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Early Permian solitary rugose corals from Kruseryggen (Treskelodden Fm., Hornsund area, southern Spitsbergen)

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Abstract

A collection of solitary rugose corals collected from the Treskelodden Formation of the Kruseryggen Hill, Hornsund area, south Spitsbergen, consists of 30 specimens representing the Bothrophyllidae family with the genera *Bothrophyllum*, *Caninophyllum*, *Hornsundia*, and *Timania* (5 species), and an indeterminate family with the genus *Svalbardphyllum* (one species). These large, dissepimental forms, dating from the Early Sakmarian (Tastubian), indicate a warm-water environment. The lithology, the thickness of the succession, the reddish hue and the abrasion of the fossils indicate that the area of the inner Hornsund showed a relief that enabled considerable erosion of the elevated areas and redeposition of the fossils at remote locations. The changing morphology of this area during the Early Permian was probably influenced by synsedimentary block tectonics.

Keywords: Rugosa, Early Permian, Treskelodden Formation, Spitsbergen

Introduction

The Hornsund area, which comprises a large part of southern Spitsbergen, is composed of Lower Proterozoic to Neogene rocks, with a few stratigraphic gaps. The most extensive Proterozoic and Caledonian orogenic complexes and a post-Caledonian platform complex (Birkenmajer, 1990). These three deformed complexes, emerging on the northern coast of Hornsund, are part of a range *folded* during the Palaeogene. Permian rocks are present in a narrow outcrop stretching NW-SE (Fig. 1).

The Treskelodden Formation, from which the corals described here have been collected, was defined by Cutbill & Challinor (1965). They distinguished, in the Upper Palaeozoic of the inner Sørkappland and Hornsund (southern Spitsbergen), three groups, viz. the Billefjorden, Gipsdalen and Tempelfjorden Groups, and four formations: the Adriabukta, Hyrnefjellet, Treskelodden and Kapp Starostin Formations (Fig. 2). Harland (1997) introduced new formations and units of a lower rank, for entire Svalbard. He placed the entire rock succession in the Bünsow Land Supergroup (Fig. 2). Even though he did not describe the upper boundary of the Kapp Starostin Formation (the uppermost Permian) precisely, his division has been generally accepted (Fedorowski, 1997; Somerville, 1997; Dallmann, 1999; Fedorowski et al., 2007).

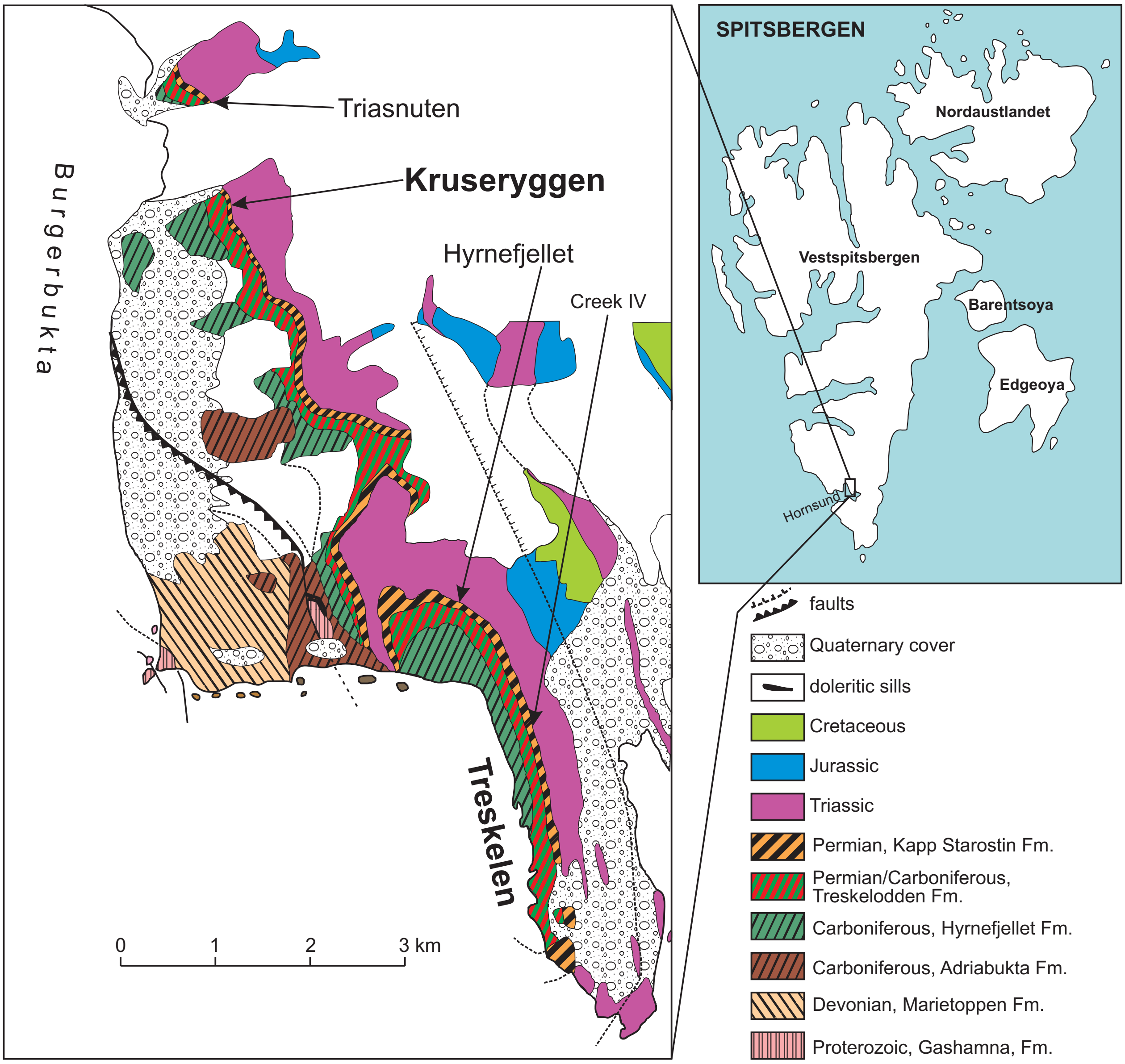

Fig. 1. Geological map of the inner Hornsund area (simplified after Birkenmajer & Fedorowski, 1980).

Palaeontological research of the Upper Palaeozoic in Spitsbergen started in the second half of the nineteenth century. This resulted in a growing number of genera and species, mainly of Rugosa corallites. The oldest work (Toula, 1875) described two species from central Spitsbergen (Nordfjorden). Later, less detailed studies (Holtedahl, 1913; Heritsch, 1929; Padget, 1954; Forbes et al., 1958; Tidten, 1972) were based on small collections or did not deal with litho- and biostratigraphic implications: corals were often collected incidently during Norwegian expeditions in the 19th and 20th centuries. Only a monograph by Heritsch (1939) contributed significantly to the knowledge of the Permo-Carboniferous corals in Spitsbergen. Unfortunately, the collection sent to Stockholm in 1939 became lost during the war (pers. comm., Fedorowski, 2008). The more recent studies of corals from the Isfjorden area, central Spitsbergen (Ezaki & Kawamura, 1992; Ezaki et al., 1994; Ezaki, 1997) are limited to preliminary notations (of three species and two left in an open terminology) and a few illustrations. Somerville (1997) did not provide any taxonomical descriptions, restricting himself to notes on the frequent occurrence of Rugosa in the Wordiekammen Formation (18 genera).

The most extensively elaborated coral sets definitely are the ones from South Spitsbergen (Hornsund area), collected by the members of Polish polar expeditions, except those described by Fedorowski (1967), which were present in Norwegian collections). Descriptions of the fauna, collected from the Lower Permian Treskelodden Formation have been provided by Fedorowski (1964, 1965, 1982, 1997), Birkenmajer & Fedorowski (1980), Fedorowski et al. (1999, 2007) and Fedorowski & Bamber (2001). Apart from the Rugosa corals, many Tabulata (Nowiński, 1982, 1991), brachiopods (Birkenmajer & Czarniecki, 1960), bivalves and snails (Karczewski, 1982), small foraminifers (Liszka, 1964), bryozoans (Czarniecki, 1964) and trilobites (Osmólska, 1968) from the Treskelodden Formation have been described.

The above studies provide an abundance of palaeontological descriptions. Nearly 40 new taxa (7 new genera) were distinguished among only the Rugosa corals. This qualitatively diverse group of organisms made Birkenmajer (1964) discriminate five coral horizons in the Treskelen area. Based on the taxonomic diversity, Fedorowski (1965) characterised corals groups of these horizons and established that the coral fauna from the Treskelodden Formation had a narrow thermal tolerance and lived in shallow water. He deduced from preliminary sedimentological observations (Fedorowski, 1982) that the whole fauna, except for the V coral horizon, was redeposited, with a transport distance diminishing towards the top of the formation, i.e. towards the V coral horizon.

Though much is known now about the Early Permian Rugosa corals in the Hornsund area, the knowledge is still incomplete. The best investigated are exposures on the Treskelen peninsula (Fedorowski, 1964, 1965, 1967, 1982; Fedorowski et al., 1999, 2007; Chwieduk, 2007). The fauna from the Triasnuten area is much less known (Birkenmajer & Fedorowski, 1980). The corals from Kruseryggen (Fig. 1), situated between these two areas, even though preliminary studied (Fedorowski, 1982), have not yet been palaeontologically described.

