercalcified sponges in reefal deposits of the Nayband Formation in Lut Block, the Garm Ab section near the village of Mehran Kushk, located about 20 km northeast of Ferdows city, was sampled. Eight horizons of reefal limestone beds are exposed in this section. The most important reef builders are hypercalcified sponges with some representatives of hexactinellids, scleractinian corals and other reef organisms. The field and lab-observations on rock units, sedimentary facies and faunal assemblages indicate the middle Norian-Rhaetian as the age of the reef horizons. Twenty-three sponge taxa, including 15 of the chambered sphinctozoans, 2 of hexactinellids sponges and 8 non-chambered inozoan were identified. The majority of recognized sponges are reported from the Nayband Formation from the other localities in central Iran. One new species identified as *Cryptocoelia maxima* n. sp. was recovered and is described here.

Introduction

The Nayband Formation, with some bioconstructions, is a widespread sedimentary unit in central Iran. The central Iran is divided in four tectonic Blocks (from west to east including Yazd, Posht-e Badam, Tabas and Lut Blocks) (Aghanabati 2004). Douglas (1929) firstly described the type locality of Nayband Formation from Tabas Block. The type section of the Nayband Formation reaches a thickness of about 2195 meters (Brönnimann et al. 1971) and is located along the southern flank of the Nayband Mount, near the town of Naybandan (Stöcklin & Setudehnia 1991; Aghanabati 2010). The Nayband Formation in central and eastern part of Iran overlies the Middle Triassic dolostone of Shotori Formation with disconformity and is overlain by siliciclastic sediments of Early Jurassic Ab-e Haji Formation.

Due to the facies similarities, it is difficult to identify the contact of the Nayband Formation from the overlying Ab-e Haji Formation in the type locality (Aghanabati 2004) and in the Garm Ab section, too.

The type section of Nayband Formation consists of five members, including Gelkan, Bidestan, Howz-e Sheikh, Howz-e Khan and Qadir members in ascending order.

Both, the Gelkan (915 m thick) and Howz-e Sheikh (365 m thick) members are composed of grey to green siltstone and sandstone. The Bidestan (450 m thick) and Howz-e Khan (465 m thick) members are composed of sponge-coral or coral-sponge constructions of biohermal and biostromal types and siliciclastics. The Qadir member (up to 1000 m thick) is composed of coal-bearing shale (Beagin et al. 1976; Kluyver et al. 1983a; Fürsich et al. 2005).

The sedimentological and palaeontological characteristics of the first four members of the type section of Nayband Formation point to the marine environment. Thin coal beds in the Qadir member support mainly the continental to deltaic environments with only few marine incursions (Kluyver et al. 1983b).

The Bidestan member contains bioconstructions mainly dominated by sponge, while scleractinian corals, especially of dendroid types, are the most important reef builder in the Howz-e Khan member (Fürsich et al. 2005).

Numerous lithological, sedimentological, palaeoenvironmental and palaeontological studies have

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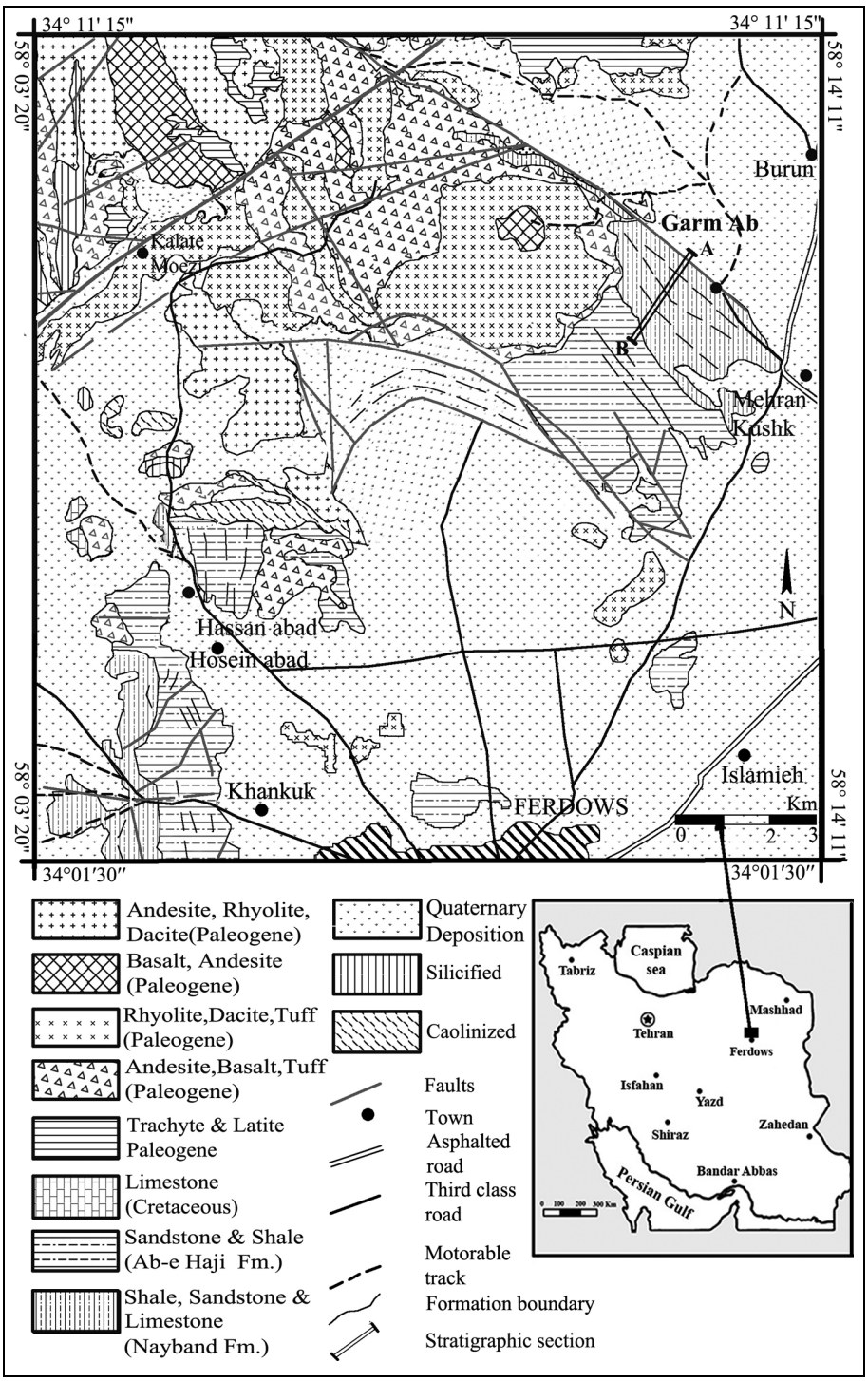

Fig. 1 - Geological map and location of the studied section of Garm Ab in the northeast of Ferdows. (Modified from Eftekhar-Nejad et al. 1977 and Purlatifi 2004).

been accomplished on the Nayband Formation. Some of the most important palaeontological works, dealing with sponges were published by Senowbari-Daryan et al. (1997), Senowbari-Daryan & Hamedani (1999), Senowbari-Daryan (2003, 2005a, b), Rashidi & Senowbari-Daryan (2011), and Senowbari-Daryan et al. (2011).

Geographical and geological setting of the studied area

Geographically the studied area is situated about 3 km southwest of the town Burun, near Mehran Kushk, almost 15 km northeast of Ferdows city (GPS-data: 34° 7' 59.40" N; 58° 12' 8.43" E; altitude of 1500 meters above sea level; Figs 1, 2). The locality can be reached by car, taking the road from Ferdows to the Garm Ab (Fig. 2).

Geologically, the studied section is a part of the Lut Block. It consists of an alternating sequence of reef carbonates and grey to green pencil shale, referred to the Nayband Formation. The unit contains a rich macrofauna, such as sponges (including sphinctozoans, inozoans, chaetetids, spongiomorphids, and rare hexactinellids), scleractinian corals, crinoids, gastropods, bi-

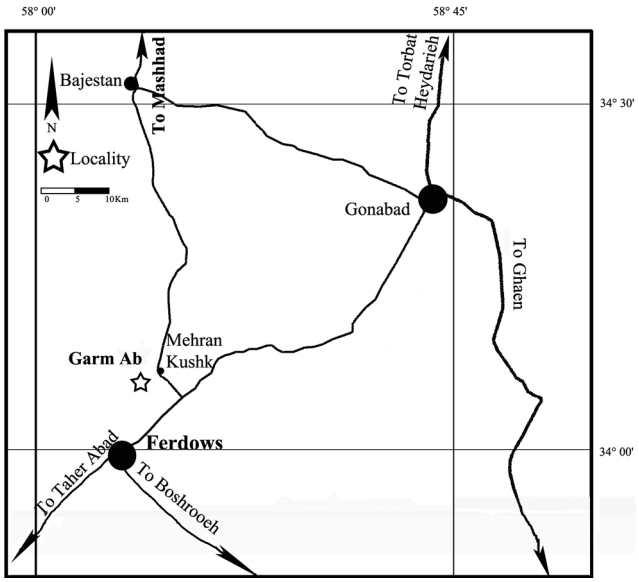

Fig. 2 - Geographical positions of the studied section in the north-east of Ferdows.

valves and microfauna, mostly foraminifers. The lower contact of Nayband Formation in the Garm Ab section is composed of grey to green siltstone and dark grey sandstone with ripple marks, comparable with the Gelkan member in the type locality. The top of Nayband Formation is marked by the disappearance of the reef carbonates (Eftekhar-Nejad et al. 1977; Purlatifi 2004).

The thickness of Nayband Formation decreases from west to east central Iran (Aghanabati 2010; Kluyver et al. 1983b; Fürsich et al. 2005). The Garm Ab section (eastern part of Iran) is about 870 meters thick. This might indicate the influence of additional factors, e.g. tectonic events and climatic fluctuations (Fürsich et al. 2005).

The Garm Ab section consists of eight horizons of sponge dominated reef carbonate beds (Figs 3, 4) and some reefal limestone. Generally, they reach thicknesses of about 2 meters and more, with some lenticular reefal limestone of smaller size in micritic matrix, embedded within the Nayband Formation. The grey colored carbonates are classified as boundstone, floatstone, and packstone. Siliciclastic rocks, including dark grey and thin beds of sandstone and grey to green shale, separate the horizons of reefal limestone.

The spherical hydrozoan *Heterastridium*, mostly with two species, namely *H. conglobatum* Reuss and *H. lobatum* Reuss, are common macrofossil in the first four units in the lower part of the section (Fig. 4). The occurrence of *Heterastridium* corresponds to its presence in the Bidestan member of the type locality (Kluyver et al. 1983b; Fürsich et al. 2005). The presence of *Heterastridium* supports biostratigraphically the Middle Norian age (late Alaunian) for this part of the Nayband Formation.

The middle part of the section is composed of thick layers of grey to green pencils shale and siltstone with disappearing of *Heterastridium*. The reefal limestone became reduced in this part and there are few lenticular reef carbonate with less than 2 meter in thickness, rather corresponding to the Howz-e Sheikh member.

Most of the carbonate deposits are developed in the last part of the section (seven horizons of reef carbonate beds) as reefal limestone which is more similar to Howz-e Khan member in type locality of Nayband Formation (Fig. 4). Based on the lithological and biostratigraphical data (e.g. sponges and foraminifers), this part of the section, from rock unit number 4 to the top in the stratigraphic column, should refer to the Late Norian-Rhaetian.

The Nayband Formation ends with the disappearance of the carbonates. According to Purlatifi (2004) and Eftekhar-Nejad et al. (1977), the Nayband Formation is overlain by the siliciclastics of the Ab-e Haji Formation, dated as Early Jurassic (Figs 1, 3). Reefal limestone with high diversity and biotic associations such as sponges, corals and other reef builders and reef dwellers like benthic foraminifers characterize the sequence, indicating tropical to subtropical, warm-water settings at low latitudes in shallow-water, which is agreement with other studies (Senowbari-Daryan 1996; Fürsich et al. 2005).

Methods

Sponges, described in this paper were collected from the reefal carbonates of the Nayband Formation. All sponges were studied in large-sized thin-sections (10 x 15 cm and 7.5 x 10 cm). Isolated sponge were cut in longitudinal and cross sections and studied in polished slabs as well as in thin sections.

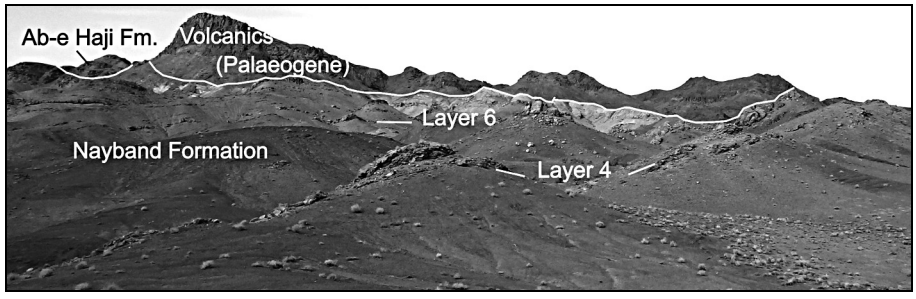

Fig. 3 - View of the Garm Ab section showing the Upper Triassic Nayband Formation with reefal carbonate beds (such as layer 4 and layer 6 shown in the photograph), overlain by the siliciclastic sediments of the Lower Jurassic Ab-e Haji Formation in beside of igneous rocks.

