

# LATE TURONIAN AND EARLY CONIACIAN VENTRICULITID SPONGES (LYCHNISCOSIDA) FROM OPOLE TROUGH (SOUTHERN POLAND) AND THEIR PALAEOECOLOGICAL SIGNIFICANCE

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**Abstract:** Eight species of ventriculitid sponges (Order Lychniscosida Schrammen, 1903) are described from the Upper Turonian marly limestones and Lower Coniacian marls of the Opole Trough (southern Poland). Among them four have not previously been noted in this area. Two species, *Astropegma stellata* (Roemer, 1840) and *Leiostracosia robusta* (Schrammen, 1902) are reported from Turonian strata for the first time. The occurrence of ventriculitid sponges in the Upper Turonian–Lower Coniacian succession of the Opole Trough indicates a soft-bottom, calm-water environment, with depths below the storm-wave base and a low rate of sedimentation.

**Key words:** Sponges, Lychniscosida, taxonomy, palaeoecology, Upper Cretaceous, Opole Trough, Southern Poland.

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## INTRODUCTION

Lychniscosidan sponges from the Family Ventriculitidae Toulmin Smith, 1848, appeared in the Late Jurassic (e.g., Hérenger, 1942; Pisera, 1997), but their most intense radiation took place during the Late Cretaceous. At the turn of the Cretaceous and the Palaeogene, most ventriculitids became extinct and only a few are noted from the Eocene (Matteucci and Russo, 2005).

The occurrence of ventriculitids in the Upper Cretaceous deposits of the epicontinental seas of Europe is restricted to limestone, white chalk, marly and opoka (siliceous limestone) facies (e.g., Schrammen, 1912; Defretin-Le-franc, 1960). In Poland, ventriculitids are common especially in the Campanian and Maastrichtian strata, exposed in the Middle Vistula River valley (Hurcewicz, 1968; Świerczewska-Gładysz, 2006) and in the Miechów synclinorium (Bieda, 1933; Hurcewicz, 1968). Ventriculitids occur also among redeposited phosphatised sponge assemblages from the Santonian of the Kraków area (Małecki, 1980; Świerczewska-Gładysz, 2010) and in the Campanian white chalk of Mielnik in eastern Poland (Olszewska-Nejbert and Świerczewska-Gładysz, 2011).

Siliceous sponges, including ventriculitids, are extremely abundant in the Upper Turonian and Lower Coniacian strata of the Opole Trough. Outside of the Opole area, Turonian and Coniacian sponges are rare in Poland; only one ventriculitid species has been noted from the Turonian of

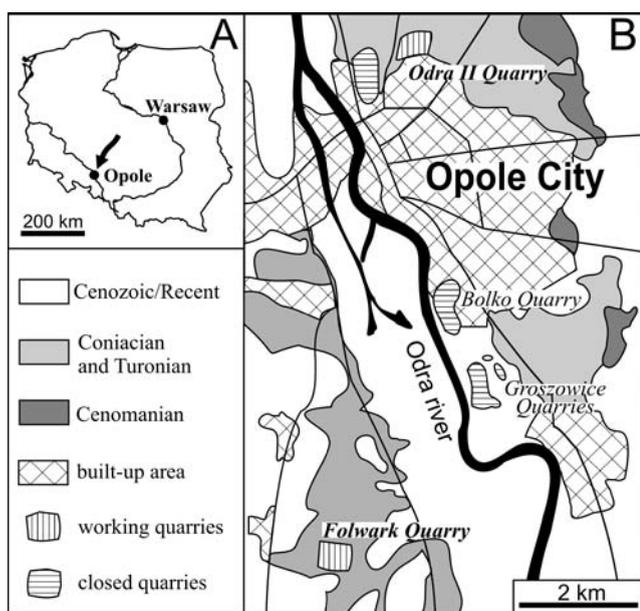
the North Sudetic synclinorium (Scupin, 1913) and four species from the Lower Coniacian of the Kraków area (Olszewska-Nejbert and Świerczewska-Gładysz, 2009).

Sponges from the Opole Trough were studied for the first time by F. A. Roemer (1841). Some specimens of sponges, collected in this area, were illustrated by F. Roemer (1870) and Quenstedt (1878). Leonhard (1897), using his own collection, as well as the specimens of F. Roemer, corrected the taxa that had been designated earlier and described 15 species of hexactinellid sponges, among them five ventriculitid species. Schrammen (1912) examined the taxonomic position of some species, described by Leonhard (1897). Much later, Tarkowski (1991) noted the occurrence of nine hexactinellid sponges in the Upper Turonian and Lower Coniacian succession of the Opole Trough. In that paper, four of them were included in the Family Ventriculitidae.

The present account of taxonomic research on sponges from the Upper Turonian and Lower Coniacian deposits of the Opole Trough supplements existing data on the composition of the ventriculitid assemblage from this area and the stratigraphic ranges of particular species. Analysis of this very rich material provides new information about the intraspecific variability of these polymorphic species. Their importance for palaeoecological reconstruction is also discussed.

## GEOLOGICAL SETTING

The Cretaceous succession of the Opole Trough (Figs 1, 2) comprises Middle Cenomanian to Middle Coniacian deposits (Walaszczyk, 1988, 1992; Tarkowski, 1991; Kędzierski, 1995, 2008). The stratigraphy of the series was studied first by F. Roemer (1870) and Leonhard (1897). Alexandrowicz and Radwan (1973) subdivided the Cretaceous sequence into six informal, lithostratigraphic units. An inoceramid zonation was established by Walaszczyk (1988, 1992) and calcareous nannofossil zones were determined by Kędzierski (2008).



**Fig. 1.** A. Location of study area on a sketch-map of Poland. B. Schematic, geological map of Opole Trough after Biernat (1960) and Walaszczyk (1988), simplified

Cenomanian glauconitic sands and sandstones are known from boreholes and exposures in the northern outskirts of the town of Opole. The sponge assemblage from the Cenomanian strata contains lithistids (Roemer, 1870; Leonhard, 1897; Tarkowski, 1991) and very rare hexactinosidans (Leonhard, 1897).

The overlying, dark grey, argillaceous marls (Lower Argillaceous Marl Unit) represent the Lower Turonian (*Mytiloides* ex gr. *labiatus* Zone). They are followed by dark marls (Lower Marl Unit), which are included in the Middle Turonian (*Inoceramus apicalis* and *Inoceramus lamarki* zones). The uppermost part of the argillaceous marls and the overlying marls are currently best exposed in the Odra II Quarry, located in the northern part of the town of Opole. Fossils are rare in both units, represented mainly by terebratulids and bivalves (Walaszczyk, 1988). Sponges are absent in this part of the succession.

In the Odra II Quarry section, the deposits, overlying the marls, are represented by light-grey marly limestones, with intercalations of dark, argillaceous marls (Marly Limestone Unit). The lower part of the marly limestones corre-

sponds to the *Inoceramus perplexus* Zone (= *I. costellatus* Zone; see Walaszczyk and Cobban, 2000), and the upper part, to the *Mytiloides scupini* Zone. The marly limestones are rich in fossils, i.e. hexactinellid sponges, bivalves (especially inoceramids, see Walaszczyk, 1988; Tarkowski, 1991), echinoids (Olszewska-Nejbert, 2007), ammonites and less numerous nautiloids (Walaszczyk, 1988).

The Lower Marl and Marly Limestone units were also exposed in the Bolko and Groźnowice Quarries (Walaszczyk, 1988; Tarkowski, 1991; Olszewska-Nejbert, 2007), located in the southern part of Opole, but are presently not accessible because of flooding in 1997 (Fig. 1).

The upper part of the Cretaceous succession is exposed in the Folwark Quarry, located about 10 km to the SW of Opole (Fig. 1). The section begins with marly limestones, with intercalations of argillaceous marls, belonging to the uppermost part of the *Inoceramus perplexus* Zone and the lower part of the *Mytiloides scupini* Zone. The overlying, grey marls, with intercalations of dark grey, argillaceous marls and light grey, siliceous marls (Upper Marl Unit), belong to the *Mytiloides scupini* and *Cremnoceramus waltersdorfensis waltersdorfensis* zones. The uppermost part of the marls, siliceous marls and the overlying, argillaceous marls (Upper Argillaceous Marl Unit) correspond to the *Cremnoceramus deformis erectus* and *Cremnoceramus crassus crassus* + *Cremnoceramus deformis deformis* zones of the Lower Coniacian (Walaszczyk, 1992; Walaszczyk and Wood, 1998). The abundant fauna is dominated by inoceramids and ammonites (Walaszczyk, 1988; Tarkowski, 1991), as well as echinoids (Olszewska-Nejbert, 2007). Hexactinosidan and lychniscosidan sponges are very numerous in the Marly Limestone and Upper Marl units, whereas lithistids are rare. Lyssacinosid sponges were noted in the Upper Marl Unit (Świerczewska-Gładysz and Jurkowska, in press). Rare sponge remains are also present in the Lower Coniacian argillaceous marls, but they could not be determined, owing to very poor preservation.

The highest part of the succession, represented by Middle Coniacian mudstones and marly clays, is known exclusively from boreholes (Radwańska, 1969).

## MATERIAL AND METHODS

The study material comprises 621 specimens. Most of the specimens, housed at the Geological Laboratory of the Łódź University (collection ULXXIV), were collected by author in two large quarries of the cement industry, Odra II and Folwark. Some of the specimens, used for the palaeontological description, came from scree material. A few specimens presented in this paper, are the property of the Geological Museum of the Polish Geological Institute, University of Wrocław (MGUWr). One of them came from marly limestones at the Bolko Quarry.

Specimens from the marls are strongly deformed because of compaction. They were crushed, as a result of weathering of the rocks. Owing to the poor state of preservation, the number of specimens from the marls, described in the systematic part, is significantly lower than that of better preserved specimens from the marly limestones.

In most sponges, the siliceous skeleton has been completely dissolved. Voids after spicules are empty (Fig. 3A) or filled with calcite, limonite or pyrite (Fig. 3B). In such case, the nodal octahedra of lychniscs are often not visible. There are instances, in which the pyrite, filling also the intraspicular spaces, masks the pyritized spicules; in these cases the recognition of the skeleton type is impossible. Siliceous skeletons are sporadically preserved in some specimens from the marls. These are almost exclusively fragments of the dictyonal cortex (Fig. 3C).

Details of the skeleton and voids after spicules were observed, using both a binocular microscope and SEM.

### VENTRICULITIDS IN SECTIONS STUDIED

Ventriculitid sponges have been detected in the sequence studied in the marly limestones and marls of the Upper Turonian and Lower Coniacian (Fig. 2). They amount to about 90% of the collection of sponges gathered from these beds.

In the entire succession, the ventriculitids are preserved with rhizoids and do not display any breakage, related to *post-mortem* transport. Small sponges occur often in their life positions. Large and wide, funnel-like specimens usually have the lower cylindrical part tilted with respect to the bedding, whereas the upper discoid parts are nearly parallel to the bedding. Large, cylindrical or conical sponges lie on one side on the bedding plane. In places between the cylindrical and discoid parts, stem and rhizoids, the skeletons of large sponges are frequently partly torn apart as a result of compaction. Two specimens show traces of damage and later regeneration of the sponge organism.

Epifauna is common on the sponge specimens collected; it is represented by bryozoans, octocorals, serpulids, foraminifers and small oysters. On wide specimens, the epibionts occur in the internal side of the cups. Particularly, oysters are relatively abundant on the flat surfaces of the discoidal, upper part in specimens of *Ventriculites chonoides* (Mantell, 1815). On the narrow, conical or cylindrical specimens, the bryozoans, octocorals and serpulids appear on different parts of the outer surface, whereas oysters are always attached to the outer surface of the sponges on one side of the specimen. Epibionts are not present on the very small specimens from marly limestones.

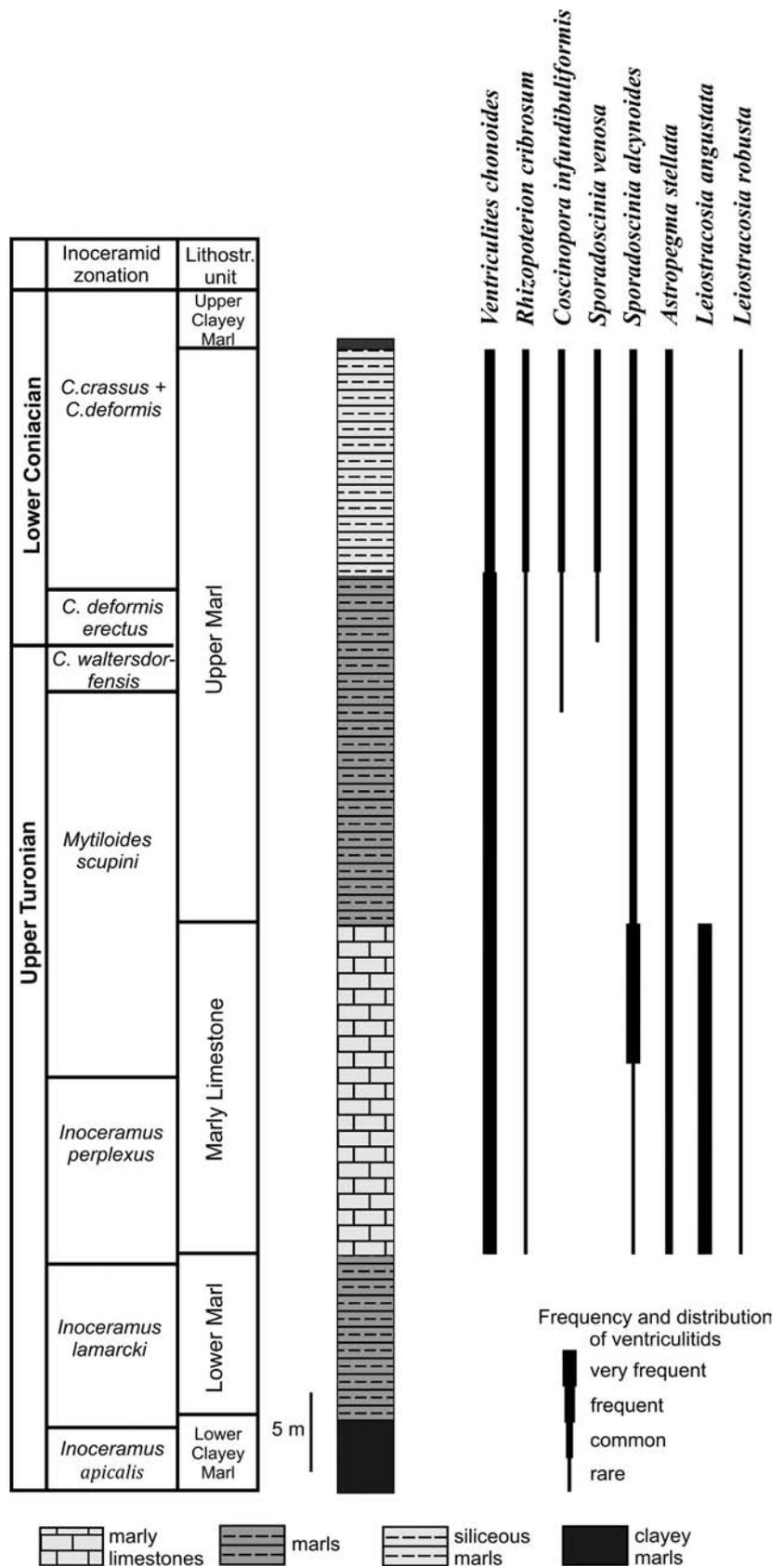
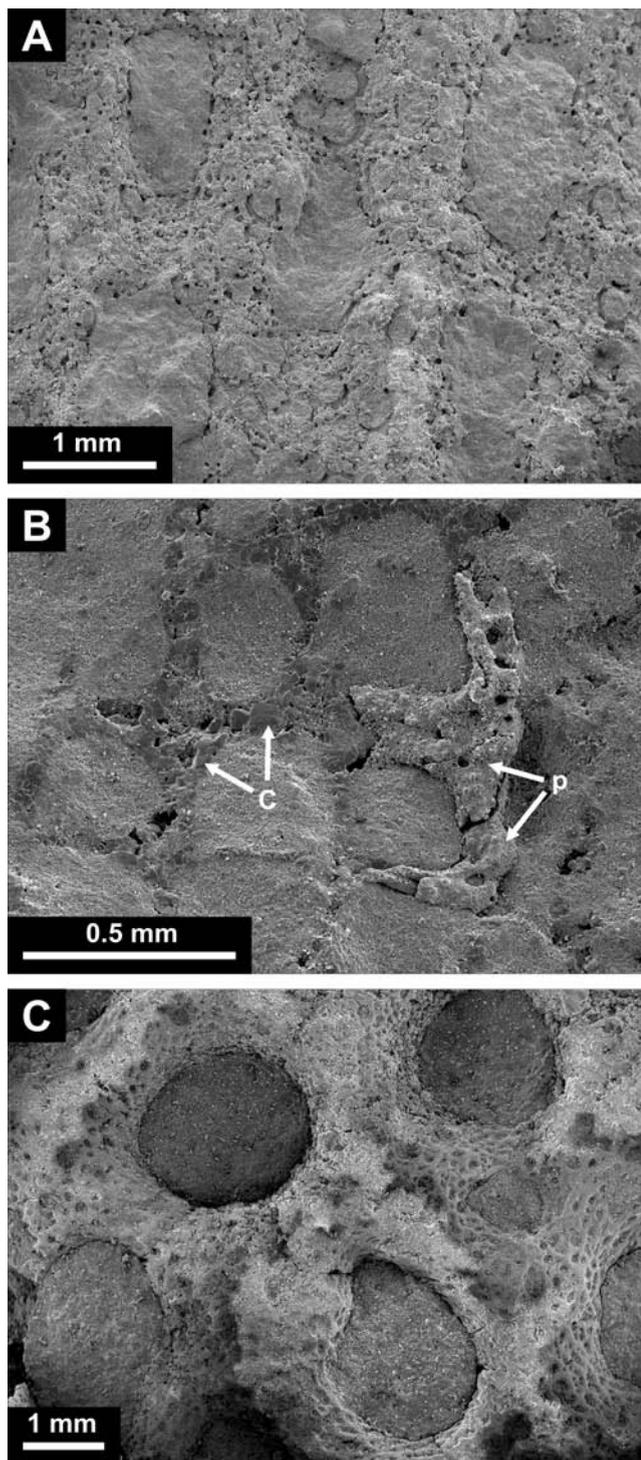
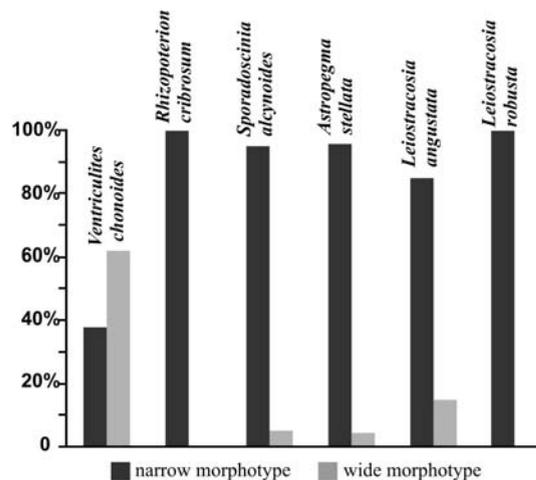


