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Middle Permian rugose corals from the Kapp Starostin Formation, South Spitsbergen (Treskelen Peninsula)

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ABSTRACT:

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The rugose corals from the topmost part of the Kapp Starostin Formation on the Treskelen Peninsula, South Spitsbergen, are described. The collection consists of 22 specimens, representing the genera *Calophyllum*, *Allotropiochisma* and *Euryphyllum*. These solitary and non-dissepimented taxa, considered to be cold-water forms, are representatives of the *Calophyllum* Province of the Cordilleran-Arctic-Uralian Realm, and confirm a biogeographical connection between Alaska, Ural Mts., Central European Basin, Sverdrup Basin, and Arctic Canada in the Middle Permian.

In southern Spitsbergen the Kapp Starostin Formation yields apparently the latest representatives of the Rugosa in the whole Hornsund region, dated to the Guadalupian and probably to the Wordian.

Key words: Solitary Rugosa, Permian, Kapp Starostin Formation, Spitsbergen.

INTRODUCTION

The Middle Permian Rugosa are poorly represented in the Cordilleran-Arctic-Uralian Realm of FEDOROWSKI (1986), and only a few of them have been described so far (HERITSCH 1939, FEDOROWSKI 1975, EZAKI & KAWAMURA 1992) from Spitsbergen.

In the Carboniferous and Early Permian the Svalbard Archipelago was located roughly on the Tropic of Cancer (~25-30°N), forming the northern margin of the drifting supercontinent of Pangea (GOLONKA & FORD 2000, SCOTESE 2000). Throughout that period, up to and including the Wuchiapingian, it migrated northward (BEAUCHAMP 1994) until it arrived in its present location, between the 75th and 80th parallel, in the northern Polar zone. In the Middle (Text-fig. 1) and Late Permian the northern shelf of Pangea reached the sub-Arctic and Arctic regions (BEAUCHAMP 1994). For details of facies distribution and sequence characteristics in time and space the reader is referred to HARLAND (1997).

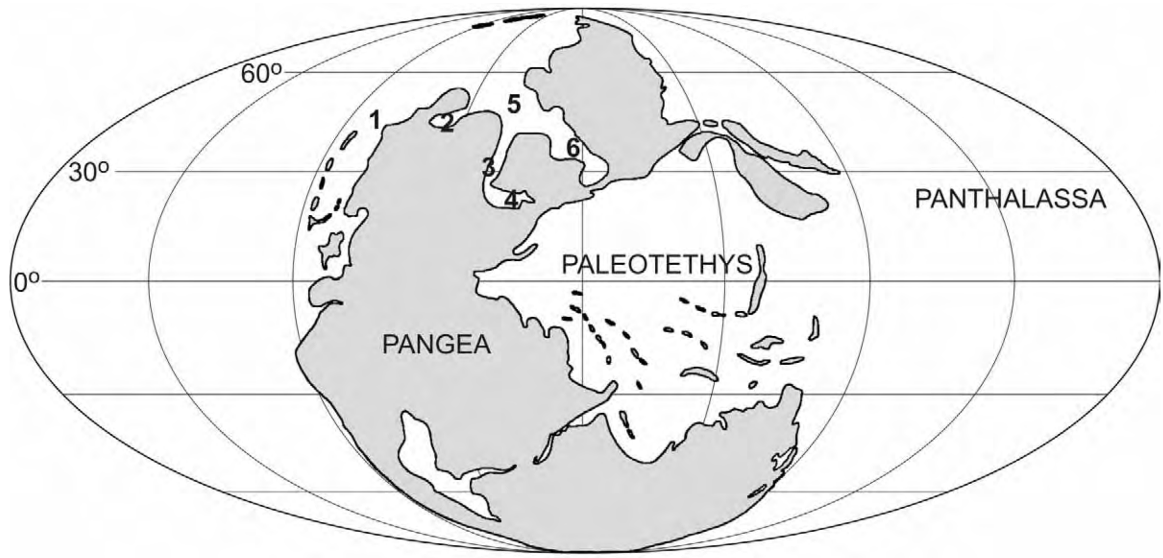

Fig. 1. Wordian–Capitanian palaeogeographic map (after FEDOROWSKI & BAMBER 2001) showing coral localities in the Cordilleran-Arctic-Uralian Realm. 1 – Alaska, 2 – Sverdrup Basin, 3 – East Greenland, 4 – Central European Basin, 5 – Svalbard Archipelago, 6 – East European Platform

The Kapp Starostin Formation (uppermost Cisuralian–lowermost Lopingian) comprises resistant siliceous rocks at the top of the Permo-Carboniferous sequence. The formation appears principally in the central part of Spitsbergen, on the northern coast of Isfjorden up to Nordaustlandet. It reaches the highest part of Hornsund in southern Spitsbergen along the western coast and extends to Barentsøya and to Edgeøya, from where its small outcrops were described (HARLAND 1997). Thus, it occurs roughly in the same area as the older Permian-Carboniferous rocks (Text-fig. 2).

The Kapp Starostin Formation contains an abundant fauna, consisting mainly of silicified brachiopods, but also including bryozoans, bivalves, sponges, echinoderms, gastropods, foraminifers and rugosans. The earliest report of the latter containing descriptions and illustrations, was that of TOULA (1875), who mentioned two species, at least one of which ("*Clisiophyllum Geinitzii*") may have been derived from that formation from Nordenfjorden (central Spitsbergen). Subsequent authors (HERITSCH 1939, PADGET 1954) reported a few specimens which, judging by their location, are probably from that formation. Unfortunately, their exact stratigraphical position cannot be established. HERITSCH (1939) and TIDTEN (1972) introduced a new genus *Sassendalia* [included subsequently in the synonymy of *Sochkineophyllum* GRABAU, 1928 by FEDOROWSKI & BAMBER (2001)]. Three rugose species from the area around Isfjorden (Skansen and Festningen), with another two left in open nomenclature, were identified by EZAKI & KAWAMURA (1992) and EZAKI & *al*. (1994).

Although the Isfjorden area yields extensive outcrops and diverse faunas, including rugose corals in the most complete Carboniferous and Permian marine strata, their rugose coral fauna is generally poorly known (HOLTEDAHL 1913; HERITSCH 1929, 1939; EZAKI & KAWAMURA 1992; EZAKI & *al*. 1994; SOMERVILLE 1997). The sequence in Central Spitsbergen is considerably thicker than in South Spitsbergen, with a greater range of facies. The Hornsund area (southern Spitsbergen), with its stratigraphically more restricted coral fauna studied primarily by Polish palaeontologists and geologists, has a more extensive literature (FEDOROWSKI 1964, 1965, 1967, 1975, 1982a, 1997; BIRKENMAJER & FEDOROWSKI 1980, FEDOROWSKI & *al*. 1999; FEDOROWSKI & BAMBER 2001; FEDOROWSKI & *al*. 2007; NOWIŃSKI 1982, 1991).

Rugose corals described in the present paper comprise the largest collection from all of the Kapp Starostin Formation described so far from the Svalbard Archipelago. Accordingly, it may