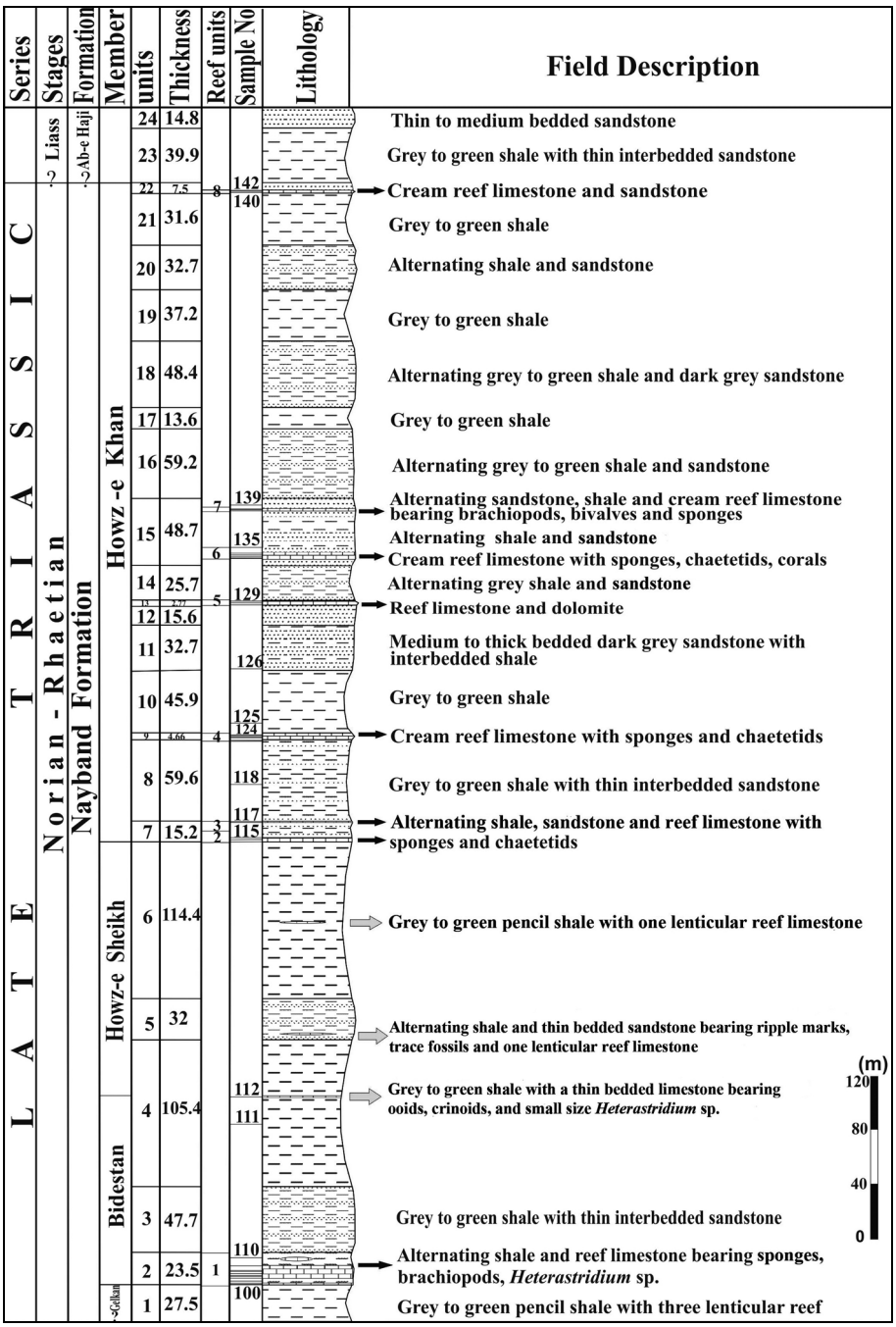

Fig. 4 - Stratigraphic column of the Nayband Formation of the Garm Ab section in the Lut Block. The small black arrows show reefal carbonate horizons; most of the carbonate deposits as reefal limestone are developed in the Howz-e Khan member. Large grey arrows show the lenticular reefs, with thickness lower than 2 meters located in Gelkan and Howz-e Sheikh members. The presence of *Heterastridium* in the lower part, supports biostratigraphically the Middle Norian same as Bidestan member in the type locality which was disappeared in Howz-e Sheikh member.

Depository

All illustrated specimens and thin sections will be deposited in the collection of the department of Geology Payame Noor University (in the Paleontological Museum), Yazd, Iran; material marked with Am-F-10-100.

Palaeontology

The systematic description of sponges is based on the classification of Finks & Rigby (2004). Because of the polyphyletic nature of Sphinctozoa and Inozoa (Senowbari-Daryan & Rigby 2011), the systematic categories for classification of these sponges are used here for their morphological descriptions.

"Sphinctozoa"

Class **Demospongiae** Sollas, 1875

Order **Agelasida** Verrill, 1907

Family Sebargasiidae de Laubenfels, 1955

Genus *Amblysiphonella* Steinmann, 1882

Remarks. *Amblysiphonella* is a long lasting sponge genus, occurring abundant in Permian and in Triassic time interval. It is, however, a relatively rare sponge genus in the Nayband Formation, particularly in the investigated reefs or reefal limestones of the Garm Ab section. Huckriede et al. (1962) reported the genus for the first time from the reef carbonates near the town of Kerman (South Iran) in the Bolbolu section of

the Nayband Formation. Senowbari-Daryan & Hamedani (1999) described two species as *A.* cf. *steinmanni* (Haas, 1909) and *A.* cf. *tubifera* from the Nayband Formation near Wali Abad, central Iran. The new species *A. najafiani* and additionally three informal species were described by Senowbari-Daryan (2005a). Two new species – *A. torabii* and *A. bisiphonata* – and three informal species were described by Rashidi & Senowbari-Daryan (2011) from the Nayband Formation, in the northeast of Esfahan, central Iran. Also Senowbari-Daryan et al. (2011) added one more informal species from the reef limestones near Yazd, central Iran to the content of the genus *Amblysiphonella*. The following two species of the genus were found in the studied section.

Amblysiphonella sp. 1

Pl. 1, fig. 3

Material: One incomplete specimen only.

Description. The species is composed of ring-shaped chambers, arranged around the two axial tubes (recognizable on the chamber roof of the last chamber in Pl. 1, fig. 3) as spongocoel allowing the attribution of the specimen to the genus *Amblysiphonella*. The available specimen reaches a length 8.4 mm with a diameter of 5.6 mm. The first chamber is cut marginally with oval appearance. The last chamber is broken. The height of the chambers is 1.5 mm. Chamber walls are thin, with a thickness of 0.06 mm to 0.15 mm and are pierced by small and un-branched pores. The spongocoel (diameter 1.8 mm) is composed of at least two tubes, running internally through the sponge. Chamber interiors are without vesiculae and other type of filling skeleton.

Remarks. The diameter of the whole sponge and the axial tubes of this species correspond to the dimensions of *Amblysiphonella bisiphonata* described by Rashidi & Senowbari-Daryan (2011). The thin chamber walls, however, distinguish this species clearly from *A. bisiphonata*. As there is only one incomplete specimen available, we refrain from describing a new species.

Amblysiphonella sp. 2

Pl. 1, fig. 2A-B

Material: Three specimens in two thin sections.

Description. The marginally longitudinal section of one species illustrated in Pl. 1, fig. 2A exhibits at least five chambers, appearing rectangle in longitudinal section. The two downward pointed chamber roofs around the spongocoel of the middle chambers indicate the axial spongocoel of the reticulate type and therefore the attribution of the species to the genus *Amblysiphonella*. The sponge reaches a height of 4 mm. Diameter of the chamber is about 1.1 mm. Height of a middle chamber is about 0.7 mm, increasing moderately during the growth. Narrow pores of chamber walls are hardly recognizable. Diameter of the spongocoel is 0.5 mm and thickness of chambers walls 0.05 mm.

Comparison. *Amblysiphonella* sp. 2 differs from *Amblysiphonella* sp. 1 by the small sponge diameter and by the low chamber heights.

? Family Thaumastocoeliidae Ott, 1967

? Subfamily Enoplocoeliinae Senowbari-Daryan, 1990

Genus *Musandamia*

Senowbari-Daryan & Bernecker, 2010

Type species: *Musandamia omanica* Senowbari-Daryan & Bernecker, 2010.

Musandamia gosaukammensis

(Senowbari-Daryan, 1994)

Pl. 1, fig. 5A, B; Fig. 5

1994 *Enoploecoelia*? *gosaukammensis* n. sp. - Senowbari-Daryan, p. 670, pl. 1, figs 1-5.

2011 *Musandamia gosaukammensis* (Senowbari-Daryan) - Rashidi and Senowbari-Daryan, p. 325, pl. 1, fig B: arrow, D, E-G.

Material: Two specimens in thin sections.

Description. This species is one of the smallest thalamid sponges in the investigated material. Like *Amblysiphonella,* it is composed of several ring-like chambers, arranged around an axial spongocoel. The typical characteristic of the sponge and the genus is the ambisiphonate type (*sensu* Seilacher 1962) of the spongocoel formation.

Specimen in Pl. 1, fig. 5A shows a longitudinal section, which has a length of 6.1 mm and is composed of four globular chambers. Diameter of the sponge and the chambers is almost constant, being 2.5 mm. Height of the chambers varies between 0.8 and 1.1 mm. Spongocoel and chamber walls are about 0.1 mm thick. The communication of the chamber interiors with the spongocoel is constructed by a large opening only, situated in the middle of the chamber endowalls. The sponge surface exhibits spine-like elements (length of the "spines" 0.1-0.16 mm), reflecting the horizontally running rips on the outer surface of the sponge skeleton.

Remarks. The sponge diameter of the specimens from Garm Ab section is moderately larger than those specimens described as *Enoplocoelia*? *gosaukammensis* from the Norian-Rhaetian reef of Gosaukamm, Austria by Senowbari-Daryan (1994) and from those specimens described by Rashidi & Senowbari-Daryan (2011) from the Nayband Formation, northeast of Esfahan. All other features of Garm Ab specimen correspond to the specimens from the two mentioned localities.

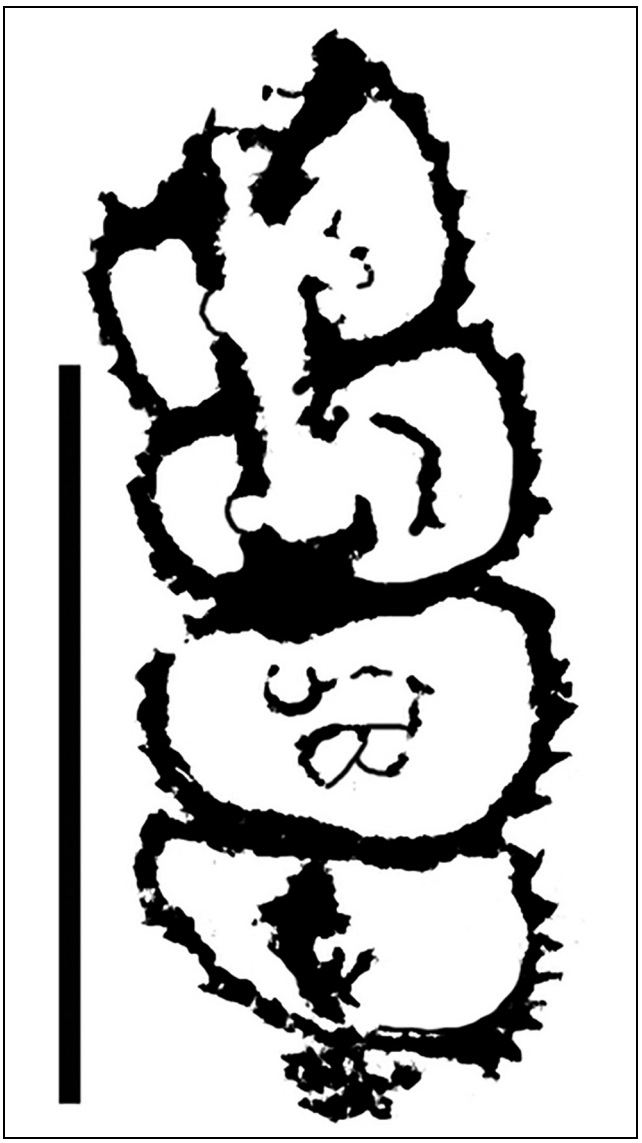

Fig. 5 - Longitudinal section through *Musandamia gosaukammensis* Rashidi and Senowbari-Daryan (was drawn from Pl. 1, fig. 5A) showing chambers with horizontal rips (spine-like appearance in the longitudinal section) of the outer surface. Scale = 10 mm.

Occurrence. The Norian-Rhaetian reef of Gosaukamm, Austria (Senowbari-Daryan 1994), the Nayband Formation in central Iran (Rashidi & Senowbari-Daryan 2011). The second species of *Musandamia*, *Musandamia omanica*, was reported from Norian reef of Jebel Agah, Oman by Senowbari-Daryan & Bernecker (2010).

Family Salzburgiidae
Senowbari-Daryan & Schäfer, 1979

Salzburgia Senowbari-Daryan & Schäfer, 1979

Salzburgia sp.

Pl. 1, fig. 1; Fig. 6

Material: One specimen only.

Description. This porate and cylindrical specimen reaches a length of about 23 mm and is composed of four spherical chambers (semicircular in section) of almost constant diameter and height of 3 mm. The inner part of the chamber walls is laminated (Fig. 6), but the outer part exhibits labyrinthic pore system. Chamber exowalls are thinner (about 1.4 mm) than the doubled chamber roofs, reaching thicknesses of up to 2.5 mm. In addition to the labyrinthic pore system the exowalls of individual chambers are pierced by usually one (in section) rimmed ostium of about 0.55 mm in diameter, only the youngest chamber exhibits two ostia. From the chamber roofs some drop-like skeletal elements hang into the chamber interior, indicating the presence of an axial canal.

Remarks. Two-layered chamber walls (laminated inner part, labyrinthic canal system of the outer layer) are characteristic for the genus *Salzburgia* (Senowbari-Daryan & Schäfer, 1979). This feature supports the at-

Fig. 6 - The longitudinal section of *Salzburgia* sp. (Pl. 1, fig. 1) shows the lamination in the internal part of the chamber walls, the labyrinthic canal system of the external part of the chamber walls, and some rimmed ostia in the exowalls (one of them is shown with black arrow). Scale = 10 mm.

tribution of the species to the genus *Salzburgia*. The rimmed ostia of the Iranian species, however, were not observed in original material of the alpine species (*S. alpina*). Because there is only one specimen in the collection, the determination of the species is not carried out.

Family Solenolmiidae Engeser, 1986

Subfamily Solenolmiinae Senowbari-Daryan, 1990

Genus *Solenolmia* Pomel, 1872

Type species: *Scyphia*? *manon* Münster, 1841.

Solenolmia sp. (n. sp.?)

Pl. 2, fig. 5

Material: One specimen.

Description. The one sectioned specimen of this sponge is cut in oblique section and illustrated in Pl. 2, fig. 5. Because of the position of the section, the true length of the cylindrical or moderately inverse conical specimen cannot be ascertained. The height of the oblique section is about 48 mm with a diameter of at least 40 mm and is composed of six chambers. The low chambers with a maximum height of 6 mm are crescent-like and their interiors contain fiber skeleton of reticulate type. Chamber exo-, inter- and endowalls are about 1.6 mm thick and pierced by single and evenly distributed pores of about 0.2 mm. An axial spongocoel of about 11.5 mm in diameter passes (most probably) internally through the whole sponge.

Remarks. *Solenolmia* occurs in Permian and Triassic time interval and is an abundant genus in Ladinian-Carnian reefs (Senowbari-Daryan & Garcia Bellido 2002). All known species of the genus are small-sized, never reaching a diameter of 40 mm. In addition, those species described from the Norian-Rhaetian reefs of Iran by Senowbari-Daryan (2005a) are distinctly smaller than the species from the Garm Ab locality. Based on the large diameter of the described specimen, it represents most probably a new species. However, because of scarce material it is described here as uncertain species.

Genus *Deningeria* Wilckens, 1937

Type species: *Deningeria mirabilis* Wilckens, 1937

Deningeria sp.

Pl. 2, figs. 1, 3; Pl. 8, fig. 1; Fig. 7

Material. Numerous specimens (observed in the field) and in thin sections.

Description. This species seems to be one of the most abundant thalamid sponges in the studied section. Several specimens were observed in the field and in thin sections but only two specimens of them are studied in thin sections (Pl. 2, figs 1, 3) and one specimen from the field (Pl. 8, fig. 1) is documented. The description of the species is mainly based on investigations of the thin sections.

The sponge is composed of numerous spherical to hemispherical chambers, arranged one above the other (moniliform, Fig. 7). The chambered construction is hardly recognizable from the outside. The sponge reaches a length of more than 15 mm with a diameter of up to 2.5 mm in thin section. Chamber interiors are filled with reticulate fiber skeleton. Height of the chambers is variable. The thicknesses of the chamber walls are about 0.25 mm and pierced by numerous pores, unevenly distributed. An axial canal is lacking in the illustrated specimens.

