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**Article**

# *Sarmentofascis*? *digitatus* n. sp., a new cladocoropsid stromatoporoid from the Tithonian-early Berriasian (Late Jurassic-Early Cretaceous) of the Ay-Petri massif (Crimea Peninsula)

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With 5 figures and 2 tables

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**Abstract:** The new stromatoporoid sponge *Sarmentofascis*? *digitatus* n. sp. (family Cladocoropsidae) is described from the Tithonian-Early Berriasian of the Crimea Peninsula. The skeleton has a digitate shape, with thin cylindrical stems, displaying characteristic subparallel (palisade-like) dichotomous branching. The internal structure of the mostly strongly recrystallized specimens is reticulate without any tube differentiation (e.g., astrorhizal canals). With the digitate and biostromal development, the skeletons of *S.*? *digitatus* acted as sediment-bafflers. The three-dimensional structures are associated with microencrusters (foraminiferans, thaumatoporellaceans) that occupy the spaces between the stem-like cylindrical forms. The skeletons accumulated to form *Sarmentofascis*-bearing biostromes that may be interpreted to represent a habitat in the outer lagoonal zone behind marginal reef flats.

**Key words:** Stromatoporoids, sponges, *Sarmentofascis*, *Cladocoropsis*, systematic, Upper Jurassic, Crimea.

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## 1. Introduction

Stromatoporoids comprise about 110 Paleozoic to Mesozoic genera (Stock 2001; Cook 2002) representing an extinct group of benthic macrofossils that have long been controversially represented in the literature as having an uncertain taxonomic status (e.g., Stearn 1972, 2010). For at least the record of Mesozoic forms, there seems to be general agreement that they are demosponges due to the general body bauplan and especially the evidence of spicules in the skeletons of some taxa (Wood & Reitner 1986; Wood 1987). Only recently, spicules have also been observed in a Devonian taxon (Da Silva et al. 2014), further substantiating the sponge nature also of Paleozoic representatives. It was already demonstrated earlier by Stearn et al. (1999), who argued for a sponge association given the nature of their calcareous skeletons and their modular form with clear-cut evidence of the presence of aquiferous systems. In Mesozoic times, an acme period representing their development has been recognized for the Late Jurassic and to a slightly lesser extent the Early Cretaceous interval (Yabe & Sugiyama 1935; Hudson 1954; Fenninger & Hötzl 1965; Turnšek 1966, 1968; Milan 1969; Turnšek et al. 1981; Termier et al. 1985; Wood 1987; Leinfelder et al. 2005). Among them, representatives of the family Cladocoropsidae, with the genera *Cladocoropsis* Felix, 1907 and *Sarmentofascis* Termier, Termier & Vachard, 1977, exhibit a cosmopolitan character (Felix 1907; Yabe & Toyama 1927; Radoičić 1957; Vachard et al. 1977; Dong 1981; Kano et al. 2007). In the present paper a new biostrome-forming stromatoporoid of the family Cladocoropsidae is described as *Sarmentofascis*? *digitatus* from the latest

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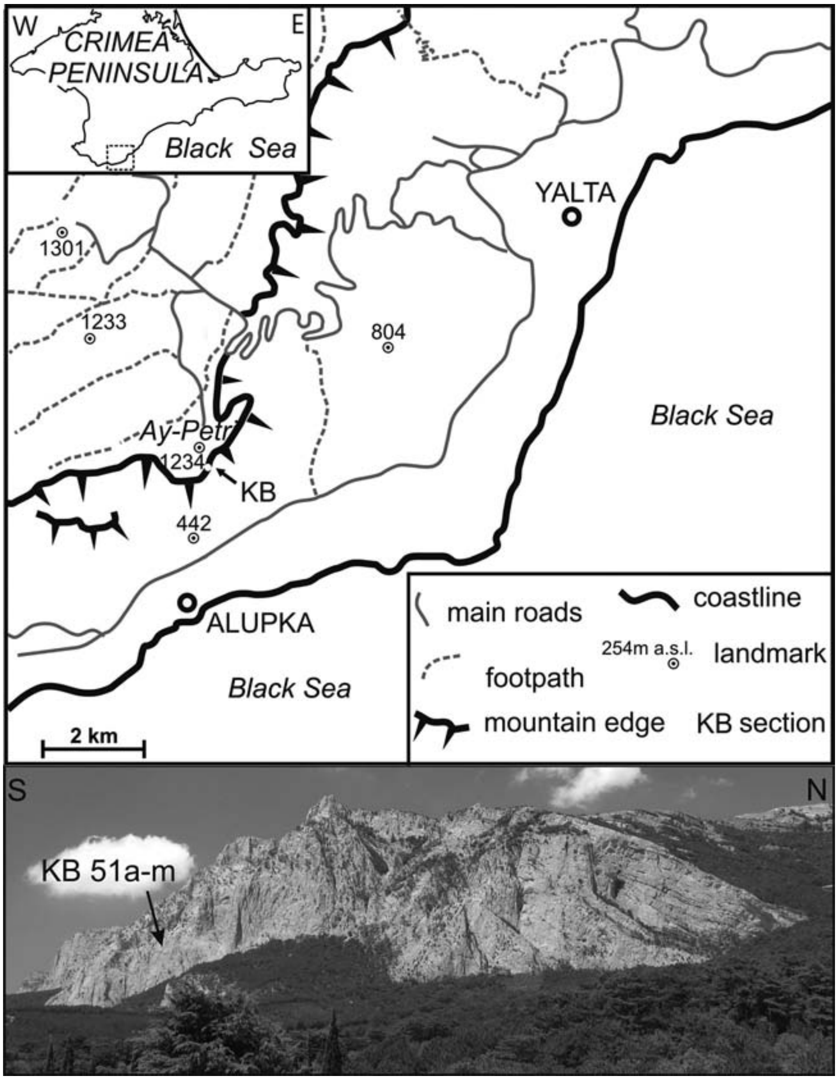