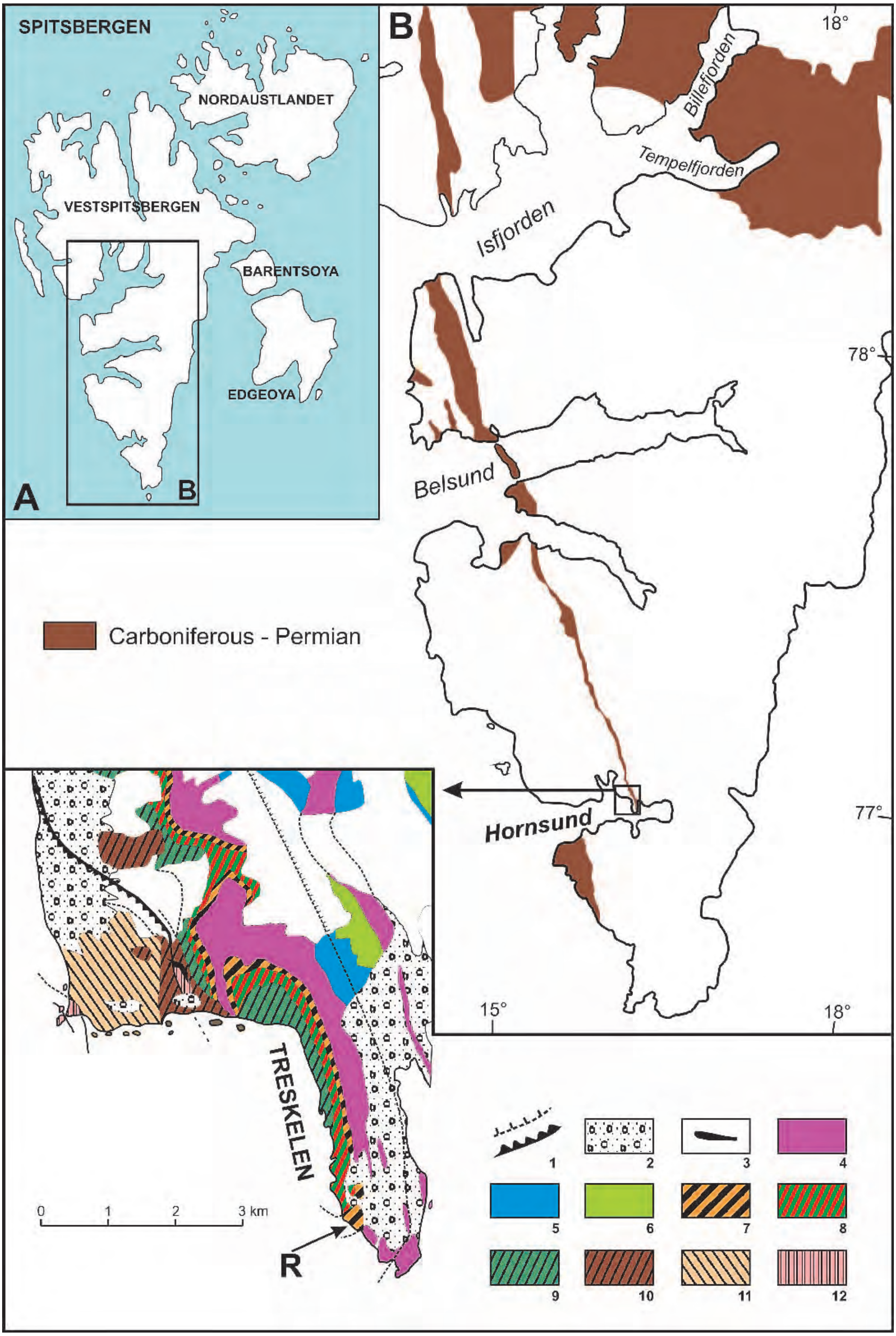

Fig. 2. Map of Treskelen, showing Formations and coral locality (**R**). Map of Svalbard (**B**) showing the locations of the exposure of Permo-Carboniferous rocks (marked in brown). 1 – faults, 2 – glacial moraines, 3 – doleritic sills, 4-6 – Mesozoic rocks (respectively Triassic, Jurassic and Cretaceous), 7 – Kapp Starostin Formation, 8 – Treskelodden Formation, 9 – Hyrnefjellet Formation, 10 – Adriabukta Formation, 11 – Marietoppen Formation, 12 – Gashamna Formation

contribute to a reconstruction of the geographical distribution of taxa known from other areas of the Cordilleran-Arctic-Uralian Realm, and thereby also to a reconstruction of their possible routes of migration.

GEOLOGICAL SETTING

The Carboniferous and Permian rocks in Spitsbergen display a considerable facies variability, which to a large extent resulted from an intense tectonism in this region at the time of their accumulation (BIRKENMAJER 1972, STEEL & WORSLEY 1984, STEMMERIK & WORSLEY 1989, STEMMERIK 1995, HARLAND 1997).

The Bünsow Land Supergroup (Text-fig. 3) includes three groups comprising rocks of Upper Famennian through to Upper Permian (HARLAND 1997). The major part of the lowermost Billefjorden Group represents the Tournaisian and Viséan and is composed of continental clastic

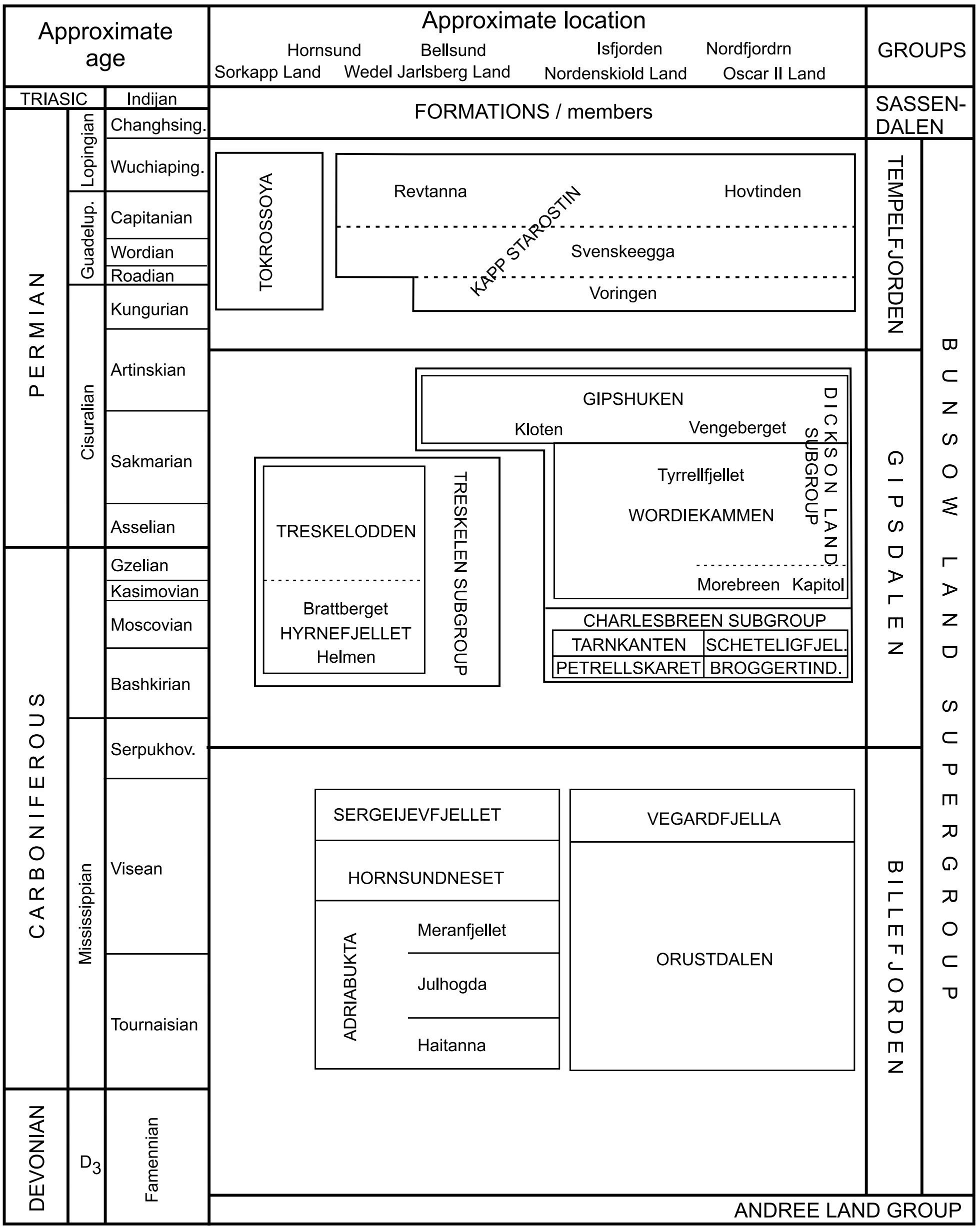

Fig. 3. Lithostratigraphic scheme for Carboniferous and Permian formations of the Bünsow Land Supergroup (after HARLAND 1997, simplified)

deposits, containing abundant plant material and coal horizons.

The overlying Gipsdalen Group is composed of red-bed clastic rocks and evaporites (ELIASSEN & TALBOT 2003) with a considerable carbonate content (Dickson Land and Treskelen Subgroups). The Wordiekammen and Treskelodden formations of those subgroups represent the Permo-Carboniferous marine transgression. Based on the rugose corals, the lower part of the Wordiekammen Formation of central Spitsbergen may belong to the Moscovian–Gzhelian of the Upper Carboniferous (SOMERVILLE 1997), whereas the basal part of the Treskelodden Formation most probably is not older than the Gzhelian Stage (in the Hornsund area). Both formations range up to the Lower Sakmarian. The richest rugose corals appear in the Upper Treskelodden Formation and in most of the Tyrrellfjellet Member of the Wordiekammen Formation (FORBES & *al*. 1958, CUTBILL & CHALLINOR 1965, SOMERVILLE 1997). In the uppermost Tyrrellfjellet Member the ongoing regression