Remarks. Wilckens (1937) described two species of the genus *Deningeria* as *D. camerata* and *Deningeria mirabilis* from the Upper Triassic of Seran, Moluccas. *D. mirabilis* is documented by a section of three chambers with reticulate fiber skeleton within the chamber interiors. Because detailed information about this "species" is lacking, we propose to limit the species-name *mirabilis* only to this specimen.

Wilckens (1937: 201) defined the genus diagnosis of *Deningeria* as vague. So it is not clear if *Deningeria* possesses an axial canal or not. He wrote on page 201: "An axial tube seems to be present, but the available material does not allow a decision for sure".

Family Colospongiidae Senowbari-Daryan, 1990

Synonymy: Colospongiidae Boiko (in Boiko et al. 1991), Parauvanelliidae Wu 1991, Imbricatocoeliidae Wu 1991.

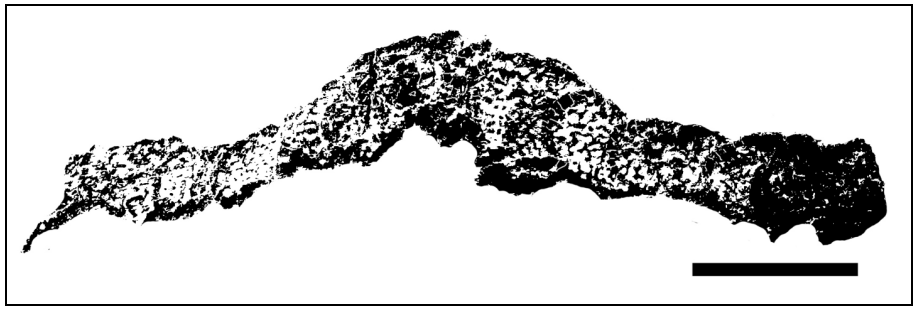

Fig. 7 - *Deningeria* sp. Longitudinal section through numerous chambers exhibiting the reticulate filling structures within the chamber interiors and the perforated chamber walls. There are two tubes indicating the possibly branching of the sponge in the margin of the large chamber (middle of the skeleton). Scale = 10 mm

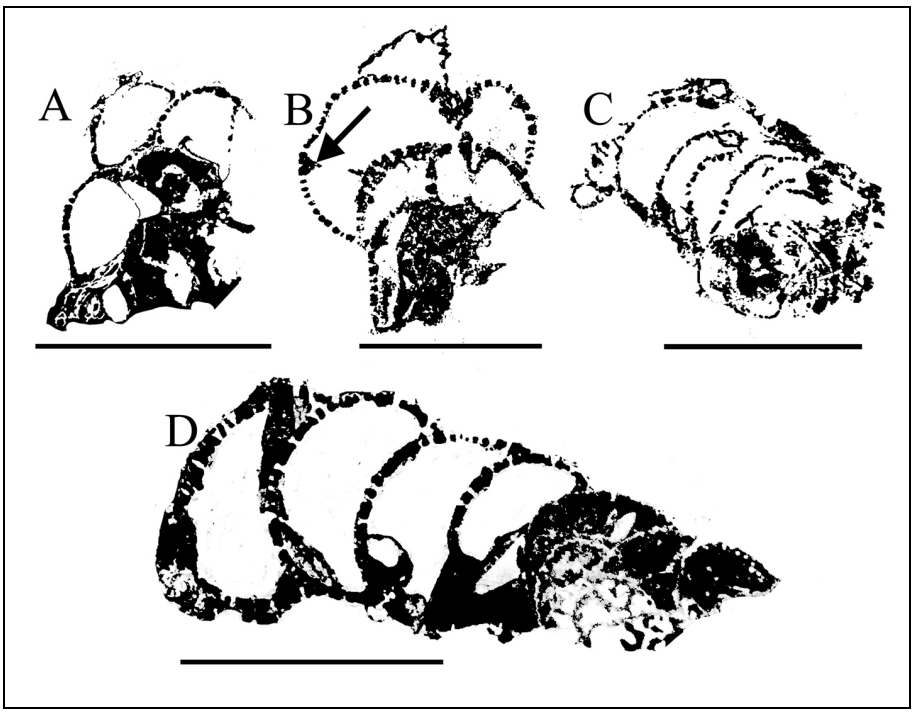

Fig. 8 - Comparison of three morphologically different species with similar appearance in thin sections. A) *Parauvanella ferdowsensis* (drawn from Pl. 3, fig. 1) shows three chambers of an uviform sponge (chamber are arranged above and beside others). The sponge is grown on an un-determinable biogenic component. B) *Parauvanella spinosa*, morphologically identical with *P. ferdowsensis*, but with spine-like extension (black arrows) of the chamber walls in the chamber interiors (drawn from Pl. 3, fig.2). C-D) Two different species of the genus *Colospongia* exhibit perforated chamber walls (like the species of *Parauvanella*), but with moniliform chamber arrangement (C is drawn from Pl. 3, fig. 4 and D from Pl. 2, fig. 4). Scale = 10 mm.

Subfamily Colospongiinae Senowbari-Daryan, 1990

Genus *Colospongia* Laube, 1865

Type species: *Manon dubium* Münster, 1841.

Colospongia sp.

Pl. 2, fig. 4; Fig. 8D

Material: At least two specimens in thin sections.

Description. Section through five spherical and moniliformly (the last two chambers are arranged beside others) arranged chambers of this sponge (Fig. 8D) exhibits chamber walls with equally and evenly distributed single pores of about 0.09 mm. The maximum height of the chambers is 1.8 mm with diameters of about 3.5 mm. Chamber walls are thin and correspond almost to the pore diameter. Chamber interiors are without filling skeleton.

Remarks. *Colospongia* is a long-lasting sponge genus occurring from Carboniferous (Kügel 1987) up to Upper Triassic. In Norian-Rhaetian reefs of the Nayband Formation, it occurs rarely.

Subfamily Corymbospongiinae Senowbari-Daryan, 1990

Genus *Parauvanella* Senowbari-Daryan & Di Stefano, 1988

Type species: *Parauvanella paronai* Senowbari-Daryan & Di Stefano, 1988

Parauvanella ferdowsensis Senowbari-Daryan, 2005a

Pl. 3, fig. 1; Pl. 8, fig. 6; Fig. 8A

2005a *Parauvanella ferdowsensis* nov. sp. - Senowbari-Daryan, p. 177, pl. 1, figs 1-8, pl. 2, figs 1-2, pl. 15, fig. 1/P; text-figs 8-9.

2011 *Parauvanella ferdowsensis* Senowbari-Daryan - Senowbari-Daryan and Link, p. 677, fig. 6f.

Material: Two specimens (one naturally weathered specimen and one in thin section).

Description. Specimens of this asiphonate species are composed of several spherical-subspherical chambers with uviform arrangement (chambers are above and beside others, Fig. 8A). In marginal sections, the number of chambers appears lower as in the specimen illustrated in Pl. 3, fig. 1. Chamber heights are almost the same size as the chamber widths, measuring usually 1.5 mm in diameter. The thin chamber walls (thickness about 0.15 mm) are pierced by un-branched pores of about 0.2 mm in diameter. Chamber interiors are without any secondary filling skeleton.

Occurrence. *Parauvanella ferdowsensis* in known from the Norian-Rhaetian reefs of the Nayband Formation (Senowbari-Daryan 2005a). Recently, it was described from the Norian of the Taurus Mountains, southern Turkey by Senowbari-Daryan & Link (2011).

Parauvanella spinosa Rashidi & Senowbari-Daryan, 2011

Pl. 3, fig. 2; Fig. 8B

2011 *Parauvanella spinosa* nov. sp. - Rashidi and Senowbari-Daryan, p. 315, pl. 1, fig. J; pl. 9, fig. G/1; pl. 10, fig. F/1)

Material: One specimen only.

Description. The sponge morphology, chamber arrangement and the perforation pattern of the chamber walls corresponds to those of *P. ferdowsensis*. *P. spinosa* differs from *P. ferdowsensis* by the spine-like extensions of the chamber walls into the chamber interior as shown in (Fig. 8B).

Occurrence. In the Norian-Rhaetian reef of the Nayband Formation in central Iran (Rashidi & Senowbari-Daryan 2011) and now in Garm Ab section of the Lut Block.

Subfamily Kashanelliinae Senowbari-Daryan, 2005b

Genus *Kashanella* Senowbari-Daryan, 2005a

Type species: *Kashanella irregularis* Senowbari-Daryan, 2005a

Kashanella irregularis Senowbari-Daryan, 2005a

Pl. 3, figs 3, 5-7

2005a *Kashanella irregularis* nov. sp. - Senowbari-Daryan, p. 181-182, pl. 5, fig. 4, pl. 19, fig. 6, pl. 20, fig. 7, pl. 21, figs. 6-7.

2009 *Kashanella irregularis* - Senowbari-Daryan, p. 115, pl. 2, figs H-I, pl. 3, figs A/2, H-I, pl. 15, fig. E.

2011 *Kashanella irregularis* - Rashidi and Senowbari-Daryan, p. 316, pl. 2, figs K-L, pl. 4, figs E, H-I.

Material: Numerous specimens in several thin sections.

Description. This irregularly growing sponge is composed of several irregular chambers, usually with moniliform arrangement. Highly characteristic of the sponge is the labyrinthic canal system of the chamber walls with "spongy" appearance. For detailed description for the species see Senowbari-Daryan (2005a).

Remarks. Senowbari-Daryan & Link (2011) describe a second species of the genus as *Kashanella cylindrica* from the Norian of southern Taurus Mountains.

Occurrence. *Kashanella irregularis* is known from the Norian-Rhaetian reefs of the Nayband Formation, Iran, (Rashidi & Senowbari-Daryan 2011), the Gosaukamm in Austria (Senowbari-Daryan 2009), and from the Norian reefs of Taurus Mountains in southern Turkey (Senowbari-Daryan & Link 2011).

Family Annaecoeliidae Senowbari-Daryan, 1978

Genus *Annaecoelia* Senowbari-Daryan, 1978

Type species: *Annaecoelia maxima* Senowbari-Daryan, 1978

Annaecoelia parva Senowbari-Daryan, 2005a

Pl. 4, fig. 1

2005a *Annaecoelia*? *parva* nov. sp. - Senowbari-Daryan, p. 184, pl. 29, figs 4, 6.

2011 *Annaecoelia parva* - Rashidi and Senowbari-Daryan, p. 318, pl. 2, fig. D, pl. 4, fig. L.

Material: Two specimens in one thin section.

Description. The small specimen of this sponge has a length of 6.7 mm and width of about 3.8 mm. It is composed of spherical chambers with diameters of about 1.6 mm. The chamber walls are with 0.09 mm very thin and pierced by extremely fine pores of 0.02 mm in diameter.

Remarks. This species was assigned to the genus *Annaecoelia* with some doubts by Senowbari-Daryan (2005a). Following the opinion of Rashidi & Senowbari-Daryan (2011) the question mark is taken away also in this paper.

Occurrence. *Annaecoelia parva* is known only from the Norian-Rhaetian reefs of the Nayband Formation in Iran (Senowbari-Daryan 2005a; Rashidi & Senowbari-Daryan 2011).

Family Cryptocoeliidae Steinmann, 1882

Genus *Cryptocoelia* Steinmann, 1882

Type-species: *Cryptocoelia zittlei* Steinmann, 1882

Cryptocoelia maxima n. sp.

Pl. 1, fig. 6; Pl. 2, fig. 2; Pl. 4, fig. 6; Fig. 9

Derivatio nominis: Named after the large size of the species.

Holotype: Specimen illustrated in Pl. 2, figs. 2 (thin section, Am-F-17).

Paratypes: Pl. 4, fig. 6, and Pl. 1, fig. 6 (thin sections, Am-F-28, 35).

Locus typicus: Nayband Formation, situated about 3 km southwest of the town Mehran Kushk, almost 15 km northeast of the Ferdows city, reef number 7 (34° 7'59.40"N, 58°12'8.43"E).

Stratum typicum: Upper Triassic (Rhaetian).

Diagnosis: Large species, stump conical-shaped with a trabecular, without recognition of the internally crescent like low chambered construction, spongocoel pro-? pseudosiphonate?, filling skeleton trabecular.

Material: Three specimens in thin sections, Am-F-17, 28, 35.

Description. The skeleton of this distinctly large thalamid sponge (height of holotype at least 60 mm, diameter of the top is about 110 mm) is externally not recognizable. Internally the sponge is well chambered and individual low chambers are crescent-shaped. Height of the chambers varies between 1 and 2.5 mm. The most of the chamber walls are secondarily thickened but the well preserved parts show chamber walls of 1 mm (Pl. 2, fig. 2 lower part left). Chamber walls are pierced by numerous unevenly distributed single pores of 0.15 mm. Chamber interiors contain scattered pillar-like filling skeleton recognizable in well preserved parts (Pl. 2, fig. 2 lower part left). The holotype seems to be branched at the upper part. Our statement is based on a) asymmetrical position of the spongocoel pro-? pseudosiphonate?, b) sediment filling in center of the top and c)

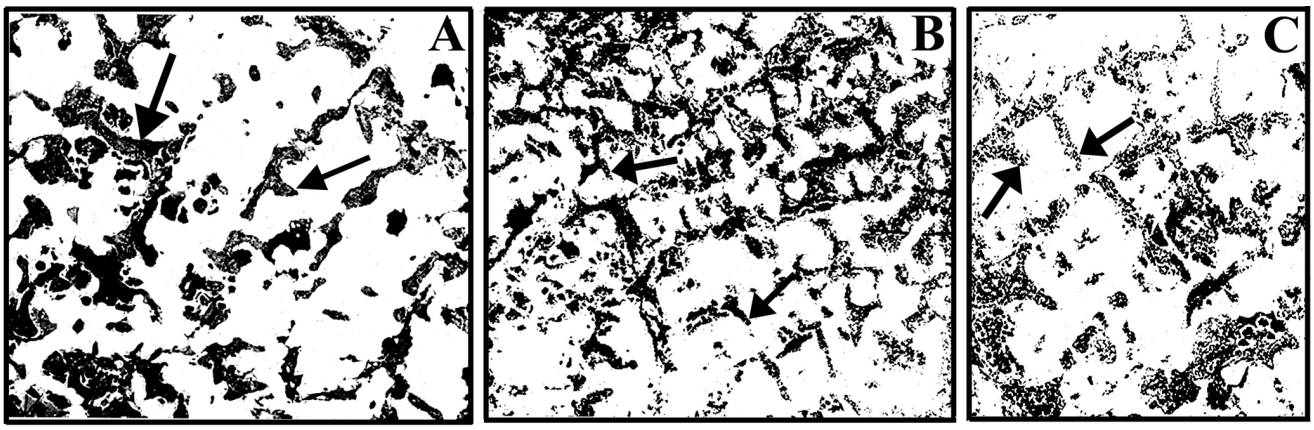

Fig. 9 - Comparison of pillar-like filling structures of *Cryptocoelia maxima* n. sp. (within several chamber interiors). (A is drawn from Paratype, Pl. 1, fig. 6; B is drawn from Holotype, Pl. 2, fig. 2 and C is drawn from Paratype, Pl. 4, fig, 6). In all three samples, the filling skeletons within the different chambers and even in different parts of the same chamber contain trabecular-filling skeleton. Not to scale.

fracture of the chamber walls and the left part of the sponge, d) turning of the chamber wall in the axial region. Recognition of the spongocoel (7 mm in diameter) as pro- or pseudosiphonate is not possible.