**Fig. 1.** Above: Topographic sketch of the Ay-Petri massif southwest of Yalta, Crimea Peninsula. The type locality is marked by the KB section. Below: View of the southern slope of the Ay-Petri massif (from east to west) with approximate position of the holotype-sample of *Sarmentofascis*? *digitatus* n. sp. within the KB section.

Jurassic-earliest Cretaceous of the Crimea Mountains (Fig. 1), an area where already several stromatoporoid taxa have been described (Pcelincev 1925; Yavorsky 1947) (see details in the systematic part).

## 2. Geological setting and sample localities

The coastal range of the Crimea Mountains is formed by sediments of Triassic to Berriasian (Early Cretaceous) age that during the earliest Cretaceous was uplifted and subjected to erosion possibly in response to compressional event (Afanasenkov at al 2007; Nikishin et al. 2015). The main range of the Crimean Mts. was a marginal portion of a broad, epicontinental basin, which rimmed the northern margin of the Tethyan Ocean in Jurassic time (e.g., Guo et al. 2011; Nikishin et al. 2015). The study area is situated in the southwestern part of the Crimean Mts., the so-called Ay-Petri reef complex. The deposits range in age from the Late Jurassic (latest Oxfordian, Kimmeridgian, and Tithonian), through to the Berriasian (e.g., Gorbatchik & Mohamad 1997; Krajewski & Olszewska 2006, 2007).

All sediments encountered in the Ay-Petri massif are products of shallow-marine deposition in various