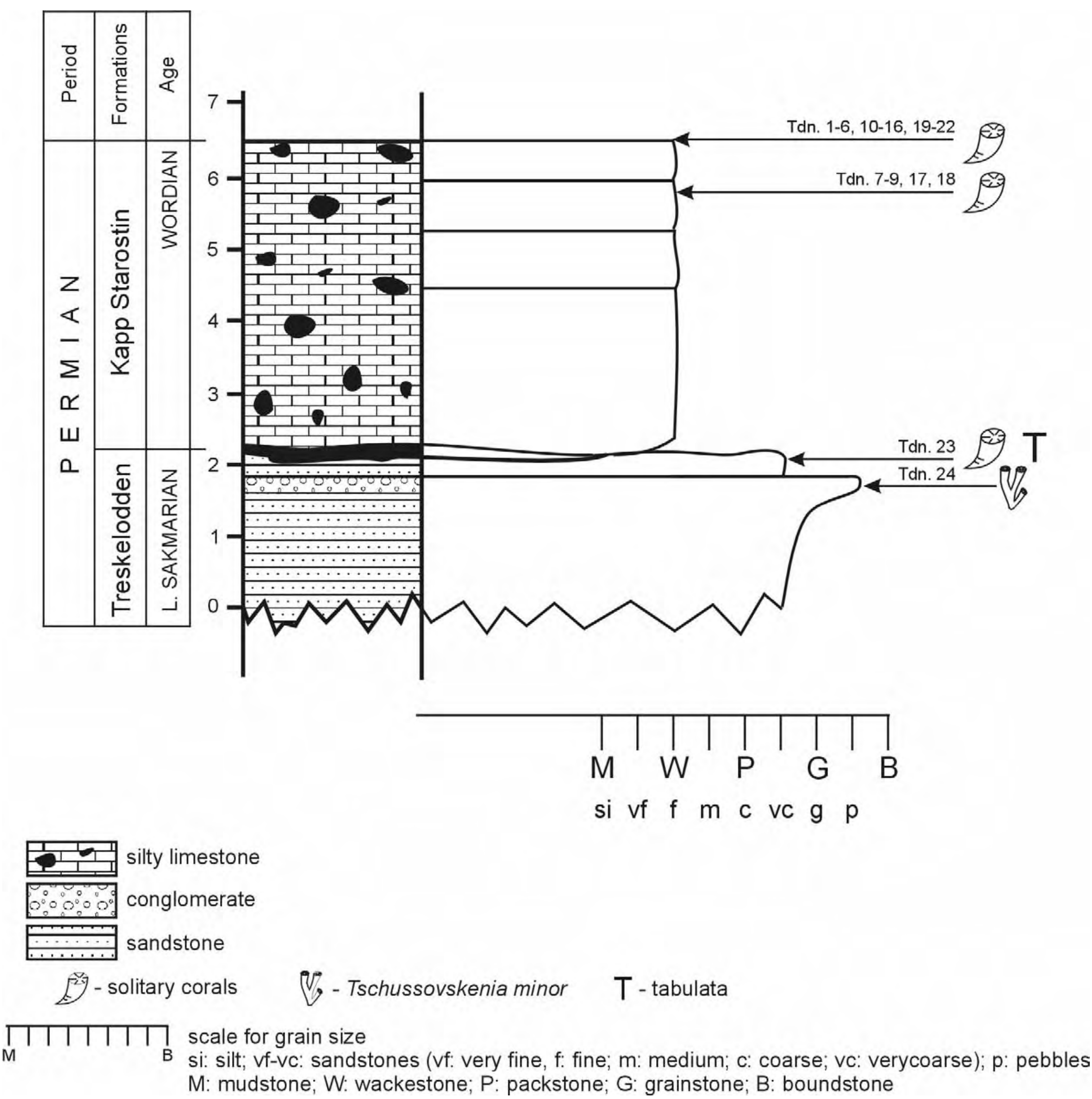

Fig. 4. Type section of Kapp Starostin Formation on Treskelen and occurrence of coral specimens (Tdn.1-24 – Rugosa, Tdn.23 – unidentified specimen, T – Tabulata); GPS data: N 76° 59,767; E 16° 12,937; 230°/15°)

is noted. The culmination of this regression is marked by the Gipshuken Formation, dated to the Late Sakmarian and Early Artinskian. The upper part of the Bünsow Land Supergroup consists of the Tempelfjorden Group, comprising mainly thick-bedded silicified rocks, most of which represent the Kapp Starostin Formation (CUTBILL & CHALLINOR 1965), the principal rock body of the group in central and western Spitsbergen. In the Kapp Starostin Formation even the rare limestone beds are silicified or contain spiculites (EHRENBERG & *al*. 2001). The predominantly transgressive character of the Kapp Starostin sequence suggests its deposition on a shallow shelf. The boundaries of the strata are diachronous up to the appearance of the chert-bearing facies, which abound in fossil invertebrates (HARLAND 1997). The transgression recorded in the Voringen Member (Text-fig. 3) coincided with a considerable cooling and a shift in the fauna toward a cold-water one (STEEL & WORSLEY 1984, WORSLEY & *al*. 1986, STEMMERIK & WORSLEY 1995, EZAKI & *al*. 1994, EZAKI 1997), although KEILEN (1992) suggested that the cold-water fauna dominated as early as during the sedimentation of the upper part of the Gipshuken Formation. This luxuriant Kapp Starostin fauna, consisting mainly of brachiopods, corals, molluscs, echinoderms, foraminifers, bryozoans and sponges, is indicative of the Kungurian–Wordian and ?Capitanian stages (USTRITSKIY 1962, 1979, and BUROVET & *al.* 1965; in HARLAND 1997). The Kungurian age for the lower parts of the formation was suggested by NYSAETHER (1977) and USTRITSKIY (1979 in HARLAND 1997). The Kungurian-Roadian age of that part is furthermore evidenced by conodonts, stratigraphically corresponding to the North American Late Leonardian/Early Roadian (SZANIAWSKI & MAŁKOWSKI 1979). The Svenskeegga and lower part of the Hovtinden (VRevtanna) members (USTRITSKIY 1962, 1979 and BUROVET & *al*. 1965; in HARLAND 1997) are dated to the Guadalupian; supported also by PCHELINA's dating (1977 in HARLAND 1997) based on the foraminifera from the glauconite facies of Edgeøya. The upper strata of the Kapp Starostin Formation, which feature characteristic brachiopods, are dated to the Kazanian (~Wuchiapingian) Stage (HARLAND 1997).

The absence of index fossils in the top beds of the Tempelfjorden Group makes it impossible at the moment to define the exact position of the Permian–Triassic boundary.

The stratotype of the Kapp Starostin Formation is located on the southwestern shore of Isfjorden, in the area of Festningen, Nordenskiöld Land, where it is about 380 m thick (EZAKI & *al*. 1994, EZAKI 1997). Southwards, toward the highest part of Hornsund (Text-fig. 2), the formation diminishes rapidly in thickness and amounts to as little as 5 m in the Treskelen Peninsula (Text-fig. 4). The rugose corals studied suggest a Wordian age for the part of the formation cropping out in the Hornsund area. This part represents the Svenskeegga Member (Text-fig. 3); the Voringen Member in the lower part of the formation, and the Revtanna and Hovtinden Members, in the upper part of the formation, are missing (Text-fig. 3).

SYSTEMATIC PALAEONTOLOGY

Abbreviations used:

UAMIG – Institute of Geology, Adam Mickiewicz University.
Tc – Tetracoralla.
Tdn.1, 2… n – Treskelen and numbers of the corallites.
n/d index – number of septa (n) to diameter (d) of corallite ratio.
[n-C,K,A/d] – number of septa (n) in quadrants minus protosepta (C-cardinal, K-counter and A-alar) to diameter (d) of corallite ratio.

All localities: Southern Treskelen Peninsula (Text-fig. 2). N 76º59,767; E 16º12,937; 6.5 m above the mean sea level (GPS data).

Order Stauriida VERRILL, 1865
Suborder Stereolasmatina HILL, 1981
Family Hapsiphyllidae GRABAU, 1928
Subfamily Hapsiphyllinae GRABAU, 1928
Genus *Allotropiochisma* FEDOROWSKI, 1982

TYPE SPECIES: *Amplexizaphrentis longiseptata* FLÜGEL, 1973

DIAGNOSIS: See FEDOROWSKI & BAMBER 2001, p. 44.

Allotropiochisma treskelense sp. nov.
(Pl. 1, Fig. 1; Pl. 2, Fig. 1; Pl. 3, Fig. 1; Pl. 9, Fig. 2; Text-figs 5-7)

2001. *Allotropiochisma* (*Allotropiochisma*) sp. FEDOROWSKI & BAMBER, text-fig. 7.2, pl. 2, fig. 4, pl. 7, fig. 3.

HOLOTYPE: UAMIG.Tc-Tdn.4 (6 thin sections, 12 acetate peels).

TYPE LOCALITY: Treskelen (N 76º59,767; E 16º12,900; 6.5 m above sea level), south Spitsbergen (see Text-fig. 2).

TYPE HORIZON: Kapp Starostin Formation (Text-fig. 4), Wordian.

ETYMOLOGY: Named after Treskelen Peninsula.

MATERIAL: Paratypes: UAMIG.Tc-Tdn.1 (45 mm long), UAMIG.Tc-Tdn.7 (30 mm long), UAMIG.Tc-Tdn.15 (80 mm long), UAMIG.Tc-Tdn.19 (25 mm long); 25 thin sections and 23 acetate peels.

DIAGNOSIS: *Allotropiochisma* with major septa approximately equally thickened in all growth stages; up to 37 major septa at corallite diameter of 22.0 mm, near calice floor; cardinal septum thin, variable in length; counter septum may be slightly longer than the other major septa in the counter quadrants; alar septa are the longest; arrangement of the major septa pinnate in the counter quadrants and radial in the cardinal quadrants in immature stages, and radial in all quadrants in the mature stages; cardinal fossula widened toward periphery and axis, outlined by successively shortened major septa of the cardinal quadrants; alar fossulae better visible in younger stages.