The main objective of the present contribution is a taxonomic inventory of the Kruseryggen corals. The selected location is important since five coral horizons have been identified on the Treskelen peninsula, wheras only two have been identified in Triasnuten (Birkenmajer & Fedorowski, 1980). Birkenmajer & Fedorowski (1980) claim that, towards the north of the area (i.e. towards Triasnuten) two lower horizons disappear and that horizons IV and V coalesce. Only corals (predominantly solitary) from horizon III occur over the entire region. One of secondary objectives of the present study was therefore to find out which coral horizons occur in Kruseryggen, which is situated

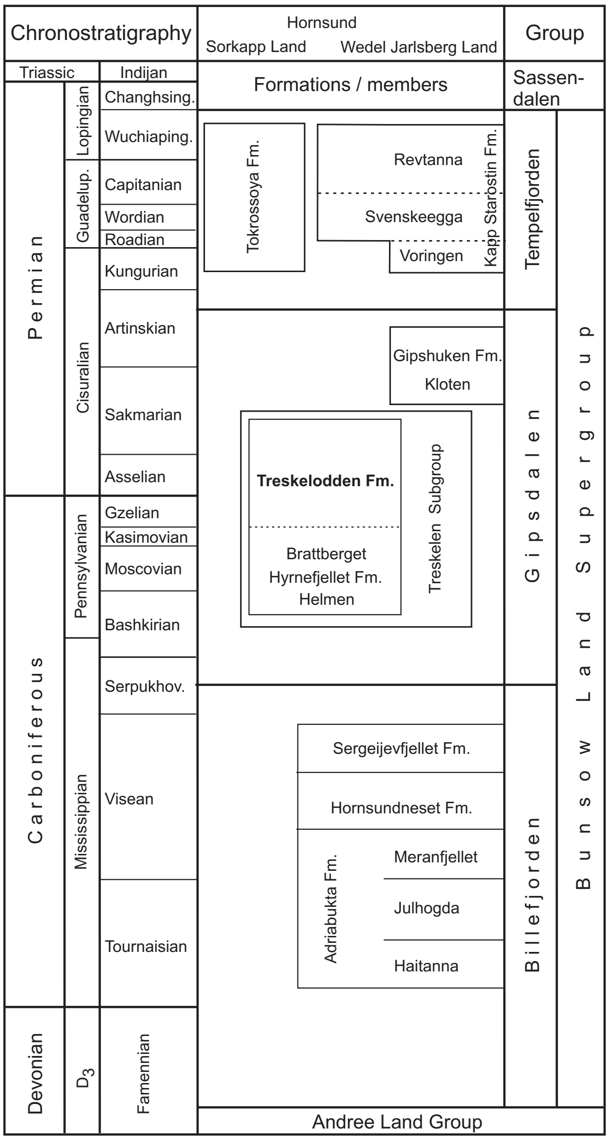

Fig. 2. Lithostratigraphic scheme of the Carboniferous and Permian formations of the Bünsow Land Supergroup recognized in the Hornsund area (simplified after Harland, 1997).

6 km to the north of Treskelen and 2 km to the south of Triasnuten.

Geological setting

Kruseryggen Hill (Fig. 1), from which the corals described here were collected, is almost entirely built of sediments from the upper part of the Lower Sakmarian Treskelodden Formation (Fedorowski, 1982; Fedorowski et al., 2007). Both the corals and the sedimentary features indicate a shallow-marine environment, in which siliciclastic sediments dominated (Fig. 3). The total thickness of the Treskelodden Formation on Kruseryggen Hill is about 150 m (Fig. 3); on Treskelen it reaches 100 m, whereas in the northern part of Burgerbukt, on the Triasnuten hillside, it exceeds 180 m. Like all over the interior of the Hornsund area, the succession from the upper part of the Treskelodden Formation has here alower part (Fig. 3) that is continental (conglomerates, sandstones and mudstones). Birkenmajer (1964) described river-channel deposits, covered by muddy delta deposits. Towards the top, marine sediments become ever more abundant with alternating siliciclastics and limestones.

Coral horizons I–III, which had been identified by Birkenmajer (1964) in the Treskelen area, include strongly abraded and broken fossils, indicating reworking (Fedorowski, 1965, 1967, 1982; Birkenmajer & Fedorowski, 1980). Palaeocurrent measurements of the fragments indicate that the currents that brought in the siliciclastics came from the east (Birkenmajer, 1964). Coral horizon IV, in the lower part of the formation, includes also significantly abraded fragments of Rugosa and Tabulata. The state of the preservation of the fossils in the upper part of this horizon, which are similar to the well preserved fauna from the carbonate rocks of coral horizon V, indicates only little transportation or no transportation at all, suggesting a to a typically marine environment.

On Kruseryggen, the oldest sediments of the Treskelodden Formation are grey sandy conglomerates, about 2 m thick, which pass upwards into sandstones, covered by light grey conglomerates about 1.5 m thick. Alternating layers of iron-rich, multi-coloured sandstones and quartz-rich light grey sandstones, rest upon the conglomerates and sandstones and have a silica or calcareous cement. The thickness of this complex is about 45 m (not shown in Fig. 3). The upper part of the Treskelodden Formation, as far as cropping out on Kruseryggen, is built of both clastic rocks (conglomerates, sandstones and mudstones) and carbonates (Fig. 3). Their total thickness is about 100 m. The faunal assemblages, consisting of abundant specimens but of a low diversity of Rugosa, Tabulata, Crinoidea, Bryozoa and Brachiopoda, are characteristic of the three upper coral horizons (III–V), which alternate with barren siliciclastic rocks.

The corals from horizon III are characterized by a pink and red colour and are often significantly abraded. They occur in a grey conglomerate of about 1.8 m thick. This horizon is covered by a red limestone and by conglomerates with a quartz/calcite cement. The total thickness of this part of the Kruseryggen section is about 4 m. The overlying grey calcareous sandstones, yellow and cherry-red mudstones and grey sandy limestones, containing abraded red and pink corallites, constitute coral horizon IV. The thickness of this horizon is about 17 m. Coral horizon V, the base of which is situated slightly more than 10 m above coral horizon IV, is separated from it by grey sandstones with a conglomerate intercalation of about 2 m thick. This coral horizon is composed of limestones alternating with layers of conglomerate and sandstone. The corals from the lower conglomeratic part of the horizon are poorly preserved. The younger grey limestones contain abundant, better preserved crinoids and corals. Unfortunately, the majority of corals, occur in a heavily fractured layer, which makes it difficult to collect material for palaeontological studies. The fragmentarily preserved coral fauna in the higher grey sandstones with calcite cement and in the grey limestones do not help either to obtain a complete picture of the fauna. Horizon V ends with fine-grained sandstones and conglomerates. The total thickness of this horizon is about 28 m.

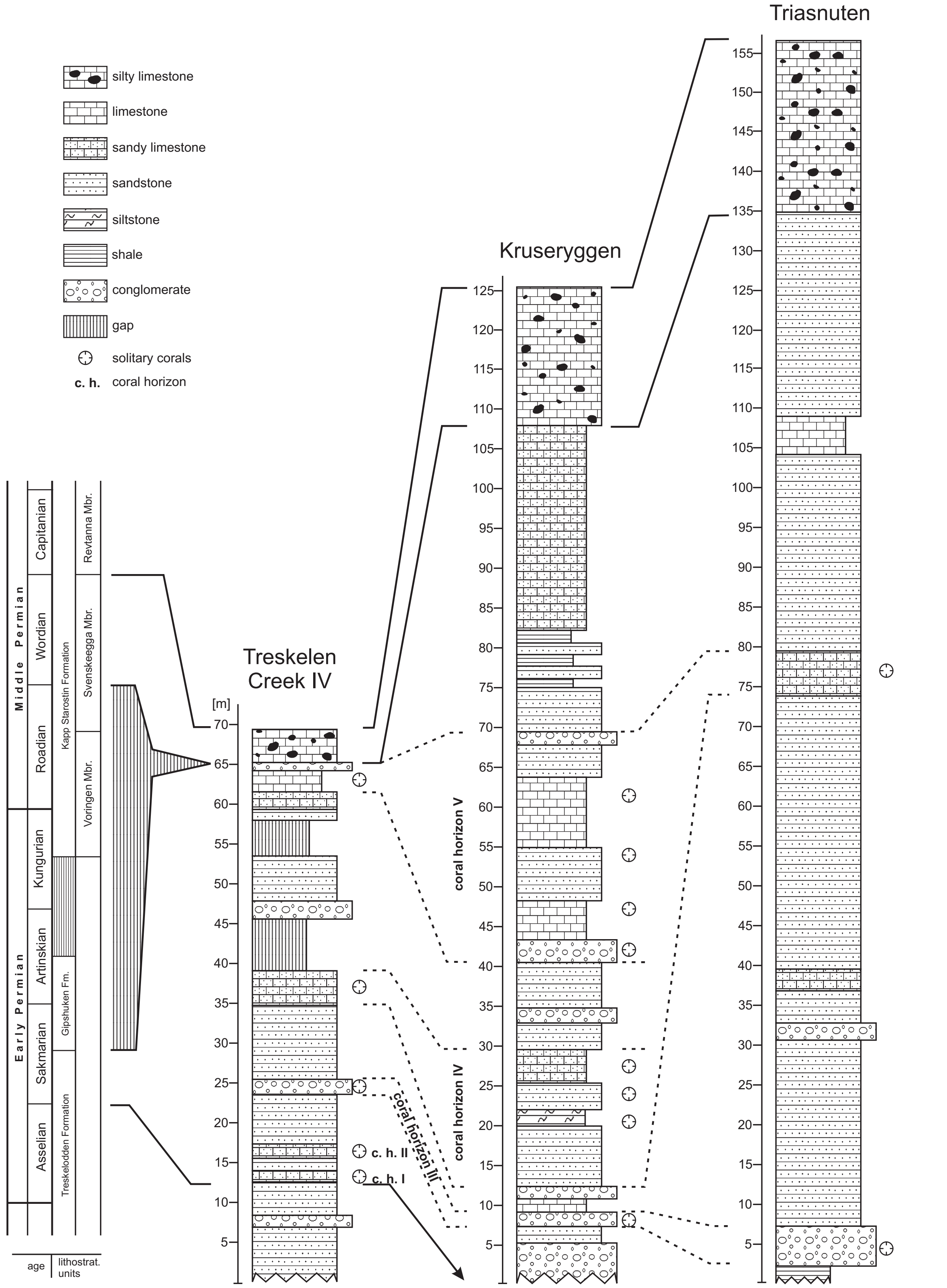

Fig. 3. Correlation of Early Permian (Early Sakmarian) rock units from the inner Hornsund area. Stratigraphic sections without the older layers of the Treskelodden Formation from which rugose corals have not been ascertained. Approximate total thicknesses: 100 m for Treskelen, 150 m for Kruseryggen and 180 m for Triasnuten (based on Nowak, 2007, modified).