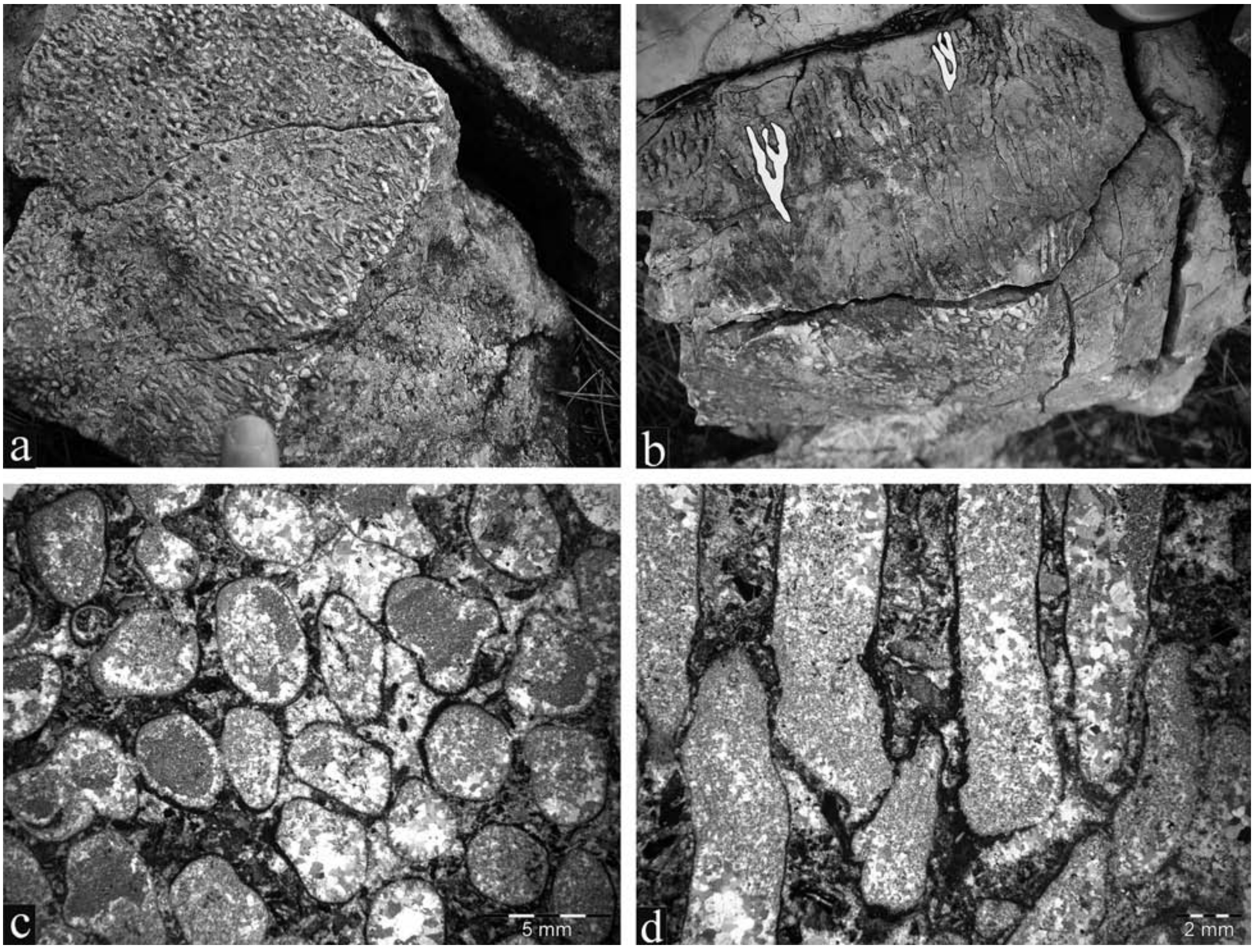

**Fig. 2.** *Sarmentofascis*? *digitatus* n. sp. from the Tithonian-Early Berriasian of the Ay-Petri massif, Crimea Peninsula. **a** – Weathered rock surface showing numerous skeletons in transverse sections (upper part of the sample) and oblique sections (lower part of the sample). **b** – Weathered rock surface showing numerous ramose skeletons (two exemplarily highlighted in yellow) arranged parallel to each other (longitudinal section) and indicating the assumed original growth position. **c** – Transverse to oblique transverse section with close-set, sometimes in direct contact, skeletons (compare to **a**). Thin-section KA 12a. **d** – Longitudinal section of close-set parallel arranged skeletons (compare to **b**). Thin-section KA 12b.

environments related to succeeding evolutionary stages of the Crimean Mts carbonate platform (Krajewski 2008, 2010; Piskunov et al. 2012; Bucur et al. 2014; Rud'ko et al. 2014). The platform developed at a continental margin (e.g., Nikishin et al. 2015) and the land only temporarily supplied siliciclastic material (Krajewski 2010).

In macroscopic observations the limestones mostly appear as a rather monotonous succession of pelitic or detrital carbonates. In the lower part, horizons of sandstones and sandy limestones are found, with thicknesses usually some tens of centimeters. In the topmost part of the Ay-Petri section, at the edge of the plateau, reddish Berriasian-Mid Valanginian breccias and neptunian dykes occur (Krajewski 2010; cf. Chatalov et al. 2015). The results of microscopic examination of these deposits led to the differentiation of different microfacies types, which, on the contrary to macroscopic observations, reveals a complicated structure of the Ay-Petri reef complex (Krajewski & Olszewska 2006; Krajewski 2008). These can be assigned to the platform slope, platform margin reefs and ooidal shoals, as well as internal platform lagoons and tidal flats. The microfacies analysis revealed that the sediments were deposited in a shallow-marine environment, within the photic zone, at depths not exceeding some tens of meters but usually in a much shallower sea (Krajewski 2008). The deepest facies, which represents platform slope deposition, are thrombolitic-*Crescentiella* bindstones with an association of *Crescentiella morronensis*-*Terebella lapilloides* microencrusters (e.g., Schmid 1996) and microsolenid biostromes, as observed in the lower parts of the sequence. Upwards the sequence has a fossil assemblage that becomes more diversified, i.e., with numerous dasycladalean and udoteacean algae, stromatoporoids, chaetetids and other sponges, corals and various microencrusters with *Lithocodium aggregatum*, *Pseudolithocodium carpathicum*, bacinellid fabrics, and *Thaumatoporella parvovesiculifera* microproblematica (Krajewski 2008, 2010; Bucur et al. 2014). In the sequence, several complexes of sediments deposited in shallow subtidal, intertidal and supratidal environments, probably related to lower-rank, transgressive-regressive cycles, can be distinguished. Commonly observed ooids-bioclasts of typical shoal-facies represent platform marginal deposits. The shallow, subtidal marginal platform facies is also represented by patch-reefs and biostromes built by various organisms (stromatoporoids and corals), as well as microbialites (Krajewski 2008). Densely packed skeletons display intensive growth of microencrusters. The described stromatoporoids associated with numerous microencrusters (Figs. 3-4) were observed in large quantities in the back reef environments, the outer lagoonal marginal zone behind the reef flat respectively. Influences from the platform margin are indicated for example with rare specimens of the dasycladalean *Steinmanniporella taurica* (Pcelinev) (Fig. 3a) (Bucur et al. 2014: “high energy environments...associated with reef facies”). The stromatoporoid biostromes were observed in many levels of the Ay-Petri reef complex but particularly abundant in its middle part. Skeletons of the described stromatoporoids are observed in both erect-upward life position and displaced often with microbial coatings. The internal structure of the skeletons is often poorly visible due to dissolution. Commonly, they are completely replaced by cement while their morphology is reflected by external envelopes built up of micoencrusters (Fig. 3). Oncoidal packstones and bioclastic wackestones-floatstones are interpreted as back-reef and lagoonal environments. Moreover, in some parts of the sequence peloidal packstones, microbial bindstones and mudstones with fenestral structures are noted, suggesting deposition in intertidal environment. In particular sequences, several discontinuities are observed, related to depositional breaks and erosion (Krajewski 2010).

The investigated material (KB-section) comes from the steep southern part of the Ay-Petri massif (Fig. 1, below).