DESCRIPTION OF THE HOLOTYPE: The corallite is ceratoid, 100 mm long, with a concave cardinal side. The calice is approximately 30 mm deep. Its external, ribbed wall is 0.1-2.2 mm thick. Major septa in the adult stages are thick, generally long, but do not meet at the corallite axis, leaving an open axial area 2-3 mm wide (Pl. 1, Figs 1f-h). They shorten gradually towards the cardinal septum in the cardinal quadrants, but are almost equal in length and radially distributed in the counter quadrants. The inner halves of the major septa are thickened to join laterally around the axial part of the corallite. Their axial margins thin adaxially, and end in thin extensions, thus not being truly rhopaloid. The resulting ring of septa opens only at the axial margin of the cardinal fossula (Pl. 1, Fig. 1h). All major septa thicken at the periphery to form the septotheca. In the later growth stages they

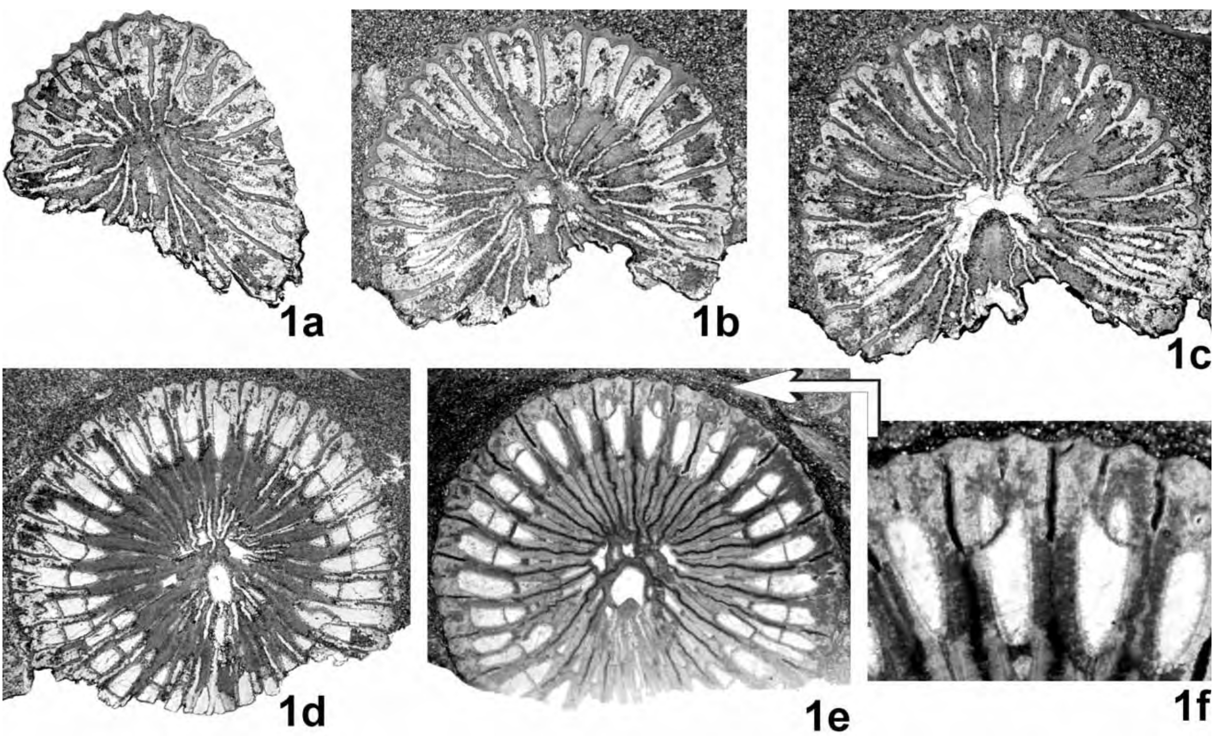

Fig. 5. *Allotropiochisma treskelense* sp. nov., UAMIG.Tc-Tdn.1, all transverse sections, 1a-c × 6, 1d-e × 4, 1f × 10

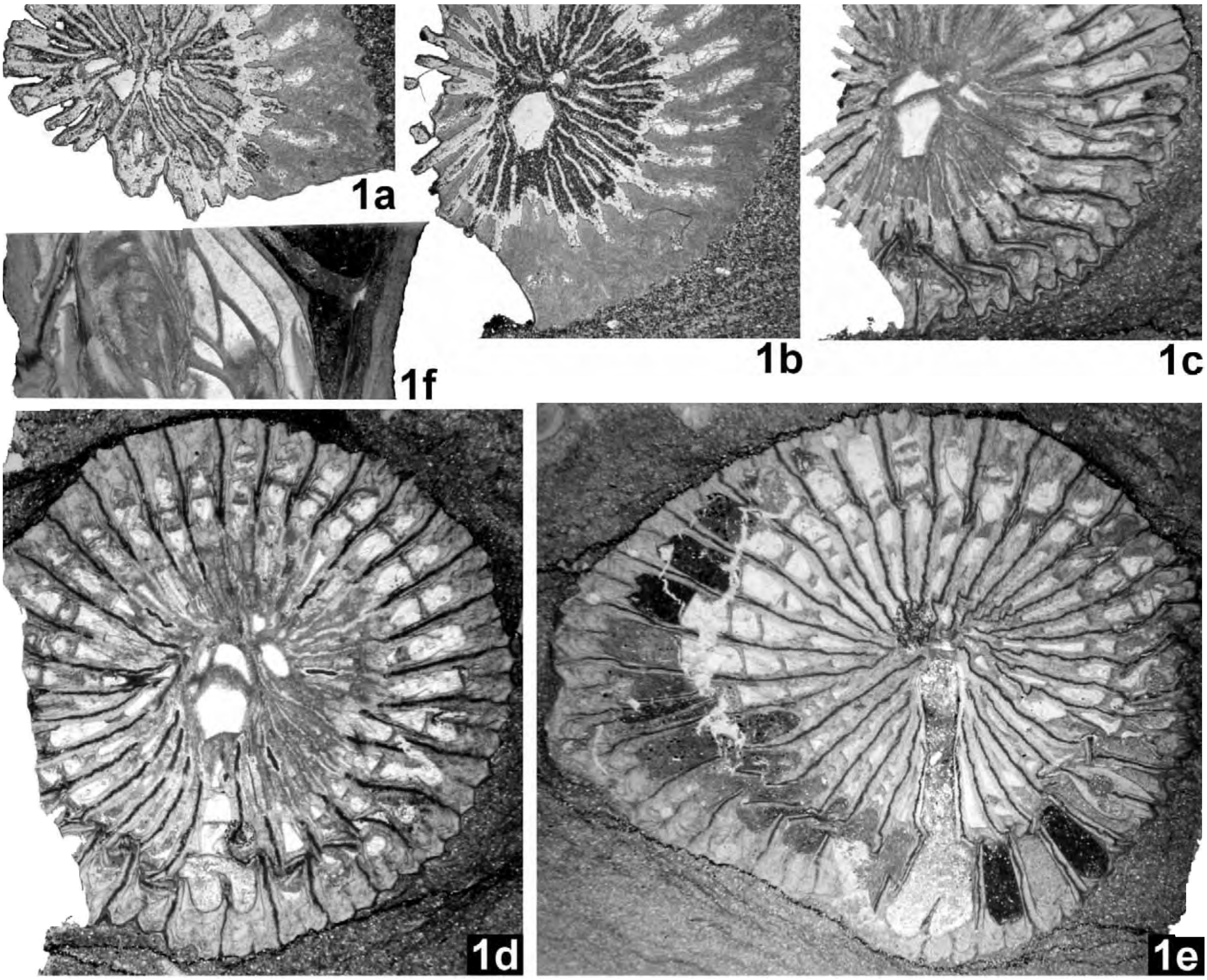

Fig. 6. *Allotropiochisma treskelense* sp. nov., UAMIG.Tc-Tdn.7, transverse sections: 1a-c × 6, 1d-e × 5, longitudinal section: 1f × 4

are inserted only in the counter quadrants (Table 1). The microstructure of the septa is trabecular, with individual trabeculae up to 0.1 mm in diameter (Pl. 9, Fig. 2). The cardinal septum grows shorter in the course of the mature stage, becoming eventually much shorter than the adjacent major septa (Pl. 1, Figs 1e-g) under the calice floor. It is only 2 mm long above the last tabula in the fossula (Pl. 1, Fig. 1h). The cardinal fossula is fairly shallow (Pl. 1, Fig. 1k, right side), closed, narrow but slightly widened towards the periphery and the corallite axis (Pl. 1, Figs 1e, g, h). It extends beyond the corallite axis into the counter quadrants, and is bordered by successively shortened major septa of the cardinal quadrants and periaxial margins of the almost equally long major septa of the counter quadrants. The counter and alar septa are slightly longer than the other major septa (Pl. 1, Figs 1e, h).