The Treskelodden Formation on Kruseryggen is nearly 40 m thick. Its top part consists of a barren complex of yellow calcareous sandstones and dark brown mudstones, separated by sandstone and thin sandy limestone layers. The Treskelodden Formation is unconformbly overlain by the upper part of the Kapp Starostin Formation, interpreted as a full-marine succession (Fig. 3). It is separated from the Treskelodden Formation by a stratigraphic hiatus representing the Late Sakmarian to Roadian (Chwieduk, 2007). The slightly angular unconformity between the two formations may be a result of the upward movements that took place in the southern part of Spitsbergen, and that were related to the Kongsfjorden-Hansbreen fault zone and the reactivation of the palaeo-Hornsund fault (Birkenmajer, 1990). The hiatus becomes smaller to the north and north-east. On Polakkfjellet (about 20 km north of Kruseryggen), gypsum-bearing claystones and dolomites of the Gipshuken Formation, dated as Late Sakmarian and Early Artinskian, occur between the Treskelodden and Kapp Starostin Formations.

Systematic palaeontology

Abbreviations used:
UAMIG – Adam Mickiewicz University, Institute of Geology
Tc – Tetracorallia
Krg. – Kruseryggen
III-V – coral horizons
1, 2… n – specimen numbers
n/d index – ratio between number of septa (n) and diameter (d) of corallite.

Phylum: Coelenterata Frey & Leuckart, 1847
Subclasses: Rugosa Milne Edwards & Haime, 1850
Order: Stauriida Verrill, 1865
Suborder: Caniniina Wang, 1950
Family: Bothrophyllidae Fomitchev, 1953

Genus: *Bothrophyllum* Von Trautschold, 1879
Type species: *Turbinolia conica* Fischer, 1830
Diagnosis: see Hill (1981), p. F346.

Bothrophyllum baeri Stuckenberg, 1895
(Fig. 4, A-E)
1895 *Bothrophyllum baeri* n. sp.; A. Stuckenberg, pp. 56–57, Pl. XVII, Fig. 6a-d
1936 *Bothrophyllum baeri* Stuckenberg; T. A. Dobrolyubova, pp. 105–106, Text-Fig. 31
1965 *Bothrophyllum baeri* Stuckenberg; J. Fedorowski, pp. 29–31, Text-Fig. 5a-b, Pl. IV, Fig. 1a-b

Diagnosis: Based on a specimen from coral horizon V from Lorchbreen (Fedorowski, 1965) and the present author's own observations: *Bothrophyllum* with major septa thickened in the cardinal quadrants within tabularium; n/d ratio 52–61/50; cardinal septum shortened in an open fossula, bordered by 3–5 pairs of successively shortened major septa; short and thin, zigzag minor septa; wide dissepimentarium reaching up to half the corallite radius; domination of herringbone dissepiments.

Material: Five specimens (UAMIG.Tc-Krg. IV/2, 9–11; UAMIG.Tc-Krg. V/21), including one (Krg. IV/2) from Bogumił Nowak's collection. All specimens are preserved without proximal ends, abraded to various degrees. Two thin sections and five acetate peels of transverse sections were made. The external parts of the corallites were damaged by abrasion.

Description: The specimens under study represent older growth stages, and are advanced to various degrees. The septal index of the more advanced specimens is 52–54/50 (Fig. 4 A). In less advanced growth stages (Fig. 4 C-D), the septal index is equal, respectively 45/23 and 51/31. The major septa vary in length. Most of them attain three fourth of the corallite radius, with only a few meeting at the corallite axis (Fig. 4 C-E). The inner margins of the septa are mainly curved. The much shortened and thickened cardinal septum attaining one fifth of the corallite radius occurs in the cardinal fossula, which reaches up to half the length of the corallite radius (Fig. 4 A-D). The fossula is bordered by 3–5 pairs of successively shortened major septa. In the corallite axis, a weak axial structure can be observed. It is built of the inner margins of the longest major septa and the tabulae (Fig. 4 A, C, D). Among the short minor septa, only a few reach 1.5 mm (Fig. 4 D). A

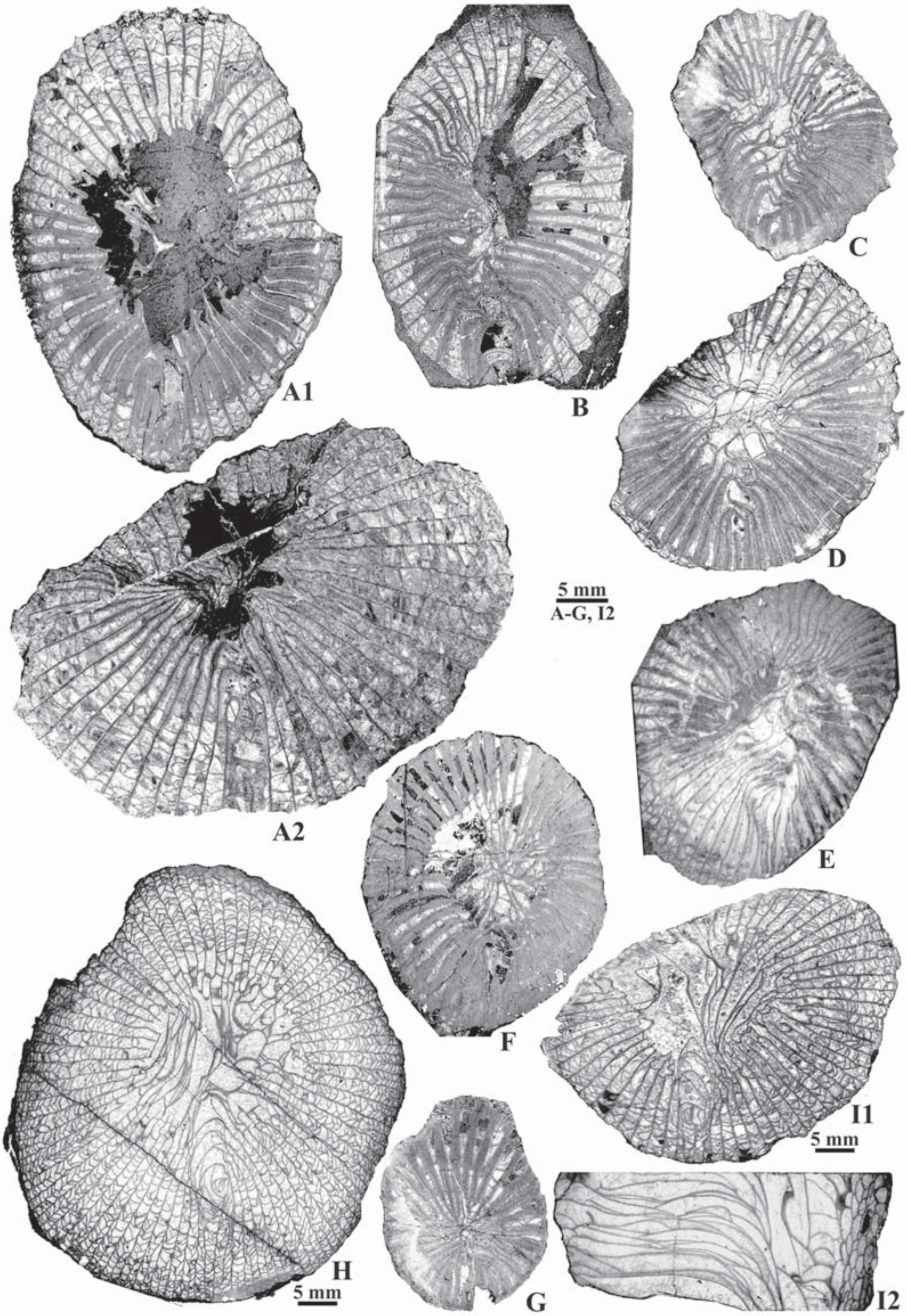

Fig. 4. *Bothrophyllum* and *Caninophyllum* specimens. A: *Bothrophyllum baeri* Stuckenberg, 1895. UAMIG.Tc-Krg. IV/10, transverse sections; B: *Bothrophyllum baeri* Stuckenberg, 1895. UAMIG.Tc-Krg. IV/11, transverse section; C: *Bothrophyllum baeri* Stuckenberg, 1895. UAMIG.Tc-Krg. IV/9, transverse section; D: *Bothrophyllum baeri* Stuckenberg, 1895. UAMIG.Tc-Krg. IV/2, transverse section; E: *Bothrophyllum baeri* Stuckenberg, 1895. UAMIG.Tc-Krg. V/21, transverse section; F: *Bothrophyllum* cf. *orvini* Fedorowski, 1967. UAMIG.Tc-Krg. V/6, transverse section; G: *Bothrophyllum* cf. *orvini* Fedorowski, 1967. UAMIG.Tc-Krg. V/16, transverse section; H: *Caninophyllum belcheri* (Harker) var. *magnum* Fedorowski, 1965. UAMIG.Tc-Krg. V/11, transverse section; I: *Caninophyllum belcheri* (Harker) var. *magnum* Fedorowski, 1965. UAMIG.Tc-Krg. V/17. I1: transverse section; I2: longitudinal section (cardinal fossula on the right side).

dissepimentarium of about 15 rows (undoubtedly diminished by abrasion) is formed mainly from the herringbone dissepiments and attains a width of 12.0 mm (Fig. 4 A2).

Discussion: The specimen from Kruseryggen is very similar to *Bothrophyllum baeri* described by Fedorowski (1965) from Sakmarian Lorchbreen in Spitsbergen. Similar specimens, also from the Permian, have been found in the Timan area and in the Ural Mountains (Stuckenberg, 1895; Dobrolyubova, 1936). However, taking into account the size of the Kruseryggen specimens, and the formation of the axial area or the dissepimentarium, they resemble the specimen from Lorchbreen described by Fedorowski (1965). The Kruseryggen specimens are smaller than the specimens from outside Spitsbergen, which may be due to abrasion, caused by long transport.

In comparison with other species of this genus (*Bothrophyllum permicum* Fedorowski, 1965 and *Bothrophyllum orvini* Fedorowski, 1967) from Hornsund, the specimens from Kruseryggen are larger and have more septa.

Occurrence: Timan, northern Ural – Asselian-Sakmarian; Spitsbergen: Lorchbreen (coral horizon V) – Early Sakmarian, Kruseryggen – on the basis of analogy – Early Sakmarian.

Bothrophyllum cf. *orvini* Fedorowski, 1967
(Fig. 4 F, G)

Material: Three specimens (UAMIG.Tc-Krg. V/3, 6, 16), without proximal or distal parts and without external wall. One thin section and three acetate peels of transverse sections have been made.