The description above is based on observations of the holotype. The two paratypes in Pl. 1, fig. 6 and Pl. 4, fig. 6 show almost identical characters, although, the spongocoel of the holotype could not be observed in the paratypes. The specimen illustrated in Pl. 1, fig. 6 clearly shows the pillar like filling skeleton in some chambers.

Comparison. *Cryptocoelia maxima* n. sp. differs from the known species of the genus by its large dimension.

"Sphinctozoa" gen. et sp. indet

Pl. 8, fig. 2; Fig. 10

Material: Three specimens in thin sections.

Description. Three specimens of this chambered sponge are cut in one sample exhibiting all features of the species. The longitudinal section through three spherical chambers of the specimen in Pl. 8, fig. 2, exhibits thin chamber walls, which are partly perforated and partly imperforated. Also the two cross sections show this feature. One of the cross section exhibits internally a perforated wall, not comparable with vesiculae or other types of filling skeleton compared within the chamber interiors of other sphinctozoans.

Such chambered sponges with partly perforated and partly imperforated chamber walls are not usual in this group of sponges. Most probably, this species can be attributed to the close neighborhood of the genus *Colospongia.* It is described as gen. et sp. ind. in this paper.

Inozoans

Class **Demospongiae** Sollas, 1875

Order **Agelasida** Verrill, 1907

Family Sestrostomellidae de Laubenfels, 1955

Genus *Sestrostomella* Zittel, 1878

Sestrostomella robusta Zittel, 1878

Pl. 5, figs 1, 4-5

1878 *Sestrostomella robusta*. Zittel, p. 41.

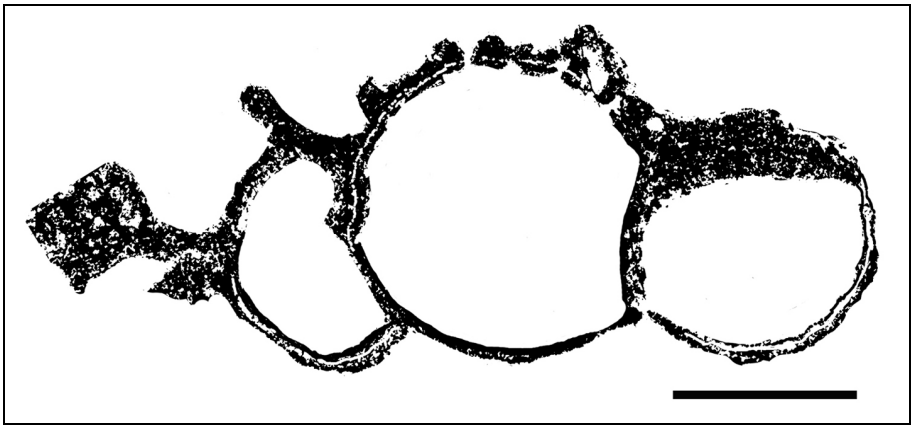

Fig. 10 - "Sphinctozoa" gen. et sp. indet. The moniliform sponge shows chamber walls (partly doubled) partly perforated and partly imperforated (middle chamber). It is drawn from Pl. 8, fig. 2. Scale = 10 mm.

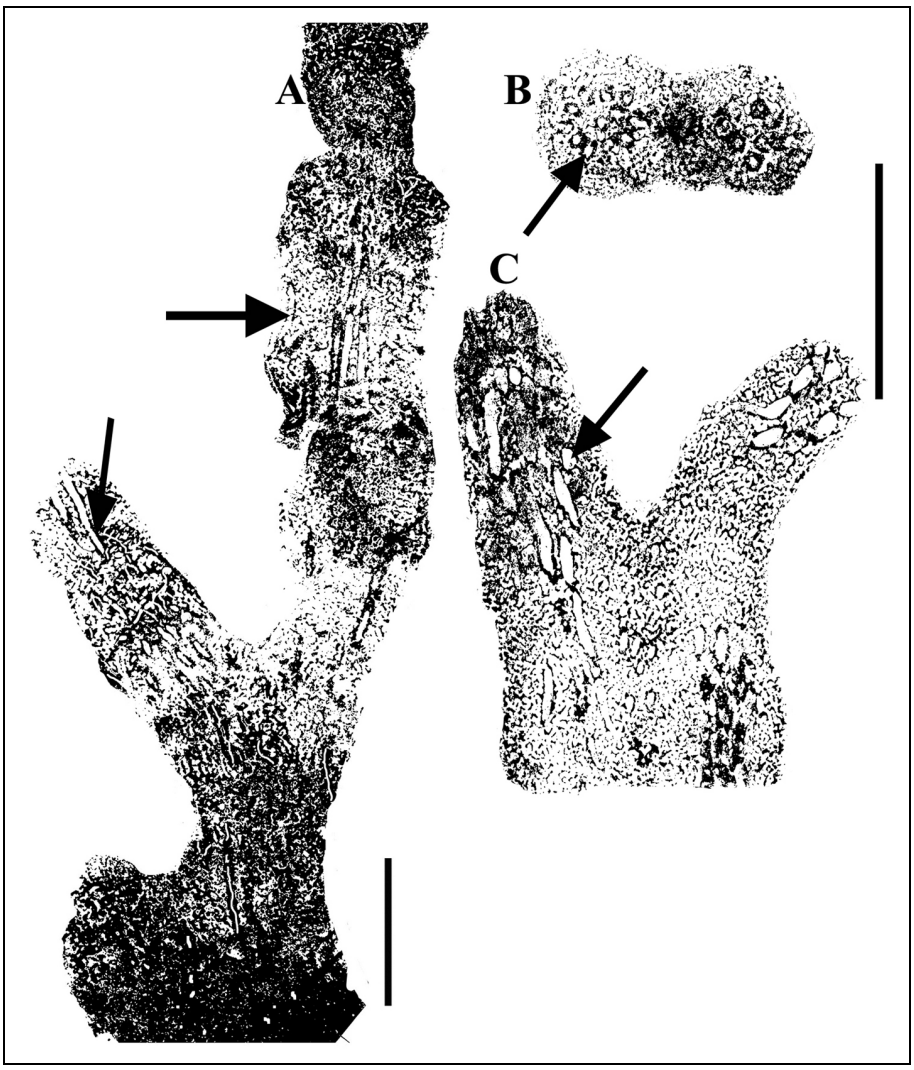

Fig. 11 - A) Longitudinal section through a multi-branched specimen of *Sestrostomella* cf. *robusta,* exhibiting the spongocoel composed of bundle of tubes (arrows) similar to *Sestrostomella robusta* Zittel. B-C) The cross and longitudinal sections through a naturally isolated specimen (see Pl. 5, fig. 2) show the identical characteristics like fig. A. Scale = 10 mm.

1997 ?*Sestrostomella robusta* - Senowbari-Daryan, Seyed-Emami & Aghanabati, p. 310, pl. 4, figs. 1-7, pl. 6, fig. 6, pl. 8, fig. 6. (cum syn.).

2009 *Sestrostomella robusta* - Senowbari-Daryan, p. 126, pl. 9, fig. B.

2011 *Sestrostomella robusta* - Senowbari-Daryan, Rashidi and Beitollah. p. 8, pl. 2, figs. B-C, F.

2011 *Sestrostomella robusta* - Rashidi and Senowbari-Daryan, p. 333, pl. 7, fig. D.

Material: Numerous naturally isolated specimens and several specimens within the carbonate rocks.

Description. This solitary and branched (Pl. 5, figs 1, 4-5) sponge is one of the most abundant inozoan species in the studied section. The largest specimen in collection is at least 20 mm long (Pl. 5, fig. 4), reaching a diameter of almost 14.5 mm (Pl. 5, fig. 1). The most characteristic of the genus and species is the axial canal bundle, which is composed of several individual tubes of about 0.5 (0.4-0.7) mm in diameter passing internally through the sponge. The tubes show a distinct wall, pierced by exhalant canals and additionally by small pores (Pl. 5, figs 1A, B). Inhalant canals connect the sponge interior with the outside. The sponge wall is composed of reticulate fiber skeleton, filling the space between the inhalant and exhalant canals. In some specimens the fibers show, particularly at the periphery of the skeleton, an orientation to the up- and outward of the sponge.

Occurrence. *Sestrostomella robusta* is known from Ladinian to Norian and Jurassic-Cretaceous deposits of several localities in the world (see Dieci et al. 1968; Hurcewicz 1975; Riedel & Senowbari-Daryan 1991; Senowbari-Daryan et al. 2011; Rashidi & Senowbari-Daryan 2011). It is an abundant sponge in Norian-Rhaetian reefs, embedded within the Nayband Formation in central Iran and has been described from several localities (see synonymy list).

Sestrostomella cf. **robusta** Zittel, 1878

Pl. 5, figs 2, 6; Pl. 8, figs 3, 5; Fig. 11

Material: Two specimens in thin sections and several naturally weathered rock surface in longitudinal, oblique and cross sections were cut on the reef number seven.

Description. The dichotomously multi-branched (Pl. 5, figs 2, 6; Pl. 8, figs 3, 5) specimens show several tubes, axially arranged as spongocoel (Fig. 11). Diameters of the individual tube are about 1 mm (Pl. 5, fig. 2A). The diameter of the whole tube bundle depends from the distribution of the tubes in the sponge, with more than 5 mm (Pl. 8, fig. 5). Numerous specimens, one beside of others were observed in the field (Pl. 8, figs 3, 5).

Comparison. This species is differentiated from *Sestrostomella robusta* by its smaller dimension and the dichotomous branching pattern.

Family Auriculospongiidae Termier and Termier (in Termier et al., 1977)

Subfamily Auriculospongiinae Termier & Termier, 1977

Genus *Anguispongia* Senowbari-Daryan, 2005b

Type species: *Anguispongia parva* Senowbari-Daryan, 2005b

Anguispongia parva Senowbari-Daryan, 2005b

Pl. 5, fig. 3

2005b *Anguispongia parva* nov. sp. - Senowbari-Daryan, p. 266-267, pl. 2, figs 1-6; pl. 3, figs 1-3; text-fig. 6.

2011 *Anguispongia parva* - Rashidi and Senowbari-Daryan, p. 330, pl. 6, figs H-I/1.

2011 *Anguispongia parva* - Senowbari-Daryan et al., p. 278, pl. 1, fig. K.

Material: Numerous specimens in the first reefal bed (see Fig. 4).

Description. The skeleton of this sheet-like or tabular sponge without any conspicuously inhalant or exhalant canals is composed of fiber skeleton. As shown by Senowbari-Daryan 2005b (pl. 3, figs 1-3 and text-fig. 6) the fiber skeleton exhibits different appearances in sections perpendicular or parallel to the sheets. Sheets reach dimensions of about 40 mm (in investigated sections) and more (according to Senowbari-Daryan 2005b up to 100 mm) with thicknesses of about 6 mm. For a detailed description of the species see the original description.

Occurrence. Until now, *Anguispongia parva* is known only from the Norian-Rhaetian reefs of the Nayband Formation in Iran.

Genus *Molengraaffia* Vinassa de Regny, 1915

Type species: *Molengraaffia regularis* Vinassa de Regny, 1915

Molengraaffia regularis Vinassa de Regny, 1915

Pl. 6, figs 4?, 5

1915 *Molengraaffia regularis* n. g. n. f. - Vinassa de Regny, p. 80, p. 64 (2), figs 1-3.

2005b *Molengraaffia regularis* - Senowbari-Daryan, p. 265, pl. 1, figs 1-6; pl. 6, figs 4-8, text-fig. 5 (cum syn.).

2009 *Molengraaffia regularis* - Senowbari-Daryan, p. 122, pl. 10, figs B-D. (cum syn.).

2011 *Molengraaffia regularis* - Rashidi & Senowbari-Daryan, pl. 8, fig. A/1.

Material: Numerous specimens in thin sections.

Description. The club- to sheet-like skeleton of *Molengraaffia regularis* is composed, like the preceding species, by a fiber skeleton without recognizable inhalant or exhalant canals. In sections parallel to the sheets the fiber skeleton shows indistinctly linear arrangement of fiber skeleton (Pl. 6, fig. 5).

The specimen illustrated in Pl. 6, fig. 4 is branched and exhibits an identical (see detail with magnification in Pl. 6, fig. 4) fiber skeleton like other specimens of the species. Because branched specimens of this sponge are not known, species assignment is doubtful.

Occurrence. Senowbari-Daryan (2009) noted the following Upper Triassic localities, from which *Molengraaffia regularis* was described: Karakoram, Bakony, Caucasia, Northern Calcareous Alps (Gosaukamm and Hohe Göll, Austria), Greece (unpublished material of him) and Iran.

Family Preperonidellidae Finks & Rigby, 2004

Sufamily Preperonidellinae Finks & Rigby, 2004

Genus *Preperonidella* Finks & Rigby, 2004

Type species: *Preperonidella magna* Rigby & Senowbari-Daryan, 1996

Preperonidella norica (Senowbari-Daryan, Seyed-Emami & Aghanabati, 1997)

Pl. 7, figs 3-4; Fig. 12E

1997 *Radiofibra norica* n. sp. - Senowbari-Daryan, Seyed-Emami and Aghanabati, p. 299, pl. 1, figs 1-7; pl. 2, figs 1-6.

2009 *Peronidella norica* - Senowbari-Daryan, p. 124, pl. 11, figs A, C-D, G. (cum syn.)

2011 *Peronidella norica* - Rashidi and Senowbari-Daryan, p. 334, pl. 5, fig. D.

Material: Two specimens.

Description. This large-sized (compared with the next described species) species of *Preperonidella* in the investigated material exhibits diameters between 15 and 21 mm (moderately smaller than the original material). The length of specimens is not known, but according to the original description it reaches length up to 120 mm (Senowbari-Daryan et al. 1997). An axial spongocoel of 2.8-4 mm in diameter passes internally through the whole sponge. The thick sponge wall is composed of

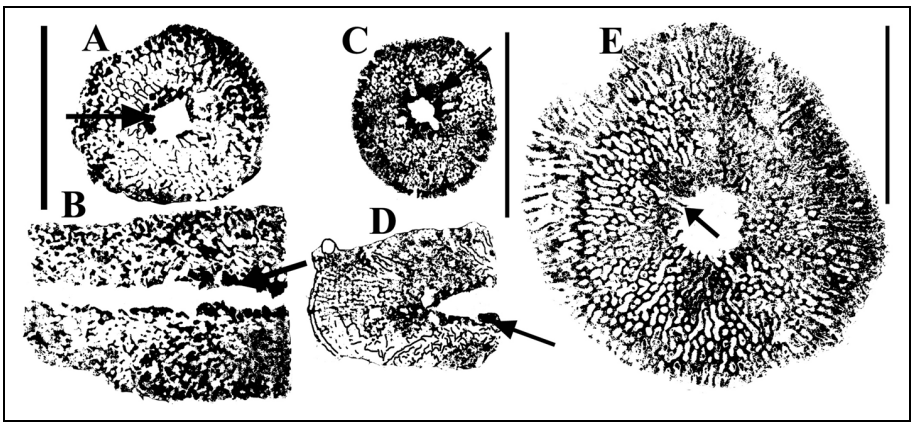

Fig. 12 - A-D) Some longitudinal and cross sections through *Preperonidella iranica* exhibiting the distinct spongocoel wall (black arrows), a characteristic feature of the species. E) Cross section of *Preperonidella norica* showing some radially arranged and curved interfiber spaces ("tube-like") (black arrow). Scale = 10 mm.

fine reticular skeleton. Inhalant and exhalant tubes are lacking, but the typical very narrow, irregular and wavy interfiber spaces run radially through the sponge wall (Fig. 12E).