## 3. Systematic palaeontology

No modern suprageneric classification of Mesozoic stromatoporoids has included the family Cladocoropsidae, hence we have adopted the earlier proposal of Termier et al. (1977) as follows here. For the descriptive terminology see Webby (2010).

Phylum Porifera Grant, 1836
Class Demospongiae Sollas, 1885
?Order Axinellidea
Family Cladocoropsidae Termier,
Termier & Vachard, 1977
Genus *Sarmentofascis* Termier,
Termier & Vachard, 1977

*Sarmentofascis*? *digitatus* n. sp.
Figs. 3-5

**Etymology:** The species name refers to the digitate morphology of the skeleton.

**Holotype:** Specimen illustrated in Fig. 3e showing branching. Thin-section KB 51j.

**Paratypes:** Specimens illustrated in Figs. 2c-d, 3a-d, f, 4.

**Depository:** The thin-sections with the numbers indicated in Figs. 2-4 are deposited at the AGH University of Science and Technology, Faculty of Geology, Geophysics and Environmental Protection, Kraków, Poland (M. Krajewski Crimea collection).

**Type locality:** Southern escarpment below summit Mount Ay-Petri, Crimea Mountains. The geographic coordinates are E34°03’18’’ longitude and N44°26’40’’ latitude (Fig. 1).

**Type horizon:** Tithonian to Early Berriasian shallow-water limestone sequence, among containing biostromal structures.

**Diagnosis:** Small-sized representative of *Sarmentofascis* with a digitate skeleton composed of more or less straight, cylindrical branches that sometimes show an alternation of swellings and constrictions along the length of associated branches. Internal structure reticulate (with longitudinal and transverse elements), transverse sections vermicular. Tube differentiation and spicules not observed. Original microstructure unknown due to intense recrystallization.

**Description:** The skeleton displays a digitate form with a dichotomous branching habit (Fig. 2b). It consists of indi-