Description: The specimens, which are abraded to various degrees, represent only young growth stages. The n/d ratio ranges from 36/17 through 51/24×30 to 53/30. Major septa vary in length, with the longest reaching the corallite axis (Fig. 4 F, G). The cardinal septum is always shortened to approximately half the length of the major septa, in the fossula, which is limited by the successively shortening major septa, with inner ends leaning towards the cardinal septum (Fig. 4 F). The counter septum is elongated and may be thinner than the other major septa (Fig. 4 F). The minor septa are vaguely recognisable and restricted to the dissepimentarium area, which may be up to 2 mm wide (Fig. 4 F). The visible dissepiments are concentric and herringbonelike The axial structure is built of the inner ends of the major septa and the tabulae (Fig. 4 F, G).

Discussion: The poor preservation of the Kruseryggen specimens, caused by long transport and abrasion, prevents their explicit classification as any of the known species of this genus. However, some features such as (1) the major septa that vary in length but that have similar thicknesses, with the longest septa reaching the corallite axis where they form a weak axial structure with the tabulae, (2) the shortened cardinal septum in the open fossula, (3) the prolonged counter septum, (4) the narrow dissepimentarium, and (5) the very short minor septa, suggest their affinity to *Bothrophyllum orvini*. However, the representatives of this species are smaller than the specimens under study, which have an n/d ratio of ?40/25.

The Kruseryggen specimens in their early growth stages are similar to their *B. permicum* counterparts, especially those from Treskelodden. Furthermore, the section presented in Figure 4 G is almost identical to the section illustrated by Fedorowski (1967) in his Text-Fig. 3b. However, in the later growth stages, the specimens under study have more septa with smaller diameters (53/30 for the Kruseryggen specimens vs. 44/28×32 for the Hyrnefjellet specimens and 41–44/38 for the Treskelodden specimens); they also have poorly developed minor septa and dissepimentarium.

The specimens under study are much smaller than the *B. baeri* specimens from Lorchbreen (Fedorowski, 1965). Furthermore, they have no thickened major septa in the cardinal quadrants' tabularium, their dissepimentarium is thinner (2 mm vs. 10 mm) and their axial structure is less complex.

Even though the differences in the appearance of the minor septa and the dissepimentarium may be the result of the poor preservation due to the abrasion of the specimens under study, both the substantial differences in the septal indices and the absence of a possibility to examine the features of the Kruseryggen specimens as existing during older growth

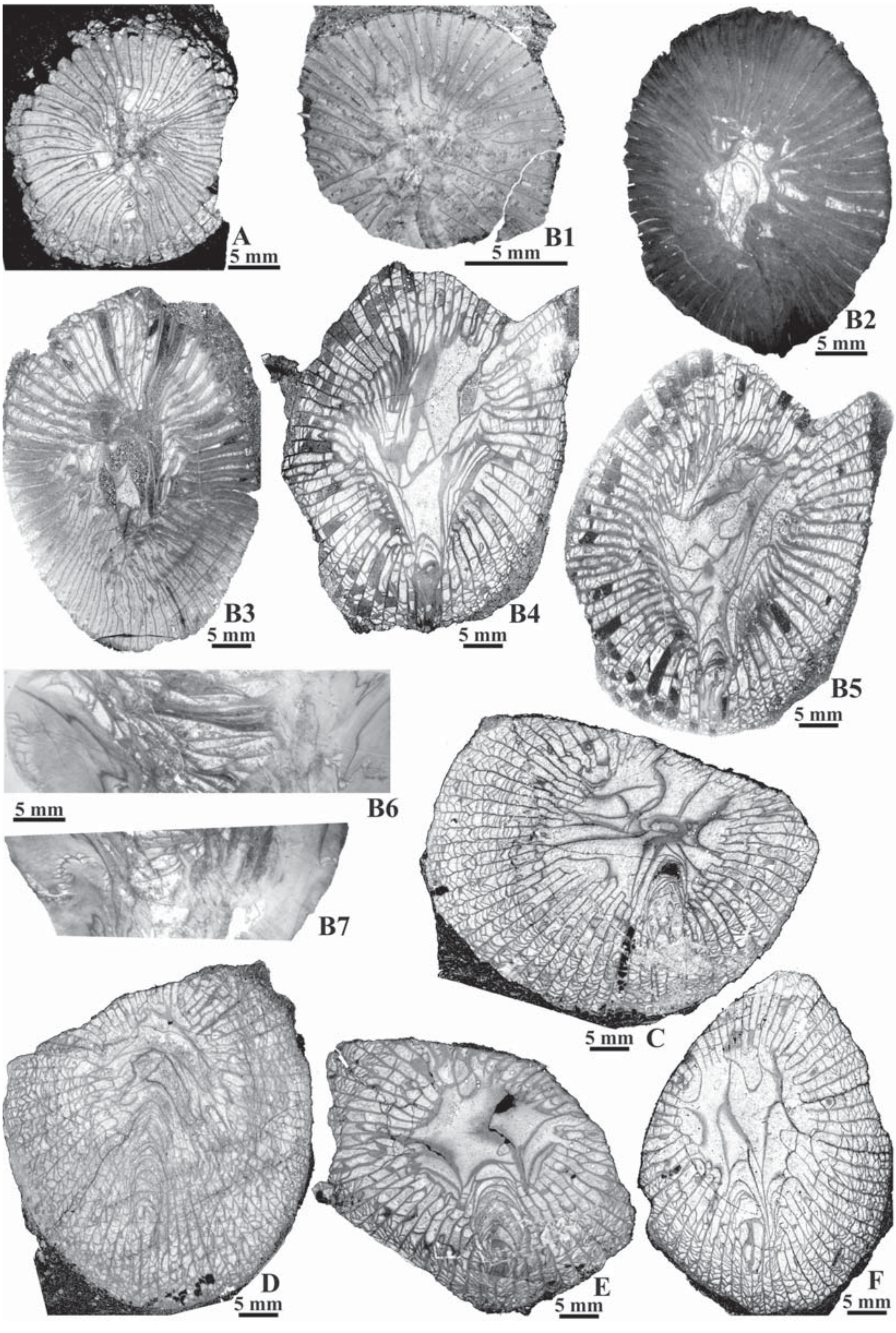

Fig. 5. ?*Timania* and *Caninophyllum* specimens. A: ?*Timania multiseptata* Fedorowski, 1965. UAMIG.Tc-Krg. IV/3, transverse section; B: ?*Timania multiseptata* Fedorowski, 1965. UAMIG.Tc-Krg. III/4. B1–5: transverse sections; B6–7: longitudinal sections (cardinal fossula on the right side); C: *Caninophyllum belcheri* (Harker) var. *magnum* Fedorowski, 1965. UAMIG.Tc-Krg. V/2, transverse section; D: *Caninophyllum belcheri* (Harker) var. *magnum* Fedorowski, 1965. UAMIG.Tc-Krg. V/15, transverse section; E: *Caninophyllum belcheri* (Harker) var. *magnum* Fedorowski, 1965. UAMIG.Tc-Krg. V/4, transverse section; F: *Caninophyllum belcheri* (Harker) var. *magnum* Fedorowski, 1965. UAMIG. Tc-Krg. V/9, transverse section.

stages, prevent an unambiguous classification of the specimens under study.
Occurrence: Spitsbergen, Kruseryggen – Early Sakmarian.

Genus: *Caninophyllum* Lewis, 1929
Type species: *Cyathophyllum archiaci* Milne Edwards & Haime, 1852
Diagnosis: see Hill (1981), pp. F346–348.

Caninophyllum belcheri (Harker) var. *magnum* Fedorowski, 1965
(Figs. 4 H, I; 5 C-F; 6 B)
1965 *Caninophyllum belcheri* (Harker) var. *magnum* Fedorowski, pp. 18–22, Pl. 2, Fig. 1, Text-Fig. 2.
Diagnosis: see Fedorowski (1965), p. 18.
Material: Eight specimens (UAMIG.Tc-Krg. V/2, 4, 9, 11, 13, 15, 17, 18), including one (Krg. V/11) from Bogumił Nowak's collection. All specimens are preserved without the youngest parts. Six thin sections, thirteen acetate peels of transverse sections and two acetate peels of longitudinal sections have been prepared for analysis.
Description: The fragments under study are up to 10 cm long, including a 4 cm calice. The fragmentarily preserved external wall is very thin, up to only 0.2 mm. The n/d ratio is 68–71/43–50. The major septa vary in length, the longest reaching up to 3/4 of the corallite radius; mainly thin (Figs. 4 H; 5 C-F; 6 B). The shortened cardinal septum is not longer than half the length of the other major septa and may be thickened (Figs. 4 I2; 5 E, F). It always occurs in an open, deep tabular fossula, which is no longer than 4/5 of the corallite radius (Figs. 4 H, I2; 5 C-E; 6 B). The fossula is limited by the shortening, neighbouring major septa, joined in pairs with the traverses of the tabulae (Fig. 5 D, E). The minor septa reach up to 1/5 of the length of the major septa. The dissepimentarium takes up to half of the corallite radius (Fig. 4 H) and is built of up to 14 rows of globose dissepiments, which in the external sphere of the dissepimentarium (containing the minor septa) are more frequent and dominated by pseudo-herringbone dissepiments (Figs. 4 H; 5 F). In longitudinal section (Fig. 4 I2), the dissepiments vary in size. They are smaller at the external wall than inside the dissepimentarium. The tabularium takes up to slightly over half of the corallite diameter (Figs. 4 H; 5 C, D, F). The nearly flat tabulae, gently leaning towards the cardinal septum (Fig. 4 I2), have a relatively dense distribution (about 10 per 1 cm). The edges of the tabulae are bent down and the surface of the tabularium is heavily lowered in the fossula (Fig. 4 I2).
Discussion: The specimens show no sign of long transport;, the absence of the proximal ends must result from damage that occurred during their collection. The preserved growth stages are morphologically very similar to those from coral horizon V, identified by Fedorowski (1965) on Hyrnefjellet. Both the n/d ratio and the long cardinal fossula that reaches the corallite axis allow unambiguous identification of this species and variety.
Occurrence: South Spitsbergen: Treskelen, Hyrnefjellet, Urnetoppen, Lorchbreen – Early Sakmarian, Kruseryggen; on the basis of analogy – Early Sakmarian.

Genus *Timania* Stuckenberg, 1895
Type Species: *Timania schmidti* Milne-Edwards & Haim, 1852
Diagnosis: see Kossovaya (1997), p. 69.