Occurrence. *Preperonidella norica* is known from the Norian-Rhaetian reefs of Gosaukamm, Austria and from the time equivalent reefs of the Nayband Formation in Iran. *P. norica* occurs also in Norian-Rhaetian reefs in Greece and in Turkey (unpublished material of BSD).

Preperonidella iranica Senowbari-Daryan, 2003

Pl. 6, fig. 7; Pl. 7, figs 1-2, 5-6; Figs 12A-D

1980 *Preperonidella fischeri* Flügel, 1962 nom nud. - Senowbari-Daryan, p. 43, pl. 7, fig. 2.

2003 *Preperonidella iranica* n. sp. Senowbari-Daryan, p. 63, pl. 1, figs 1-6; pl. 2, figs 1-6; pl. 3, figs 1-3.

Material: Numerous specimens in thin sections.

Description. The multi-branched species of this *Preperonidella*-species is usually smaller (about 10 mm) than the preceding one, but large specimens up to 21 mm were observed. An axial spongocoel attains diameters between 0.8 mm and 2.5 mm. Typical for this species is the distinct and perforated wall around the spongocoel. The sponge wall is composed of reticulate fiber skeleton. Exhalant canals pierce the spongocoel wall and are extended as short tubes into the sponge wall, which seems to be typical for this sponge (Pl. 7, fig. 5).

Remarks. The diameters of some specimens from Garm Ab are moderately larger than the dimensions of specimens of the original description, but other characters are identical.

Occurrence. Until now, *Preperonidella iranica* is known from the Norian-Rhaetian reefs of Nayband Formation in Iran and from the Rhaetian of Austria (Senowbari-Daryan 2003).

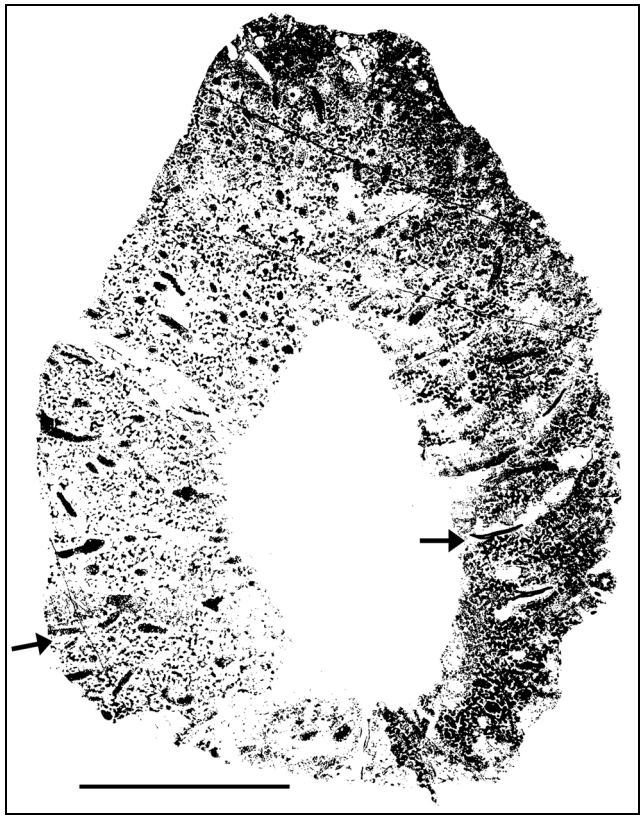

Fig. 13 - The oblique section through the specimen (Pl. 6, fig. 6) of *Permocorynella maxima* shows inhalant and exhalant canals marked by black arrows. Scale = 10 mm.

Subfamily Permocorynellinae
Rigby & Senowbari-Daryan, 1996

Genus *Permocorynella*
Rigby & Senowbari-Daryan, 1996

Permocorynella maxima Senowbari-Daryan, Seyed-Emami & Aghanabati, 1997

Pl. 6, fig, 6; Fig. 13

1997 *Permocorynella maxima* nov. sp. - Senowbari-Daryan, Seyed-Emami & Aghanabati, p. 302, pl. 3, figs 1-8; pl. 6, fig. 5; pl. 7, figs 1-3, 6, text-fig. 7 (cum syn.).

2009 *Permocorynella maxima* - Senowbari-Daryan, p. 125, pl. 9, fig. E, pl. 12, figs D-E, pl. 17, fig. A/1.

2011 *Permocorynella maxima* - Rashidi and Senowbari-Daryan, p. 331, pl. 5, figs A-C, E.

2011 *Permocorynella maxima* -Senowbari-Daryan et al., p. 276, pl. 2, figs A, D, G.

Material: Three specimens (two specimens on the rock surface and one isolated specimen in thin section).

Description. The description of the species is based on the observation on the specimen in thin section. According to Senowbari-Daryan et al. (1997), the cylindrical to moderately conical specimens of this sponge reaches almost a diameter of 30-40 mm. The maximum diameter of the specimen from Garm Ab is 42 mm, close to the dimension of the original description. The axial spongocoel measures 6 mm. The thick sponge wall exhibits two types of more or less radial running canals: inhalant canals, ending to the sponge surface and exhalant canals to the spongocoel. Diameter of canals varies between 0.3 mm and 0.6 mm. Both canals show an indistinct tiny wall with pores of about 0.01 mm in diameter. The space between the canals is filled by the skeletal fibers of a reticulate type.

Occurrence. *P. maxima* is known from the Norian-Rhaetian reefs of Gosaukamm, Austria (described as *Corynella* by Wurm 1982: see Senowbari-Daryan 2009) and from several reef localities of the Nayband Formation in Iran (see synonymy).

Family Maeandrostiidae Finks, 1971

Genus *Maeandrostia* Girty, 1908

Maeandrostia? sp.

Pl. 6, fig. 3

Material: One specimen only.

Description. The longitudinal section of the specimen illustrated in Pl. 6, fig. 3 is composed of a thin outer wall with some coarse fiber skeleton in the sponge interior. The wall contains some rare openings. The skeleton reaches a diameter of 3 mm and a length of 18 mm. The specimen seems to be branched.

Remarks. *Meandrostia* is a "typically" Permian sponge genus. The only species from the Triassic deposits has been described by Senowbari-Daryan et al. (1993) as *Meandrostia triassica* from the Anisian of Dolomites, Italy. The genus is not known from Upper Triassic deposits.

Class **Hexactinellida** Schmidt, 1870

Order **Innaecoeliida** Boiko, 1990

Family Craticulariidae Rauff, 1893

Remarks. The family Craticulariidae Rauff (1893) is referred to the order Hexactinosa Schrammen, 1903 by Finks and Rigby (2004). Based on the chambered construction of the genus *Casearia* and other chambered hexactinellids they are classified as Innaecoeliida by Senowbari-Daryan & Fürsich (2013). This classification is used in this paper.

Genus *Casearia* Quenstedt, 1858

Remarks. *Casearia* (= *Caesiospongia*) was the only one representative of the chambered hexactinellid sponge for a long time, occurring abundant in the Upper Jurassic of southern Germany. The genus was described from the Carnian of China by Wu (1989a), Rigby et al. (1998), and by Senowbari-Daryan & Amirhassankhani (2012) from the Norian-Rhaetian of Iran. A revision of the genus *Casearia* and description of further species from the Jurassic of central Iran were published by Senowbari-Daryan & Fürsich (2013).

Casearia cf. **iranica** Senowbari-Daryan & Amirhassankhani, 2012

Pl. 4, figs 2, 4 B; Figs 14A-B

2002 *Casearia* sp. - Senowbari-Daryan & Garcia-Bellido, p. 1516, figs 5C, 5E.

2011 *Caesaria* sp. - Senowbari-Daryan et al., p. 276, pl. 1, fig. I.

2012 *Casearia iranica* n. sp. - Senowbari-Daryan & Amirhassankhani, pl. 1, figs 1-4; pl. 3, figs 2-3, 7.

Material: Two specimens in thin sections.

Description. There is only one incomplete specimen available (Pl. 4, fig. 2) which exhibits a spongocoel (6 mm in diameter) of retrosiphonate type passing internally through the whole sponge. The poorly preserved outer annulation corresponds to the internal segmentation. Both heights and widths of the chambers are less than 2 mm (Pl. 4, fig. 2; Fig. 14B and Pl. 4, fig. 4 B; Fig. 14A). The diameter of the sponge is 8.3 mm. Chamber walls are 0.3 mm thick and pierced by small pores. They are formed by coarse and loosely packed hexactine lattices (Pl. 4, fig. 2).

Remarks. The dimensions (chambers widths and heights) of specimens from Garm Ab are smaller than *Casearia iranica* described by (Senowbari-Daryan et al. 2011) and by Senowbari-Daryan & Amirhassankhani (2012) from the Norian-Rhaetian reefs of Iran. Based on the small dimensions of specimens from Garm Ab, they are identified as *Casearia* cf. *iranica*.

Occurrence. *Casearia iranica* is known exclusively from the Norian-Rhaetian reefs within the Nayband Formation in Iran.

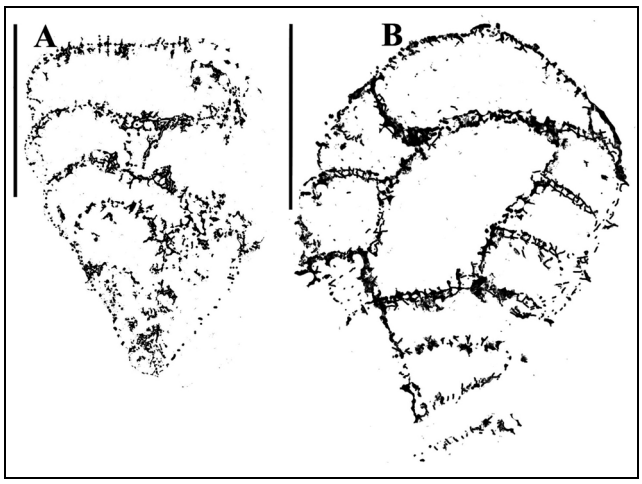

Fig. 14 - A-B) Sections through two specimens of *Casearia* cf. *iranica*. A) An incomplete and marginally axial section (Pl. 4, fig. 4B). B) Oblique section exhibiting the ring-shaped chamber and the wide spongocoel (Pl. 4, fig. 2). Both specimens show thin chamber walls formed by hexactine lattice. Scale = 5 mm.

Casearia vezvanensis Senowbari-Daryan & Amirhassankhani, 2012

Pl. 8, fig. 4

1999 *Casearia articulata* (Schmidel, 1780) - Senowbari-Daryan & Hamedani, p. 94, pl. 7, figs 1-4.

2012 *Casearia vezvanensis* n. sp. - Senowbari-Daryan and Amirhassankhani, p. 252, pl. 2, fig. 4; pl. 3, fig. 4; text-fig. 4

Material: One naturally weathered specimen in carbonate rock.

Description. The poorly preserved skeleton of this species has a length of more than 60 mm with numerous chambers. The width of each chamber is 8 mm, four-times larger than the height. The diameter of the sponge is 23 mm with outer annulations corresponding to the internal segmentation. Chamber walls are formed by coarse and loosely packed hexactine lattices (Pl. 8, fig. 4). Diameter of the spongocoel is 5 mm.

Occurrence. *Casearia vezvanensis* is only known from the Norian-Rhaetian reefs embedded within the Nayband Formation in Iran.

Discussion and conclusion

The occurrence and systematic positions of hypercalcified sponge in the construction of reef-type deposits in Garm Ab section has been beneficial for paleogeographic distributions of sponges, paleodepositional conditions and comparing taxa in different stratigraphic levels during the upper Triassic.

Hypercalcified sponge shows a widespread global distribution during Norian-Rhaetian time in warm tropical conditions (Stanley 2001; Flügel & Kiessling 2002). They are known from numerous localities in southern and northern America (Panthalassa), Europe (Northern Tethys) and Asia (Cimmeria such as Turkey and central part of Iran), (Senowbari-Daryan & Maurer 2008).

Norian-Rhaetian sponge associations of the Tethys are best developed in Northern Calcareous Alps (Shepherd et al. 2012). They formed reef belts in platform-edge positions facing the open marine northwestern Tethys basins, or as smaller patch reefs in intraplatform basins or on the platform ramps (Bernecker 2005). Reefs within the Nayband Formation also were formed on carbonate ramps in suitable depths below the wave base (Senowbari-Daryan 1996).

Taxa here studied, except hexactinellid sponges, are closer to Northern Calcareous Alps in Austria (Senowbari-Daryan 2003) than to other parts of Upper Triassic terrenes and it could suggest similar environmental conditions during Norian-Rhaetian. From Turkey though, two taxa, *Kashanella irregularis* and *Parauvanella ferdowsensis*, have been previously reported and only *Parauvanella ferdowsensis* has been identified from North America (Tab. 1).

Current Geographic Distribution	**Europe (Northern Tethys)**	**North America (Panthalassa)**	**Middle East (Cimmeria)**	
			Turkey	**Iran, Nayband Formation**
Taxa: this study	Occurrences: Paleobiology Database (pbdb.org)			
Anguispongia parva				**B, D, M, T**
Annaecoelia parva				**B, T**
*Casearia iranica**				**D**
*Casearia vezvanensis**				**D**
Cryptocoelia maxima n. sp.				
Kashanella irregularis	**A**		+	**B, D, M**
Molengraaffia regularis	**A**			**B, D, M, T**
Musandamia gosaukammensis	**A**			**B**
Parauvanella ferdowsensis		**Al**	+	**D, M, T**
Parauvanella spinosa				**D**
Permocorynella maxima	**A**			**B, D, M, T**
Preperonidella iranica	**A**			**D, K, M, T**
Preperonidella norica	**A**			**B**
Sestrostomella robusta	**A, I**			**B, D, K, M, T**

Tab. 1 - Current geographic distribution of hypercalcified and hexactinellid sponge taxa described in this paper and their occurrence in other Norian-Rhaetian localities. Turkey (+occurrence), Iran (different localities of the Nayband Formation): B= Bagherabad area, D= Delijan area, K= Kerman area, M= Marawand area, T= Tabas area, Europe (Northern Tethys): A= Austria, I= Italy, North America (Panthalassa) Al= Alaska, (based on Paleobiology Database, pbdb.org) and *Hexactinellids (Senowbari-Daryan & Amirhassankhani 2012).