Fig. 2. Geological section of Upper Turonian and Lower Coniacian deposits from Opole Trough with distribution of ventriculitid species; inoceramid zonation based on Walaszczyk (1992), Walaszczyk and Wood (1998) and Walaszczyk and Cobban (2000); lithostratigraphic units after Alexandrowicz and Radwan (1973)



**Fig. 3.** Different types of ventriculitid skeleton preservation from Upper Turonian and Lower Coniacian of Opole Trough. **A.** Empty voids after cortex on gastral surface of *Sporadoscinia venosa* (Roemer, 1840). **B.** Voids after dictyonal skeleton of *Ventriculites chonoides* (Mantel, 1815) filled with calcite (c) and pyrite (p). **C.** Siliceous cortex on dermal surface of *Coscinopora infundibuliformis* Goldfuss, 1826

In the Marly Limestone Unit, the ventriculitids are very abundant, though not evenly distributed, in the particular beds. In the uppermost part of the Odra Quarry section, 1–2 sponges were observed on an area of 1 m<sup>2</sup> of the bedding



**Fig. 4.** Percentage content of narrow and wide morphotypes of six species in sample from Marly Limestone Unit

surface (3 measurements). In the uppermost part of the marly limestones in the Folwark Quarry, 6–10 ventriculitids were noted per 1 m<sup>2</sup> (5 measurements). A considerable part of the ventriculitid sponges, occurring in this unit, are small, measuring 10–30 mm in height. The Upper Turonian marly limestones contain six ventriculitid species (Fig. 2). In the *Inoceramus perplexus* Zone, *Leiostracosia angustata* (Roemer, 1840) is very numerous, especially in the Odra section, whereas *Sporadoscinia alcynoides* (Mantell, 1822) is rare. *V. chonoides* is less abundant in this zone than in the overlying deposits. In turn, in the marly limestones exposure of the Folwark section, corresponding to the lower part of the *Mytiloides scupini* Zone, specimens of *L. angustata* are less frequent, whereas *S. alcynoides* and *V. chonoides* are very abundant. *Astropegma stellata* (Roemer, 1840) is quite common in the Marly Limestone Unit in both localities, while *Leiostracosia robusta* (Schrammen, 1902) and *Rhizopoterion cribrosum* (Phillips, 1829) are very rare.

Specimens of *V. chonoides*, occurring in the Marly Limestone Unit, are mainly trumpet-shaped or narrow funnel-like (Fig. 4). Four species, i.e. *A. stellata*, *L. angustata*, *L. robusta* and *S. alcynoides* are represented almost exclusively by narrow conical to almost cylindrical morphotypes (Fig. 4). A significantly high number of these specimens has one or several transverse narrowings. One nearly complete specimen of *R. cribrosum* is also narrowconical in shape. Other specimens of this species from the marly limestones are broken, therefore their precise shapes are difficult to determine.

The abundance of ventriculitids in the Upper Marl Unit seems to be slightly lower than in the Marly Limestone Unit (measurement of the number of sponges per a square metre could not be done because of the poor quality of the exposure).

The taxonomic composition of the ventriculitid assemblages from the lower part of the Upper Marl Unit (the uppermost Turonian, *Mytiloides scupini* and *Cremnoceramus waltersdorfensis waltersdorfensis* zones) is similar to the sponges from the Marly Limestone Unit (Fig. 2). In these deposits, all species known from the marly limestones ex-

cept for *L. angustata*, as well as additionally a *Coscinopora infundibuliformis* Goldfuss, 1826 were noted. This latter species is rare and represented almost entirely by wide, trumpet-like specimens (Fig. 5). The most abundant species is *V. chonoides*, represented by very large specimens, with a discoid, upper part. In turn, *S. alcynoides* and *A. stellata* are less common. Other species are rare. Most specimens of *S. alcynoides*, *A. stellata* and *L. robusta* are wider (Fig. 5) and larger than the specimens from the marly limestones. *R. cribrosum* from these beds is crushed and its shape is indefinable.

In the upper part of the Upper Marl Unit (Lower Coniacian, *Cremonoceras deformis erectus* and *Cremonoceras crassus crassus* + *Cremonoceras deformis deformis* zones), wide cup-shaped specimens of *Sporadoscinia venosa* (Roemer, 1840) appear (Figs 2, 5). *V. chonoides* is less frequent, whereas *R. cribrosum* and *C. infundibuliformis* become more abundant in the siliceous marls (Fig. 2). Specimens of *R. cribrosum*, like the specimens of *V. chonoides*, are very large, with a flat upper part (Fig. 5). The frequency, size and shapes of other species in these deposits are similar to those of sponges from the lower part of the marls (Figs 2, 5).

## SYSTEMATIC PALAEOLOGY

Class HEXACTINELLIDA Schmidt, 1870

Order LYCHNISCOSIDA Schrammen, 1903

Family VENTRICULITIDAE Toulmin Smith, 1848

Genus *Ventriculites* Mantell, 1822

Type species *Alcyonium chonoides* Mantell, 1815

*Ventriculites chonoides* (Mantell, 1815)

Figs 6, 7

- \*1815 *Alcyonium chonoides* – Mantell, pp. 401–407.
- 1822 *Ventriculites radiatus* – Mantell, p. 168, pl. 10–14.
- 1848 *Ventriculites mammilaris* – Toulmin Smith, pp. 213–215, pl. 13, figs 7, 14.
- 1848 *Ventriculites decurrens* – Toulmin Smith, p. 215, pl. 13, fig. 8.
- 1864 *Retiospongia radiata* Mantell – F. A. Roemer, p. 15, pl. 6, fig. 2.
- 1870 *Retiospongia radiata* Roemer – F. Roemer, p. 302, pl. 32.
- 1878 *Ventriculites radiatus* Mantell – Quenstedt, p. 449, pl. 136, figs 24–32.
- 1883 *Ventriculites radiatus* Mantell – Hinde, p. 108.
- 1883 *Ventriculites mammilaris* Toulm. Smith – Hinde, pp. 111–112.
- 1883 *Ventriculites decurrens* Toulm. Smith – Hinde, p. 111.
- 1883 *Ventriculites radiatus* Mant. – Pošta, pp. 32–33.
- 1889 *Ventriculites radiatus* Mant. – Frič, p. 105, fig. 142.
- 1897 *Ventriculites decurrens* Toulm. Smith – Leonhard, p. 33, text-fig. 4
- 1889 *Ventriculites glauconiticus* n. sp. – Dunikowski, pp. 79–80, pl. 1, fig. 7; pl. 3, fig. 2.
- 1944 *Ventriculites radiatus* Mantell – Hérenger, p. 106, fig. 9c.
- 1960 *Ventriculites radiatus* Mantell – Defretin-Lefranc, pp. 56–58, pl. 3, figs 1–4; text-fig. 16.
- 1960 *Ventriculites mammilaris* T. Smith – Defretin-Lefranc, p. 59, pl. 3, figs 5, 7.

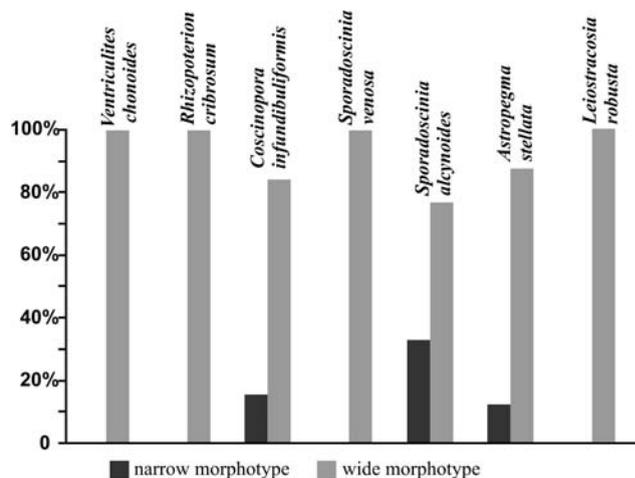
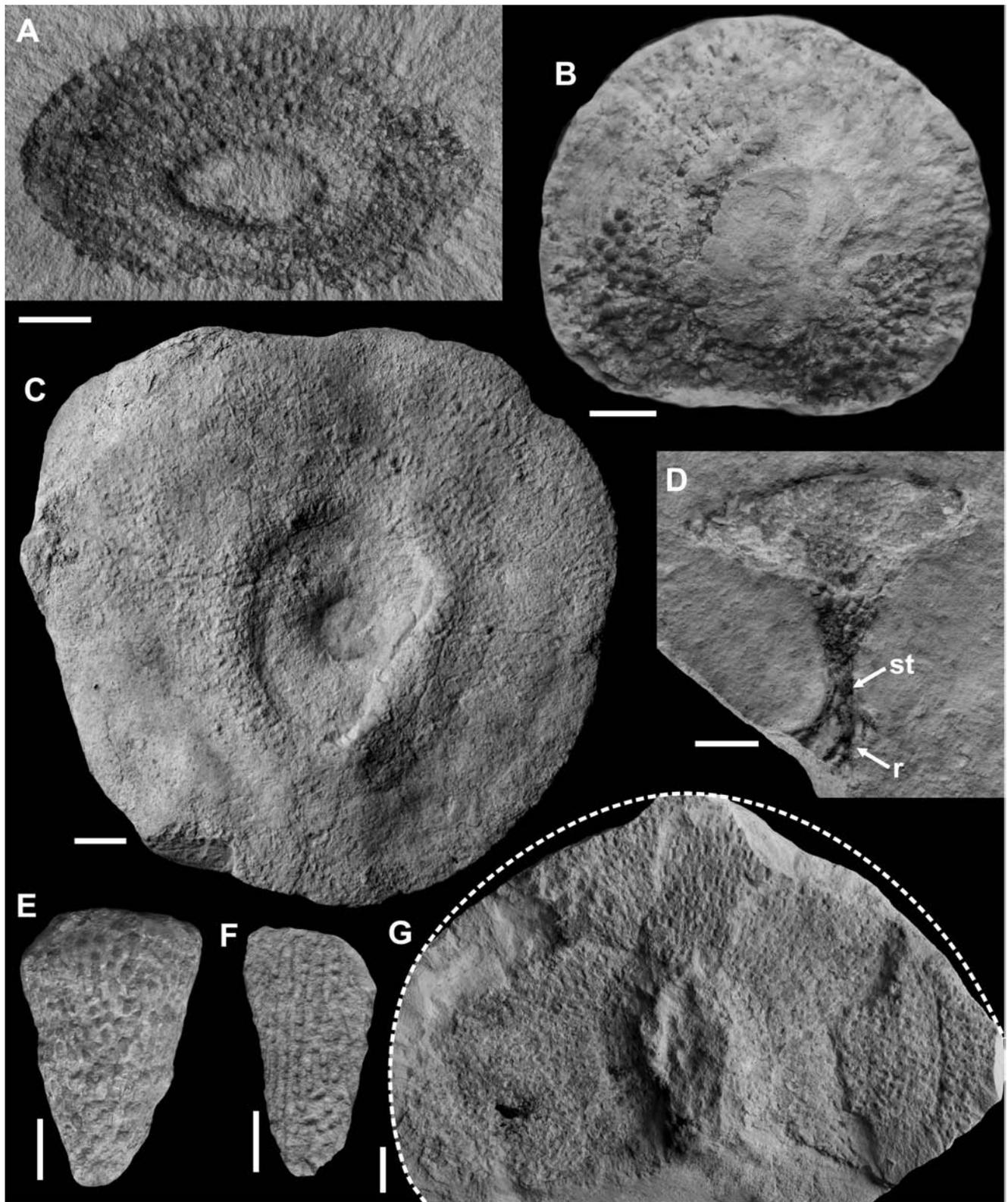


Fig. 5. Percentage content of narrow and wide morphotypes of seven species in sample from Upper Marl Unit

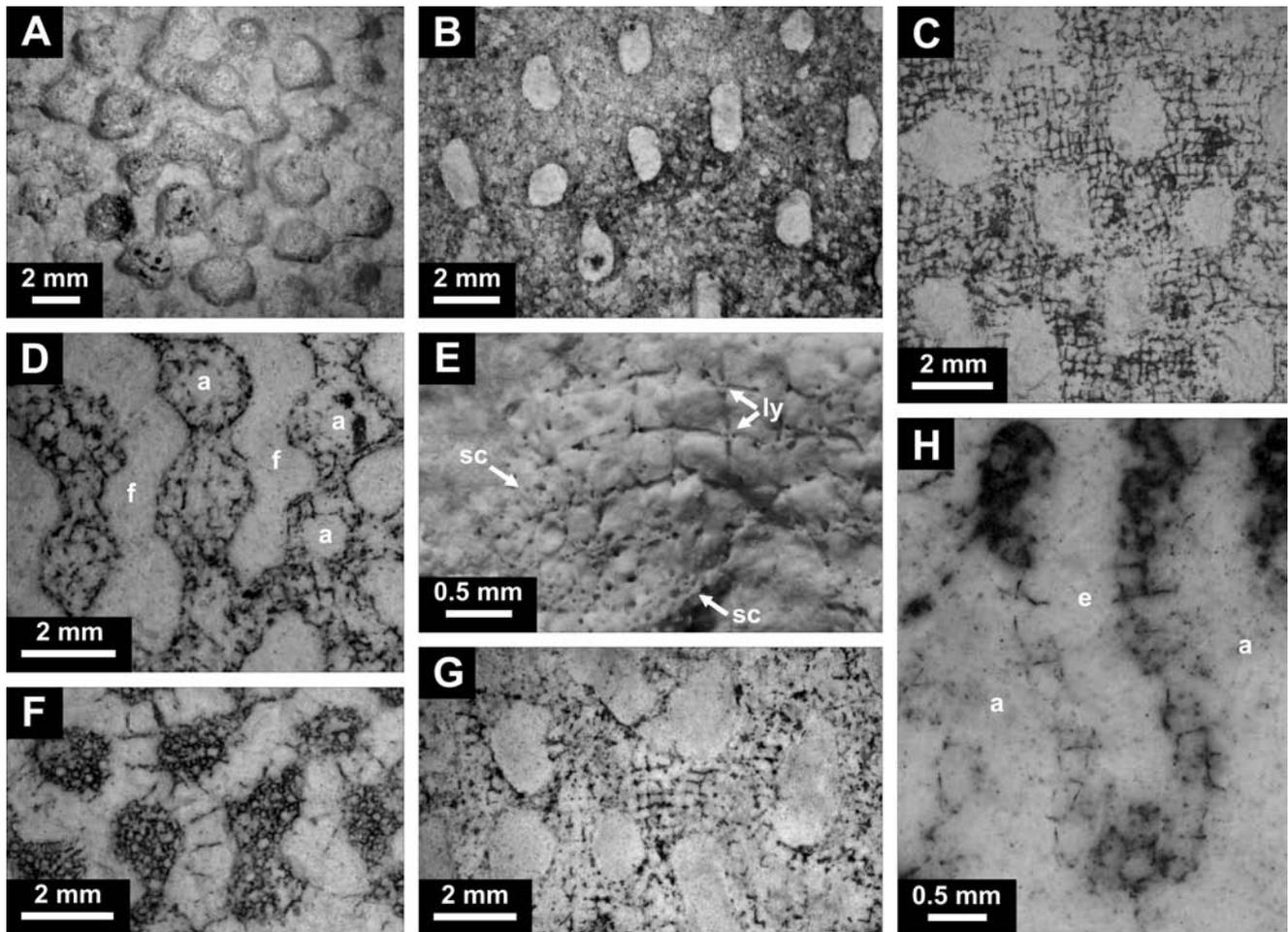
- 1962 *Ventriculites radiatus* Mantell – Lagneau-Hérenger, pp. 92–93, text-pl. 14, fig. 1.
- 1973 *Ventriculites radiatus* Mantell – Pajaud, pp. 104–106, pl. 1, fig. 3a–b; text-fig. 2
- 1991 *Ventriculites radiatus* Mantell – Tarkowski, p. 91, pl. 2, figs 3–4.
- 1992 *Ventriculites chonoides* (Mantell, 1815) – Mehl, p. 127, pl. 20, fig. 4.
- 2002 *Ventriculites chonoides* (Mantell) – Wood, p. 32, pl. 1, figs 4–5.
- 2009 *Ventriculites chonoides* (Mantell) – Vodrážka *et al.*, fig. 7e.
- 2009 *Ventriculites chonoides* (Mantell) – Vodrážka, text-fig. 1c–d.