Timania multiseptata Fedorowski, 1965
(Fig. 7 C)
1965 *Timania multiseptata* Fedorowski, pp. 22–27, Pl. 3, Figs 1–3, Text-Fig. 3.
Diagnosis: see Fedorowski (1965), p.24.
Material: One specimen (UAMIG.Tc-Krg. V/20), without proximal and distal part, with partly preserved external wall. Three acetate peels of transverse sections and one acetate peel of a longitudinal section have been prepared for analysis.
Description: This ceratoid corallite, with the cardinal septum on the concave side is 10 cm long. The calice is up to 20 mm deep. The external wall, which is up to 0.2 mm thick, is covered in distinct septal furrows. The n/d ratio reaches 59/4.0×3.3. The major septa attain three fourth of the corallite radius. They are heavily thickened in the cardinal quadrants (up to 1.5 mm), and thin both in the counter quadrants and in the dissepimentarium (about 0.1 mm). The

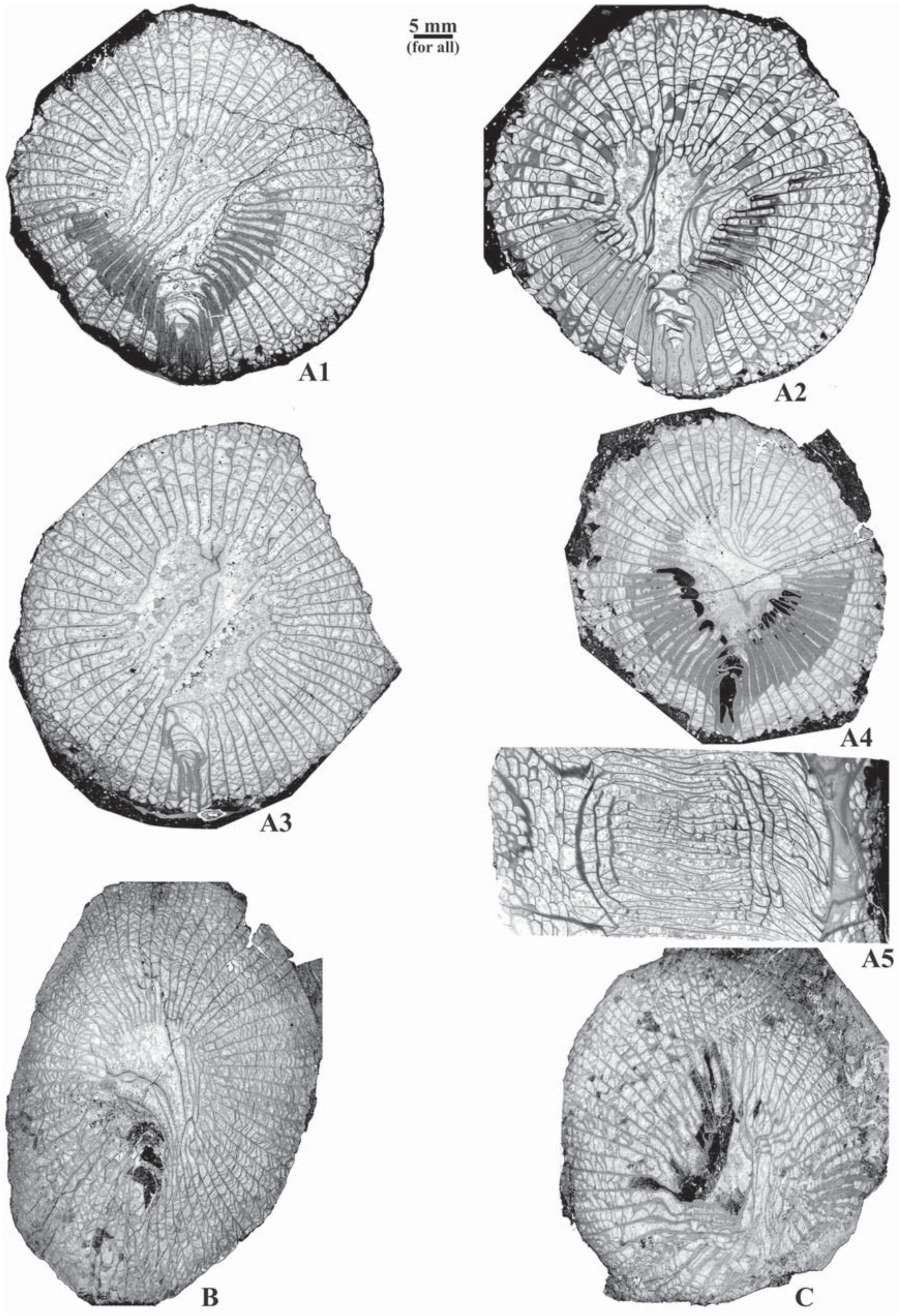

Fig. 6. ?*Timania* and *Caninophyllum* specimens. A: ?*Timania multiseptata* Fedorowski, 1965. UAMIG.Tc-Krg. V/23. A1–4: transverse sections; A5: longitudinal section (cardinal fossula on the right side); B: *Caninophyllum belcheri* (Harker) var. *magnum* Fedorowski, 1965. UAMIG.Tc-Krg. V/18, transverse section; C: ?*Timania multiseptata* Fedorowski, 1965. UAMIG.Tc-Krg. V/1, transverse section.

thick cardinal septum, which reaches half of the length of the major septa, occurs in a closed tabular fossula (Fig. 7 C1, C2), restricted by 3–4 pairs of shortened major septa. The counter septum is slightly longer than the other major septa. The alar septa do not vary in size from the rest of the major septa. The very short minor septa vary in size with a maximum of one fifth of length of the major septa. A two-zone dissepimentarium of variable width, built of concentric, herringbone and pseudo-herringbone dissepiments, reaches almost half of the corallite radius in the widest part, i.e. in the counter septum (Fig. 7 C2). It tapers to 1/7 of the corallite radius at the cardinal septum (Fig. 7 C1). In its external part (with minor septa), it is built of about five rows of small dissepiments, and in the internal part it consists of seven larger and vertically prolonged rows of dissepiments (Fig. 7 C3). The tabularium attains about half of the length of the corallite diameter. It consists of complete, almost flat tabulae, leaning towards the cardinal septum, with a heavy depression at the very cardinal septum. Close to the counter septum, the tabulae are accompanied by additional, convex tabellae (Fig. 7 C3).

Discussion: The morphological structure and the septal index of the specimen under study are very similar to the specimens form coral horizon V at Treskelen, described by Fedorowski (1965).

The fragmentarily preserved wall and the lack of the youngest growth stages or calice indicate little transportation.

Occurrence: South Spitsbergen: Treskelen, Hyrnefjellet, Lorchbreen – Early Sakmarian; Kruseryggen – on the basis of analogy – Early Sakmarian.

?*Timania multiseptata* Fedorowski, 1965

(Figs 5 A, B; 6 A, C; 7 A, B)

Material: Nine specimens (UAMIG.Tc-Krg. III/4; UAMIG.Tc-Krg. IV/1, 3; UAMIG.Tc-Krg. V/1, 7, 14, 19, 22, 23). All abraded to different degrees; no proximal parts preserved. Twenty four acetate peels of transverse sections and one acetate peel of a longitudinal section, along with nine thin sections of transverse sections and five of longitudinal sections, have been prepared for analysis.

Description: The fragments under study (the youngest parts excluded) are 9 cm (ceratoid forms with the cardinal septum placed on the convex side) to 17 cm (cylindrical forms) long. The preserved calices in the biggest specimens are up to 5 cm deep. The n/d ratio is 56–72/45–53. The major septa vary in length. The shortest septa are those directly neighbouring the cardinal septum. The longest reach up to 3/4 of the corallite radius (Figs. 6 A2; 7 B3). In the old growth stages, the major septa (except the cardinal septum) may be thin (Figs. 5 B4, B5; 6 A3; 7 A2). In some cases (Figs. 6 A1, A2, A4; 7 A1, B2, B3), the thin septa have been found in the counter quadrants only; in one specimen it was observed that the major septa were gradually thinner from the alar septa, indistinctive in length, towards the counter septum (Fig. 5 B3). After a stage with mostly thin septa (Fig. 6 A3), stages with thick septa (Fig. 6 A4) in the cardinal quadrants may occur. It may therefore be concluded that the thickness of the septa in the cardinal quadrants may change during individual development from thick to thin and then back to thick (Fig. 6 A2–A4).

The cardinal septum is always thicker and shorter than the other septa. Its length attains at most one third of the length of the major septa and it occurs in an open, tabular fossula, which is as long as the major septa (Figs. 6 A; 7., A, B). The walls of the fossula are restricted by the shortened, neighbouring major septa, which inside are joined in pairs by traverses of tabulae. The counter septum may be slightly longer (Figs. 6 A2; 7 B3) and thinner (Fig. 5., B3) then the other major septa. The alar septa are basically as long as the major septa. It was observed only in one section (Fig. 6 A2) that they can be much shorter. The minor septa reach from one sixth (Fig. 5 B5) up to one third (Fig. 7 B2) of the length of the major septa. The dissepimentarium of variable width reaches from one third up to half the length of the corallite radius (Figs. 6 A; 7 A). The widest one, which consists of ten rows of globose dissepiments (Fig. 6 A1), occurs in the counter quadrants. It gradually tapers in the cardinal quadrants getting to only a few dissepiments by the cardinal septum (Figs. 6 A2; 7 B3). The globose and pseudo-herringbone dissepiments are dis-