	Reef Numbers							
Sponges	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**
Salzburgia sp.	*							
Amblysiphonella sp.1	*							
Amblysiphonella sp. 2				*			*	
Cryptocoelia maxima n. sp.		*	*					
Musandamia gosaukammensis		*		*				
Colospongia sp.					*			
Kashanella irregularis	*	*	*		*		*	*
Casearia cf. *iranica*	*							
Casearia vezvanensis	*							
Deningeria sp.	*				*			
Sestrostomella robusta	*	*		*		*	*	
Sestrostomella cf. *robusta*							*	
Molengraaffia regularis		*		*	*			*
Solenolmia sp.	*				*			
Anguispongia parva	*							
Parauvanella ferdowsensis				*	*			
Parauvanella spinosa	*							
Maeandrostia? sp.	*	*						
Annaecoelia parva		*						
Permocorynella maxima	*	*					*	
Preperonidella norica	*							
Preperonidella iranica	*		*			*	*	*
Hexactinellida	*	*	*	*		*		

Tab. 2 - Occurrence and abundance of sphinctozoan and inozoan sponges in reefal horizons of the Garm Ab section. The first horizon (R1) at the bottom of the section offered the most abundant sponge species. Apparently the abundance of the sponge decrease during the formation time of Garm Ab section from bottom to the top (from horizons R1 to R8).

Beyond *Salzburgia* and *Cryptocoelia maxima* n. sp., all described sponge taxa are known form the reef carbonates of other localities of Nayband Formation including Bagherabad, Delijan, Kerman, Marawand and Tabas area, (Tab. 1) being Norian-Rhaetian in age. Remarkable is the absence of *Iranothalamia*, *Nevadathalamia* and *Grossotubenella* – three abundant hypercalcified sponges – in other known Nayband localities. In this regard, the sponge fauna of Garm Ab section is very similar to the sponge association known from the Rhaetian section exposed south of the town of Bagherabad, north of Esfahan (Rashidi & Senowbari-Daryan 2011), where these genera are also absent.

In contrast to the abundance of hexactinellid sponges in Carnian reefs of China (Wu 1989a, 1989b; Wu & Xiao 1989; Rigby et al. 1998), this group of sponges is extremely rare in Norian-Rhaetian reefs in the northwestern Tethys (Alps and adjacent areas, Senowbari-Daryan & Zankl 2010). Furthermore, the chambered hexactinellied sponges occur rarely in the time equivalent reefs in the central and northern Tethys (Caucasus: Boiko 1990; Iran: Senowbari-Daryan & Hamedani 1999; Senowbari-Daryan & Amirhassankhani 2012). However, hexactinellid sponges in the Garm Ab section were found in the reefal limestone beds R1 to R6 (Tab. 2). The occurrence of the hexactinellid sponges was also reported from the reefal limestone near the town of Delijan (Tab. 1) in the western part of central Iran (Senowbari-Daryan & Amirhassankhani 2012) and it could testify for similar depositional condition in the east and west parts of central Iran during the Upper Triassic.

Isolated spicules of hexactinellid sponges occur in most thin sections in micritic matrix indicating the quick destructibility of this group after death. In general, hexactinellids are indicative of deep-water environments in the Palaeozoic, the Mesozoic and Cenozoic (e.g. Nose et al. 2013; Wendt et al. 1989; Krautter 1997). On the other hand, the association of sponges, corals and other reef builders and reef dwellers like benthic foraminifers with hexactinellids in the Garm Ab section suggests a deposition more closed to shallow water environment.

Sphinctozoans, inozoans and some hexactinellid, from the eight horizons of reefal limestone in different stratigraphic levels, indicate Norian-Rhaetian age. Based on sponges and other organisms (e.g. *Heterastridiums*) the stratigraphical age of the Garm Ab section continues from the Middle Norian to Rhaetian. The faunal assemblage cannot define the Norian/Rhaetian boundary.

The most abundant sponges occur in the first reefal carbonate horizon at the lower part of the section (Tab. 2). The abundance of sponges decrease to the younger horizons of the section. Two inozoan genera, *Preperonidella*, *Molengraaffia* and only one sphinctozoan genus *Kashanella* were found in the last reefal layer. Tectonic events and climatic fluctuations may cause additional feeding of siliciclastic sediments and an oversupply of nutrients, which could have limited growth of taxa during the end of Triassic.

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PLATE 1

Fig. 1 - *Salzburgia* sp. Marginally axial longitudinal section through a specimen exhibiting four chambers. Chamber walls are internally laminated (see Fig. 6), externally are pierced by labyrinthic canal system. The rimmed ostia in the exowalls are cut in two chambers. The drop-like skeletal elements hanging from the chamber roofs indicate to the possibly axial spongocoel. Chamber interwalls are doubled and thick. Thin section Am-F-15.

Fig. 2 - *Amblysiphonella* sp. 2. A) The oblique longitudinal section through several chambers shows axial spongocoel cut in the middle chambers. B) Oblique cross section through a specimen in the same thin section. Both specimens are poorly preserved. Thin section Am-F- 14.

Fig. 3 - *Amblysiphonella* sp. 1. Longitudinal section through an incomplete specimen was colonized on a chaetetid sponge. Thin section Am-F-12.

Fig. 4 - *Amblysiphonella* cf. sp. 2. Oblique longitudinal section through a specimen exhibiting perforated walls of ring-shaped chambers. It differs from *Amblysiphonella* sp. 2 (Fig. 2) with relatively wide spongocoel and bigger size of specimen. Thin section Am-F-42.

Fig. 5 - *Musandamia gosaukammensis* (Senowbari-Daryan). A) The longitudinal section through the sponge shows the ring-shaped chambers, the ambisiphonate type of the spongocoel and the horizontally ripped exowalls appearing as spine-like extensions in section. B) Oblique cross section through a second specimen showing the spine-like elements of the exowalls in part. Thin section Am-F-38.

Fig. 6 - *Cryptocoelia maxima* n. sp. (Paratype), ?Oblique ?Longitudinal section, cut through an internally well chambered specimen. The chambered nature is not recognizable from the outside of the sponge. The walls of crescent-like low chambers are clearly perforated. The filling structure within the chamber interiors as trabecular (pillar-like), especially within the young chambers is well recognizable. Thin section Am-F-35.

Scale in figs 1-5 = 5 mm, in fig. 6 = 10 mm.

PLATE 2

Fig. 1 - *Deningeria* sp. Longitudinal section through numerous chambers. Because of the coarse and abundant filling skeleton within the chamber interiors the chamber roofs are not well recognizable. Thin section Am-F-58.

Fig. 2 - *Cryptocoelia maxima* n. sp. (Holotype) ?Marginal ?longitudinal section exhibiting the crescent-like low chambers pierced by an apparently narrow ?spongocoel (for further information see the explanation of fig. 6 in Pl. 1). Thin section Am-F-17.

Fig. 3 - A) *Deningeria* sp. Similar section like fig. 1 (detail explanation see fig. 1) B) *Colosponiga* sp. Thin section Am-F-13.

Fig. 4 - *Colospongia* sp. Longitudinal section through several spherical chambers with evenly perforated chamber walls. The sponge encrusted by its basal part another undeterminable sponge with reticular fiber skeleton. Thin section Am-F-56.

Fig. 5 - *Solenolmia* sp. (n. sp. ?). Oblique section through several crescent-like chambers with perforated walls. Chamber interiors contain reticular fiber skeleton. The axial canal with own wall is cut. Thin section Am-F-20.

Scale in all figs = 10 mm, except in fig. 3, 4 = 5 mm.

PLATE 3

Fig. 1 - *Parauvanella ferdowsensis* Senowbari-Daryan. Marginal section through three globular chambers (sub-globular in section) exhibiting thin and evenly perforated chamber walls. The sponge encrusted a biogenic component. Thin section Am-F-59.

Fig. 2 - *Parauvanella spinosa* Rashidi and Senowbari-Daryan. Section through several chambers exhibiting thin and evenly perforated walls. The spine-like extended skeletal elements from the chamber walls into the chamber interiors are cut in two chamber roofs. Thin section Am-F-10.

Figs. 3, 5-7- *Kashanella irregularis* Senowbari-Daryan. 3) Almost identical section through four moniliform chambers exhibiting the specific characteristic labyrinthic canal system of the chamber walls. Thin section Am-F-18. 5) Section through three chambers with relatively thick outer walls. Thin section Am-F- 27. 6) Thin section Am-F-39. 7) Section through a specimen exhibiting clearly the thick exowalls and thin interwalls like fig. 5. Thin section Am-F-57.

Fig. 4 - Longitudinal section through several low chambers with perforated chamber walls (compare Fig. 8C). Thin section Am-F-77.

Scale in all figs = 5 mm.

PLATE 4

Fig. 1 - *Annaecoelia parva* Senowbari-Daryan. Longitudinal section through several glomerately arranged chambers of a poorly preserved specimen. Thin section Am-F-23.

Fig. 2 - *Casearia* cf. *iranica* Senowbari-Daryan and Amirhassankhani. Longitudinal section through several ring-shaped chambers arranged around a relatively wide axial spongocoel (for observation turn the photo 90° in clockwise direction, compare with Fig. 14B). Thin section Am-F-11.

Fig. 3 - Hexactinellid sponge gen. et sp. indet. Section through a non-chambered specimen builds by hexactine lattice. Thin section Am-F-11.

Fig. 4 - A) *Casearia* sp. Longitudinal section exhibiting some crescent-like low chambers. B) *Casearia* cf. *iranica* Senowbari-Daryan and Amirhassankhani. Marginally longitudinal section through an incomplete specimen exhibiting the poorly recognizable chamber walls. Thin section Am-F-30.

Fig. 5 - Cross section through a hexactinellid sponge gen. et sp. indet. The extremely wide spongocoel is surrounded by the thin sponge wall. Numerous large and radially running openings connected the spongocoel with the outside of the sponge. Thin section Am-F-34.

Fig. 6 - *Cryptocoelia maxima* n. sp. (Paratype) Oblique longitudinal section through a relatively well preserved specimen showing pillar-like infilling within some chambers. Thin section Am-F-28.

Scale in figs 1-4 = 5 mm, in figs 5-6 = 10 mm.

PLATE 5

Figs 1, 4-5 - *Sestrostomella robusta* Zittel. 1) Longitudinal (A) and cross (B) sections from the same specimen exhibiting the tubes of the axial canal bundle concentrated in the center and the oblique running exhalant tubes ending into the tubes of the canal bundle. The thin and perforated walls around the tubes are clearly recognizable. Thin section Am-F-16. 4) Longitudinal (A) and cross section (B) through the same specimen exhibiting clearly the axial canal bundle composed of several individual tubes. Thin section Am-F-22. 5) The cross to oblique section through a specimen shows the axial canal bundle, some vertically running tubes of the spongocoel (circles in the center of the sponge). At least an inhalant canal (left in the photograph) is cut and the reticular fiber skeleton of the sponge wall is clearly visible. Thin section Am-F-43.

Figs. 2, 6 - *Sestrostomella* cf. *robusta.* 2) Longitudinal section (A) of a branched specimen, cross section (B) through the same specimen exhibiting similar characteristics like Fig. 6. The tubes of the spongocoel are scattered through the sponge wall. Thin section Am-F-52. 6) Longitudinal section through a dichotomously multi-branched specimen exhibiting similar characteristics like another illustrated specimen in Pl. 8, fig. 5. The tubes of the spongocoel are scattered from the center through the wall to periphery of the sponge. Thin section Am-F-71.

Fig. 3 - *Anguispongia parva* Senowbari-Daryan. Sections perpendicular (A) and parallel to the tabular sponge (B) of the same specimen exhibit the reticular fiber skeleton without any inhalant and exhalant canals. Thin section Am-F-21.

Scale in all figs = 10 mm.

PLATE 6

Figs 1-2, 4 - ?*Molengraaffia* sp. 1) Sections through two, not exactly determinable specimens. Thin section Am-F-25. 2) Sections through two specimens exhibiting reticular fiber skeleton without other sponge features. Thin section Am-F-47. 4) Section through a dichotomously multi-branched specimen exhibiting similar or almost identical fiber skeleton (see the magnification) like *Molengraaffia* (compare fig. 5), but branched specimens of this genus are not known. Thin section Am-F-53.

Fig. 3 - *Maeandrostia*? sp. The longitudinal section of an apparently branched specimen shows the thin exowall of the sponge pierced by large openings. Internally the sponge contains some coarse fiber skeleton. Thin section Am-F-88.

Fig. 5 - *Molengraaffia regularis* Vinassa de Regny. The longitudinal section, pependicular to the tabular sponge exhibits the linear arrangement of the fiber skeleton. Thin section Am-F-66.

Fig. 6 - *Permocorynella maxima* Senowbari-Daryan, Seyed-Emami and Aghanabati. Oblique section through a relatively well preserved specimen exhibiting the axial spongocoel and numerous inhalant and exhalant canals passing through the thick sponge wall composed of reticular fiber skeleton. Thin section Am-F-24.

Fig. 7 - *Preperonidella iranica* Senowbari-Daryan. The cross and oblique sections through dichotomously and multi-branched specimens show the sponge wall, composed of reticular fiber skeleton. The thick spongocoel wall with white appearance is pierced by openings. Thin section Am-F-29.

Scale in figs 1-2 and 4-6 = 10 mm, in figs 3 and 7 = 5 mm.

PLATE 7

Figs 1-2, 5-6 - *Preperonidella iranica* Senowbari-Daryan 1) A - Cross section of the same specimen, whose longitudinal section is illustrated in B. Both sections show the thick sponge wall and the axial spongocoel with distinct wall pierced by several openings. Thin section Am-F-33. 2) Similar sections as in Fig. 1 exhibiting similar characteristics of the sponge. Thin section Am-F-62. 5) Cross section of a specimen exhibiting some radially arranged exhalant tubes, ending to the narrow spongocoel. Thin section Am-F-73. 6) Several oblique sections exhibit similar features of the sponge like other specimens. The narrow axial spongocoel is remarkable. Thin section Am-F-82.

Figs 3-4 - *Preperonidella norica* (Senowbari-Daryan, Seyed-Emami and Aghanabati). 3) Cross (A) and (B) longitudinal sections from the same specimen. Both sections show the thick sponge wall and the axial spongocoel without a wall. The connection between the spongocoel and the sponge wall is produced by the interfiber spaces. Thin section Am-F-26. 4) Cross section exhibiting similar sponge characteristics like Fig. 3A. Thin section Am-F- 31.

Scale in all figs = 10 mm.

PLATE 8

Fig. 1 - *Deningeria* sp. Longitudinal section of a specimen on a naturally weathered rock surface. Internally the species exhibits clearly the chambered construction with reticular fiber skeleton within the chamber interiors. The sponge seems to be asiphonate (sample FR2).