Tdn.4 [n-C,K,A/d]	Tdn.15 [n-C,K,A/d]	Tdn.1 [n-C,K,A/d]	Tdn.19 [n-C,K,A/d]
$\frac{5?\,\vert\,5?}{3\,\vert\,2}$/3.5			
		$\frac{7\,\vert\,7}{3\,\vert\,3}$/7	
$\frac{7\,\vert\,7}{5\,\vert\,4}$/9	$\frac{7\,\vert\,7}{4\,\vert\,4}$/9		
		$\frac{9\,\vert\,9}{5\,\vert\,4}$/9	
	$\frac{8\,\vert\,8}{4\,\vert\,4}$/11		$\frac{8\,\vert\,8}{5\,\vert\,4}$/10-12
$\frac{9\,\vert\,10}{5\,\vert\,4}$/15			
	$\frac{10\,\vert\,9}{4\,\vert\,4}$/14	$\frac{9\,\vert\,9}{5\,\vert\,4}$/14	
$\frac{11\,\vert\,11}{5\,\vert\,4}$/17			$\frac{9\,\vert\,10}{5\,\vert\,4}$/15-18
	$\frac{11\,\vert\,12}{4\,\vert\,4}$/20		
$\frac{11\,\vert\,11}{5\,\vert\,4}$/21-22			

Table 1. *Allotropiochisma treskelense* sp. nov. The numbers of the major septa (excluding the cardinal, counter and alar septa), broken down into quadrants, at various stages of the ontogeny of the holotype (Tdn. 4) and of three paratypes (Tdn.1, 15, 19)

Minor septa are confined mostly to the external wall; near the calice floor, they are prolonged slightly into the corallite lumen; the Km septa are somewhat longer than the other minor septa (Pl. 1, Fig. 1h). The shape of the tabularium depends on the orientation of a given section. It rises asymmetrically, with its highest point corresponding to the inner margin of the fossula, when sectioned along the cardinal–counter septum (C- K) line. The tabulae are shortened and rise steeply adaxially in the counter quadrants of such a section, but are long and rise gently within the fossula (Pl. 1, Fig. 1k). In longitudinal sections cut perpendicular or oblique to the C-K plane, the tabularium is hemispherical, with a deep depression in the axis (Pl. 1, Fig. 1l). There are four tabulae per 10 mm at the corallite external wall.

ONTOGENY OF THE HOLOTYPE: The ontogenetically earliest skeleton is missing. In the youngest growth stage available for the study (Pl. 1, Figs 1a-b) with n/d ratio of 19/3.2 × 4.0, the major septa are zaphrentoidally arranged, with some joining in the corallite axis. The cardinal fossula and alar pseudo-fossulae are well developed. The cardinal fossula is parallel-walled and bordered by two pairs of major septa. The cardinal and counter septa are as long as the longest major septa. The external wall is 0.2 to 0.3 mm thick. The minor septa are absent from the corallite lumen on the external wall in this growth stage.

The section cut approximately 5.0 mm above the previous one (Pl. 1, Fig. 1c), with n/d ratio 26/8, is characterized by major septa that are radially arranged in the cardinal quadrants and pinnately arranged in the counter quadrants. The counter and alar septa are longest. The cardinal septum is as long as the other metasepta. The cardinal fossula is narrow. Minor septa appeared in the 0.1 mm-thick external wall, but are hardly recognizable in the corallite lumen. The corallite surface is ribbed, with septal furrows corresponding to both major and minor septa.

In the later growth stage with n/d ratio 29/9.5 (Pl. 1, Fig. 1d), the arrangement of the major septa resembles the earlier one, but they leave open an axial area, reaching 1 mm in width. The cardinal septum crosses the long, parallel-walled cardinal fossula. The counter septum is as long as the adjacent counter-lateral septa. The alar septa remain the longest septa in the cardinal quadrants, but the alar pseudo-fossulae are less distinct than during the earliest growth stage studied. The septothecal external wall is 0.7 mm thick.

The mature growth stage with n/d ratio 34/15 and 37/17-20 (Pl. 1, Figs 1e-h) was described above. It should be added that the minor septa and the shape of the peripheral parts of the tabulae indicate a biform morphology (*sensu* FEDOROWSKI 1987) in the peripheral part of the tabularium.

In the lower part of the calice with n/d ratio 37/22 (Pl. 1, Fig. 1j), the major septa are radially arranged, and extend from the corallite wall up to 1/3 of the corallite diameter. The counter septum is as long as the other major septa. The cardinal septum attains 1/2 the length of the major septa. The minor septa reach 1/6 the length of the major septa.

INTRASPECIFIC VARIABILITY: Four paratypes are distinguished from the holotype by slightly different numbers of septa at comparable diameters (Text-fig. 7). Furthermore, the cardinal septum may be much less shortened in the adult stages than in the holotype, reaching 3/4-4/5 of the major septa length (Pl. 2, Figs 1e-g), and the cardinal fossula may be deeper (Pl. 2, Fig. 1i). The density of tabulae may also vary, reaching up to seven per 10 mm (Pl. 1, Fig. 1l).

DISCUSSION: *Allotropiochisma treskelense* sp. nov. from the Kapp Starostin Formation of the Treskelen Peninsula shows a unique combination of characteristics. These features resemble the diagnostic characters of particular subgenera of *Allotropiochisma*, established by FEDOROWSKI (1987) and hence that taxonomic level was omitted. Whilst some of these characteristics occur in the earlier known species of *Allotropiochisma* (see Table 2), none of them shows this particular combination.

The holotype shares a few characteristics in common with *A.* (*Abeophyllum*) *texanum* FEDOROWSKI, 1987, including its n/d index = 37/22 (Pl. 1, Fig. 1h). However *A. treskelense* sp. nov. differs from *A.* (*Abeophyllum*) *texanum* in the zaphrentoid arrangement of the septa and the distinct alar fossulae in the early growth stages (Pl. 1, Figs 1a-d; Pl. 2, Fig. 1b). These features make *A. treskelense* sp. nov. more similar to *A.* (*Alligia*) *flabellum* FEDOROWSKI, 1987, while the free axial area occurring in the late neanic stage, which in subsequent stages is surrounded by laterally joined septa (Pl. 1,

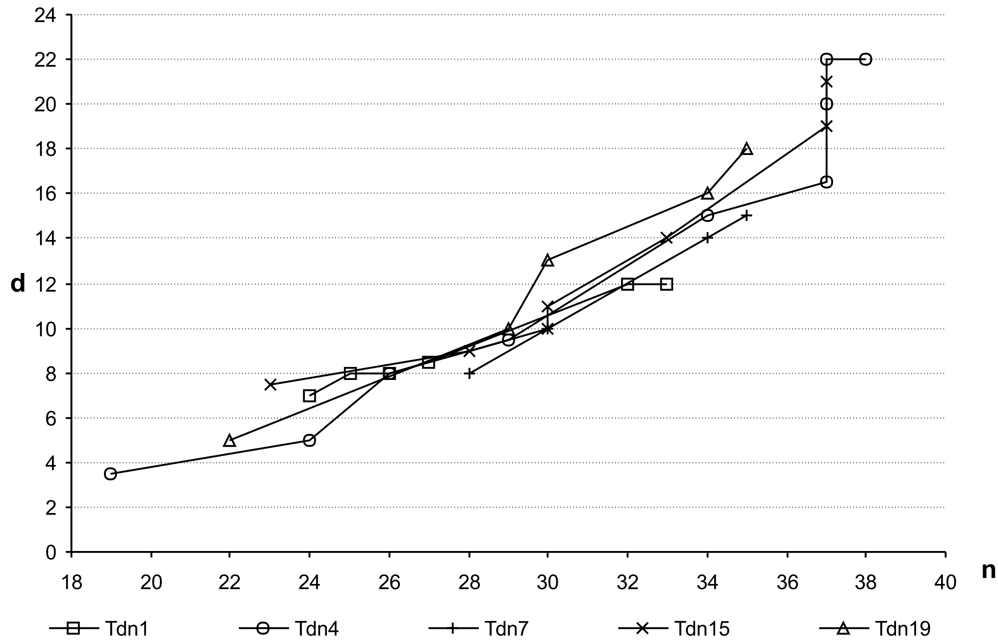

Fig. 7. *Allotropiochisma treskelense* sp. nov., number of major septa *vs*. diameter for specimens described in this paper; n – number of major septa, d – diameter (mm); symbols joined by lines represent values taken from individual specimens

Figs 1c-h), resembles *A.* (*Allotropiochisma*) *uddenitense* FEDOROWSKI, 1987. However, *A.* (*A.*) *uddenitense* has a characteristic fossula, bordered by 2 major septa, smaller dimensions and longer minor septa. In the specimens from Treskelen Peninsula, the fossula is always delimited by successively shortened major septa of the cardinal quadrants (Pl. 1, Pl. 2, Pl. 3, Fig. 1; Text-figs 5, 6, 8).

The calice floor described by FEDOROWSKI (1987, p. 10), as "hemispherical, sagging axially", corresponds closely to the longitudinal section perpendicular or oblique to the C-K plane (Pl. 1, Fig. 1l) in specimens from Treskelen. However, it differs from characters exposed by the section made along the C–K line as described above (Pl. 1, Fig. 1k). Thus, longitudinal sections in both directions should be made in order to characterize the morphology of the tabularium in *Allotropiochisma*.

The different length of the major septa in the cardinal and counter quadrants (e.g. Pl. 2, Figs 1f, g) may be apparent and the length of the former may result from an obliqueness of sections. The corallites are horn-shaped. Perpendicularly orientated transverse sections cut some of their growth lines, i.e. are in fact oblique. That supposition is substantiated by transverse sections of the tabulae, of which 1-3 are seen in the counter quadrants, and 3-7 in the cardinal ones (Pl. 3, Figs 1f, 1g).

It also seems a significant characteristic that the final number of major septa in the cardinal quadrants (viz. 3:3, 4:4, 5:4 or 5:5) is reached at a fairly early stage. The early major septa in subsequent stages of the ontogeny were inserted only in the counter quadrants, where their number is typically more than doubled in the mature stages (Table 1).