**Material:** 74 specimens from the Odra II Quarry, 186 specimens from the Folwark Quarry.

**Description:** These are trumpet-, funnel- or umbrella-shaped sponges (Fig. 6A–G). The solid, initial stalks are not developed or very short, terminated by thin and relatively short rhizoids (Fig. 6D). The discoid, upper part (Fig. 6A–C, G) of the largest specimens is 120–190 mm in diameter, whereas the lower, conical part is short, up to 50 mm high (Fig. 6D–F). The wall thickness is 2–4 mm and up to 5 mm in the lower part of the sponges. The canal openings on the dermal surface are oval or round, 0.8–2 × 0.8–3 mm in size (Fig. 6A, G). They are situated in the bottoms of the furrows, arranged in a quincunx, 12–24 per cm<sup>2</sup>. The regular arrangement of the canal openings is often disturbed, especially in the lower part of the sponges, where the canal openings may be smaller (0.4–0.8 mm in size) and densely distributed. The ribs between the furrows are slightly to strongly concave, 1–1.5 mm wide. The ribs and furrows divide dichotomously. The very prominent ribs and deep furrows occur usually on the narrow specimens and on the conical portion of large sponges (Fig. 6F), rarely on the discoidal part (Fig. 6A). Some of the specimens have hemispherical tubercles on the ribs; these are 1–3 mm in diameter (Fig. 6B, E). They are isolated, but in some cases the adjacent tubercles may be linked by a high, skeletal band and form elongated or irregular bulges (Fig. 7A). The furrows between the well-developed tubercles are very deep and narrower than for the neighbouring tubercles. The canal openings on the gastral surface are round to elliptical, 1.5–2 mm in size (Figs 6C, 7B). The elongated openings occur mainly near the centre of the disc and in the conical portion. They are distributed in a quincunx, 14–16 per cm<sup>2</sup>. The skeletal bands separating the canal openings are flat or slightly concave, about 0.5 mm wide.



**Fig. 6.** *Ventriculites chonoides* Mantell, 1815; scale bar equals 10 mm. **A.** Upper part of sponge; dermal surface with prominent ribs; Folwark Quarry, Upper Turonian, ULXXIV/F453. **B.** Upper part of sponge; dermal surface with tubercles; Odra II Quarry, Upper Turonian, ULXXIV/O59. **C.** Upper part of sponge; visible gastral surface; Folwark Quarry, Upper Turonian, ULXXIV/F630. **D.** Lateral view of almost complete specimen, with stalk (st) and rhizoids (r); Folwark Quarry, Upper Turonian, ULXXIV/F451. **E.** Lower part of sponge; dermal surface with tubercles; Odra II Quarry, Upper Turonian, ULXXIV/O468. **F.** Lower part of sponge; dermal surface with prominent ribs; Folwark Quarry, Upper Turonian, ULXXIV/F825. **G.** Fragment of upper part of sponge; its supposed shape is marked with white line; dermal surface with flat ribs; Folwark Quarry, Upper Turonian, ULXXIV/F454



**Fig. 7.** *Ventriculites chonoides* Mantell, 1815. **A.** Dermal surface with tubercles; Folwark Quarry, Upper Turonian, ULXXIV/F608. **B.** Gastral surface with voids after cortex and canal openings; Folwark Quarry, Lower Coniacian, ULXXIV/F814. **C.** Limonitized subgastral part of dictyonal skeleton; Odra II Quarry, Upper Turonian, ULXXIV/O283. **D.** Deep furrows (f) and ribs with tubercles on dermal surface; terminal parts of aporhyse (a) visible in damaged tubercles; Odra II Quarry, Upper Turonian, ULXXIV/O69. **E.** Voids after dictyonal skeleton with lychniscs (ly) and synapticular cortex on dermal surface (sc); Folwark Quarry, Upper Turonian, ULXXIV/F545. **F.** Limonitized synapticular filaments between tubercles on dermal surface; Odra II Quarry, Upper Turonian, ULXXIV/O61. **G.** Limonitized dictyonal skeleton from central part of wall with canals; Folwark Quarry, Upper Turonian, ULXXIV/F413. **H.** Transverse section of wall; note epirhyse (e) and aporhyse (a) in dictyonal skeleton; Folwark Quarry, Upper Turonian, ULXXIV/F424

The dictyonal skeleton is regular, mainly with square or rectangular meshes, 0.25–0.3 × 0.25–0.4 mm in size (Fig. 7C, E, G). In transverse section square meshes, about 0.25 mm in size, dominate (Fig. 7H). In the subdermal part, the network is locally less regular and contains secondary small lychniscs. A thick, fine-porous synapticular cortex covers both surfaces (Fig. 7B, E). On the dermal surface, thin, synapticular filaments (preserved only on a few specimens) spread radially from the tubercles and form bridges, stretched over the furrows (Fig. 7F). Straight, long canals run perpendicularly to the wall (Fig. 7H). In specimens with tubercles, aporhyse terminate inside the tubercles (Fig. 7D). A few longitudinal canals appear in the rhizoids.

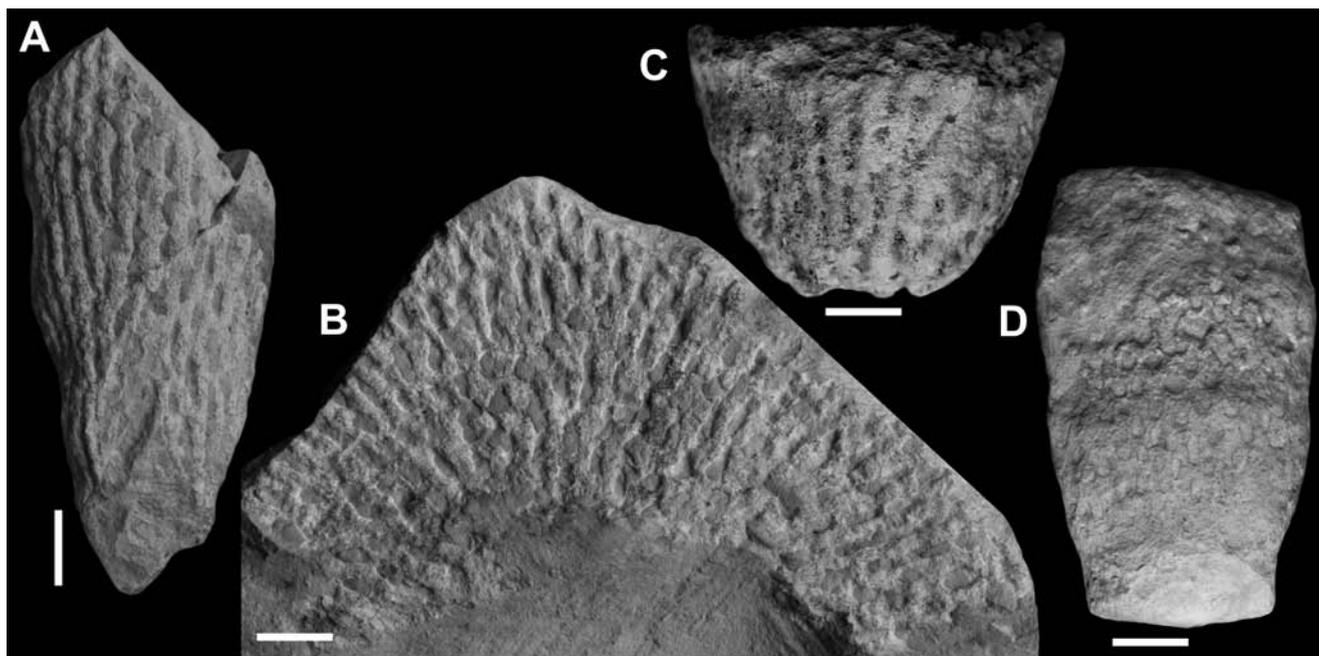
**Remarks:** *V. chonoides* is a very polymorphic species. In the opinion of Reid (1962), the morphotypes with tubercles were described by some authors as *V. mammilaris* (see Toulmin Smith, 1848; Hinde, 1883; Defretin-Lefranc, 1960) and specimens with prominent ribs were assigned to *V. decurrens*. In the material studied, specimens with shallow furrows and flat or slightly convex ribs (Fig. 6G), typical of the form “radiatus” (see also Roemer, 1870, pl. 30, figs 5, 6), dominate, but the other two morphotypes

are also present. So far, the tuberculate morphotype has not been described from the Opole Trough.

According to Reid (1962), the tubercles occur on the cylindrical, lower part of the wide sponges, but entire, tuberculate specimens are known from England and France (e.g., Defretin-Lefranc, 1960; Wood, 2002). The latter sponges are relatively narrow, while in the collection studied, the tuberculate specimens have very different shapes and some of them are very wide, even discoidal (Fig. 6B).

The bridges between the tubercles on the dermal surface, observed in some specimens from the Opole area, were also noted by Defretin-Lefranc (1960) in the strongly limonitized specimens, described as *V. mammilaris*, from the Upper Turonian and Coniacian of northern France. According to Defretin-Lefranc (1960), the bridge is composed of one very large lychnisc with curved rays. In the opinion of the autor, the bridge is formed by synapticular filaments.

According to Toulmin Smith (1848), furrows occur on the gastral surface of specimens from the English Chalk. The specimens from the collection of J. Toulmin Smith were investigated by



**Fig. 8.** *Rhizopoterion cribrosum* (Phillips, 1829); scale bar equals 10 mm. **A.** Lower part of sponge; Folwark Quarry, Lower Coniacian, ULXXIV/F546. **B.** Fragment of discoidal upper part of sponge; visible dermal surface; Folwark Quarry, Lower Coniacian, ULXXIV/F550. **C.** Upper part of goblet-like specimen, Folwark Quarry, Upper Turonian, ULXXIV/F108. **D.** Cylindrical specimen; Odra II Quarry, Upper Turonian, ULXXIV/O509

Hinde (1883) and Reid (1962), who did not confirm the presence of furrows. However, furrows are mentioned in the description of Defretin-Lefranc (1960). The study specimens do not have furrows; instead, elongated canal openings frequently imitate the furrows on some specimens that were deformed by compaction.

Tarkowski (1991) noted *V. radiatus* (= *V. chonoides*) in a few beds of the Odra and Folwark sections (see Tarkowski, 1991, figs 8, 12). The present author's observations have shown that *V. chonoides* is a very abundant species in the Cretaceous of the Opole area, occurring in the entire Upper Turonian and Lower Coniacian succession from the base of the *Inoceramus perplexus* Zone.

**Occurrence:** In Poland, the Opole area (Upper Turonian–Lower Coniacian); France (Albian, Cenomanian, Upper Turonian, Coniacian); Belgium (Cenomanian); England (Upper Turonian); Czech Republic (Upper Turonian); western Ukraine (Cenomanian).

Genus *Rhizopoterion* Zittel, 1877

Type species *Scyphia cervicornis* Goldfuss, 1826

*Rhizopoterion cribrosum* (Phillips, 1829)

Figs 8, 9

- \*1829 *Spongia cribrosa* – Phillips, pl. 1, fig. 7.
- 2006 *Rhizopoterion cribrosum* (Phillips) – Świerczewska-Gładysz, pp. 252–254, figs 18a–d, 19, 20a–f [cum syn.].
- 2010 *Rhizopoterion cribrosum* Schrammen – Świerczewska-Gładysz, pp. 272–273, fig. 14a.
- 2011 *Rhizopoterion cribrosum* Schrammen – Świerczewska-Gładysz (in Olszewska-Nejbert & Świerczewska-Gładysz, 2011), pp. 403–404, figs 17a–b, 18a–b.

**Material:** 3 specimens from the Opole Odra II Quarry, 12 specimens from the Folwark Quarry.

**Description:** The specimens studied are fragments of trumpet-, funnel- or goblet-shaped sponges (Fig. 8A–C). The diameter of the incomplete, discoidal upper part of the largest specimen is 120 mm (Fig. 8B). The lower conical part is up to 62 mm high (Fig. 8A).

The wall thickness is 6–10 mm. One incomplete specimen is cylindrical (Fig. 8D). Some specimens have a massive stem preserved, up to 20 mm long, as well as a fragment of rhizoids. The stem and rhizoids are with numerous, tightly packed, longitudinal canals. On the dermal surface elliptical canal openings occur, 1.5–2 × 3–4 mm in size, arranged in a quincunx. The openings are situated in shallow furrows, separated by sinusoidal, slightly convex ribs that are 1–2 mm wide. The deeper furrows and the prominent ribs occur usually on the lower, conical part of the sponges. The internal surface is not visible.

The dictyonal skeleton is irregular in transverse section, with rectangular or quadrangular meshes, 0.3–0.4 mm in size (Fig. 9A). Synapticules are present in some places in the network, mainly in the subdermal part. The synapticular cortex on the dermal surface is thick, with small spines directed inwards the canal openings (Fig. 9B). The remains of loosely entangled, synapticular filaments, filling the lower part of the spongocoel, are visible in one specimen. Straight, long epirhyses, perpendicular to the wall, terminate blindly under the surface of the inner side. The aporhyses are connected with the longitudinal canals, running inside the wall (Fig. 9A).

**Remarks:** The shape of the body and the morphology of both surfaces of *R. cribrosum* are very similar to those in *Ventriculites chonoides* (Mantell, 1815) (= *V. radiatus* Mantell, 1822). Therefore the specimens of both species were often wrongly identified. Reid (1962) pointed out several differences between the species, which are readily observable in the study material. *R. cribrosum*, in contrast to *V. chonoides*, is characterized by an irregular skeleton, the presence of longitudinal canals in the wall, and numerous canals in the stalk and rhizoids. Thickenings on the ribs located on the outer surface, common in *V. chonoides*, are absent in *R. cribrosum*. The study has also shown other subtle differences between these species. The canal openings on the dermal surface in *R. cribrosum* are large and oval, whereas in *V. chonoides*, they are smaller, oval, but also round. The stem of *R. cribrosum* is massive, whereas the spongocoel in *V. chonoides* is very deep and the stalk

usually is not developed. The wall thickness in the specimens of *R. cribrosum* studied reaches up to 10 mm, whereas in *V. chonoides* it is up to 6 mm.

*R. cribrosum* is one of the most common species in the Campanian and Maastrichtian deposits of Poland (Świerczewska-Gładysz, 2006, 2010; Olszewska-Nejbert and Świerczewska-Gładysz, 2011). It occurs also in the Coniacian and Santonian deposits of the Kraków area, whereas it has not been recorded so far in the Turonian and Coniacian of the Opole Trough.

According to Defretin-Lefranc (1960), *R. cribrosum* occurs in the Turonian of northern France. However, Defretin-Lefranc (1960) distinguished *R. cribrosum* from *V. chonoides* only on the basis of body shape (*V. chonoides* – funnel-, goblet- or fungi-like; *R. cribrosum* – tube-like). These shapes occur in both species (Reid, 1962); therefore the assignment of the French specimens to *R. cribrosum* remains an open question. Longitudinal canals were not described in the incomplete specimen from the Turonian of the Czech Republic presented by Frič (1889, p. 105, fig. 142) and thus its assignment to *R. cribrosum* is also doubtful.

**Occurrence:** In Poland, the Opole area (Upper Turonian–Lower Coniacian), eastern Poland (Campanian), the Kraków area (Coniacian, Coniacian or/and Santonian sponges redeposited in Santonian deposits, Upper Campanian), the Middle Vistula River valley (Upper Campanian–Maastrichtian); northern Germany (Campanian); the Island of Rügen (Lower Maastrichtian); England (Santonian–Maastrichtian); northern Ireland (Santonian–Campanian); Ukraine: Crimea (Maastrichtian) and the northern Donbas region (Maastrichtian); Russia (Saratov area, Lower Santonian); ?France (Turonian); ?Czech Republic (Turonian).