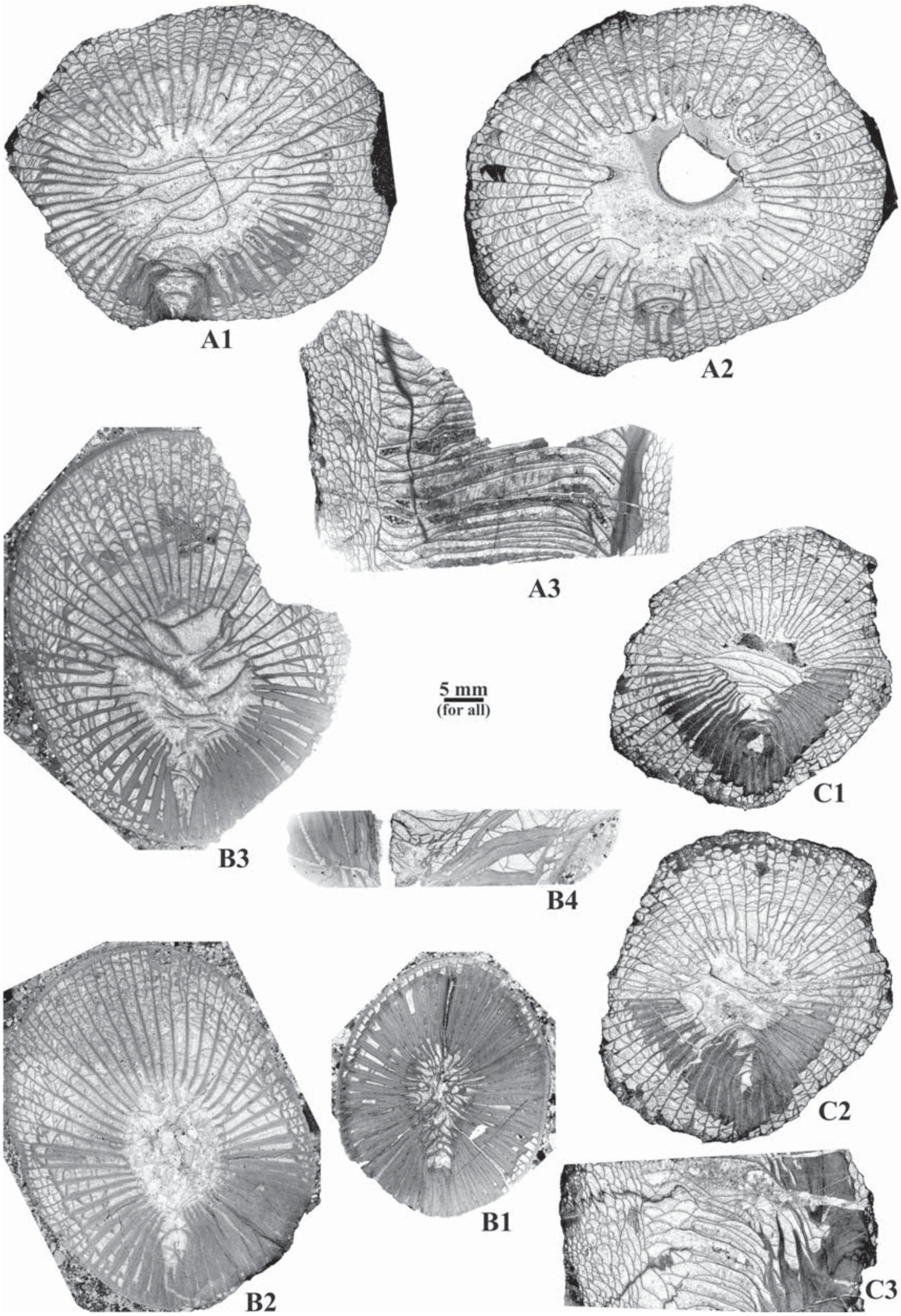

Fig. 7. *Timania* specimens. A: ?*Timania multiseptata* Fedorowski, 1965. UAMIG.Tc-Krg. V/19. A1–2: transverse sections; A3: longitudinal section (cardinal fossula on the right side); B: ?*Timania multiseptata* Fedorowski, 1965. UAMIG. Tc-Krg. V/7. B1–3: transverse sections; B4: longitudinal section (cardinal fossula on the right side); C: *Timania multiseptata* Fedorowski, 1965. UAMIG.Tc-Krg. V/20. C1–2: transverse sections; C3: longitudinal section (cardinal fossula on the right side).

tributed more densely in the external sphere (containing the minor septa) than in the internal sphere, where the more sparsely spaced herringbone dissepiments are prevailing and seem prolonged in longitudinal section (Figs. 6 A5; 7 A3). The tabularium reaches nearly two thirds of the corallite diameter (Fig. 7 A2, A3). The incomplete tabulae (about 14 per 10 mm) are nearly flat, gently leaning towards the counter septum, with the edges bent down and with a heavy depression in the fossula (Figs. 6 A5; 7 A3). From the side of the counter septum, they are accompanied by concave, flat or less frequently convex tabellae. The external wall is 0.3-0.5 mm thick.

In the youngest section (Fig. 5 B1), the n/d ratio reaches 31/14. The only visible major septa vary in length and are so thickened that they fill almost the whole diameter of the corallite. The alar and the counter septa are the longest, but they do not reach the corallite axis. The cardinal septum is the longest septum in the cardinal quadrants, but not as long as the alar or counter septa.

In the older growth stages (Fig. 5 A, B2 with an n/d ratio of 43–55/25×34; and Fig. 7 B1 with an n/d ratio of 50/28), the major septa of various length, with the longest coming nearly to the corallite axis, are always thickened. Only their short, slightly curved internal parts may be thin (Figs. 5 A; 7 B1). The cardinal septum reaches about half the length of the major septa. The fossula is restricted by shortening, neighbouring major septa with the internal ends bent toward the cardinal septum (Figs. 5 A; 7 B1). The counter septum reaches the corallite axis (Figs. 5 A; 7 B1). The alar septa are, except in the UAMIG.Tc-Krg. IV/3 specimen (Fig. 5 A) which has one shortened alar septum, not different from the other major septa.

The minor septa, are, in these stages not all fully developed and they are very thin (Fig. 7 B1). The dissepimentarium width is variable, both between the specimens and in the ontogenesis, from 1 row (Fig. 7 B1) to relatively wide, reaching one fourth of the corallite radius (Fig. 5 A). This change during ontogenesis is illustrated for a case where the dissepiments are visible not in the transverse section (Fig. 5 B2), but in the longitudinal section (Fig. 5 B7).

Discussion: The specimens lack proximal ends and are abraded to different degrees. The most damaged specimens are those from horizon III (Fig. 5 B), whereas the less damaged come from the horizons IV and V (Figs. 5 A; 7 B, respectively).

Despite the poor state of preservation, the Kruseryggen specimens are morphologically similar to the *Timania multiseptata* holotype, from coral horizon V from Urnetoppen (Fedorowski, 1965, his Text-Fig. 3). One of the differences is the occurrence of the prolonged counter septum (a feature characteristic of *Timania*) only in few sections of the Kruseryggen specimens. This observation is significant, since the specimens under study, the sections of which do not show a prolonged counter septum, refer morphologically to a specimen in its older growth stage, cited in the literature as *Caninophyllum ovibos.* However, the name ?*Timania multiseptata* is used in the present contribution because it was found – when Fedorowski examined the *Caninophyllum ovibos* holotype (borrowed from the British Museum of Natural History, by courtesy of Dr Bamber) – that this species has an axial structure with pseudocolumella in its young growth stage (pers. comm., Fedorowski, 2008), which has not been observed in the young Kruseryggen specimens (Figs. 5 B2; 7 B1).

Another difference is that the thickness of the septa in the ontogenetic development of the Kruseryggen specimens is repeatedly changing. The septa of the specimens in their young growth stages are always thickened (Figs. 5 B2; 7 B1). These septa got gradually thinner as the corallites grew, in the direction from the counter septum to the cardinal septum (Fig. 5 B3). However, the stage with the thin septa (Fig. 6 A3) is not always the oldest one, as has been stated in previous literature. It was observed that, after a stage with thin septa, a stage with thick septa may appear again in the cardinal quadrants (Fig. 6 A4).

Occurrence: South Spitsbergen: Urnetoppen, Treskelen, Hyrnefjellet, Lorchbreen – Early Sakmarian; Kruseryggen – on the basis of analogy – Early Sakmarian.

Genus: *Hornsundia* Fedorowski, 1965

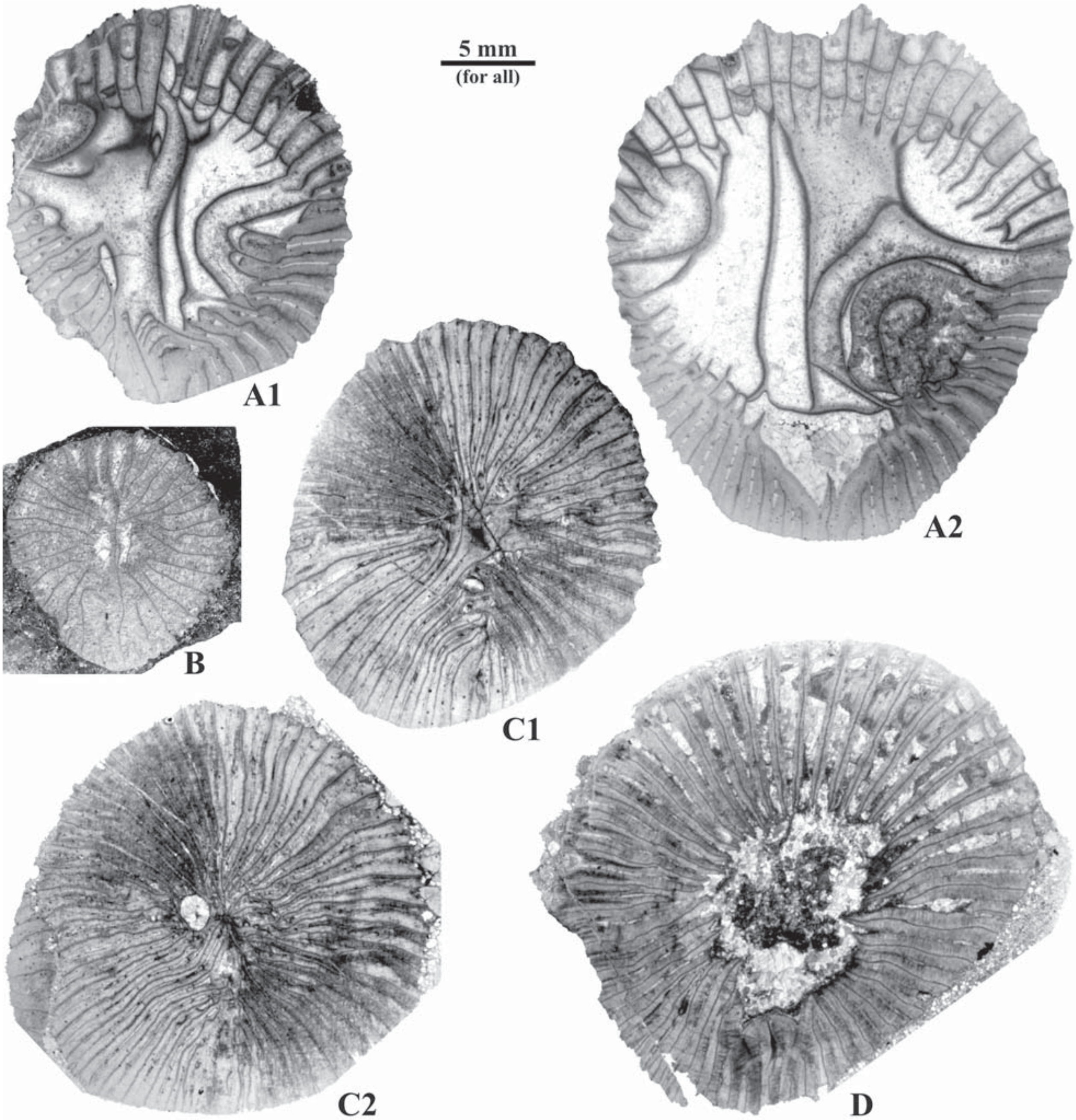

Fig. 8. *Hornsundia* and *Svalbardphyllum* specimens. A: *Hornsundia lateseptata* Fedorowski, 1965. UAMIG.Tc-Krg. V/24, transverse sections; B: *Hornsundia lateseptata* Fedorowski, 1965. UAMIG.Tc-Krg. V/10, transverse section; C: *Svalbardphyllum pachyseptatum* Fedorowski, 1965. UAMIG.Tc-Krg. III/20, transverse sections; D: *Svalbardphyllum pachyseptatum* Fedorowski, 1965. UAMIG.Tc-Krg. III/22, transverse section.