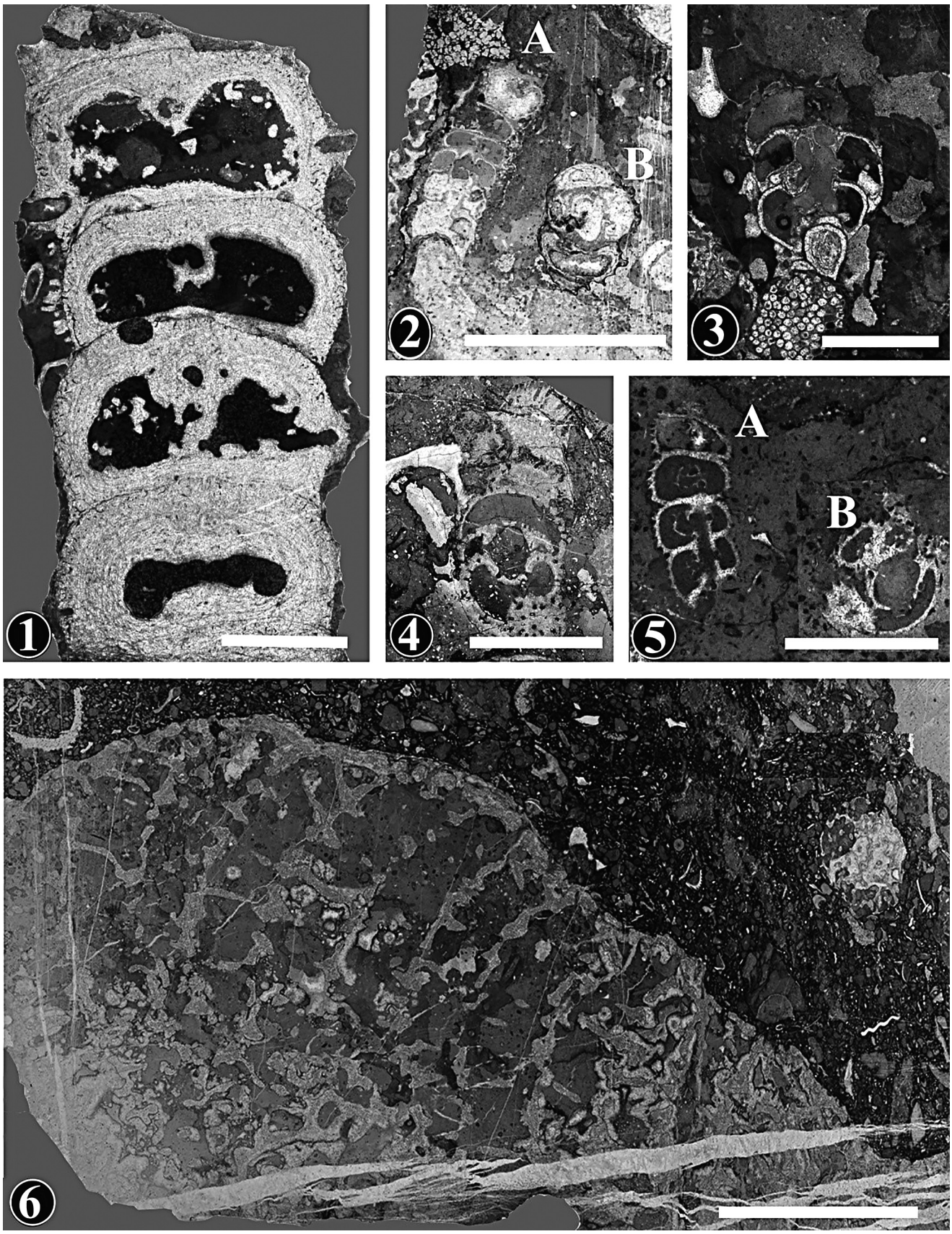
Fig. 2 - Sphinctozoan sponge gen. et sp. indet. Longitudinal and cross sections through three specimens show partly perforated and partly imperforated chamber walls. Chamber interiors contain rare vesiculae, separating the cements from the sediment. Thin section Am-F-36.

Fig. 4 - *Casearia vezvanensis* Senowbari-Daryan & Amirhassankhani. Longitudinal section on the naturally weathered rock surface shows well preserved, crescent-like low chambers on the left side of the photographs. The chambered construction of the species is hardly or even not recognizable from the outside of the sponge (sample FR1).

Figs 3, 5 - *Sestrostomella* cf. *robusta* Zittel. Several longitudinal, oblique and cross sections cut on naturally weathered rock surface (samples FR7). The dichotomously multi-branched specimen (fig. 5) and all other specimens in both photos show the several axially arranged tubes as spongocoel.

Fig. 6 - *Parauvanella ferdowsensis* Senowbari-Daryan. Section through several chambers of a specimen on naturally weathered rock surface. The thin chamber walls are pierced by evenly distributed single pores (sample FR4).

Scale in all figs = 10 mm.



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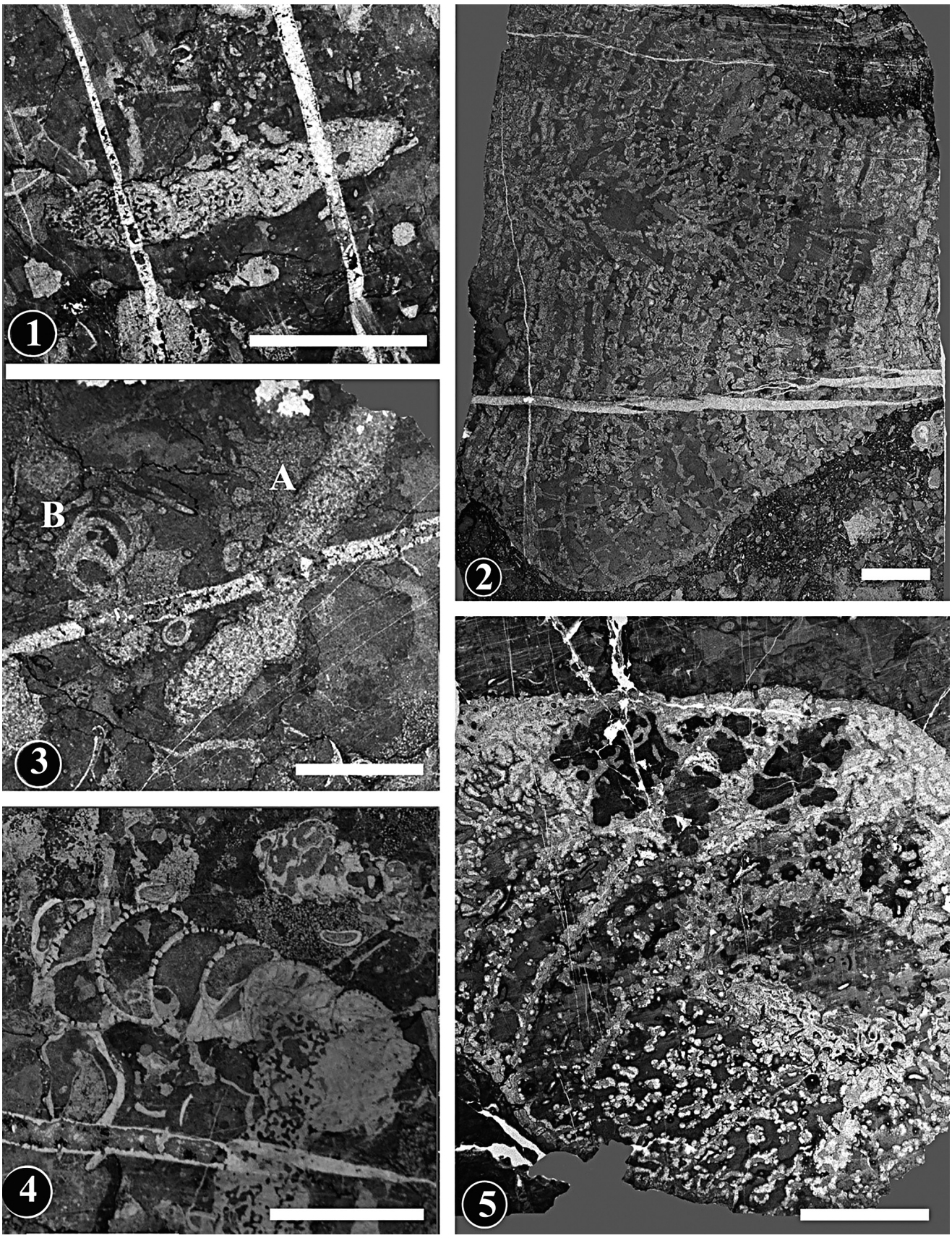

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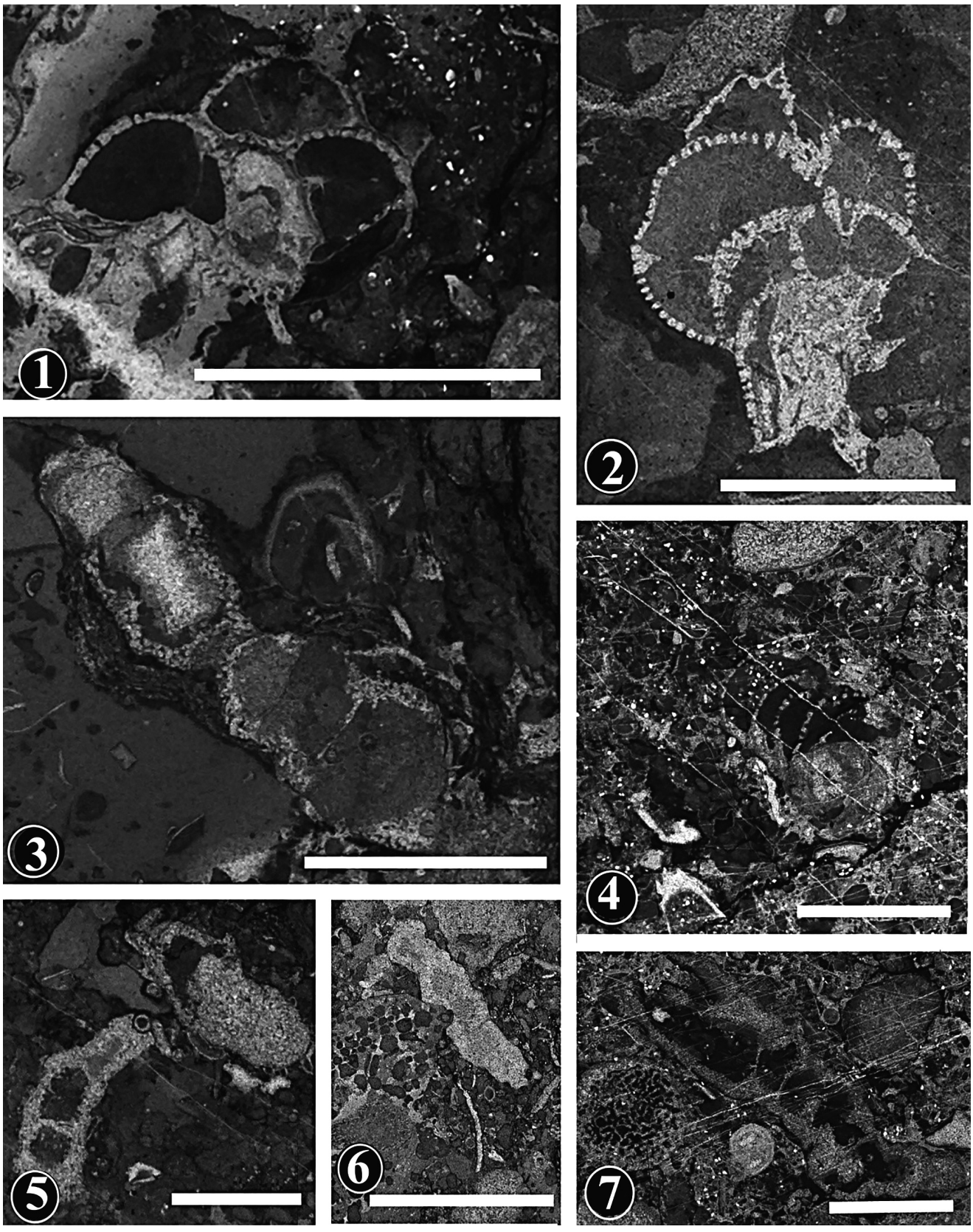

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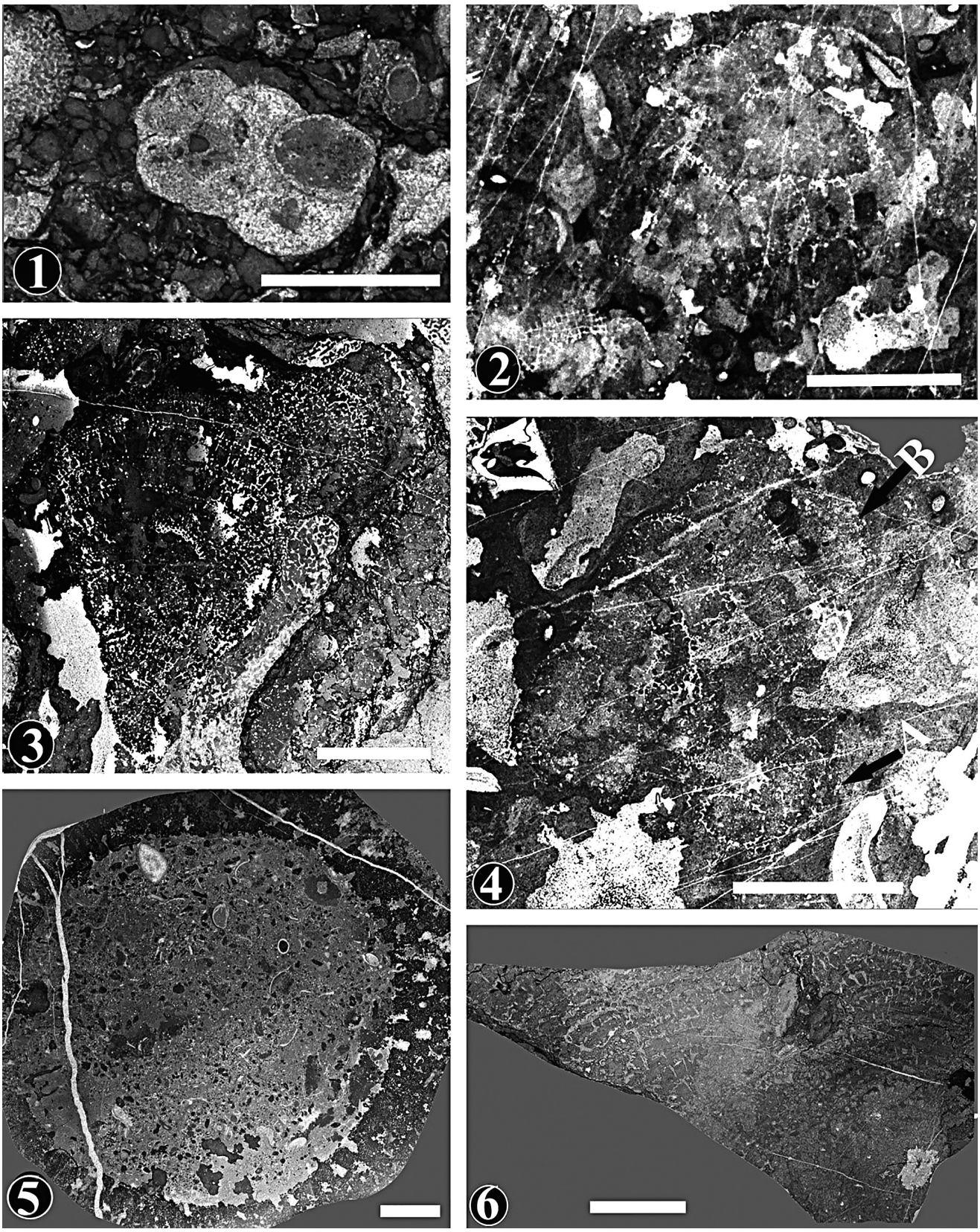