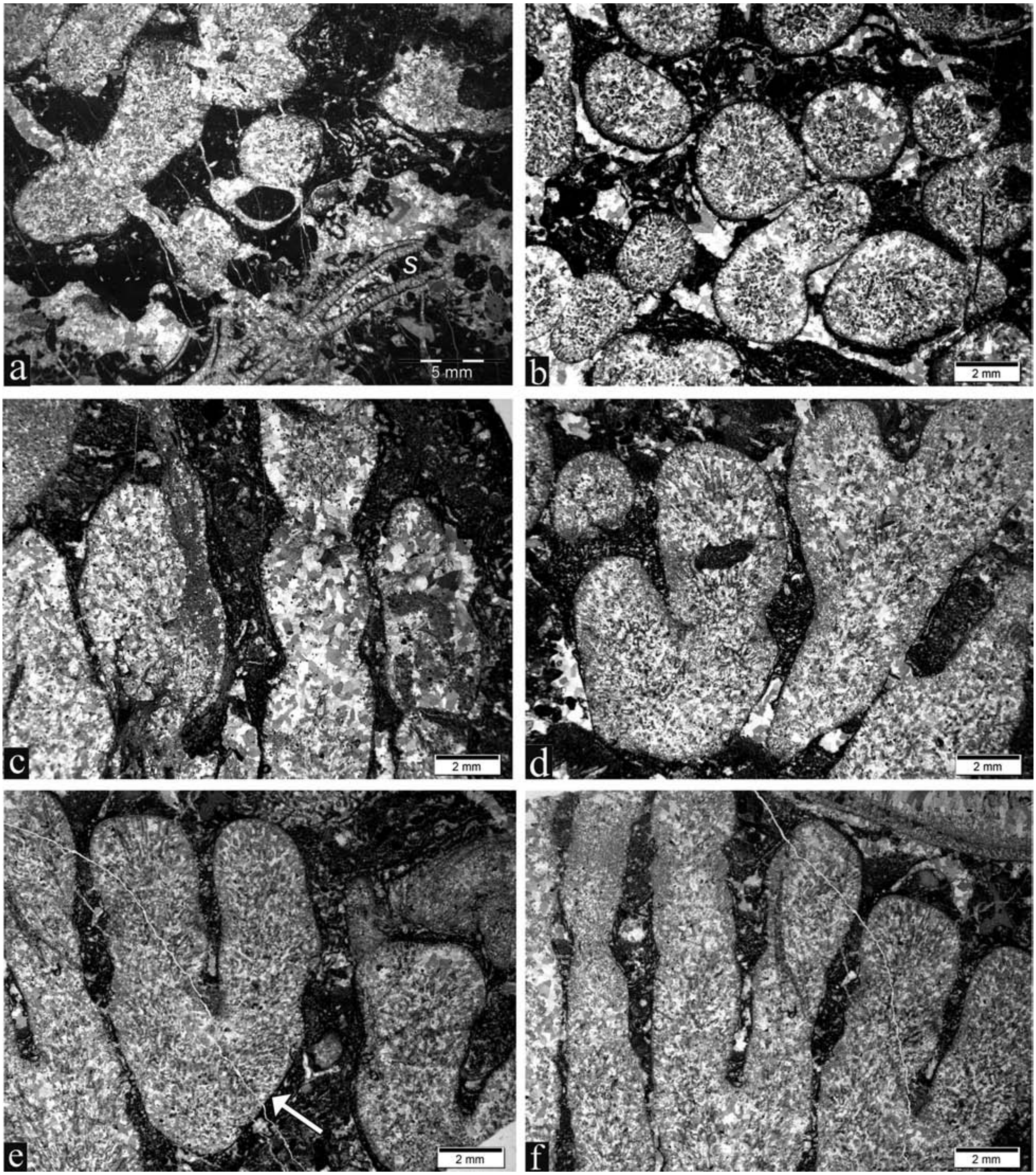

**Fig. 3.** *Sarmentofascis*? *digitatus* n. sp. from the Tithonian-Early Berriasian of the Ay-Petri massif, Crimea Peninsula. **a** – Different (mostly oblique) sections. Note the longitudinal section of the dasycladale *Steinmanniporella taurica* (Pcelinev) (*S*). Thin-section KB 38b. **b** – Different (mostly transverse) sections. Thin-section KB 51o. **c** – Longitudinal sections. Note the complete recrystallization of the two right specimens (one displaying alternation of constrictions and swelling) to a coarse mosaic of calcite crystals. Thin-section KB 47k. **d** – Oblique section of two skeletons showing short laterals branches. Thin-section KB 51c. **e** – Slightly oblique longitudinal section of branching skeleton. Holotype (arrow). Thin-section KB 51j. **f** – Close-set and parallel to each other arranged skeletons displaying branching Note the constrictions and swellings of the specimen in the middle. Thin-section KB 51j.