Of the taxa described so far, only *A.* (*Allotropiochisma*) sp. from the Wordian of the Sverdrup Basin (FEDOROWSKI & BAMBER 2001, text-fig. 7.2a) closely resembles *A. treskelense* sp. nov. Its n/d index (38/23), shape of the cardinal fossula, the free axial area and the arrangement of the major septa agree with the characteristics of *A. treskelense* sp. nov. and allows inclusion of the Canadian specimen in the synonymy of that species.

OCCURRENCE: Canadian Arctic Archipelago, Ellesmere Island (Sverdrup Basin, Degerböls Formation), Wordian; Spitsbergen, Hornsund, Treskelen Peninsula, Kapp Starostin Formation, Wordian (Text-fig. 4).

Allotropiochisma euryphylloides sp. nov.
(Pl. 3, Fig. 2; Pl. 4, Fig. 1; Pl. 5, Fig. 1; Pl. 9, Fig. 1; Text-fig. 8)

Taxa	N/d ratio	C	C-fossula	K	Alar septa	Alar fossulae	Axial area	Major septa	Minor septa	Tabularium	Range
A. svalbardicum (HERITSCH, 1939)	33/16.8	in maturity shortened	distinct	as other majors	as other majors	absent	stereocolumn	conjoined axially	very short	?	?
A.(*Allotropiochisma*) *longiseptata* (FLÜGEL, 1973)	30/13 33/18 38/18	as major septa	little different from normal septal loculi	elongated, up to corallite axis	equal to other majors	absent	in maturity majors conjoined around it	Allotropiophyl-loidally arranged	1/3-1/5 of majors length	?	Productus-Kalk U.Perm
Allotropiochisma exzentrica (FLÜGEL, 1973)	33/12 36/17	as long as other major septa; in maturity shortened	closed, bordered by 2 major septa	does not differ from other majors of the counter quadrants	slightly elongated	weakly developed	stereocolumn or free of septa	conjoined axially or not	free in corallite lumen	?	Productus-Kalk U.Perm
Allotropiochisma birkenmajeri FEDOROWSKI, 1982	32/22	very thin; shortened	little different from normal septal loculi	does not differ from other majors of the counter quadrants	unrecognisable	?	wide, free of septa	do not reach corallite axis; leave wide, free axial area	very long, up to the length of majors; contratingent or free	biform	Foldvik Creek Fm. (Upper Permian)
A.(*Allotropiochisma*) *uddenitense* FEDOROWSKI, 1987	28/9 30/12 34/15-19	as long as other major septa; shortened from early maturity	elongated over corallite axis; closed; bordered by 2 major septa	slightly elongated in early ontogeny	slightly elongated in early ontogeny	absent in maturity	in late neanic free; in maturity majors conjoined around it	Allotropiophyl-loidally arranged; withdrawn early from corallite axis	in early ontogeny only at K septum (form triad), in maturity long, contratingent and contraclined	biform; sagging axially	Gaptank Fm. (U. Carboniferous)
A. (*Alligia*) *flabellum* FEDOROWSKI, 1987	24/8 25/9 29/14-16 30/15-19	shortened from early maturity	elongated over corallite axis; closed; slightly widened axially; bordered by 2 major septa	slightly elongated in early ontogeny	slightly elongated in early ontogeny	moderately to well developed	stereocolumn permanently present	Allotropiophyl-loidally arranged; almost zaphrentoid; conjoined eccentrically	free in corallite lumen	incipient biformity at periphery; sagging axially	Gaptank Fm. (U. Carboniferous)
A. (*Abeophyllum*) *texanum* FEDOROWSKI, 1987	32/15 34/14-17 **36/21-22**	in neanic long; in maturity shortened	open; parallel walls bordered by successively shorter septa	elongated	equal to other majors	absent	free, penetrated by some major septa	pinnately arranged with free axial ends	in some loculi may be absent	incipient biformity at periphery; deeply sagging axially	Gaptank Fm. (U. Carboniferous)
Allotropiochisma treskelense sp. n.	25/8 33/15 37/20 37/22	shortened from early maturity or earlier	narrow; widened toward periphery and axis; bordered by successively shorter septa	slightly elongated in all growth stages	slightly elongated	moderately to well developed	3-4 mm open axial area; in maturity majors conjoined around it	in early ontogeny almost zaphrentoid; radially on cardinal quadrants, pinnately on counter quadrants	very short	biform; in transverse sections along to C-K plane asymmetrical	Wordian
A. euryphylloides sp. n.	28/10 36/19 39/20	varies in length	narrow; closed; variable in morphology	elongated	elongated	distinct	penetrated by some major septa or major septa conjoined around it	zaphrentoid throughout early ontogeny	very short; in some loculi may be absent	in transverse sections along to C-K plane asymmetrical	Wordian

Table 2. Morphologically comparative table of species *Allotropiochisma* FEDOROWSKI, 1982

HOLOTYPE: UAMIG.Tc-Tdn.3, 15 thin sections, 8 acetate peels; Pl. 4, Fig. 1.

TYPE LOCALITY: Treskelen (N 76º59.767; E 16º12.900; 6.5 m above sea level), southern West Spitsbergen (see Text-fig. 2).

TYPE HORIZON: Kapp Starostin Formation (Text-fig. 4), Wordian.

ETYMOLOGY: Named after its morphological similarity to the genus *Euryphyllum* HILL, 1938.

MATERIAL: Paratypes: UAMIG.Tc-Tdn.8 (50 mm long), UAMIG.Tc-Tdn.10 (30 mm long), UAMIG.Tc-Tdn.12 (45 mm long); 10 thin sections and 19 acetate peels.

DIAGNOSIS: *Allotropiochisma* with major septa

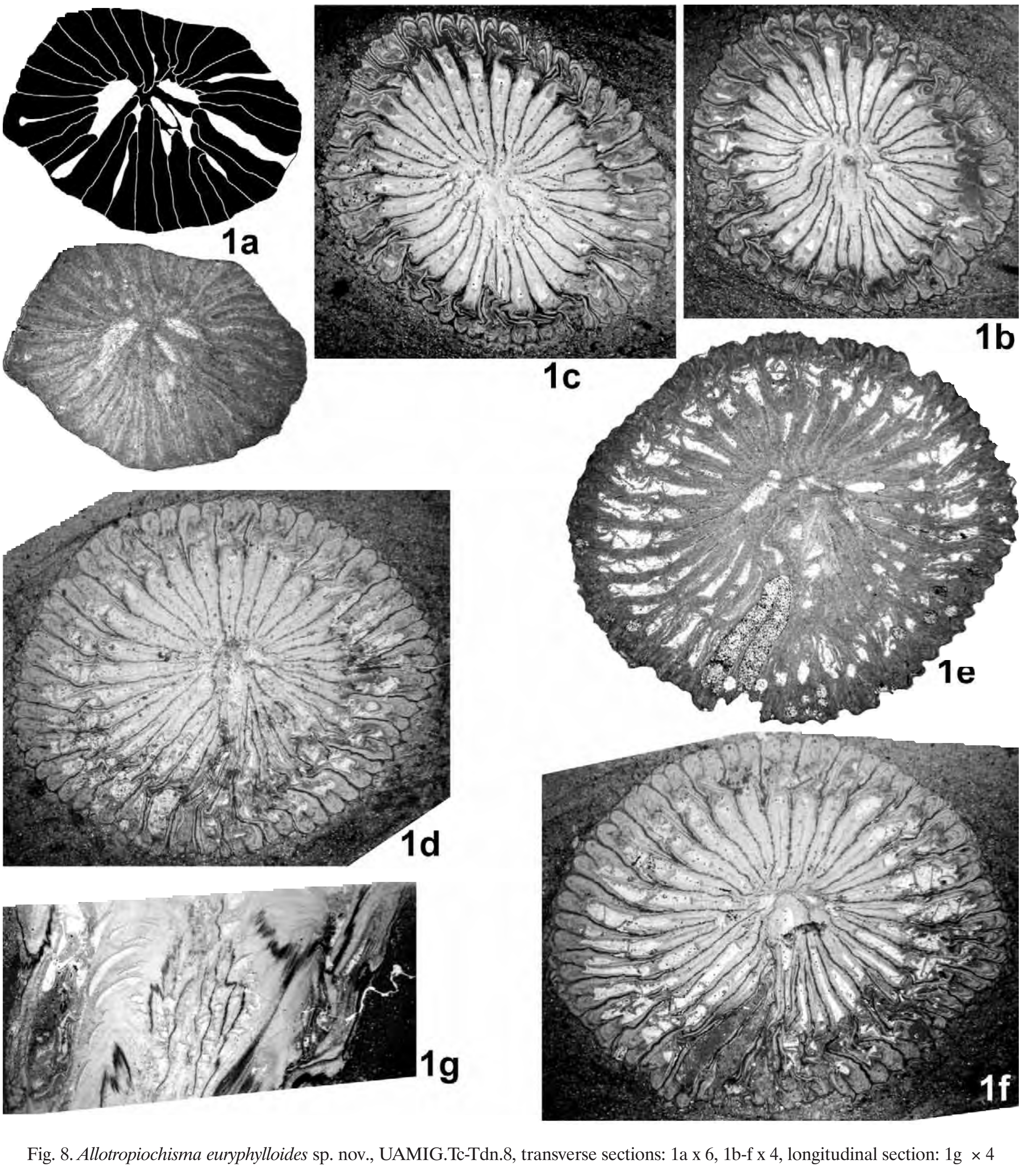

Fig. 8. *Allotropiochisma euryphylloides* sp. nov., UAMIG.Tc-Tdn.8, transverse sections: 1a x 6, 1b-f x 4, longitudinal section: 1g × 4

approximately equally thickened in all growth stages; up to 39 major septa at corallite diameter of 20 mm, near calice floor; major septa zaphrentoid throughout early ontogeny up to a position below the calice floor; counter and alar septa longer than other major septa; cardinal septum varies in length at different growth stages; cardinal fossula deep, narrow and closed, variable in morphology; Km somewhat longer than other minor septa; surface of tabularium asymmetrically raised or hemispherical and sags axially.