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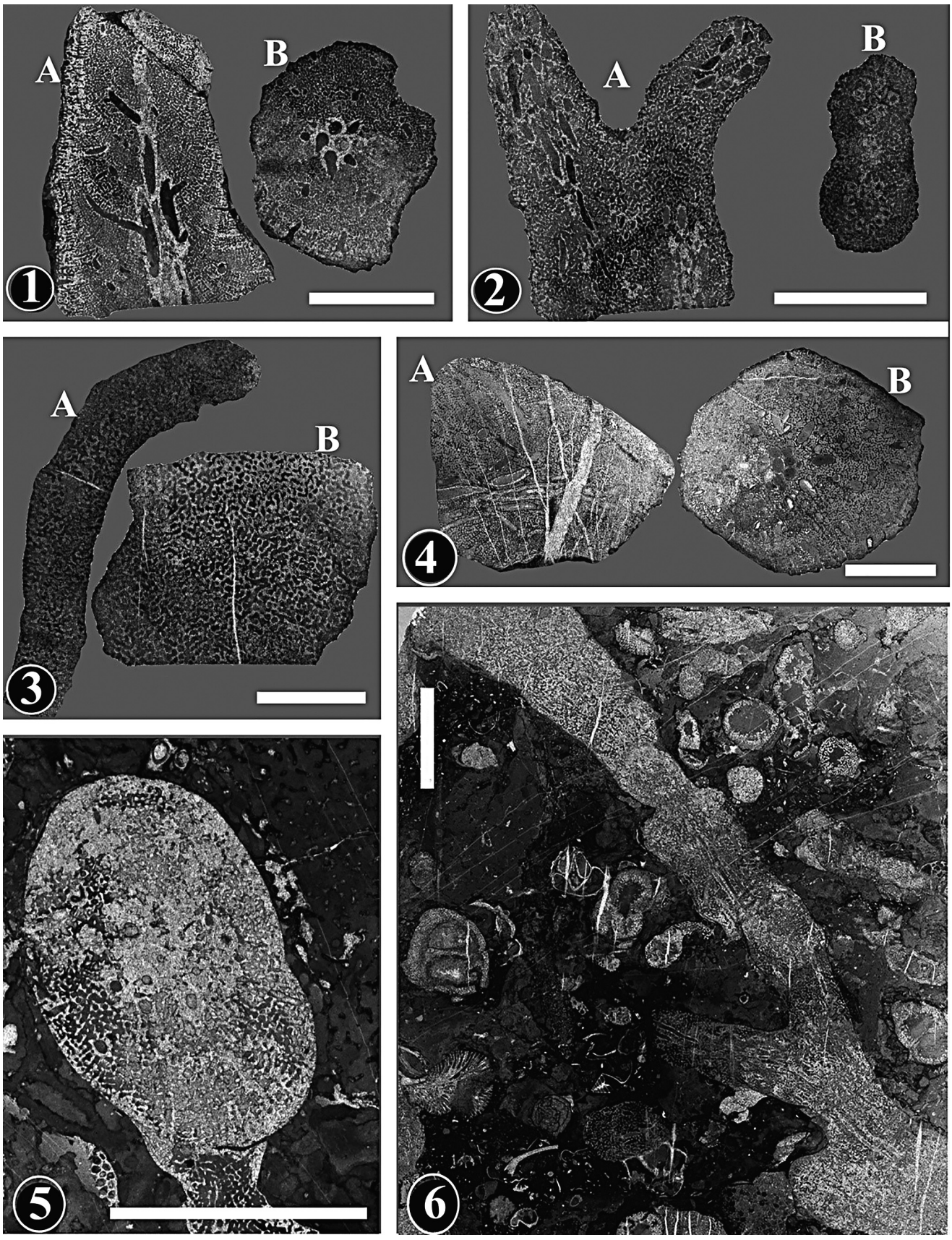

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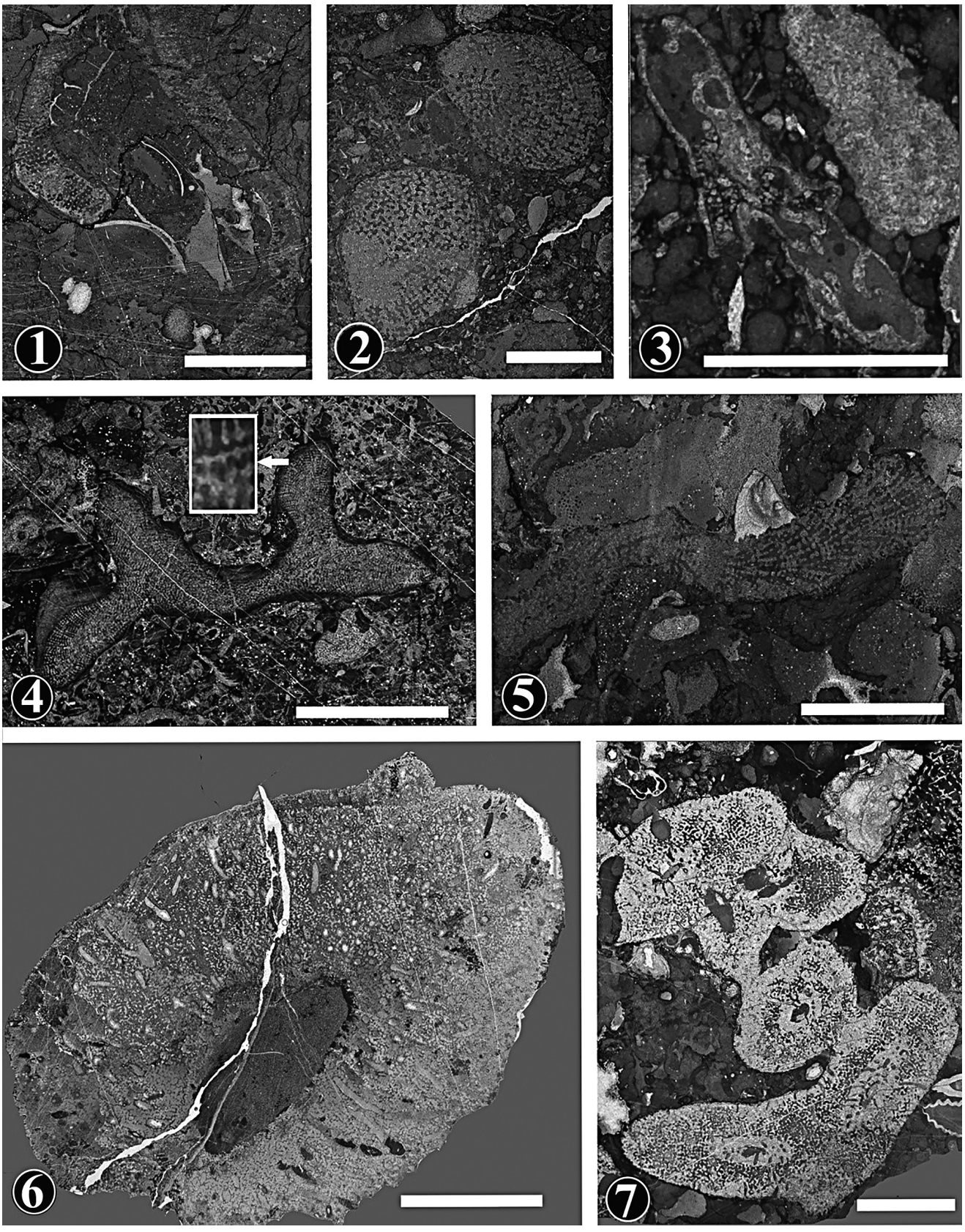

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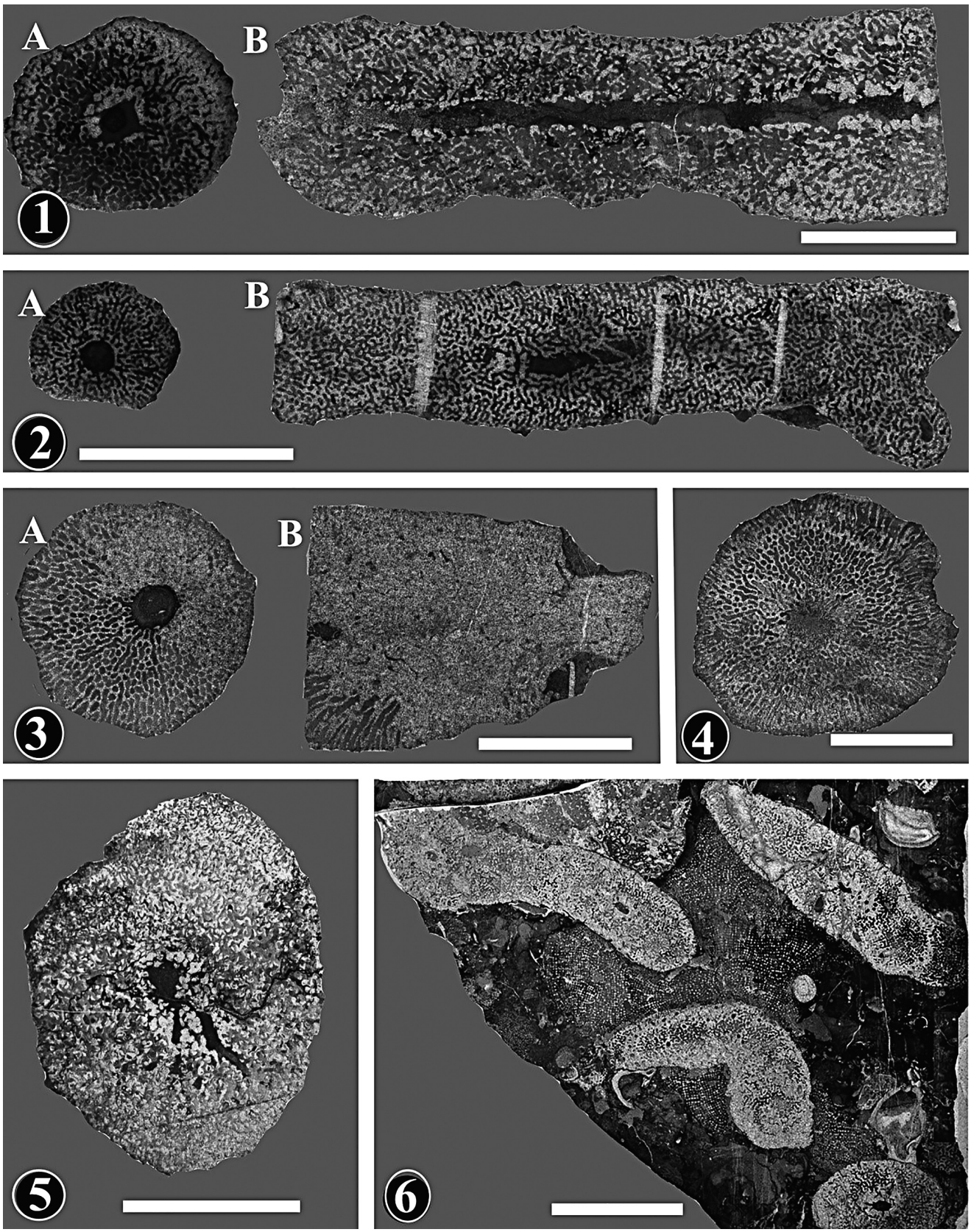

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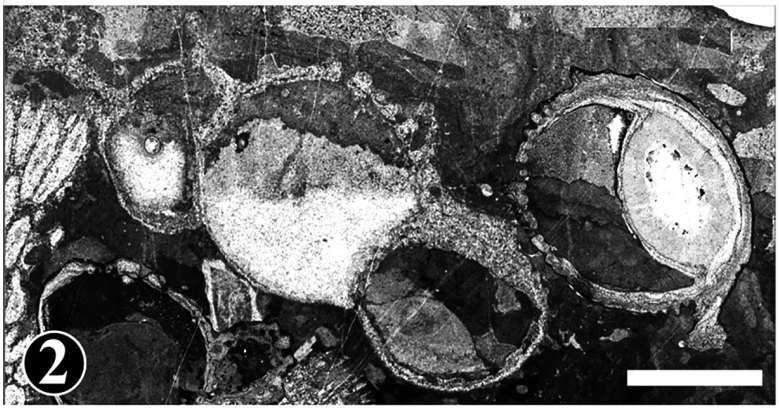

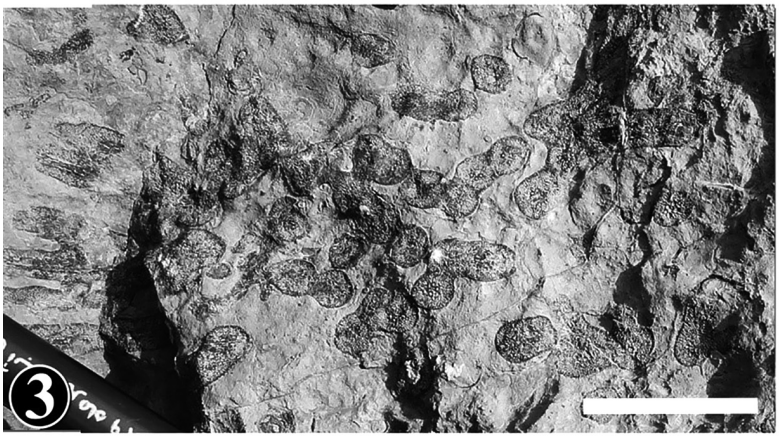

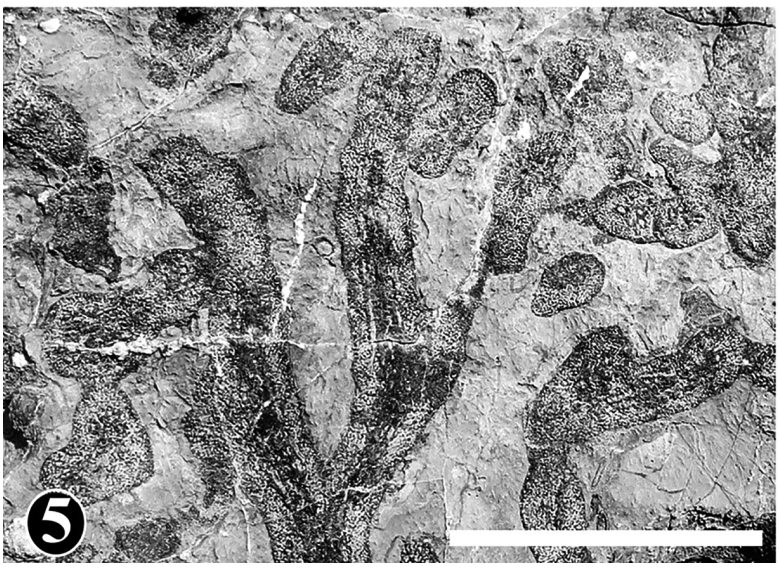

PLATE 8

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