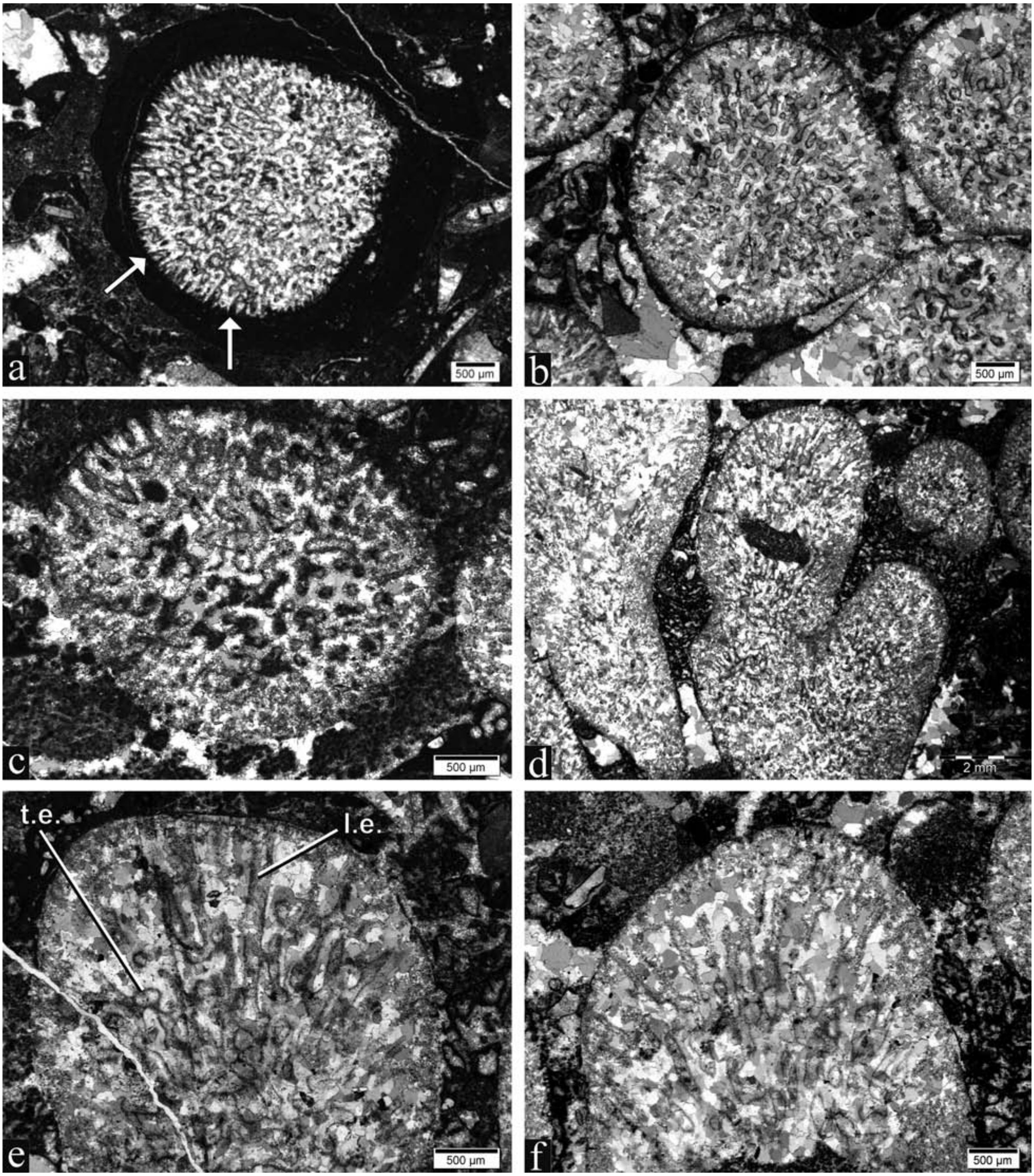

**Fig. 4.** *Sarmentofascis*? *digitatus* n. sp. from the Tithonian-Early Berriasian of the Ay-Petri massif, Crimea Peninsula. **a** – Oblique transverse section of an individual (most likely transported) skeleton displaying microbial coating. Arrows: pores. Thin-section KB 44a. **b** – Oblique transverse section of a colony. Thin-section KB 51o. **c** – Transverse section showing vermiculate inner structure of skeleton. Thin-section KB 51a. **d** – Slightly oblique longitudinal section of branched skeleton. Thin-section KB 51c. **e** – Longitudinal section of a flattened branch tip showing reticulate inner structure with interconnected longitudinal elements. Thin-section KB 51j. **f** – Detail from **e** showing interconnected preserved longitudinal skeletal elements. Interstices are filled with coarse-grained calcite crystals. Thin-section KB 51c. Abbreviations: l.e. longitudinal skeletal elements, t.e. transversal skeleton elements.

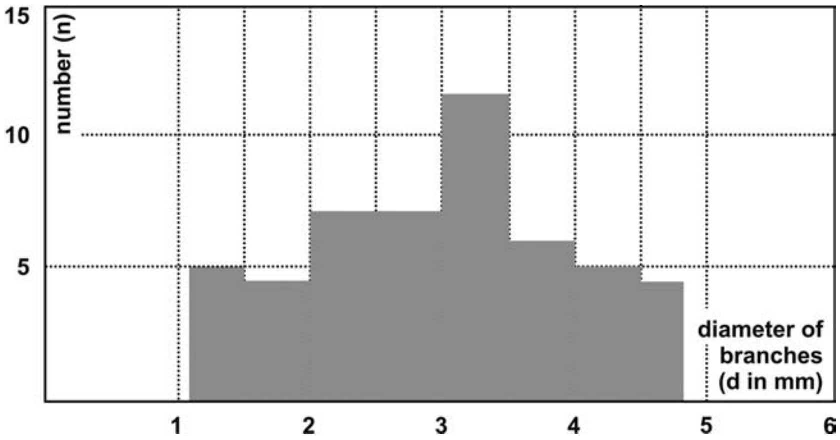

**Fig. 5.** Statistic distribution (n = number) of the diameter (d = diameter) of individual branches of *Sarmentofascis*? *digitatus* n. sp. from the Tithonian-Early Berriasian of the Ay-Petri massif, Crimea Peninsula.

vidual cylindrical branches that sometimes display alternating constrictions and swellings along their axes (Fig. 3c). As most skeletons do not show annulations, it cannot be considered a principal systematic feature but may represent growth interruptions or disturbances. The angle of branching is usually rather low with about 10 to 15 degrees (Fig. 3f) but can also reach up to 45 degrees (Fig. 3d). Side branches usually change their growth direction into an erect manner so that altogether they develop more or less parallel to the main branches giving rise to a palisade-like appearance (Fig. 3e). The tips of individual branches are usually rounded but may also show planar terminations in lateral continuity within the skeleton. This observation might be related to effects of erosion or abrasion (storm events?). Transverse sections are rounded to slightly ovoid (Fig. 4a-c). Internally the skeletons are mostly heavily affected by recrystallization. This can lead to a complete destruction of the internal structures resulting in a preservation mode where the skeletons consist entirely of a coarse-grained mosaic of calcite crystals.

The internal structure where better preserved may consist of a three-dimensional reticulate network of skeletal elements. In longitudinal sections, elements with both longitudinal (pillars) and transverse orientation, more or less equal in thickness, can be observed (Fig. 4e-f). The skeletal elements are slightly thinner than the system of pores between them. Towards the skeleton margin, pores appear to become slightly reduced in width so that the skeletal elements between them get a more dense aspect compared to the main internal part. The tubes do not show any differentiation with larger tubes of special orientation or varying sizes (e.g., astrorhizal canals). There is no dermal layer (cortex) so the outer skeleton surface is marked by open pores (Fig. 4c). Any differentiation into inhalant or exhalant pores is not possible. Spicules have not been observed.

**Dimensions:** Diameter of branches: 1.1-4.8 mm (mostly between 3 and 3.5 mm, see Fig. 5). Diameter of skeletal elements: 0.05-0.17 mm. Diameter of pore spaces between skeletal elements: 0.1-0.22 mm. Maximum length of vertical branches forming the skeleton: up to about 4 cm

**Remarks:** From the Upper Jurassic of Crimea, YAVORSKY (1947) reported several new taxa (species, genera) of stromatoporoids (Table 2). These belong to the genera *Actinostromaria* DEHORNE, *Stromatopora* GOLDFUSS, *Parastromatopora* YABE & SUGIYAMA, *Crimestroma* YAVORSKY, *Desmopora* YAVORSKY, Tosastroma YABE & SUGIYAMA, *Milleporella* DENINGER, and *Milleporidium* STEINMANN. A review of these taxa would need a careful revision of the type-material, a study that is the beyond the scope of the present case. In any case, it is unnecessary since the Crimean taxa described does not include a cladocoropsid-type stromatoporoid.