DESCRIPTION: The corallite is ceratoid, 80 mm long, with a slightly concave cardinal side. The calice is approximately 30 mm deep. The septothecal external wall is 1.0-2.5 mm thick and bears shallow septal grooves. The major septa almost meet at the corallite axis (Pl. 3, Figs 2a-c; Pl. 4, Figs 1i-l; Pl. 5, Figs 1a-f) and are laterally contiguous around the axial area, without being truly rhopaloid. It is only in the calice floor that the number of septa in the counter quadrants is approximately double that in the cardinal quadrants, while in earlier stages those two figures are very similar (Table 3). In the middle part of the calice (Pl. 4, Fig. 1m), major septa, except for the shortened cardinal septum, are equal in length, reaching 1/2 of the corallite radius. The cardinal septum varies in length (Pl. 3, Figs 2a-c; Pl. 4, Figs 1i-l), apparently due to its withdrawal to the margin (Pl. 5, Figs 1a-g). The counter septum is slightly longer than the counter-lateral septa (Pl. 4, Figs 1k-l). The alar septa are the longest septa in the cardinal quadrants (Pl. 4, Figs 1k-l). The narrow, closed cardinal fossula, bordered by successively shortened major septa (Pl. 3, Fig. 2b; Pl. 4, Figs 1i-l; Text-fig. 8), or by only two pairs of septa (Pl. 3, Fig 2c; Pl. 4, Fig. 1k; Pl. 5, Figs 1a, c, f), broadens at the periphery and slightly toward the axis (Pl. 4, Fig. 1l). It reaches or slightly extends beyond the corallite axis into the counter quadrants. The minor septa are distinguishable in the microstructure of the external wall already in early growth stages, but penetrate the corallite lumen only near and within the calice (Pl. 4, Figs 1k-m). The tabularium is "biformly reduced" *sensu* FEDOROWSKI (1987, p. 10); the calice floor is elevated much more in the periaxial part of the K-quadrants than in the C-quadrants (Pl. 4, Fig. 1n). The microstructure of the septa is trabecular; the trabeculae are 0.07-0.1 mm in diameter (Pl. 9, Fig. 1).

Tdn.3 [n-C,K,A/d]	Tdn.8 [n-C,K,A/d]	Tdn.12 [n-C,K,A/d]
$\frac{1\vert 2}{1\vert 1}/1.0$ $\frac{1\vert 2}{2\vert 1}/1.5$		
$\frac{2\vert 2}{2\vert 2}/2.0$ $\frac{3\vert 2}{3\vert 3}/2.5$		
$\frac{4\vert 3}{3\vert 3}/4.0$ $\frac{4\vert 3}{3\vert 3}/5.0$		
$\frac{5\vert 3}{4\vert 3}/7.0$ $\frac{6\vert 5}{4\vert 4}/8.0$		
$\frac{7\vert 6}{5\vert 4}/10$ $\frac{9\vert 9}{6\vert 5}/15$	$\frac{8\vert 8}{4\vert 4}/12$ $\frac{9\vert 9}{4\vert 4}/12.5$	$\frac{9\vert 9}{6\vert 5}/13\text{-}14$ $\frac{10\vert 10}{6\vert 5}/17$
$\frac{9\vert 10}{6\vert 5}/19$ $\frac{10\vert 11}{6\vert 5}/20$	$\frac{11\vert 10}{5\vert 5}/17$ $\frac{11\vert 10}{5\vert 5}/18$	$\frac{10\vert 11}{6\vert 5}/18$ $\frac{10\vert 11}{6\vert 5}/20$

Table 3. *Allotropiochisma euryphylloides* sp. nov. The numbers of major septa (excluding the cardinal, counter and alar septa), broken down into quadrants, at various stages of the ontogeny of the holotype (Tdn. 3) and of paratypes (Tdn. 8, 12)

ONTOGENY OF THE HOLOTYPE: At the earliest preserved ontogenetic stage (n/d ratio 11/2, Pl. 4, Fig. 1a), the cardinal, counter, counter-lateral and alar septa join in the corallite axis. The stereoplasm is developed in all septal loculi. The minor septa are not evident. The external wall is 0.2 mm thick and smooth.

In a section cut 2 mm above the previous one (n/d ratio 12/1.5, Pl. 4, Fig. 1b) and in subsequent sections (n/d ratio 14/2 and 17/2.5; Pl. 4, Figs 1c-d respectively), cut every 4 mm, the cardinal, counter, counter-lateral and alar septa remain the longest. The other major septa vary in length. The cardinal septum becomes slightly shortened at the end of this part of growth (Pl. 4, Fig. 1d). It is located in a distinct, wide fossula with almost parallel walls. The alar pseudo-fossulae are distinct (Pl. 4, Fig. 1d), and constitute the only spaces free of the stereoplasm. The external wall is up to 0.3 mm thick and bears shallow ribs.

In the next five sections, cut between 10 and 30 mm higher up (with n/d of 19/4, 21/7, 25/8 and 28/10; Pl. 4, Figs 1e-j), the major septa are arranged zaphrentoidally. The cardinal septum, located in a keyhole fossula, is equal in length to the shorter major septa. The alar septa are the longest, meeting the counter and counter-lateral septa in the calice eccentrically. The external wall is 0.2-0.3 mm thick and bears septal furrows, the depth of which depend on the state of preservation; they are deep when not abraded (Pl. 4, Fig. 1h). The minor septa are very short. Only the Km septa are slightly longer (Pl. 4, Figs 1h-i). The alar pseudo-fossulae remain distinct. The deposition of sclerenchyme is either unequal or its intensity depends on the position above or below a tabula. Thus, either a stereoplasm (Pl. 4, Figs 1e, g, i, k, l) or an almost complete infilling of the corallite axis and septal loculi is observed.

Approximately 20 mm above the preceding section (Pl. 4, Fig 1k), the n/d index = 35/15, the major septa vary in length, with the longest (alar, counter-lateral, counter and the second pair of major septa of the cardinal quadrants) reaching the corallite axis and some meeting. The cardinal septum occupies 1/2 of the long and narrow cardinal fossula, which extends to the corallite axis. The walls of the cardinal fossula are almost parallel in the peri-axial part but widen toward the periphery. The alar pseudo-fossulae are well developed. The minor septa are confined to the septotheca.

In the section cut approximately 10 mm above the previous one and immediately beneath the calice floor (Pl. 4, Fig. 1l), with n/d ratio 36/19, the major septa are of variable length, with the longest (alar and counter) reaching the corallite axis. The distinctly shortened cardinal septum is located in a narrow fossula, which reaches the corallite axis and broadens slightly in the axial part and at the external wall. The very short minor septa are essentially confined to the septotheca, with only the Km septa being somewhat longer. Positions of traverse of the tabulae (Pl. 4, Fig. 1 – see arrows; Pl. 5, Fig. 1 – see arrows), document the biform tabularium.

At 1/3 of the calice height, the major septa, except for the shorter cardinal septum, are radially arranged and equal in length. The minor septa remain very short.

INTRASPECIFIC VARIABILITY: The paratype UAMIG.Tc-Tdn.12 (Pl. 5, Fig. 1) differs from the holotype only in the slightly thinner cardinal septum and lesser stereoplasmic infilling of the septal loculi (cf. Pl. 5, Figs 1c-e). The paratype UAMIG.Tc-Tdn.8 (Text-fig. 8) differs from the holotype in the slightly higher number of septa and the somewhat smaller diameter: respectively 36 at 19 mm (holotype), and 37 at 18 mm (UAMIG.Tc-Tdn.8, Text-fig. 8.1f). Unfortunately, the number of specimens available for the study is too limited to consider the intraspecific variability established.

DISCUSSION: *Allotropiochisma euryphylloides* sp. nov. differs from all other species of the genus in its n/d indexes (39/20 *vs*.: 37/22 – *A. treskelense* sp. nov.; 32/22 – *Allotropiochisma birkenmajeri*; 30/15-19 – *A.* (*Alligia*) *flabellum*, see Table 2). Its tabularium resembles that in *A. treskelense* sp. nov. except for having the inner margins of the major septa extending to the corallite axis. It also differs from that species in the higher number of major septa in the cardinal quadrants (cf. Table 1 and 3), the very short minor septa, slightly longer Km septa, and in the cardinal septum, which begins to shorten from early maturity and is placed in a deep fossula.

OCCURRENCE: Spitsbergen, Hornsund Treskelen Peninsula, Kapp Starostin Formation, Wordian (Text-fig. 4).