Type Species: *Hornsundia lateseptata* Fedorowski, 1965
Diagnosis: see Fedorowski (1965), p. 37.

Hornsundia lateseptata Fedorowski, 1965.
(Fig. 8 A, B)
1965 *Hornsundia lateseptata* n.sp., Fedorowski, pp. 37–42, Text-Fig. 7, Pl. 2, Fig. 8.

Diagnosis: see Fedorowski (1965), p. 40.
Material: Three specimens (UAMIG.Tc-Krg. III/27; UAMIG.Tc-Krg. V/10, 24), representing small fragments that have become abraded to a considerable degree. Seven thin sections of transverse sections and one of a longitudinal section have been prepared for analysis.

Description: The preserved fragments represent various growth stages. The youngest (Fig 8, B) are characterised by an n/d ratio of 30/12. All the septa are thickened, and the longest (cardinal and counter septa) meet in the corallite axis. In the older stages (Fig. 8 A1, A2), the major septa vary in length and thickness but their cardinal and counter septa are always prolonged. The n/d ratio ranges from 42/18 (Fig. 8 A1) to 55/25×30 (Fig. 8 A2). The cardinal fossula is especially visible in the sections of the older growth stages (Fig. 8 A2); it is wide and open. The alar septa do not vary in length from the first metasepta in the cardinal quadrants. Probably due to abrasion, the minor septa and the dissepimentarium are not visible.
Discussion: The specimens illustrated in Figure 8 A, B, taken from coral horizon V, are very similar to the holotype from Urnetoppen , which was also collected from this horizon, and which has been described by Fedorowski (1965). They differ only in having thicker septa in the cardinal quadrants, thinner in the counter quadrants and a slightly shorter cardinal septum in the subsequent growth stages. The specimen UAMIG.Tc-Krg. V/10 (Fig. 8 B) corresponds to the fifth growth stage (*sensu* Fedorowski, 1965) of this species. Being too damaged, undoubtedly by long transport, the specimens from coral horizon III are not illustrated.
Occurrence: Spitsbergen: Hyrnefjellet, Urnetoppen – Early Sakmarian; Kruseryggen – on the basis of analogy – Early Sakmarian.

Family *incertae sedis*
Genus: *Svalbardphyllum* Fedorowski, 1965
Type Species: *Svalbardphyllum pachyseptatum* Fedorowski, 1965
Diagnosis: Fedorowski (1965), pp. 45–46, corrected: the counter septum is of equal length to the longest major septa in the counter quadrants.

Svalbardphyllum pachyseptatum Fedorowski, 1965
(Fig. 8 C, D)
1965 *Svalbardphyllum pachyseptatum* n. sp.; Fedorowski, pp. 45–49, Text-Fig. 9a-f
1980 *Svalbardphyllum pachyseptatum* Fedorowski; Birkenmajer & Fedorowski, pp. 14–15, Pl. 1, Fig. 3
Diagnosis: *Svalbardphyllum* with an n/d ratio ranging from 32/11×13 to 42/18×22.
Material: Two specimens (UAMIG.Tc-Krg. III/20, 22), abraded to various degrees: UAMIG.Tc-Krg. III/20 without proximal parts, and UAMIG.Tc-Krg. III/20 without the distal part. Three thin sections of transverse sections have been prepared for analysis.
Description: The septal indices of the specimen under study range from 45/23 to 50/25. In the younger growth stages, the thickened major septa of various length fill the whole diameter of the corallite (Fig. 8 C1, C2); in the older stages (Fig. 8 D) they are shortened, and in the counter quadrants they are also thinner. The cardinal septum is shortened and occurs in a closed fossula, restricted by successively shortened major septa of the cardinal quadrants (Fig. 8 C) or just by one pair of the neighbouring septa (Fig. 8 D). In the young stages, the counter septum and the longest major septa reach the corallite axis (Fig. 8 C). The alar septa are prolonged (Fig. 8 C, D). The dissepimentarium is noticeable only in the calice (Fig. 8 D), built of 1 or 2 rows of concentric dissepiments.
Discussion: The Kruseryggen specimens differ from the previously known specimens from Treskelen (Fedorowski, 1965) and Triasnuten (Birkenmajer & Fedorowski, 1980), only in slightly larger sizes and a higher amount of septa (for the Triasnuten specimen, the n/d ratio reaches 38/21, and for the specimens from Treskelen from 32/11×13 to 42/18×22). The diagnostic features of the morphological structure are the shortened cardinal septum, the long counter septum, the prolonged alar septa and the structure of the fossula that correspond to the diagnostic features of *Svalbardphyllum pachyseptatum*, and that supplement them with a new parameter, viz. the long counter septum. This feature confirmed in the original material excludes affiliation to *Svalbardphyllum pachyseptatum*, and thus the *Svalbardphyllum* genus to the Polycoeliidae family. Due to lack of more complete research material, this genus has been temporarily left in the *incertae sedis* family.

Occurrence: Spitsbergen: Treskelen, Triasnuten – Early Sakmarian; Kruseryggen – on the basis of analogy – Early Sakmarian.

Conclusions

The large, ontogenetic, dissepimental Rugosa corals (Table 1) found in the outcrop on Kruseryggen, in the lower part of the Treskelodden Formation (Lower Sakmarian), indicate a taxonomical diversification comparable to the one documented on Treskelen (Fedorowski, 1964, 1965, 1967, 1982). Characterised by Fedorowski (1965) as shallow-water and having a narrow thermal tolerance, they also indicate similar environmental conditions for Kruseryggen. The changing character of the sediments in the upper part of the Treskelodden Formation probably reflects a changing configuration of the coast and of the sedimentary environments along the shoreline (Birkenmajer, 1975, 1990; Fedorowski, 1982). These changes were probably caused by factors of both regional and global nature (the Inner Hornsund Basin became relatively quickly under the influence of the "rapid" sea-level changes by the end of the Carboniferous; these were caused by glacial factors, resulting in a shallow-marine environment during the Early Permian: Hartland, 1997). At the time, the Hornsund area was subject to local tectonics, as suggested by the characteristics of the rock successions (Fedorowski, 1982).

Based on the changes in lithology and the collected species, it was found thatonly the three uppermost (out of five recognized in total elsewhere) coral horizons exist now at Kruseryggen (Fig. 3). This confirms an earlier observation by Birkenmajer & Fedorowski (1980) who stated that the two lower coral horizons on Treskelen (Fig. 3) are absent in the northern part of Burgerbukta (not only in the Triasnuten region, but also in the Kruseryggen area). Moreover, latest research (Nowak, 2007) shows that the coalescence of coral horizons IV and V (Birkenmajer & Fedorowski, 1980) takes place only to the north of Kruseryggen. Both are, however, still separated from one another in the study area by sandstones and conglomerates with a significant thickness.

The lack of the lower coral horizons (I and II) was so far explained by unstable sedimentation conditions in the inner Hornsund from the Late Carboniferous till the Early Permian (Birkenmajer, 1964; Czarniecki, 1969; Fedorowski, 1982; Harland, 1997). The just mentioned workers ascribed this to eustatic changes of the sea level or to large-scale tectonics related to the elevation of the Hornsund horst, which became the source area for the clastic material deposited in the study area from the Carboniferous onwards.

Based on the present author's field observations and the documented coral horizons, it seems quite probable that the variations in thickness of the layers and the diminishing number of the coral horizons from the south to the north, may be related to the synsedimentary block movements in the northern part of the area. These movements could well have resulted in the wedging out of the coral horizons I and II towards the north. The Triasnuten and Kruseryggen areas must have been very shallow seas at the time that the coral horizons I and II were formed on Treskelen, and the Kruseryggen area may even have been emerged, as evidenced by the red sandstones and conglomerates. After this phase of continental conditions, probably a short-term ingression took place (coral horizon III, known from the entire area: Fig. 3), and thus to erosion and reworking of the fauna from the layers that had been exposed to the atmosphere or fresh-water currents (heavy abrasion of the multi-coloured corals). The state of the preservation of the specimens from coral horizon III indicates that they were transported over a significant distance, most probably from the area to the north or south-east of Kruseryggen. This area (Sørkapp Land) was land during the Early Permian (Birkenmajer, 1964). The age of the reworked fauna (Early Sakmarian) is, however, comparable to that of coral horizon III (also Early Sakmarian), as indicated by the biostratigraphic zonation of the corals.

The shallow-water conditions that developed during the ingression only in the Triasnuten region lasted until the end of the deposition of coral horizon V, leading to a condensed sequence. Birkenmajer and Fedorowski (1980) also mentioned the co-existence of coral horizons IV and V on Triasnuten, in a sandy limestone unit of about 5 m thick (Fig. 3). The Kruseryggen region (situated about 2 km to the south of Triasnuten) had probably subsided, however, as suggested by the increased thickness of the coral horizons IV and V, which are there separated by thick siliciclastic sandstones and conglomerates (Fig. 3). Thus, it seems that at least one synsedimentary fault must exist somewhere between Kruseryggen and Triasnuten. Since the total thickness of the coral horizons III-V on Kruseryggen is larger than on Treskelen, it is probable that a synsedimentary fault existed also between these regions, thus giving rise to difference in subsidence for these areas.