**Comparisons:** The family Cladocoropsidae was introduced by TERMIER et al. (1977) to include mostly rod-shaped branching or unbranching stromatoporoids with a reticulate ("sarmentoide") internal structure of skeletal elements normally displaying a fibrose calcitic microstructure. Following TERMIER et al. (1977), the Cladocoropsidae comprise the Mesozoic representatives *Cladocoropsis* FELIX, 1907, and *Sarmentofascis* TERMIER, TERMIER & VACHARD, 1977 (Fig. 6). The latter, "sister taxon" of *Cladocoropsis* (Paleobiology Database, fossilworks.org), is differentiated by the former in lacking a cortex, "a thin, rindlike external layer of the rigid skeleton, usually with a structure different from that of the interior part of the skeleton" (WEBBY 2010). It was already remarked by FELIX (1907: 4, translated), originally describing *Cladocoropsis* as a coral (although already noting that the structure recalls more a sponge), that "the outer termination is formed by a more or less thick theca". The microstructure of *Cladocoropsis* is fasciculated fibrous (e.g., YABE & SUGIYAMA 1936). The contrasting striated aspect of the cortex was already accentuated in the drawings

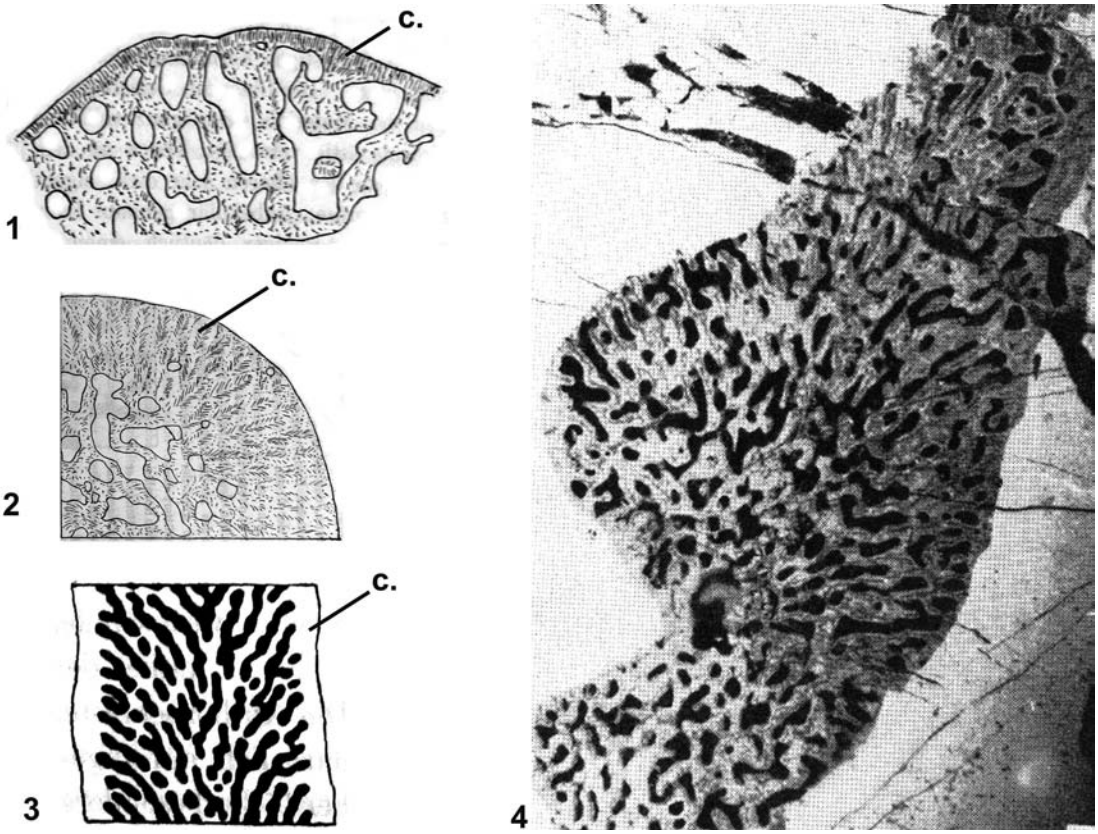

**Fig. 6.** *Cladocopsis mirabilis* Felix, 1907 (1-3), type species of *Cladocoropsis* Felix, 1907 and *Sarmentofascis cretacica* (Turnšek, 1968), type species of *Sarmentofascis* Termier, Termier & Vachard, 1977 (without scale). Note the cortex (c.) of *Cladocoropsis* with differing, finely striated microstructure (e.g., in 1). Skeletal elements and cortex in white in (3). 1-3 from Felix (1907, figs. 2-4); 4 from Turnšek (1968, pl. 5, fig. 2, holotype).

provided by Felix (1907) (e.g., Fig. 6a). Termier et al. (1977: 168) remarked that this peculiar aspect of the cortex might possibly be caused by a spicular texture. According to our knowledge, however, spicules were so far not evidenced in *Cladocoropsis*. The following *Cladocoropsis* species (in chronological order) were described so far: *C. mirabilis* Felix, 1907, *C. dubertreti* Hudson, 1954, *C. nanosi* Turnšek, 1966, *C. memorianaumanni* (Yabe, 1927) (transferation to *Cladocoropsis* by Beauvais & Nouiat 1993), *C. lata* Fenninger in Fenninger & Hötzl 1965, *C. grossa* Dong, 1981, *C. hybridina* Dong, 1981, *C. mirabilis abeona* Dong, 1981, *C. dongqiaoensis* Wang & Dong, 1984, and *C. lindstroemi* Kano et al., 2007. They are here not further considered as none of them shows a digitate morphology and moreover, should posses a cortex. A revision of these taxa, though needed, is beyond the scope of the present contribution. Morphologically, *S.*? *digitatus* is differentiated from the mostly irregular rod-shaped *Cladocoropsis* species and also the other representatives of *Sarmentofascis* by its subparallel multibranched columns (branches) (compare e.g., Webby & Kershaw 2011, fig. 25.2).