Genus *Coscinopora infundibuliformis* Goldfuss, 1826

Type species *Coscinopora infundibuliformis* Goldfuss, 1826

*Coscinopora infundibuliformis* Goldfuss, 1826

Figs 10, 11

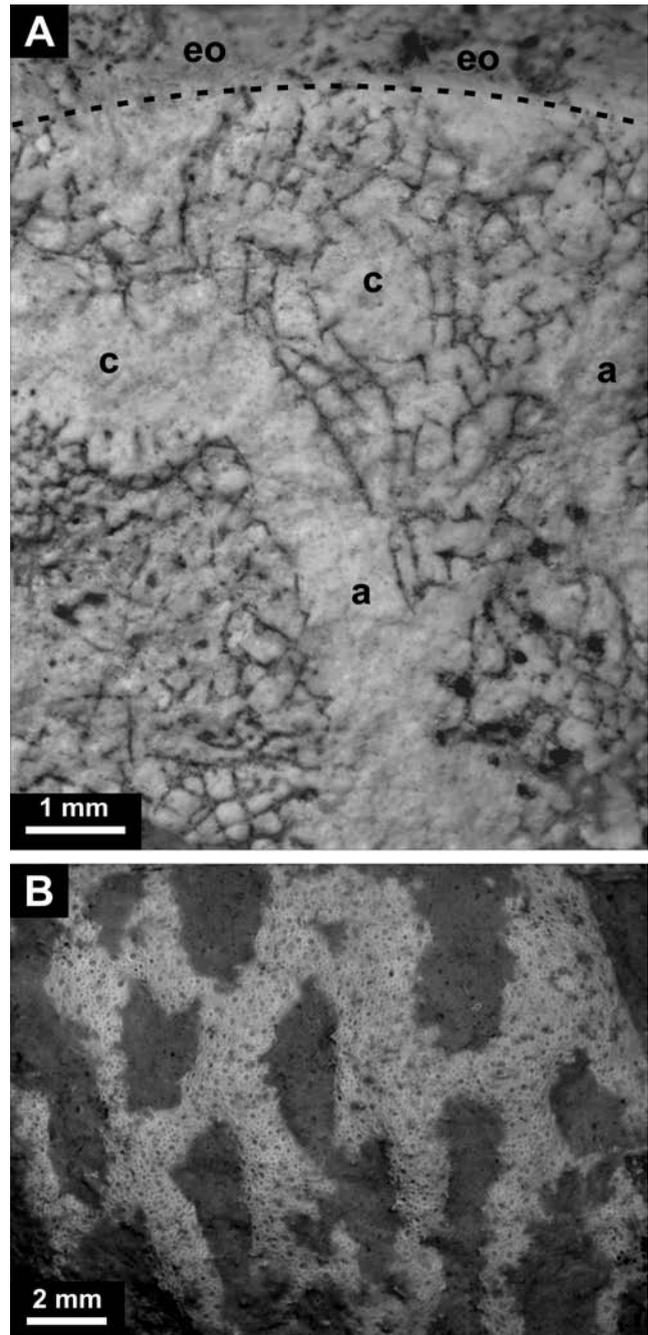
- \*1826 *Coscinopora infundibuliformis* nobis – Goldfuss, p. 30, pl. 9, fig. 16; pl. 30, fig. 10.
- 1991 *Coscinopora infundibuliformis* Goldfuss – Tarkowski, p. 94, pl. 3, fig. 8.
- 2010 *Coscinopora infundibuliformis* Goldfuss – Świerczewska-Gładysz, pp. 274–275, figs 14b, 15a [cum syn.].
- 2011 *Coscinopora infundibuliformis* Goldfuss – Świerczewska-Gładysz (in Olszewska-Nejbert & Świerczewska-Gładysz, 2011), pp. 411–412, fig. 20f.

**Material:** 14 specimens from the Folwark Quarry.

**Description:** These are trumpet-like (Fig. 10A, C), rarely narrow conical (Fig. 10B), sponges, with a very thin wall (1–1.5 mm in thickness). The large, crushed specimens reach about 120 mm in height and 150 mm in diameter. A few specimens have preserved fragments of thin stems. Round canal openings, 0.4 mm in diameter and arranged in a quincunx, occur on the dermal surface. They are separated by convex, skeletal bands, on average 0.3 mm wide. In the lower part of the sponges, the skeletal bands are usually wider, whereas the canal openings are smaller (0.3 mm in diameter) and less regularly distributed. The inner surface is not visible.

The voids after the dictyonal skeleton are poorly preserved; small fragments of the network, with longitudinally elongated, rectangular meshes, 0.2–0.3 × 0.35–0.4 mm in size, are visible only locally (Fig. 11A). The dermal surface is covered by a finely-porous, thick, synapticular cortex (Fig. 11B). The straight canals are perpendicular to the wall. In some specimens, the synapticular membrane is preserved on the wall of the epirhytes (Fig. 11A).

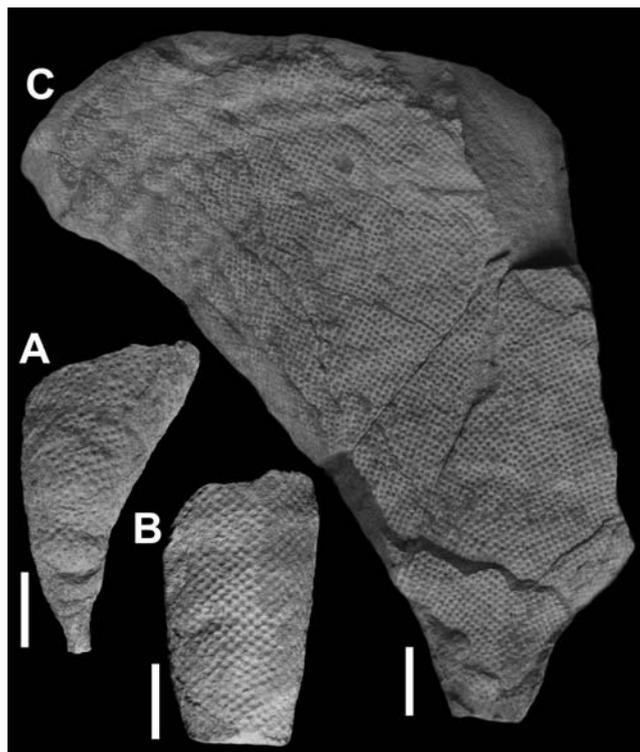
**Remarks:** The features recognized in the specimens from the Opole area fully correspond to the characteristics of *C. infun-*



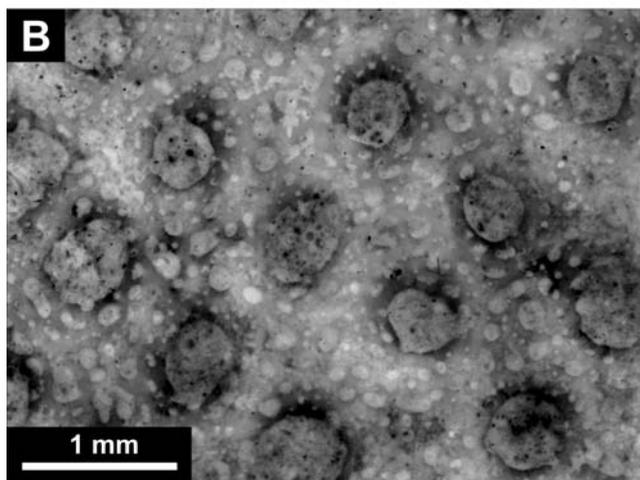
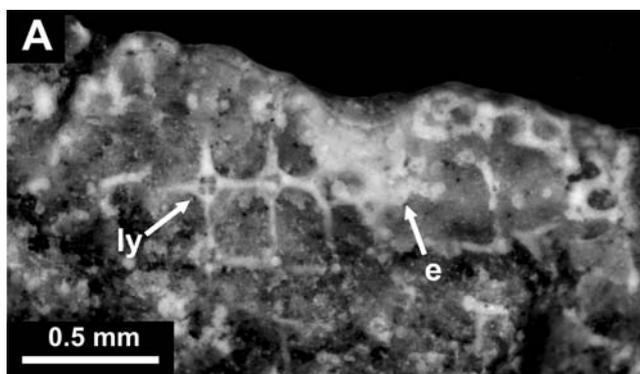
**Fig. 9.** *Rhizopoterion cribrosum* (Phillips, 1829). **A.** Transverse section of wall; note apophyses (a) connected with longitudinal canals (c) in dictyonal skeleton; in upper part (above line) visible dermal surface, with epirhyse openings (eo); Odra II Quarry, Upper Turonian, ULXXIV/O235. **B.** Cortex on dermal surface; Folwark Quarry, Lower Coniacian, ULXXIV/F557

*dibuliformis*. In contrast to the narrow conical specimens of *C. infundibuliformis*, abundant in the Santonian deposits of the Kraków area, the specimens from the Folwark section are wide, trumpet-like and similar to specimens from the Coniacian of France, described by Defretin-Lefranc (1960). Only two specimens in the assemblage coming from the uppermost Turonian marls represent the narrow conical morphotype.

**Occurrence:** In Poland, the Opole area (uppermost Turonian–Lower Coniacian), the Kraków area (Coniacian or/and Santonian sponges redeposited in Santonian deposits, Campanian), eastern



**Fig. 10.** *Coscinopora infundibuliformis* Goldfuss, 1826; scale bar equals 10 mm. **A.** Lower part of trumpet-like sponge; Folwark Quarry, Lower Coniacian, ULXXIV/F142. **B.** Fragment of narrow conical sponge; Folwark Quarry, Upper Turonian, ULXXIV/F178. **C.** Upper part of trumpet-like sponge; Folwark Quarry, Lower Coniacian, ULXXIV/F538



Poland (Campanian); France (Coniacian); northern Germany (Campanian); England (Coniacian–Campanian).

Genus *Sporadoscinia* Pommel, 1872

Type species *Scyphia retiformis* Roemer, 1840

*Sporadoscinia venosa* (Roemer, 1840)

Figs 12, 13

\*1840 *Scyphia venosa* N. – F. A. Roemer, p. 8, pl. 3, fig. 4.

2010 *Sporadoscinia venosa* (Roemer) – Świerczewska-Gładysz, p. 275, fig. 16a [cum syn.].

**Material:** 26 specimens from the Folwark Quarry.

**Description:** These are cup- or bowl-like sponges (Fig. 12A), reaching c. 50 mm in height and over 90 in diameter, with a thin stalk that is up to 50 mm long. The wall thickness is 1.5 mm. The dermal surface is covered by transversally elongated, oval or circular canal openings,  $0.5 \times 0.5$ –1 mm in size (Fig. 12B). The canal openings are evenly distributed, usually in indistinct longitudinal rows, on average 88–96 per  $\text{cm}^2$ . The skeletal bands between the canal openings are sharp and very thin (0.3–0.4 mm wide). The canal openings are oval on the gastral surface,  $0.7$ – $1 \times 1.3$ – $1.8$  mm in size (Fig. 12B), separated by flat or slightly concave, skeletal bands. The canal openings are arranged alternately, about 42 per  $\text{cm}^2$ .

The dictyonal skeleton (poorly visible, only in the subdermal part of one specimen) is irregular, with rectangular or quadrangular meshes, 0.25 mm in size (Fig. 13A). A thick, finely porous synapticular cortex is developed on both surfaces of the dictyonal skeleton (Fig. 13B). The canals are not visible inside the wall.

**Remarks:** By comparison with the representatives of *S. venosa*, described by Schrammen (1912), Bieda (1933) and Ulbrich (1974), the specimens from the Opole Trough have a less clear arrangement of the canal openings in longitudinal rows on the dermal surface. Similarly distributed canal openings are observed on specimens of this species from the Santonian of the Kraków area (Świerczewska-Gładysz, 2010). Some of the specimens examined are very wide, almost plate-like, but this shape seems to be the result of the compaction of sponges preserved on the sea bottom in the life position.

*Sporadoscinia venosa* has not been noted previously in the Cretaceous of the Opole area.

**Occurrence:** In Poland, the Opole area (Lower Coniacian), the Kraków area (Coniacian or/and Santonian sponges redeposited in Santonian deposits, Campanian); northern France (Coniacian); northern Germany (Upper Campanian); England (Coniacian–Campanian); Russia – Saratov area (Lower Santonian).

*Sporadoscinia alcynoides* (Mantell, 1822)

Figs 14–16

\*1822 *Ventriculites alcynoides* – Mantell, p. 176.

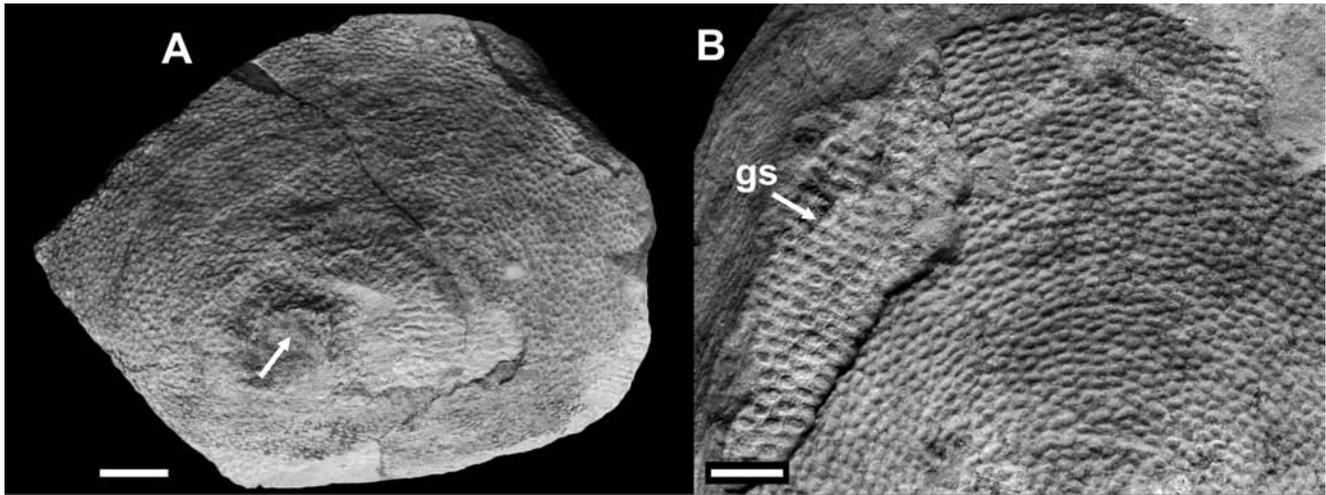
1840 *Scyphia cribrosa* Phillips – F. A. Roemer, p. 9, pl. 4, fig. 2.

1846 *Scyphia Zippei* Reuss – Reuss, p. 76, pl. 18, fig. 5.

1870 *Cylindrospongia angustata* Roemer – F. Roemer, p. 309, pl. 30, figs 7–8.

1878 *Ventriculites angustatus* – Quenstedt, p. 437, pl. 136, figs 2–4, 7, 9–14.