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References

Birkenmajer, K., 1964. Devonian, Carboniferous and Permian formations of Hornsund, Vestspitsbergen. *Studia Geologica Polonica* 11, 47–123.

Birkenmajer, K., 1975. Caledonides of Svalbard and plate tectonics. *Bulletin of the Geological Society of Denmark* 24, 1–19.

Birkenmajer, K., 1990. Geology of the Hornsund area, Spitsbergen – explanations to the map 1:75 000 scale. Silesian University, Katowice.

Birkenmajer, K. & Czarniecki, S., 1960. Stratigraphy of marine Carboniferous and Permian deposits in Hornsund (Vestspitsbergen), based on brachiopods. *Bulletin de l'Academie Polonaise des Sciences, Série des Sciences Géoloqiques et Géographiques* 8, 203–209.

Birkenmajer, K. & Fedorowski, J., 1980. Corals of the Treskelodden Formation (Lower Permian) at Triasnuten, Hornsund, South Spitsbergen. *Studia Geologica Polonica* 66, 7–27.

Chwieduk, E., 2007. Middle Permian rugose corals from the Kapp Starostin Formation, South Spitsbergen (Treskelen Peninsula). *Acta Geologica Polonica* 57, 281–304.

Cutbill, J.L. & Challinor, A., 1965. Revision of the stratigraphical scheme for the Carboniferous and Permian rocks of Spitsbergen and Bjørnøya. *Geological Magazine* 102, 418–439.

Czarniecki, S., 1964. Occurrence of genus *Archimedes* (Hall) in Hornsund, Vestspitsbergen. *Studia Geologica Polonica* 11, 147–153.

Czarniecki S., 1969. Sedimentary environment and stratigraphical position of the Treskelodden beds. *Prace Muzeum Ziemi* 16, 201–336.

Dallmann W.K. (Ed.), 1999. *Lithostratigraphic lexicon of Svalbard*. Norsk Polarinstitut, Oslo.

Dobrolyubova, T.A., 1936. Corals from the Upper Carboniferous of the western slope of the central Urals and their stratigraphic significance. [In Russian, English summary]. *Trudy Vsesoyuznogo Nauchno-issledovatelskogo Instituta, Mineralnogo Syriya*, 103, 1–68.

Ezaki, Y., 1997. Cold-water Permian Rugosa and their extinction in Spitsbergen. *Boletin de la Real Sociedad Española de Historia Natural (Sección Geología)* 92, 381–388.

Ezaki Y. & Kawamura T., 1992. Carboniferous-Permian corals from Skansen and Festningen, Central Spitsbergen: their faunal characteristic. [In:] K. Nakamura (Ed.): *Investigations on the Upper Carboniferous-Upper Permian successions of West-Spitsbergen by Japanese-Norwegian Research Group*. Hokkaido University, Sapporo, 59–75.

Ezaki, Y., Kawamura, T. & Nakamura, K., 1994. Kapp Starostin Formation in Spitsbergen: a sedimentary and faunal record of Late Permian palaeoenvironments in an arctic region. [In:] A.F. Embry (Ed.): Pangea: global environments and resources. *Canadian Society of Petroleum Geologists, Memoir* 17, 647–665.

Fedorowski, J., 1964. On Late Palaeozoic Rugosa from Hornsund, Vestspitsbergen. *Studia Geologica Polonica* 11, 139–146.

Fedorowski, J., 1965. Lower Permian Tetracoralla of Hornsund, Vestspitsbergen. *Studia Geologica Polonica* 17, 1–173.

Fedorowski, J., 1967. The Lower Permian Tetracoralla and Tabulata from Treskelodden, Vestspitsbergen. *Norsk Polarinstitut, Skrifter* 142, 1–44.

Fedorowski, J., 1982. Coral thanatocoenoses and depositional environments in the upper Treskelodden beds of the Hornsund area, Spitsbergen. *Paleontologia Polonica* 43, 17–68.

Fedorowski, J., 1997. Diachronism in the development and extinction of Permian Rugosa. *Geologos* 2, 59–164.

Fedorowski, J., Bamber, W. & Stevens, C., 1999. Permian corals of the Cordilleran-Arctic-Uralian Realm. *Acta Geologica Polonica* 49, 159–173.

Fedorowski, J. & Bamber, W., 2001. Guadalupian (Middle Permian) solitary rugose corals from the Degerbols and Trold Fiord Formations, Ellesmere and Melville islands, Canadian Arctic Archipelago. *Acta Geologica Polonica* 51, 31–79.

Fedorowski, J., Bamber, E.W. & Stevens, C.H., 2007. *Lower Permian colonial rugose corals, Western and Northwestern Pangea: taxonomy and distribution*. National Research Council of Canada Research Press, Ottawa, 231 pp.

Fischer von Waldheim, S., 1830. *Oryctographie du Gouvernement de Moscou*. A. Semen, Moscow, 1–202.

Fomitchev, V.D., 1953. *Rugose corals and stratigraphy of the Middle and Upper Carboniferous and Permian deposits of the Donetsk Basin* [in Russian]. Trudy Vsesoyuznyi Nauchno-Issledovatel'skyi Geologicheskyi Institut (VSEGEI), Gosudarstvennoe Isdatel'stvo Geologicheskoi Literatury, 622 pp. [91 pp. + 44 plates under separate cover].

Forbes, C.L., Harland, W.B. & Huges, N.F., 1958. Palaeontological evidence for the age of the Carboniferous and Permian rocks of Central Vestspitsbergen. *Geological Magazine* 95, 465–490.

Frey, H. & Leuckart, R., 1847. Beiträge zur Kenntnis wirbelloser Tiere, mit besonderer Berücksichtigung der Fauna des Norddeutschen Meeres. Braunschweig, 1–170.

Harland, W.B., 1997. *The geology of Svalbard*. Geological Society (London) Memoir 17, 521 pp.

Heritsch, F., 1929. Eine *Caninia* aus dem Karbon des de Geer-Beiges im Eisfjordgebiet auf Spitzbergen. *Skrifter om Svalbard og Ishavet* 24, 1–21.

Heritsch, F., 1939. Die Korallen des Jungpaläozoikums von Spitsbergen. *Arkiv für Zoologie* 31A (16), 138 pp.

Hill, D., 1981. Supplement 1, Rugosa and Tabulata. [In:] C. Teichert (Ed.*): Treatise on invertebrate paleontology, Part F. Coelenterata*. Geological Society of America, Boulder, and University of Kansas Press, Lawrence, 72–762

Holtedahl, O., 1913. Zur Kenntnis der Karbonablagerungen des westlichen Spitzbergens. II. Allgemeine stratigraphische und tektonische Beobachtungen. *Videnskapsselskapets Skrifte*, 23, 1–91.

Karczewski, L., 1982. Some gastropods and bivalves from the Treskelodden and Kapp Starostin Formations, Hornsund region, Spitsbergen. *Palaeontologica Polonica* 43, 97–105.

Kossovaya, O.L., 1997. Rugosa of the type sections of the Gzhelian-Artinskian stages of northern Timan and the western slope of the Urals [in Russian]. [In:] G.A. Stukalina (Ed.): *Atlas of standard complexes of Palaeozoic benthonic fauna of northeastern European Russia*. P. Karpinskyi All-Russian Scientific-Research Geological Institute (VSEGEI), 53–96.

Lewis, H.P., 1929. On the Avonian coral *Caninophyllum,* gen. nov. and *C. archiaci* (Edwards & Haime). *Annals and Magazine of Natural History* 10, 456–468.

Liszka, S., 1964. Occurrence of Lower Permian Foraminifera in the Treskelodden Beds of Hornsund, Vestspitsbergen. *Studia Geologica Polonica* 11, 169–172.

Milne Edwards, H. & Haime, J., 1850–1855. *A monograph of the British fossil corals*. Palaeontographical Society, London. 1850 (pp. 1–71), 1852 (pp. 147–210), 1853 (pp. 211–244), 1855 (pp. 245–299).

Nowak, B., 2007. Rugose corals from Kruseryggen (southern Spitsbergen). *In Polish only.* Msc. Thesis, Poznań University.

Nowiński, A., 1982. Some new species of Tabulata from the Lower Permian of Hornsund, Spitsbergen. *Palaeontologia Polonica* 43, 83–96.

Nowiński, A., 1991. Late Carboniferous to Early Permian Tabulata from Spitsbergen. *Palaeontologia Polonica* 51, 3–74.

Osmólska, H., 1968. The new trilobites from the Treskelodden beds of Hornsund. *Acta Palaeontologica Polonica* 13, 605–613.

Padget, P., 1954. Notes on some corals from late Paleozoic rocks of inner Isfjorden, Spitsbergen. *Norsk Polarinstitut, Skrifter* 100: 1–10.

Somerville, D. I., 1997. Biostratigraphy and biofacies of Upper Carboniferous-Lower Permian rugose coral assemblages from the Isfjorden area, central Spitsbergen. *Boletin de la Real Sociedad Española de Historia Natural (Sección Geología)* 92, 363–378.

Stuckenberg, A.A., 1895. *Corals and bryozoans from the Carboniferous deposits of the Urals and Timan* [in Russian with German summary]. Trudy Geologicheskago Komiteta 10, 244 pp.

Tidten, G., 1972. Morphogenetisch-ontogenetische Untersuchungen an Pterocorallia aus dem Permo-Karbon von Spitsbergen. *Palaeontographica, Abteilung A* 139, 1–63.

Toula, F., 1875. Permo-Karbon Fossilien von der Westküste von Spitsbergen. *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie* 1875, 227–264.

Verrill, A.E., 1865. Classification of polyps (Extract condensed from a synopsis of the polyps of the North Pacific Exploring Expedition, under Captains Ringgold and Rodgers, U.S.N.). *Proceedings of the Essex Institute* 4, 145–149.

Von Trautschold, H.A., 1879. Die Kalkbrüche von Mjatschkova: eine Monographie des oberen Berkalks. *Nouveaux Mémoires de la Société Impériale des Naturalistes de Moscou, Mémoire* 14, 1–82.

Wang, H.C., 1950. A revision of the Zoantharia Rugosa in the light of their minute skeletal structures. *Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences* 611, 175–264.

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