It is worth mentioning that the type-species of *Sarmentofascis*, *Sarmentofascis cretacica*, was originally described as *Cladocoropsis cretacica* by Turnšek (1968) from the Hauterivian of Montenegro. Altogether 4 species of *Sarmentofascis* were described from the Late Oxfordian to Santonian interval (see Table 1). Among these, *S.*? *digitatus* is characterized by its small size and digitate habit with predominantly subparallel branching. Unfortunately the two species *S. benesti* and *S. chabrieri* were poorly illustrated by Termier et al. (1977) and without indication of any dimensions. In Table 1 we therefore have included some data measured directly from the original illustrations. Concerning *S. benesti*, Termier et al. (1977) remarked that the dimensions are distinctly larger than those of common cladocoropsids. *S. fasciculata* was originally described as a representative of *Milleporella* Deninger and transferred to *Sarmentofascis* by Termier et al. (1985). *S. fasciculata* is different from all other species of the genus by its broad columnar skeleton, as displayed in addition astrorhizal canals (Yabe & Sugiyama 1935; Termier et al. 1985). Although the skeletal morphology and the internal organization fit the

**Table 1.** Mesozoic species of *Sarmentofascis*. Dimensions in mm. Abbreviations: ac = axial canals, ds diameter skeleton (= individual branch), dse diameter skeletal elements, dt diameter tubes. Asterisks mark data measured from the literature as not previously indicated. For terminology of external skeleton morphology see Webby & Kershaw (2011). The parentheses refer to the original designation of the morphology.

| Species | Occurrence | Morphology | ds | dse | dt | ac |
|---|---|---|---|---|---|---|
| *S. benesti* Termier, Termier & Vachard, 1977 | Late Oxfordian-Early Kimmeridgian of Algeria | dendroid (ramose) | - | ~0.1-0.15* | ~0.07-0.25* | no |
| *S. chabrieri* Termier, Termier & Vachard, 1977 | Santonian of France | dendroid (ramose) | ~8.3 | ~0.1-0.4* | ~0.1-0.3* | no |
| *S. cretacica* (1968), type species | Hauterivian of Montenegro | dendroid (rod-like) | 4-8 | 0.1-0.2 | 0.13-0.23 | no |
| *S. fasciculata* (Yabe & Sugiyama, 1935) | Tithonian? of Japan | columnar (fasciculate columns) | up to 15 | 0.05-0.08 | 0.06-0.1 | yes |
| *S.? digitatus* n. sp. | Tithonian-Early Berriasian of Crimea | digitate | 1.1-4.8 | 0.05-0.17 | 0.1-0.22 | no |

**Table 2.** Stromatoporoid-like taxa described and revised by Yavorsky (1947) from the Upper Jurassic of Crimea.

| Taxon | Stratigraphy |
|---|---|
| *Actinostromaria taurica* Yavorsky | Tithonian |
| *Actinostromaria yvonnei* Yavorsky | |
| *Actinostromaria weberi* (Pcelinzev) | Kimmeridgian? („Sequanian“) |
| *Actinostromaria androussovi* Yavorsky | Tithonian |
| *Actinostromaria varuma* Yavorsky | |
| *Actinostromaria pcelinzevi* Yavorsky | |
| *Actinostromaria peculiaris* Yavorsky | |
| *Actinostromaria vogdti* Yavorsky | |
| *Actinostromaria pavlovi* Yavorsky | Kimmeridgian? („Sequanian“) |
| *Stromatopora tamanica* Yavorsky | Tithonian |
| *Stromatopora riabinini* Yavorsky | |
| *Stromatopora pontica* Yavorsky | |
| *Stromatopora* (*Parastromatopora*) *helminthoidea* Yavorsky | |
| *Crimestroma borissiaki* Yavorsky | |
| *Desmopora listrigonorium* Yavorsky | |
| *Tosastroma jurassica* Yavorsky | |
| *Tosastroma kurassuense* Yavorsky | |
| *Milleporella iphigeniae* Yavorsky | |
| *Milleporella coilona* Yavorsky | |
| *Milleporella solomkoana* Yavorsky | |
| *Milleporidium gertrudae* Yavorsky | |
| *Milleporidium multitabulata* Yavorsky | |
| *Milleporella cylindricum* Yavorsky | Kimmeridgian? („Sequanian“) |

diagnosis of *Sarmentofascis* there are some reservations remaining because it is not possible to observe the typical fibrous microstructure.

**Stratigraphy:** Based on the associated species of benthic foraminifera and calcareous algae, *S.*? *digitatus* may be assigned a (late) Tithonian – early Berriasian age (Krajewski 2010; Krajewski & Olszewska 2007; Bucur et al. 2014).

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