**Fig. 11.** *Coscinopora infundibuliformis* Goldfuss, 1826; Folwark Quarry, Lower Coniacian, ULXXIV/F538. **A.** Dictyonal skeleton with lychniscs (ly); part of wall of epirhyse (e) with synapticular membrane. **B.** Dermal surface with canal openings and synapticular cortex

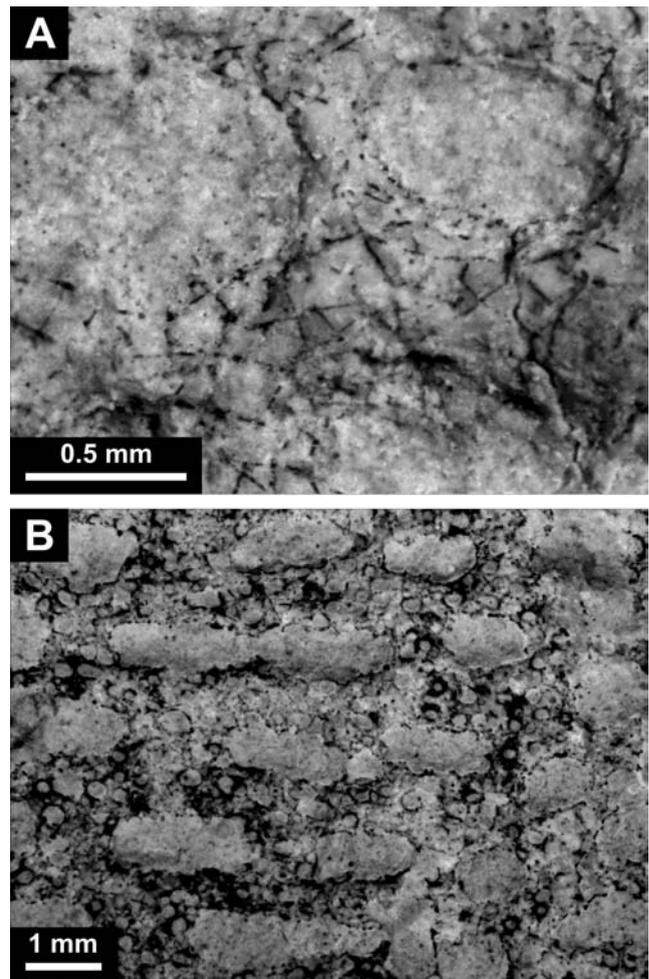


**Fig. 12.** *Sporadoscinia venosa* (Roemer, 1840); scale bar equals 10 mm. **A.** Lower view of nearly complete specimens with remains of stalk (arrowed); Folwark Quarry, Lower Coniacian, MGUWr/5526. **B.** Fragment of dermal surface with canal openings; on left visible imprint of gastral surface (gs); Folwark Quarry, Lower Coniacian, ULXXIV/F535

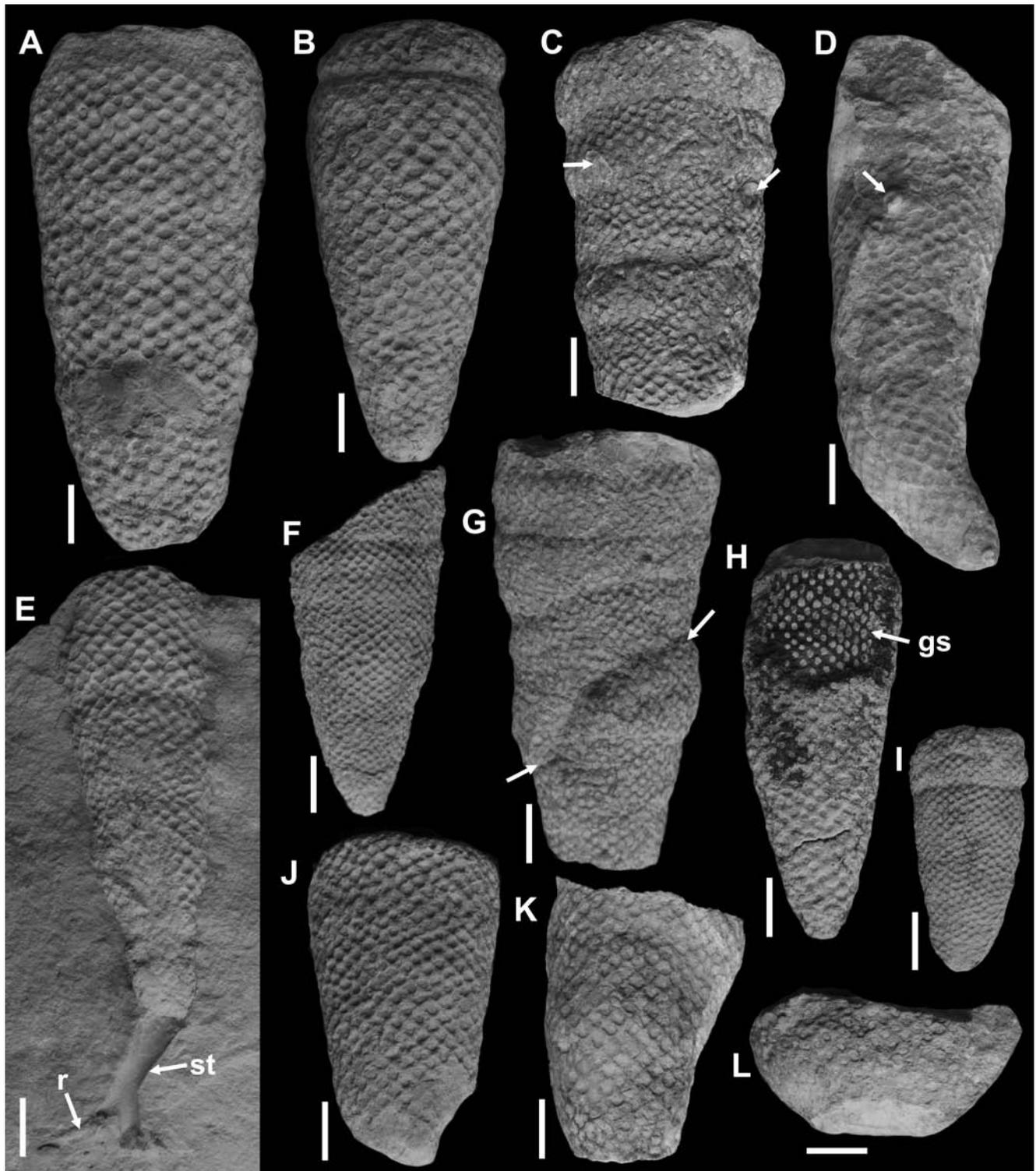
- 1897 *Ventriculites angustatus* s. str. Roemer – Leonhard, p. 31.  
 1897 *Ventriculites Zippei* Reuss – Leonhard, p. 33.  
 1883 *Ventriculites Zippei* Reuss – Počta, p. 32.  
 1912 *Leiostracosia alcynoides* Mant. sp. – Schrammen, p. 284.  
 1960 *Sporadoscinia zippei* – Defretin-Lefranc, pp. 75–76, pl. 7, figs 8–9.  
 1991 *Sporadoscinia eutactopora* Defretin-Lefranc – Tarkowski, p. 92, pl. 3, figs 2, 5.  
 2009 *Ventriculites alcynoides* Mantell – Vodrážka, text-fig. 1g–j.  
 2010 *Sporadoscinia alcynoides* (Mantell) – Świerczewska-Gładysz, p. 25, figs 16c, 17a–b [with additional synonyms].

**Material:** 27 specimens from the Odra II Quarry, 61 specimens from the Folwark Quarry.

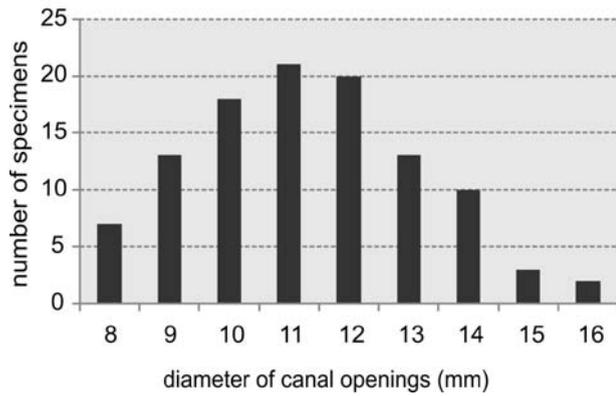
**Description:** These are usually cylindrical or conical sponges, up to 100 mm high and 40 mm wide (Fig. 14A–K). Only three incomplete specimens are cup-like (Fig. 14L). The thin, smooth stem, 20–30 mm long, is terminated by fine, short rhizoids (Fig. 14E), with rare, longitudinal canals. The upper margins of the conical specimens are usually curved inward. Part of the sponges are with 1–2, rarely 3 narrowings (Fig. 14B, C, E, I). A few sponges have the lower part asymmetrically curved (Fig. 14D). The wall thickness is 2–3 mm. On the dermal surface round canal openings occur, 0.8–1.6 mm in diameter (Fig. 15), arranged in a quincunx, 9–36 per cm<sup>2</sup>. The canal openings are usually smaller and distributed less regularly in the lower part of the sponges. The disturbed arrangement of the canal openings occurs also close to the narrowings. An extremely irregular layout is visible on one specimen with a trace of damage and subsequent regeneration (Fig. 14G). A skeletal band occurs between the canal openings, 1–1.5 mm wide, flat or slightly convex. In some of the specimens, the thickened band is very prominent, with a triangular shape in cross-section. The canal openings on the gastral surface are oval, 1–1.5 × 1.5–3 mm in size, alternately arranged, 18–36 per cm<sup>2</sup> (Fig. 14H). The dictyonal skeleton is very regular in the subgastral part, where square meshes, 0.2–0.3 mm in size are present. In the central part of the wall and in the subdermal part, the variably oriented lychnises form a rather irregular network, mainly with quadrangular meshes, 0.15–0.3 mm in size (Fig. 16A). Both surfaces are covered by a thick, finely-porous, synapticular cortex (Fig. 16C). The



**Fig. 13.** *Sporadoscinia venosa* (Roemer, 1840); Folwark Quarry, Lower Coniacian, ULXXIV/F533. **A.** Pyritized subdermal part of dictyonal skeleton. **B.** Voids after cortex on dermal surface



**Fig. 14.** *Sporadoscinia alcynoides* (Mantell, 1822); scale bar equals 10 mm. **A.** Lateral view; Folwark Quarry, Upper Turonian, MGUWr/5527. **B.** Lateral view; Folwark Quarry, Upper Turonian, ULXXIV/F816. **C.** Lateral view of specimens with cemented oysters (arrowed); Folwark Quarry, Upper Turonian, ULXXIV/F660. **D.** Asymmetric specimen with serpulid (arrowed); Folwark Quarry, Upper Turonian, ULXXIV/F567. **E.** Specimens with external mould of stalk (st) and rhizoids (r); Folwark Quarry, Upper Turonian, ULXXIV/F135. **F.** Lateral view; Folwark Quarry, Upper Turonian, ULXXIV/F235. **G.** Specimen with regeneration trace (arrowed); Folwark Quarry, Upper Turonian, MGUWr/5528. **H.** Lateral view; imprint of gastral surface (gs) visible in upper part of specimen; Folwark Quarry, Upper Turonian, ULXXIV/F571. **I.** Lateral view; Folwark Quarry, Upper Turonian, ULXXIV/F615. **J.** Lateral view; Folwark Quarry, Upper Turonian, ULXXIV/F235. **K.** Fragment of an asymmetric specimen; Folwark Quarry, Upper Turonian, ULXXIV/F492. **L.** Fragment of cup-like specimen; Odra II Quarry, Upper Turonian, ULXXIV/499



**Fig. 15.** Size of canal openings of *Sporadoscinia alcynoides* (Mantell, 1822); measurements were made in middle part of specimens

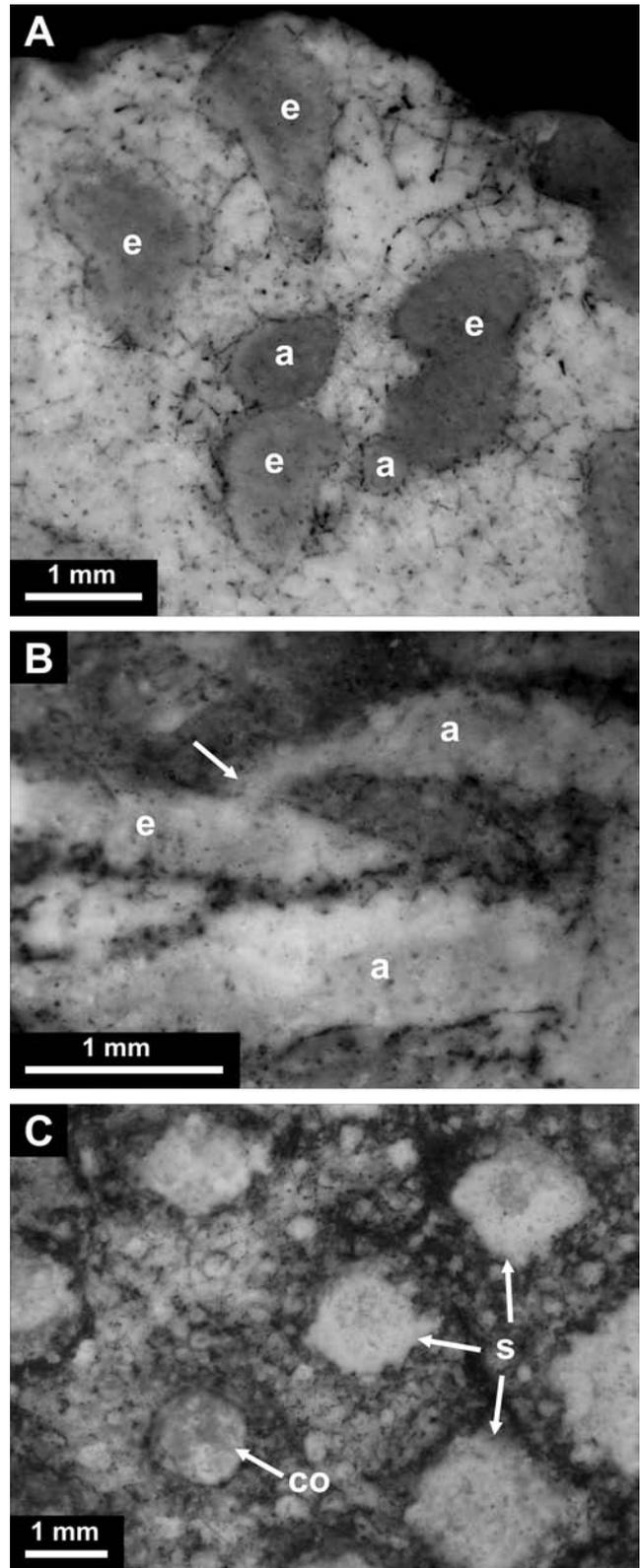
epirhyses terminate below the gastral surface or run into small, elongated chambers. The aporhyses are straight or bifurcating and terminate blindly below the dermal surface or are connected with the neighbouring epirhyses (Fig. 16A, B). The canal walls are covered with a synapticular membrane.

**Remarks:** The species discussed was initially included in the genus *Ventriculites* (Mantell, 1822; Hinde, 1883) and later in *Sporadoscinia* (Defretin-Lefranc, 1960; Reid, 1968; Świerczewska-Gładysz, 2006, 2010). In contrast to *Ventriculites*, characterized by straight, unbranched canals that are perpendicular to the wall, this species has a complex canal system (see also Świerczewska-Gładysz, 2006).

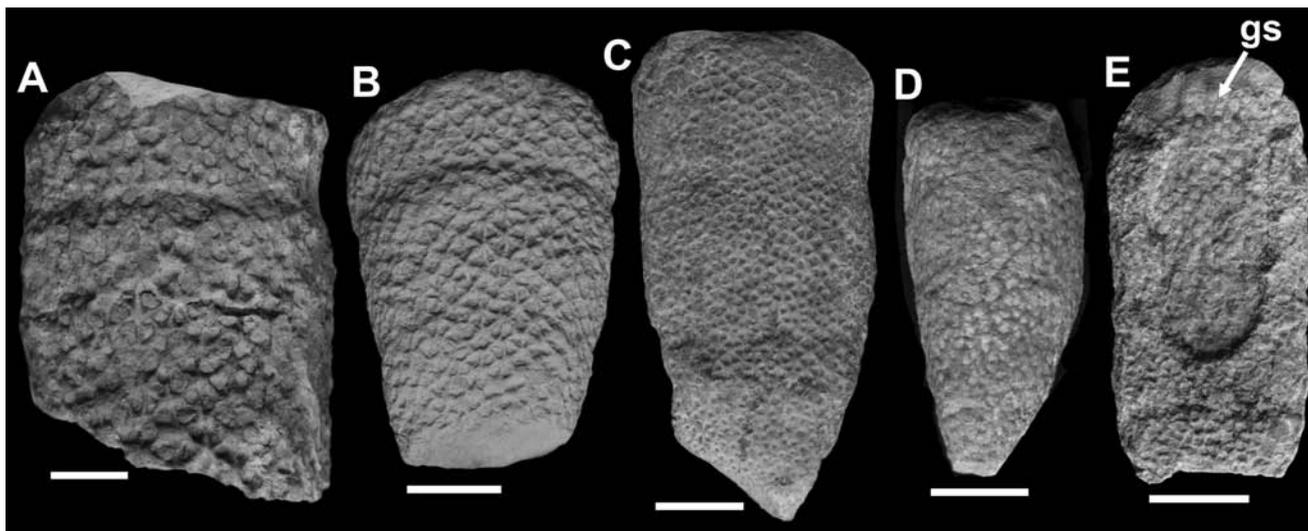
The size of the canal openings on both surfaces in *S. alcynoides* is very different (Fig. 15). Tarkowski (1991) assigned the morphotype with small canal openings to *Sporadoscinia eutactopora* Defretin-Lefranc, 1960. The latter specimen differs from *S. alcynoides* in having much smaller canal openings, which are densely distributed at about 80 per 1cm<sup>2</sup>.

Analysis of the rich material from the Opole Trough shows that in this species the skeletal bands between the canal openings on the dermal surface have a different form, from slightly convex to very prominent. The round canal openings in the specimens with prominent bands are rarely visible, being covered with sediment. The spaces under the canal openings, filled with sediment, are surrounded by sharp ridges of the band and have a rhomboidal shape (Fig. 16C). The specimens with a prominent band and rhomboidal spaces on the dermal surface, described incorrectly as rhomboidal canal openings, were included in *Ventriculites zippei* Reuss, 1846 (Počta 1883; Leonhard, 1897; Defretin-Lefranc, 1960 – as *Sporadoscinia zippei*). In the opinion of the present author, this species can be regarded as a junior synonym of *S. alcynoides*.

Specimens of *S. alcynoides* from the Opole area were described for the first time by F. A. Roemer (1840), who recognized them as *Scyphia cribrosa* Phillips [= *Rhizopoterion cribrosum* (Phillips)]. The specimen illustrated by F. A. Roemer (1840), in contrast to *R. cribrosum*, which is characterized by oval canal openings on the dermal surface, has round openings, typical of *S. alcynoides*. Later, F. Roemer (1870) assigned specimens with round openings from the Opole area to *Cylindrospongia angustata* Roemer, 1840 [in the original description of F. A. Roemer (1840) as *Scyphia angustata*; here described as *Leiostracosia angustata*]. This concept was accepted by Quenstedt (1878) and later also by Leonhard (1897), who distinguished the variant *Ventriculites angustatus* s. str. which is synonymised with *Ventriculites alcynoides* Mantell, and the variant *Ventriculites angustatus distortus* corresponding to *Scyphia angustata* Roemer, 1840. Schrammen (1912) considered



**Fig. 16.** *Sporadoscinia alcynoides* (Mantell, 1822). **A, B.** Dictyonal skeleton with epirhyses (e) and aporhyses (a); Folwark Quarry, Lower Coniacian, ULXXIV/F494. **A** – section parallel to wall surface. **B** – transverse section of wall; connection of aporhyses with epirhyses is arrowed. **C.** Dermal surface with cortex and canal opening (co); some rhomboidal spaces (s) above canal opening are infilled by sediment; Folwark Quarry, Upper Turonian, ULXXIV/F573



**Fig. 17.** *Astropegma stellata* (Roemer, 1840); scale bar equals 10 mm. **A.** Lateral view; Folwark Quarry, Upper Turonian, MGUWr/5529. **B.** Lateral view; Folwark Quarry, Upper Turonian, ULXXIV/F228. **C.** Lateral view; Folwark Quarry, Upper Turonian, MGUWr/5530. **D.** Lateral view; Odra II Quarry, Upper Turonian ULXXIV/O65. **E.** Lateral view; visible imprint of canal openings on gastral surface (gs); Folwark Quarry, Upper Turonian, ULXXIV/F704

these variants as two separate species, included in the genus *Leiostracosia*. However, Schrammen (1912) could not examine the inner surfaces of the two specimens from the Opole area and the specimens from Lower Saxony, described by him as *L. alcynoides*. The specimens of this species from the Cretaceous of the Opole area are devoid of the furrows that are characteristic of the genus *Leiostracosia*.

*Sporadoscinia alcynoides* is a long-living Upper Cretaceous species, known from the Cenomanian of Ukraine (Olszewska-Nejbert and Świerczewska-Gładysz, in review) to the Maastrichtian (Świerczewska-Gładysz, 2006). It was noted in some localities from Poland (compare Świerczewska-Gładysz, 2006, 2010), but it is abundant only in the Upper Turonian marly limestone in the Folwark section.

**Occurrence:** In Poland, the Opole area (Upper Turonian–Lower Coniacian), the Kraków area (Coniacian or/and Santonian sponges redeposited in Santonian deposits, Campanian), the Middle Vistula River valley (Upper Maastrichtian); Germany – Lower Saxony (Turonian–Lower Coniacian); France (Upper Turonian, Coniacian); Czech Republic (Upper Turonian); Russia – Saratov area (Lower Santonian); England (Middle Turonian–Santonian); western Ukraine (Cenomanian).

*Astropegma* Pomel, 1872

Type species *Scyphia stellata* Roemer, 1840

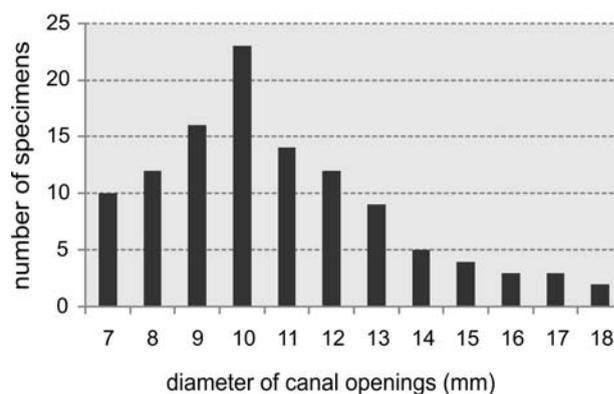
*Astropegma stellata* (Roemer, 1840)

Figs 17–19

- \*1840 *Scyphia stellata* N. – F. A. Roemer, p. 7, pl. 3, fig. 3.
- 1992 *Ventriculites stellatus* (Roemer) – Mehl, p. 128, text-fig. 32 [cum syn.].
- 2010 *Astropegma stellata* (Roemer) – Świerczewska-Gładysz, pp. 277–278, figs 15d–e, 16d [with additional synonyms].

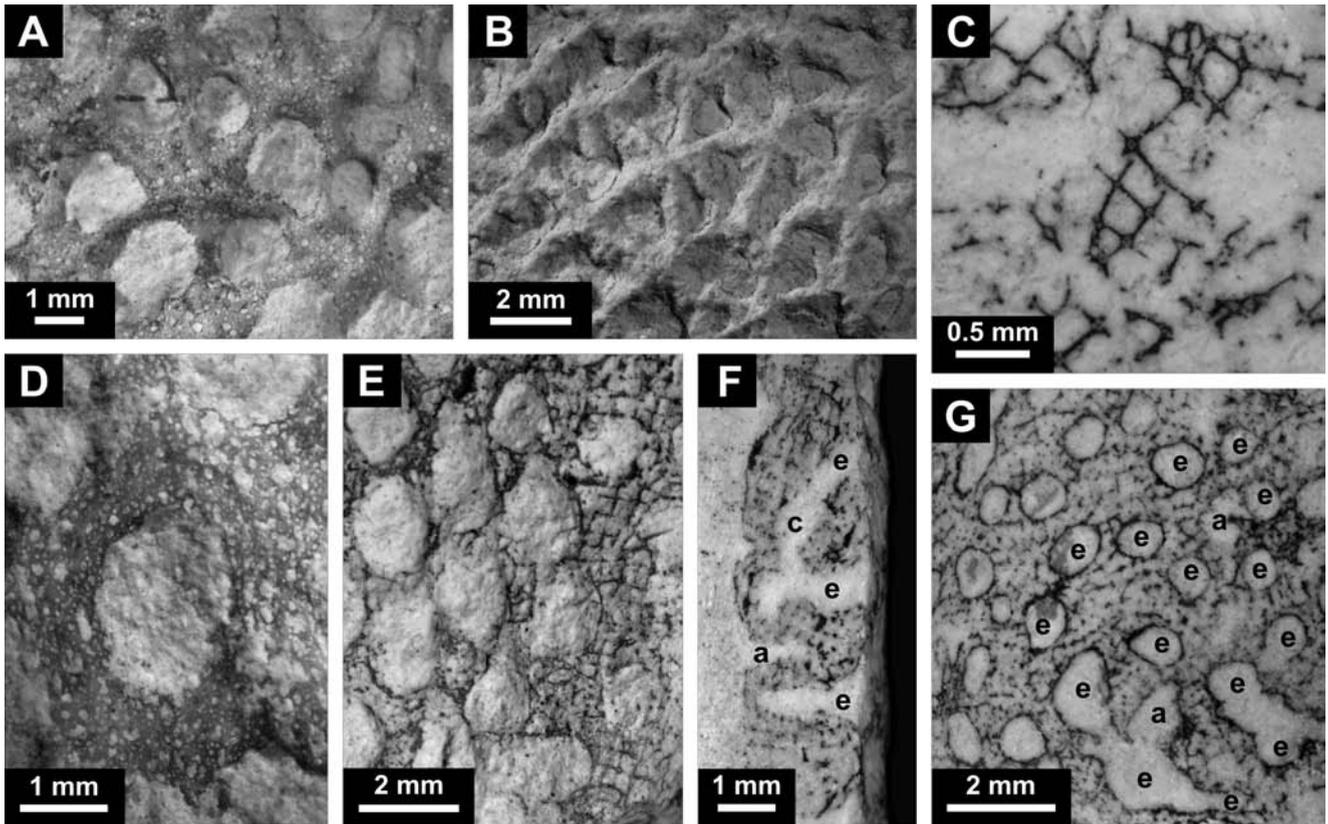
**Material:** 35 specimens from the Odra II Quarry, 58 specimens from the Folwark Quarry.

**Description:** These are conical to nearly cylindrical sponges (Fig. 17A–E) with a thin stalk, 15–35 mm in length. The wall thickness



**Fig. 18.** Size of canal openings of *Astropegma stellata* (Roemer, 1840); measurements were made in middle part of specimens

is 3–6 mm. The narrow specimens do not exceed 50–60 mm in height (measured without the stalk). Most of them are narrower in the uppermost part. Some of them have 1–2 transverse narrowings (Fig. 17A, B). Rarely, the sponges are slightly curved asymmetrically. The conical specimens are usually large, up to 90 mm in height and 50 mm in diameter. On the dermal surface, the canal openings measure 0.7–1.8 mm (Fig. 18). In the lower part of some sponges, the canal openings are very small (c. 0.4 mm) and their diameters are smaller than the widths of the skeletal bands. The large canal openings are rounded, triangular or irregular, whereas the smaller ones are usually round or elliptical. The canal openings are arranged in star-like groups (Fig. 19A, B). The star-like groups usually consist of 6, rarely 4–5 or 7 canal openings (Fig. 19B). Sporadically, in the lower part of some specimens, they are distributed in indistinct, longitudinal rows. The bands between the canal openings are sharp and narrow (0.5–0.7 mm wide). The bands in the centre of the groups are flat, slightly convex (Fig. 19B) or very prominent and pyramid-like (Fig. 19A). Fragments of the gastral surface, visible only on a few specimens, are with oval canal openings, 1–1.5 × 1.5–2.5 mm in size, regularly arranged in a quincunx (Fig. 17E).



**Fig. 19.** *Astropegma stellata* (Roemer, 1840). **A.** Dermal surface with remains of cortex; Folwark Quarry, Upper Turonian, MGUWr/5529. **B.** Dermal surface with star-like groups of canal openings consisting of 4–6 canal openings; Folwark Quarry, Upper Turonian, ULXXIV/F228. **C.** Limonitized dictyonal skeleton with clearly visible lychnises; longitudinal section of wall; Odra II Quarry, Upper Turonian ULXXIV/O37. **D.** Gastral surface with cortex; Folwark Quarry, Lower Coniacian, ULXXIV/F278. **E.** Limonitized subgastral part of dictyonal skeleton with epirhyses; Odra II Quarry, Upper Turonian ULXXIV/488. **F.** Limonitized dictyonal skeleton with epirhyses (e), internal chamber (c) and aporhyses (a); longitudinal section of wall; Odra II Quarry, Upper Turonian ULXXIV/O514. **G.** Pyritized dictyonal skeleton with epirhyses (e) and aporhyses (a); note connection between canals (in lower part of photograph); Folwark Quarry, Upper Turonian, ULXXIV/F363

The dictyonal skeleton is irregular in the subdermal and middle part of the wall (Fig. 19C). Quadrangular meshes, 0.25–0.35 mm in size, dominate. In the subgastral part, the network is more regular, with rectangular meshes, 0.25–0.35 mm in size (Fig. 19E). The thick, synapticular cortex covers the dermal surface of the dictyonal skeleton (Fig. 19A). The cortex is thinner on the gastral surface (Fig. 19D). The straight epirhyses and aporhyses are usually long and perpendicular to the wall. Inside the wall, the neighbouring canals are linked together by irregular chambers (Fig. 19F, G).

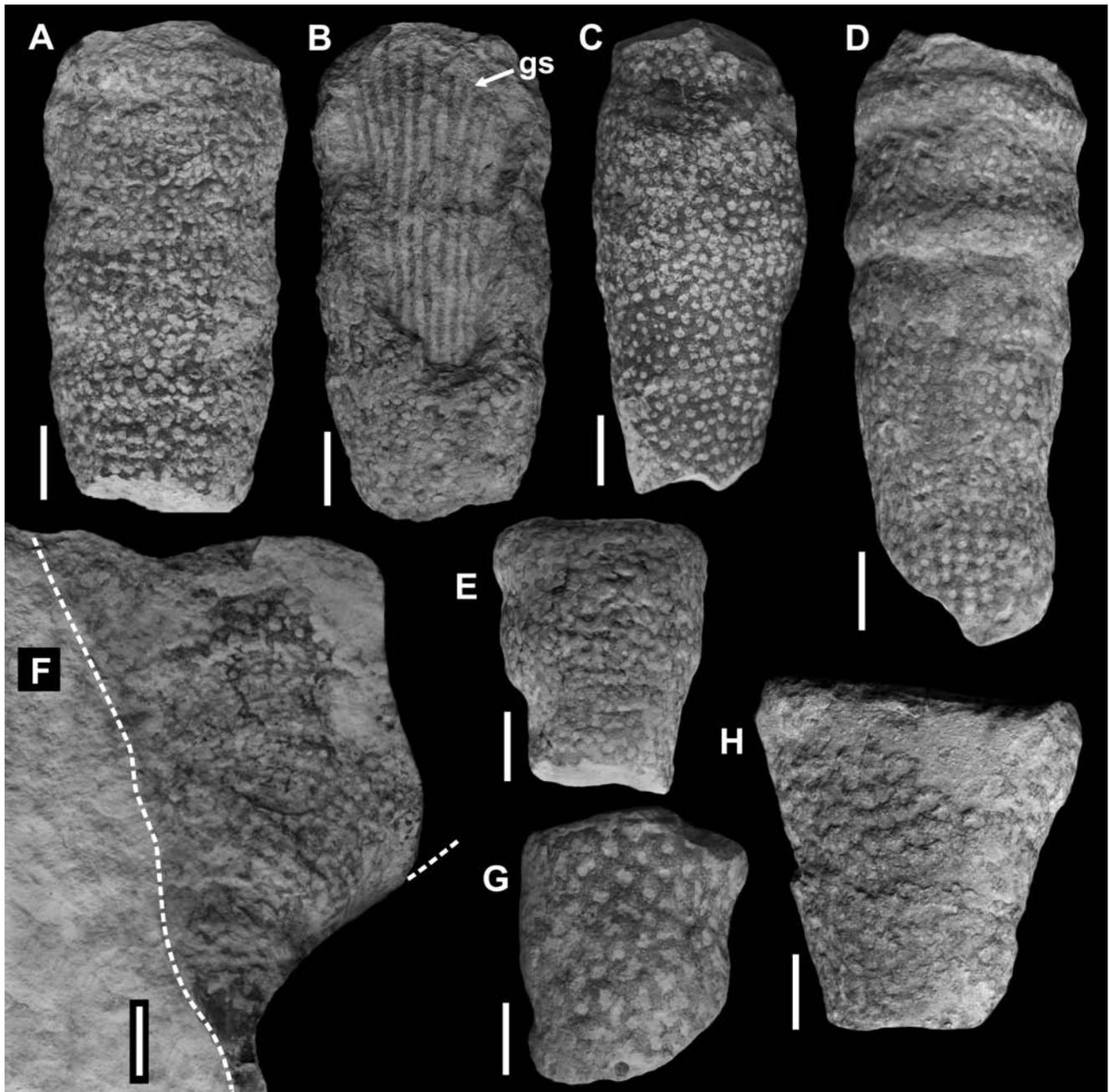
**Remarks:** Pomel (1872) included this species in the new genus *Astropegma*, although later it often was described as a representative of the genus *Ventriculites* (Schrammen, 1902, 1912; Hérenger, 1942; Lagneau-Hérenger, 1950; Ulbrich, 1974; Mehl, 1992). Owing to the star-like patterns of the canal openings on the dermal surface, Reid (2004) accepted the monotypic genus *Astropegma*. In the opinion of the present author, the canalization of the dictyonal skeleton is another important feature that distinguishes this species from *Ventriculites*. The canal system in *Ventriculites* is composed of simple radial epirhyses and aporhyses. In *Astropegma stellata*, the radial epirhyses and aporhyses have additional connections. According to Ulbrich (1974), the epirhyses and aporhyses are connected with the paratangential canals, running under the gastral and dermal surfaces. In the specimens studied, these ca-

nals are not developed, though epirhyses and aporhyses, linked with irregular chambers, are observed.

The star-like groups of the canal openings characteristic of *A. stellata* are composed usually of 6 or more openings (see Mehl, 1992, text-fig. 32), whereas in the specimens studied, groups with 4 and 5 openings also occur. In most of the representatives of this species described, the canal openings in the lower part of the body are arranged in longitudinal rows, separated by wide longitudinal, skeletal bands (e.g., Ulbrich, 1974, pl. 11, fig. 2). Such a pattern of canal openings is very rare in specimens from the Opole Trough. In the known representatives of *A. stellata*, the wall thickness is up to 10 mm and the diameter of the canal openings reaches up to 2.5 mm (e.g., Ulbrich 1974). In the material examined thin-walled specimens with relatively small canal openings on the dermal surface dominate, on average 1 mm in diameter (Fig. 18). Similar specimens occur in the Santonian deposits of the Kraków area.

*A. stellata* has not been previously noted in the Cretaceous of the Opole area, despite the fact that this species is very numerous in the Upper Turonian and Lower Coniacian strata.

**Occurrence:** In Poland, the Opole area (Upper Turonian–Lower Coniacian), the Kraków area (Coniacian or/and Santonian sponges redeposited in Santonian deposits); France (Santonian); northern Germany (Upper Campanian); Spain (Coniacian–Maastrichtian).



**Fig. 20.** A–F. *Leiostracosia angustata* (Roemer, 1840); scale bar equals 10 mm. A – lateral view. B – opposite side of same specimen; visible imprint of gastral surface (gs); Odra II Quarry, Upper Turonian, ULXXIV/O106. C – lateral view; Bolko, Upper Turonian, MGUWr/5531. D – later view; Odra II Quarry, Upper Turonian, ULXXIV/O107. E – lateral view, Odra II Quarry, Upper Turonian, ULXXIV/O524. F – lateral view of wide specimen; supposed shape of sponge is marked with white line; Odra II Quarry, Upper Turonian, ULXXIV/O453; G, H. *Leiostracosia robusta* (Schrammen 1902); G – fragment of cylindrical specimen; Odra II Quarry, Upper Turonian, ULXXIV/O520; H – fragment of conical specimen; Folwark Quarry, Upper Turonian, ULXXIV/F664

Genus *Leiostracosia* Schrammen, 1902  
(= *Pachylepisma* Schrammen, 1902)

Type species *Leiostracosia punctata* Schrammen, 1902

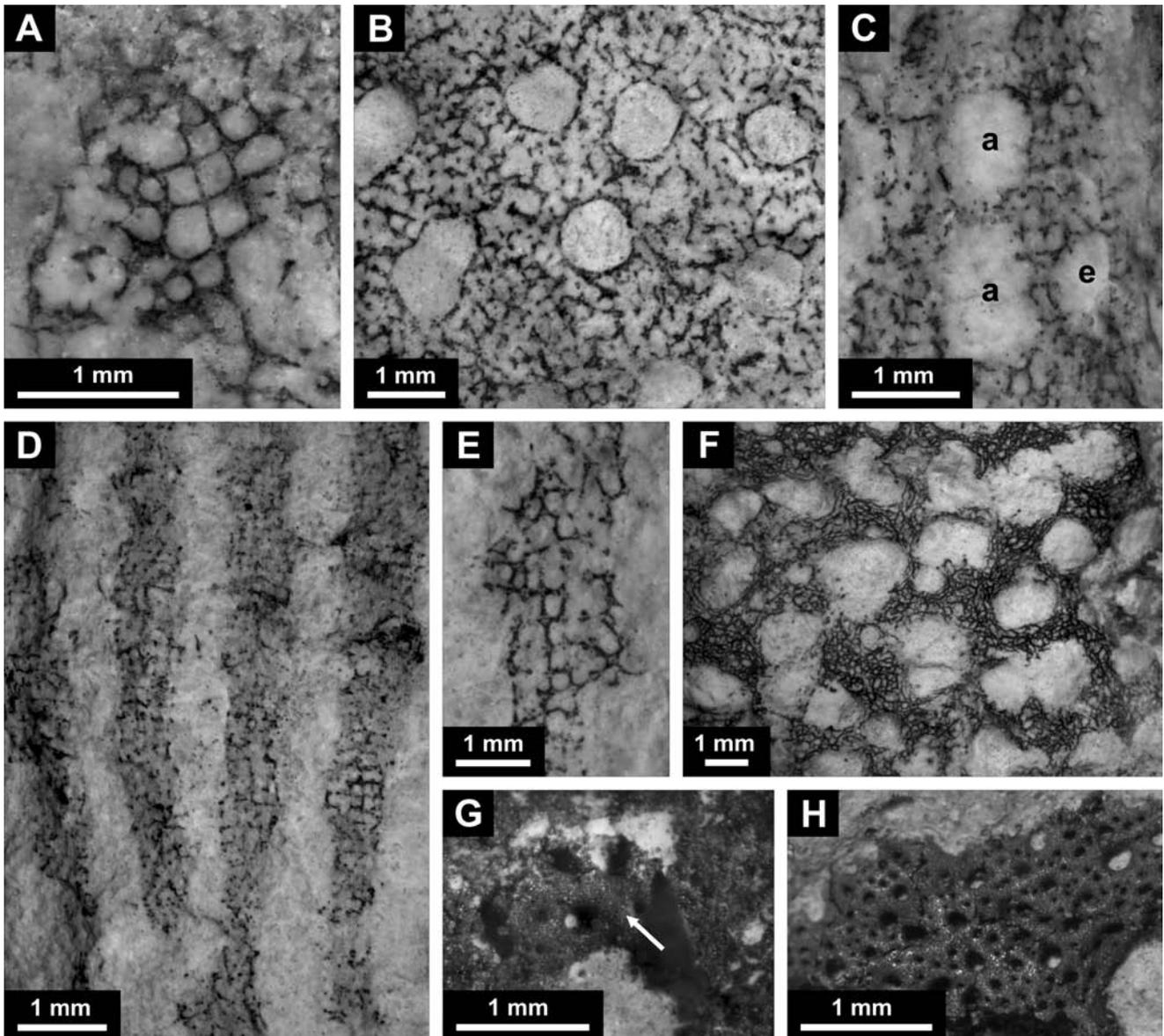
**Remarks:** According to Reid (2004), the genus *Leiostracosia* is poorly defined. In the opinion of the present author, this genus can be clearly distinguished from other ventriculitids. In *Leiostracosia* the canal openings on the inner surface lie within the furrows, unlike in the representatives of *Sporadoscinia* Pomel with a similar morphology of the outer surface. In contrast to *Ubiquiradius* de Laubenfels, 1955 (= *Actinocyclus* Schrammen, 1912 and *Poro-*

*cyclus* Defretin-Lefranc, 1960), also characterized by furrows on the inner surface, the cortex in *Leiostracosia* is developed only on the dermal surface (see Schrammen, 1902, 1912). On the inner surface of the related ventriculitid, the canal openings have an alternate arrangement, whereas in representatives of *Leiostracosia*, they are distributed mainly in horizontal rows.

*Leiostracosia angustata* (Roemer, 1840)

Figs 20, 21

\*1840 *Scyphia angustata* N. – F. A. Roemer, p. 8, pl. 3, fig. 5.



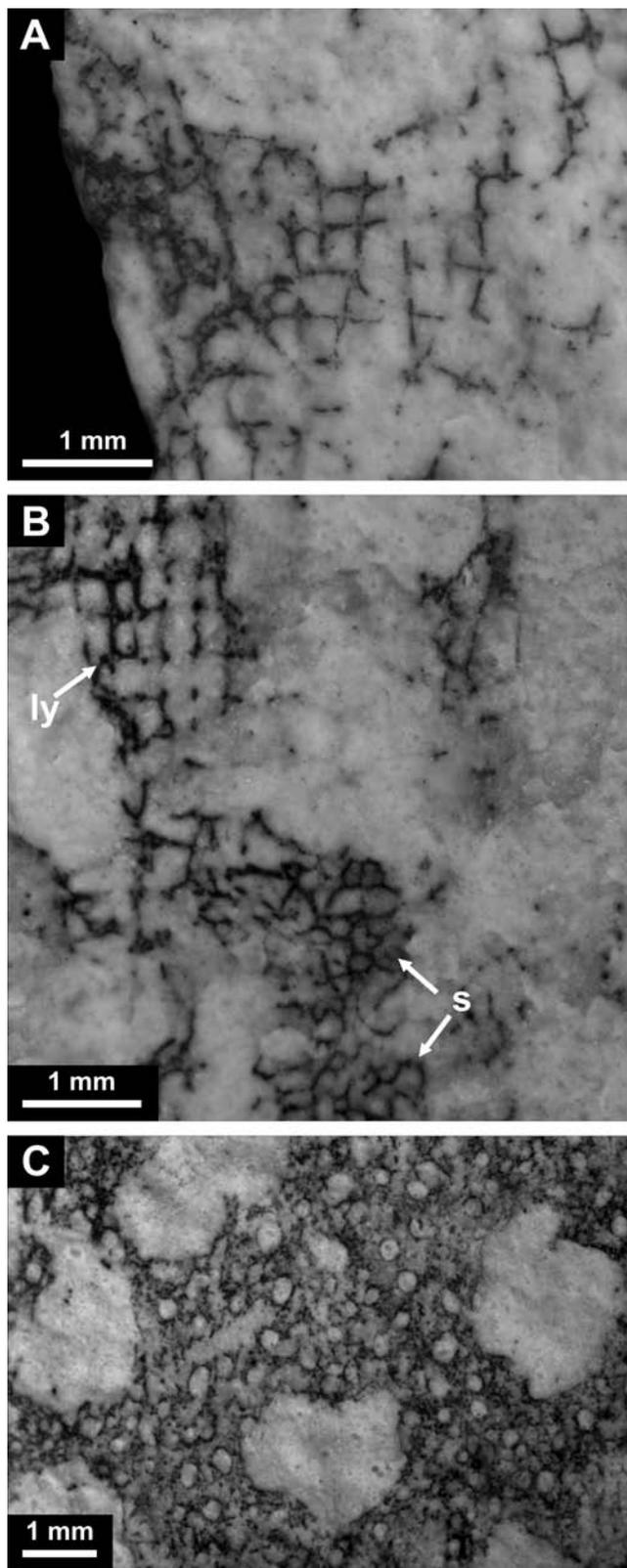
**Fig. 21.** *Leiostracosia angustata* (Roemer, 1840). **A.** Dictyonal skeleton; longitudinal section of wall. **B.** Subdermal part of dictyonal skeleton with epirhyses. **C.** Gastral surface with aporhyses openings (a) situated in furrows; termination of epirhyse (e) visible at place where surface of rib is damaged. **D.** Ribs and furrows on gastral surface. **E.** Dictyonal skeleton on surface of rib on gastral surface. **F.** Dermal surface with cortex and canal openings. **G.** Fragment of epirhyse with synapticular membrane (arrowed). **H.** Detail of synapticular cortex on dermal surface. A, C–F – Odra II Quarry, Upper Turonian, ULXXIV/O106. B, G, H – Folwark Quarry, Upper Turonian, ULXXIV/F607

- non 1883 *Ventriculites angustatus* Roemer – Hinde, p. 114, pl. 26, fig. 3 [= *Sporadoscina* sp.].  
 1878 *Ventriculites angustatus distortus* – Quenstedt, p. 437, pl. 136, figs 15–19.  
 1897 *Ventriculites angustatus distortus* Roemer – Leonhard, p. 31.  
 1912 *Leiostracosia angustata* Roem. sp. – Schrammen, p. 284.  
 1991 *Leiostracosia angustata* (Roemer) – Tarkowski, p. 92, pl. 3, figs 3, 6.  
 2010 *Leiostracosia angustata* (Roemer) – Świerczewska-Gładysz, p. 275, fig. 14c [with additional synonyms].

**Material:** 82 specimens from the Odra II Quarry, 1 specimen from the Bolko Quarry, 10 specimens from the Folwark Quarry.

**Description:** These are narrow conical to nearly cylindrical spon-

ges, up to 80 mm in height, usually with 1–2 or even 5 narrowings (Fig. 20A–E). The upper edge is straight or bent inwards. Rare specimens may be funnel-like and reach 80 mm in diameter (Fig. 20F). The wall thickness is 2–3 mm. The dermal surface is covered with irregular or roundish canal openings that are 1–2 mm in size. They are distributed irregularly or in indistinct vertical rows, 18–25 per cm<sup>2</sup>. The regular arrangement of the canal openings is usually most clear in the lower part of the sponges (Fig. 20D). The skeletal bands separating the canal openings, up to 2 mm wide, are slightly concave. Thick protuberances occur at the junction of the bands on some specimens. On the gastral surface round or oval canal openings occur, lying on the bottom of longitudinal furrows, separated by 1–1.5 mm wide ribs. The canal openings, 1.2–1.5 mm in diameter, are arranged in horizontal rows. They are rarely visible, because the furrows are usually filled with sediment. The



**Fig. 22.** *Leiostracosia robusta* (Schrammen, 1902); Odra II Quarry, Upper Turonian, ULXXIV/0520. **A.** Longitudinal section of wall; note pyritized regular dictyonal skeleton inside wall (central and right part of photograph) and less regular skeleton in subdermal part (left part of photograph). **B.** Gastral surface with pyritized dictyonal skeleton with lychniscs (ly) on surface of rib and secondary network above furrows, composed of synapticular filaments (s). **C.** Cortex on dermal surface and canal openings

transverse skeletal bands between the canal openings are c. 1–1.5 mm wide. In the wide specimens, the ridges bifurcate once or twice.

The dictyonal skeleton is regular, mainly with square meshes, 0.3 mm in size (Fig. 21A). Locally the meshes are rectangular, 0.25–0.3 × 0.3–0.35 mm in size. The skeleton is irregular in the subdermal part (Fig. 21B) and on the gastral surface. A thick, finely-porous cortex with small spines, is developed only on the dermal surface (Fig. 21F, H). Tangled, synapticular fibres occur above the cortex in the lower part of the sponges. The gastral surface is without a cortex (Fig. 21D, E). The cylindrical canals are perpendicular to the wall and terminate below the opposite surfaces (Fig. 21C). A synapticular membrane covers the wall of the epirhyses (Fig. 21G).

**Remarks:** According to Schrammen (1912), the canal openings on the inner surface are situated in furrows and have an alternating arrangement. In the specimens studied, the canal openings are distributed in horizontal rows, similar to the specimen, illustrated by Quenstedt (1878, pl. 136, fig. 18). Specimens from England, described by Hinde (1883) as *L. angustata*, have canal openings, arranged in a quincunx on the gastral surface and are devoid of furrows. Moreover, their skeleton is irregular, which precludes their assignment to this species.

Most of the specimens studied are narrow conical; only eight specimens are funnel-like. A wide morphotype has not been described yet for this species. The wide, funnel-like specimens are similar to *L. punctata* Schrammen, 1902, but in that species the canal openings are round and distributed in vertical and horizontal rows on the dermal surface (Schrammen, 1902, 1912; Świerczewska-Gładysz, 2006). In *L. angustata*, the canal openings are irregular. A regular arrangement of canal openings in vertical and horizontal rows occurs only in the lower parts of some specimens.

**Occurrence:** In Poland, the Opole area (Upper Turonian), the Kraków area (Coniacian or/and Santonian sponges redeposited in Santonian deposits); in Germany, the Lower Saxony (Turonian–Lower Coniacian), the Island of Rügen (Lower Maastrichtian).

*Leiostracosia robusta* (Schrammen, 1902)  
Figs 20G, H, 22

- \*1902 *Pachylepisma robusta* Schrm. n. sp. – Schrammen, p. 14, pl. 1, fig. 2.  
2006 *Leiostracosia robusta* (Schrammen) – Świerczewska-Gładysz, p. 262, fig. 27c–d [cum syn.].

**Material:** 8 specimens from the Odra II Quarry, 5 specimens from the Folwark Quarry.

**Description:** These are cylindrical or conical sponges (Fig. 20G, H) with a relatively thick wall, up to 5–6 mm. The nearly complete, conical specimen is 89 mm high and 45 mm wide; the largest fragment derived from a cup-like form is 50 mm in diameter. Irregular or rounded canal openings occur on the external surface; they are 2–3 mm in diameter, distributed without a clear pattern (Fig. 22C). The canal openings are separated by wide (up to 3 mm), flat or slightly concave skeletal bands. On the inner surface oval canal openings occur, 1.5–2 mm in size, situated on the bottom of the furrows that are 1.5–2 mm wide. The ribs between the furrows are flat, 2 mm wide. The straight epirhyses and aporhyses are perpendicular to the wall and arranged in independent vertical series. The epirhyses terminate below the surface of the ridges on the gastral surface.

The dictyonal skeleton is regular, with longitudinally rectangular meshes, 0.3 × 0.4 mm in size (Fig. 22A, B). The skeleton is less regular in the subdermal part (Fig. 22A). The synapticular cortex on the dermal surface is thick, with numerous protrusions and cone-like spines (Fig. 22C). Some spines are directed into the canal openings and therefore the outline of the openings is jagged (a

Table 1

Stratigraphic distribution of ventriculitid species in succession studied (grey bar), as reported from various areas of Europe (black bar)

Ventriculitid species	Albian	Cenomanian	Turonian	Coniacian	Santonian	Campanian	Maastrichtian
<i>Ventriculites chonoides</i> (Mantell, 1815)	F	B,F,U	E,F,Cz	F			
<i>Rhizopoterion cribrosum</i> (Phillips, 1829)*			?F?Cz	E,K	E,I,R	E,I,G,K,M,V	E,G,K,U,V
<i>Coscinopora infundibuliformis</i> Goldfuss, 1826				E,F	E	E,G,K,M	
<i>Sporadoscinia venosa</i> (Roemer, 1840)*				E,F,K	E,R	E,G,K	
<i>Sporadoscinia alcynoides</i> (Mantell, 1822)		U	Cz,E,F,G	E,F,G	E,R	K	V
<i>Astropegma stellata</i> (Roemer, 1840)*				S	F,S	G,S	S
<i>Leiostracosia angustata</i> (Roemer, 1840)			G	G			G
<i>Leiostracosia robusta</i> (Schrammen, 1902)*				E,?F	E	G,V	V

B – Belgium (after Defretin-Lefranc, 1960), Cz – Czech Republic (after Počta, 1883; Frič, 1889; Vodrážka *et al.*, 2009), E – England (after Hinde, 1883; Reid, 1968; Wood, 2002), F – France (after Moret, 1926; Defretin-Lefranc 1960; Lagneau-Hérenge, 1962; Pajaud, 1973), G – Germany (after Schrammen, 1912; Rauff, 1933; Nestler, 1961; Ulbrich, 1974; Mehl, 1992), I – Northern Ireland (after Reid, 1968), K – Kraków area, Poland (after Bieda, 1933; Hurciewicz, 1968), N – north-eastern Poland; R – Saratov region, Russia (after Sinzov, 1871-72; Pervushov 1998, 2002), S – Spain (after Lagneau-Hérenge, 1950), U – Ukraine (after Świerczewska-Gładysz, 2006, Olszewska-Nejbert and Świerczewska-Gładysz, in review); V – Middle Vistula River valley, Poland (after Świerczewska-Gładysz, 2006); white bar with oblique black lines represents probable stratigraphic ranges of sponges redeposited in Upper Santonian deposits in Kraków area, southern Poland (after Olszewska-Nejbert and Świerczewska-Gładysz, 2009; Świerczewska-Gładysz, 2010); species, recognized in Upper Turonian or Lower Coniacian of Opole Trough for first time, marked with asterisk

feature that is visible on specimens with a well preserved outer surface). A synapticular membrane covers the wall of the epirhyses. The gastral surface is devoid of a cortex. Limonitized, synapticular filaments that are preserved on one specimen form a loose network above the furrows (Fig. 22B).

**Remarks:** By comparison to specimens of this species from the Campanian of Germany (see Schrammen, 1902, 1912) and the Upper Campanian and Lower Maastrichtian of Poland (see Świerczewska-Gładysz, 2006), some of the specimens studied have a wide skeletal band between the canal openings on the dermal surface.

*Leiostracosia robusta* is a rare species in the succession studied and has not been previously noted in the Opole Trough.

**Occurrence:** In Poland, the Opole area (Upper Turonian–Lower Coniacian), the Middle Vistula River valley (Upper Campanian–Lower Maastrichtian); north-western Germany (Campanian); ?France (Coniacian); England (Upper Coniacian–Santonian).

## REMARKS ON DISTRIBUTION OF VENTRICULITIDS STUDIED

The ventriculitid species identified in the study succession are typical taxa for the Late Cretaceous in the North European Province (Table 1). According to Reid (1968), *Ventriculites chonoides* (Mantell, 1815) is a species typical of the Turonian, whereas the morphologically very similar *Rhizopoterion cribrosum* (Phillips, 1829) appears for the first time in the Upper Coniacian deposits and is very common in the upper stages of the Upper Cretaceous. In the Opole Trough, the co-occurrence of both species in the Upper Turonian and Lower Coniacian is noted for the first time. However, *R. cribrosum* is very rare in the sections studied and its abundance is highest in the Lower Coniacian, in which *V. chonoides* is less frequent. *R. cribrosum* was recognized also in another late Early Coniacian sponge assemblage from Wielkanoc in the Kraków area, but *V. chonoides*

was not observed there (Olszewska-Nejbert and Świerczewska-Gładysz, 2009).

*L. robusta* (Schrammen, 1902) is a rare species in the succession studied and was documented from the Upper Turonian and Lower Coniacian. Until now, this species was reported from Coniacian–Lower Maastrichtian deposits. Other species from the Opole Trough have wide stratigraphic ranges, spanning the Turonian and Coniacian (Tabl. 1).

The composition of the ventriculitid assemblage from the Upper Turonian–Lower Coniacian of the Opole Trough is fairly similar to that recognized among phosphatized sponges, redeposited in Santonian deposits of the Kraków area. The two regions share six species, i.e. *C. infundibuliformis*, *R. cribrosum*, *S. venosa* (Roemer, 1840), *S. alcynoides* (Mantell, 1822), *A. stellata* (Roemer, 1840) and *L. angustata* (Roemer, 1840). The first four species also were recorded in the Campanian deposits of the Kraków area.

## REMARKS ON ECOLOGY AND POLYMORPHISM OF VENTRICULITIDS

Recent Lychniscosida are relict groups, represented by only a few species (e.g., Mehl, 1992, Leys *et al.*, 2007; Reisinger and Kelly, 2011), which like other hexactinellid groups, inhabit mainly the bathyal zone (Ijima, 1927; Van Soest and Stentoft, 1988). A deep-water environment is preferred by the hexactinellids, because their morphology and life functions are adapted to low turbulence, low water temperature, low sedimentation rate and oligotrophic conditions (Krautter, 1997, 1998; Leys *et al.*, 2007). Therefore, these sponges occur sporadically in shelf seas and inhabit almost invariably their deeper regions. The shallowest depth at which lychniscosidans were noted was about 80 m (Finks and Rigby, 2004).

Assemblages with abundant lychniscosidans are common in the Upper Cretaceous of the North European Province, but appear to be limited to the calcareous and marly facies of the deeper regions of epicontinental seas (e.g., Defretin-Lefranc, 1960; Nestler, 1961; Reid, 1968; Termier and Termier, 1981; Wiese *et al.*, 2004; Žitt *et al.*, 2006; Schneider *et al.*, 2011). According to Defretin-Lefranc (1960), the distribution of different groups of siliceous sponges in the Upper Cretaceous deposits of France indicates that lychniscosidans preferred a deeper-water habitat than that of the hexactinosidans. This hypothesis is not confirmed in some Jurassic assemblages (e.g., Leinfelder *et al.*, 1996) and in other Cretaceous assemblages (Świerczewska-Gładysz, 2006). Most probably, the bathymetric preferences of both groups are similar. The environmental requirements of Recent lychniscosidans and their distribution in Cretaceous deposits permit to conclusion that the Upper Turonian–Lower Coniacian marly limestones and marls were deposited below the storm wave-base. A precise determination of the basin bathymetry, based on the ventriculitid species recognized is not possible, owing to the lack of present-day analogues. Additionally, changes in the taxonomic composition of ventriculitid sponges, observed in the Upper Turonian–Lower Coniacian sequence, are probably connected with other factors, as well as the stratigraphic range of the particular species (Table 1).

Numerous species of siliceous sponges, characterized by very high intraspecific variability, are usually connected with variable environmental conditions (e.g., Trammer, 1979; Mehl and Niebuhr, 1995; Krautter, 1998). Among the Late Cretaceous lychniscosidans, the Ventriculitidae are one of the most polymorphic groups. An extremely variable feature, observed in numerous ventriculitid taxa, is the size of the canal openings. In the assemblage studied, *V. chonoides*, *S. alcynoides* and *A. stellata* are characterized by very different sizes of canal openings. Similar variability was observed in *R. cribrosum* from younger stages of the Upper Cretaceous (e.g., Ulbrich, 1974; Świerczewska-Gładysz, 2006), but this species is rare in the material studied and thus measurements of its canal openings do not display this variability. The size of the canal openings in other species is relatively constant.

Thickenings of the cortex on the dermal surface were described for *V. chonoides* (Reid, 1962; Wood, 2002). In the material studied, a similar trend to form different types of thickenings of the dermal cortex, was observed in *S. alcynoides*, *A. stellata* and to a smaller extent in *L. angustata*. Morphotypes with small and large openings and with or without thickenings of the cortex were noted in the marly limestones, marls and siliceous marls. The relationship between the variation of these features and environmental factors, if present, cannot be identified on the basis of the assemblage studied.

Another variable feature of the ventriculitids is the shape of the sponge body. In the study material, the shape of the body can be clearly correlated with the deposit type. Species from the Marly Limestone Unit of the Opole Trough typically are represented by the narrow morphotypes. Specimens of the same species in the Upper Marl Unit, like the co-occurring specimens of *C. infundibuliformis* and *S. venosa*, are

wide. Narrow morphotypes occur in the two latter species; they are known from the Santonian and Campanian of the Kraków area (Bieda, 1933; Świerczewska-Gładysz, 2010). Quenstedt (1878) documented narrow specimens of *Ventriculites angustatus* (= *Leiostracosia alcynoides* after Schrammen, 1912; here designated as *S. alcynoides*) from the Opole area with a narrow osculum and transverse narrowing. Defretin-Lefranc (1960) observed also a narrow osculum and narrowings in specimens of this species from the Upper Turonian of France and considered these features to be species-diagnostic. The presence of narrowings in other species (*A. stellata*, *L. angustata* and *L. robusta*) from marly limestones and their absence in sponges from the marls indicate that this element is not species-diagnostic and should rather be attributed to environmental factors.

Hexactinellid sponges are adapted to low sedimentation rates and rapid accumulation drastically reduces their occurrence (e.g., Mehl and Niebuhr, 1995; Krautter, 1997, 1998; Pisera, 1997; Duarte *et al.*, 2001; Leys *et al.*, 2004). Therefore, fossil hexactinellids are useful for determining the sedimentation rate. Particularly, dish-shaped sponges are considered to be indicators of a very low sedimentation rate (Krautter, 1997). Sediments, covering the upper surface of the dish-shaped sponges or trapped in the cup- and funnel-like body, may cause the death of the organisms. Therefore, in environments with higher sedimentation rates, sponges with a large spongocoel protect themselves from filling with sediment by narrowing the osculum (Conway *et al.*, 2004; Cook *et al.*, 2008). The narrowed osculum produces a bundled, exhalant water current, which prevents the accumulation of sediment particles in the spongocoel (Krautter, 1997, 1998).

With regard to this observation, the sedimentation rate seems to be the environmental factor that could have influenced the shape of the sponges studied. Accumulation of the deposits was low; however, during the sedimentation of the marly limestones, the sedimentation rate was slightly higher than during deposition of marls and siliceous marls. Narrowings in the sponge specimens were probably connected with episodes of relatively rapid sedimentation. In the material studied, many sponges have several, up to five, narrowings, suggesting that such episodes occurred cyclically during the life of a sponge. According to Kędzierski and Uchman (2001), the supply of clay was constant during the sedimentation of the Turonian and Coniacian deposits in the Opole Trough and changes in lithology resulted from fluctuations in the production of carbonate, derived from calcareous nannoplankton (Kędzierski, 1995). Episodes of relatively rapid sedimentation could have been related to seasonal phytoplankton blooms.

Environments with slow sedimentation that are preferred by the hexactinellid sponges are also suitable for the growth of epibionts. Therefore, the cementing epibionts commonly occur on fossil sponges (e.g., Mehl and Niebuhr, 1995; Žitt *et al.*, 2006; Charbonnier *et al.*, 2007); likewise, they may be found on the specimens studied. The presence of root-like processes (rhizoids) in the ventriculitids studied indicates that they lived on a soft bottom. Therefore, skeletons of dead sponges, lying on a muddy bottom, acted as a solid substratum for the settlement of epibionts. In recent

seas, numerous and diverse epibionts, such as annelid worms (terebellids and serpulids) and bryozoans, may be observed on the skeletons of dead sponges (Leys *et al.*, 2007). Cementing epibionts occur also on living hexactinellid sponges, but in these cases, they attach themselves to the long spicules, projecting from the soft sponge bodies.

Bryozoans, octocorals and serpulids, found on the conical or cylindrical sponges from the marly limestones, occur on various sides of the same specimens, allowing a conclusion that after death, the sponges remained propped up on the sea bottom, allowing free colonization by fast-growing, encrusting organisms. Attachment of the epibionts to any part of the sponge surface would also be possible during rolling of the dead sponge bodies on the sea bottom. However, the good state of preservation of the specimens studied and their arrangement in the sediment with rhizoids excludes such explanation. According to Žitt *et al.* (2006), well preserved epibionts on hexactinellid sponges indicate a low sedimentation rate and rapid final burial. Relatively rapid episodes of burial in the case studied were probably connected with the overturning of dead sponges with attached epibionts. The presence of oysters, mainly on the upper surface of wide, flat specimens and on one side of the narrow, cylindrical or funnel-shaped sponges, may indicate that the oysters preferred horizontal surfaces for colonization and therefore were attached to the narrow-shaped sponges, after these were overturned but before their burial in the sediment.

In the material examined, two specimens of *S. alcynoides* have traces of damage and later regeneration (Fig. 14G). Recent lychniscosidans are poorly known and regeneration in these sponges has not been described yet, while this process has been established in other groups of hexactinellids, including hexactinosidans that are also characterized by a dictyonal skeleton (Leys *et al.*, 2007). Damage of the sponge body is usually connected with the attack of asteroids or nudibranchs (e.g., Dayton *et al.*, 1974; Dayton, 1979, 1989; Teixidó *et al.*, 2006; Chu and Leys, 2012). Predator attacks often do not cause the death of a sponge and the sponge body may be rebuilt (Dayton, 1979; Teixidó *et al.*, 2006).

The growth rate differs among the various species of the Hexactinellida, but is generally low, a few centimetres per a year (Dayton *et al.*, 1974; Leys and Lauzon, 1998; Austin *et al.*, 2007). Small individuals grow faster, whereas later the growth rate decreases (Austin *et al.*, 2007). The growth rate and the maximum sizes of the individuals depend also on local, environmental conditions (Leys *et al.*, 2007). The presence of large individuals indicates excellent environmental conditions and a resulting low sponge mortality (Teixidó *et al.*, 2006), where the large sizes of the sponges may be sometimes negatively correlated with their abundance in a given area (Teixidó *et al.*, 2006; Kahn *et al.*, 2012). In the Opole Trough, the ventriculitids, occurring in the Upper Marl Unit, are slightly less numerous than in the Marly Limestone Unit, but they are usually larger. Therefore, the depositional environment of the uppermost Turonian–Lower Coniacian marls seems to be more favourable for the development of these sponges than the environment during the deposition of the Upper Turonian marly limestones. The development of siliceous sponges depends on various interrelated factors (Krautter, 1997, 1998; Pisera,

1997; Duarte *et al.*, 2001; Whitney *et al.*, 2005) and indicating the crucial features, responsible for the improvement of living conditions of the studied sponges is difficult. Besides the previously discussed low rate of sedimentation, a larger food supply or deeper environment could favour the growth of sponges. The deepening of the sea in the latest Turonian and Early Coniacian in the Opole Trough is also suggested by the bathymetric interpretations, based on ichnofabrics (Kędzierski and Uchman, 2001), analysis of shark assemblages (Niedźwiedzki and Kalina, 2003) and lyssacinosid sponges (Świerczewska-Gładysz and Jurkowska, in press).

The absence of ventriculitids in the Lower Argillaceous Marl and Lower Marl units is difficult to explain. According to Alexandrowicz (1974) and Tarkowski (1991), the Upper Cretaceous sequence of the Opole Trough represents a single transgressive-regressive cycle and the Upper Turonian marly limestones are correlated with the maximum transgression. In accordance to this concept, it may be considered that in the Early–Middle Turonian the depositional environment of argillaceous marls and marls was too shallow for the development of hexactinellids. However, in the shallow-marine Cretaceous deposits, where hexactinellid sponges are absent or extremely rare, calcareous and lithistid sponges are relatively common (e.g., Defretin-Lefranc, 1960; Ulbrich, 1974; Žitt *et al.*, 2006; Wilmsen *et al.*, 2011). In the Opole Trough, such case is noted in the Cenomanian sandstones (Leonhard, 1897; Tarkowski, 1991), the deposition of which was connected with the beginning of the transgression in this region (Aleksandrowicz, 1974; Tarkowski, 1991). Both groups of sponges are absent in the discussed marly deposits. Therefore, in the opinion of the present author the bathymetric conditions did not limit settlement by the sponges. Moreover, Kędzierski and Uchman (2001) suggested that these deposits represented palaeoenvironments, deeper than those of overlying marly limestones, where ventriculitids are abundant. According to these authors, some deposits in the Opole Trough were deposited conditions of oxygen depletion. The crisis in the assemblages of sponges and other benthic fauna in the Early Turonian corresponds with the Cenomanian/Turonian oceanic anoxic event (OAE-2). On the other hand, ventriculitids are very numerous in the Lower Coniacian siliceous marls deposited during the next anoxic event (OAE-3). The Hexactinellida prefer well oxygenated waters (Leys *et al.*, 2004), but they also tolerate a lower oxygen content (Whitney *et al.*, 2005). It can be concluded that during the deposition of the Upper Marl Unit, the oxygen concentration did not drop below the critical value for the life of sponges, as well as for some other benthic animals (e.g., echinoids, inoceramids), the fossil remains of which occur in these layers.

## CONCLUSIONS

1. The assemblage of ventriculitid sponges, occurring in the Upper Turonian and Lower Coniacian deposits of the Opole Trough, comprises eight species. Among them, four species, *Rhizopoterion cribrosum* (Phillips, 1829), *Sporadoscinia venosa* (Roemer, 1840), *Astropegma stellata* (Roemer, 1840) and *Leiostracosia robusta* (Schrammen, 1902), are described from this area for the first time.

2. Two species, *Astropegma stellata* (Roemer, 1840) and *Leiostracosia robusta* (Schrammen, 1902), are reported from Turonian strata for the first time. Until now, these species were known from the Coniacian and succeeding stages of the Cretaceous.

3. Up to now, the occurrence of *Rhizopoterion cribrosum* (Phillips, 1829) in the Upper Turonian deposits was not well documented. In the Opole Trough, this species is rare, while the morphologically very similar species, *Ventriculites chonoides* Mantell, 1815, is abundant.

4. The occurrence of ventriculitid sponges in the Upper Turonian–Lower Coniacian succession of the Opole Trough indicates a soft-bottom and calm water environment, below the storm wave-base. The sedimentation rate was generally low. The ventriculitid species from the Upper Turonian marly limestones are represented mainly by narrow morphotypes, frequently with narrowings, which suggest that the rate of sedimentation during the deposition of the marly limestones was slightly higher than during the deposition of the uppermost Turonian–Lower Coniacian marls and siliceous marls, in which wide morphotypes dominate.

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