Genus *Euryphyllum* Hill, 1938

TYPE SPECIES: *Euryphyllum reidi* Hill, 1938.

EMENDED DIAGNOSIS: See Fedorowski & Bamber 2001, p. 36.

Euryphyllum sp. A.
(Pl. 9, Fig. 4; Text-fig. 9)

MATERIAL: UAMIG.Tc-Tdn.18, 5 thin sections and 7 acetate peels.

DESCRIPTION: The n/d ratio ranges from 22/7.5 through 24/9, 26/10-11, 27/11 to 31/13. The major septa are thick and their inner margins are laterally contiguous. The number of major septa in the cardinal quadrants is 3-5 times lower than in the counter quadrants. The cardinal septum is shortened to approximately 1/2 the length of the neighbouring major septa (Text-fig. 9.1a-c); at the calice floor, its length is reduced to a vaguely visible rib in the wall (Text-fig. 9.1e-f). The cardinal fossula, keyhole-shaped in young growth stages and triangular in adult stages, extends beyond the corallite axis into the counter quadrants, and is bordered by the successively shortened major septa of the cardinal quadrants and periaxial margins of the almost equally long major septa of the counter quadrants. The length of the counter septum does not differ from those of the other major septa of the counter quadrants, and only in the calice is it slightly longer than the adjacent counter-lateral septa. The minor septa are noticeable in the septotheca only over the calice floor (Text-fig. 9). The septal microstructure is trabecular, with the individual trabeculae ranging from 0.07 to 0.1 mm in diameter (Pl. 9, Fig. 4). The external wall is 1.0 mm thick, with marked septal furrows.

DISCUSSION: The genus *Euryphyllum* is widely discussed in FEDOROWSKI (1987) who emphasized several fundamental characteristics of the genus. FEDOROWSKI & BAMBER (2001) supplemented that discussion. Thus, the main characteristics of that genus need not to be repeated here.

The specimen described differs from all known species of *Euryphyllum* (cf. Table 4) in its septal index, variable shape of the fossula, with a permanently shortened cardinal septum, very slow increase in the major septa in the cardinal quadrants, and the larger trabeculae, reaching 0.1 mm in diameter (Pl. 9, Fig. 4).

Some features of the morphology of the specimen described are similar to those of the *Euryphyllum* sp. A of EZAKI & KAWAMURA (1992, pl. 4, figs 1a-d) from the Kapp Starostin Formation at Festningen. Both posses a similar cardinal fossula, keyhole-shaped in young growth stages and triangular in more advanced growth, and a n/d ratio 22/7.5-24/9.0 in early growth (cf. Table 5). That ratio forms the main difference in the most advanced growth stage of both corallites. In the calice of the specimens from Festningen it amounts to 22/6 and 24/8.0, i.e. as much as in specimens from Treskelen beneath the calice floor (Table 5; Text-fig. 9.1c).

The lower n/d index in the specimen from Festningen may suggest a younger growth stage, whereas the compatible numbers of septa in the cardinal and counter quadrants in that specimen suggest a different taxonomic position. According to FEDOROWSKI & BAMBER (2001), *Euryphyllum* sp. A of EZAKI & KAWAMURA (1992) belongs in *Allotropiochisma*, as indicated by its biform tabularium.

OCCURRENCE: Spitsbergen, Hornsund, Treskelen Peninsula, Kapp Starostin Formation, Wordian (Text-fig. 4, Tdn.18 locality).

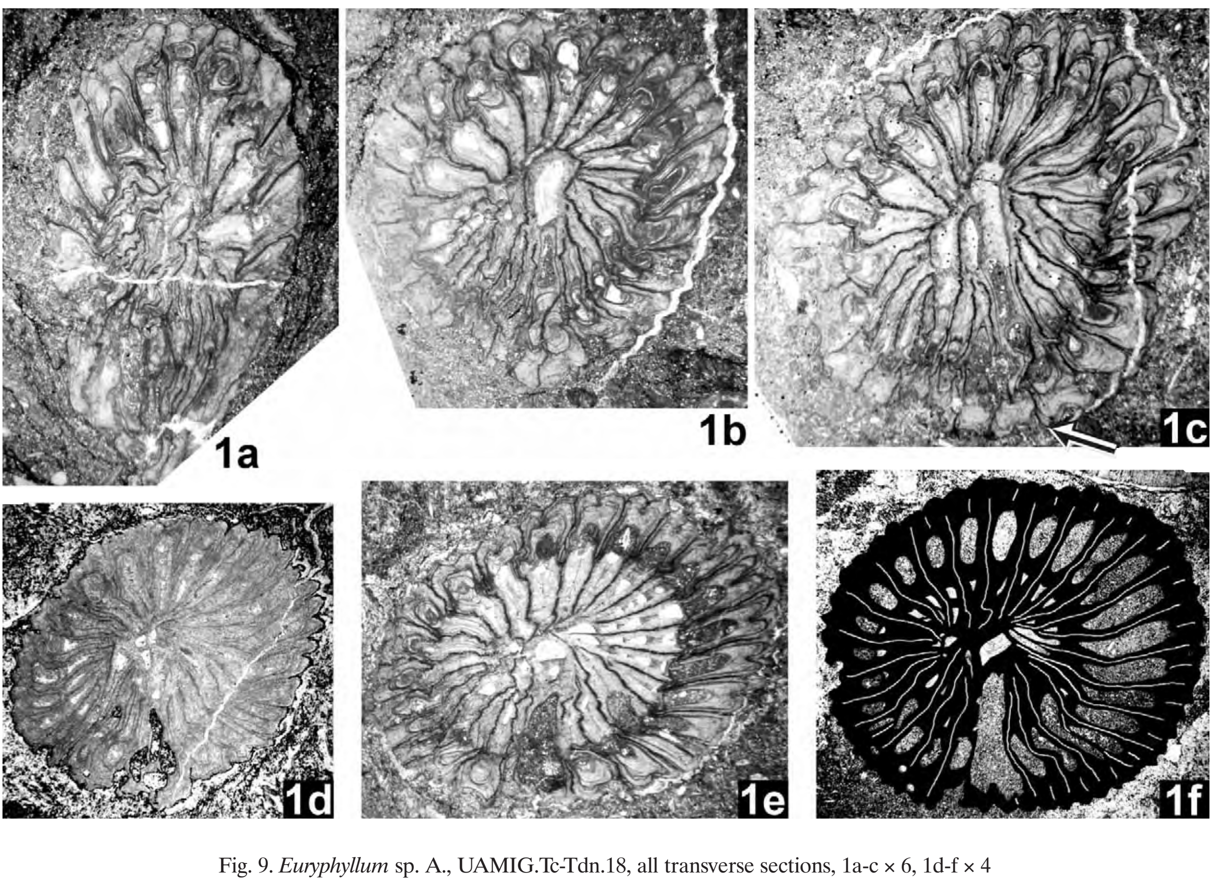

Fig. 9. *Euryphyllum* sp. A., UAMIG.Tc-Tdn.18, all transverse sections, 1a-c × 6, 1d-f × 4

characteristics	*Euryphyllum* sp. A	*E.boreale*	*E.troldfjordense*	*E.robustum*	*E.profundum*
n/d index	22/7.5, 24/9, 26/10-11, 27/11, 31/13	33:14 (holotype) 30:12 – 36:15,5	25:7; 31:12,5; 35:14; 37:20	25:7,5; 31:17; 32:19; 33:13	16:7; 19:10; 23:11; 28:17
cardinal septum	in early maturity 1/2 the length of major septa; in lower part of calice 1/6 the length of majors	varies slightly in length, generally long, do not reach corallite axis; in middle part of calice distinctly shortened	slightly shortened below calice floor; in early growth stage reaching corallite axis	in early maturity slightly shortened, thinner than other major septa; together with last pair of the major septa in the cardinal quadrants very short in mature growth stage	distinctly shortened, elongated along the cardinal fossula floor almost to the axial part of it; in early ontogenetic stage rather long
counter septum	slightly longer than adjacent counterlateral septa only in calice	slightly longer than adjacent counterlateral septa only in calice	in early growth stage slightly longer than counterlateral septa	slightly thicker and longer than the adjacent major septa	little longer than the counterlateral septa
cardinal fossula	well developed, narrow and closed; deep	well developed, narrow and closed	inconspicuous; in early growth stage distinct, parallel-walled, almost reaching corallite axis	very deep	closed axially, laterally bordered by successively shortened major septa
alar septa	longest septa in cardinal quadrants	longest septa in cardinal quadrants; become indistinguishable from other majors in middle of calice	longest septa in cardinal quadrants	slightly elongated	longest septa of all
alar fossulae	well developed, narrow and closed	well developed, narrow and closed	absent	recognizable	well seen; their axial parts are narrow
major septa	semi-radial	zaphrentoid throughout early ontogeny, up to lower part of calice; in middle part of calice almost radially arranged; shorter in the counter quadrants than in the cardinal quadrants	zaphrentoid throughout early ontogeny; in mature growth stage equally thickened; almost meet at corallite axis and contiguous laterally; not truly rhopaloid; slightly withdrawn from corallite axis, radially arranged; in calice thin in cardinal quadrants	thickened, meet at corallite axis and touching laterally; pinnately arranged in quadrants; in counter quadrants shorter and slightly thicker; in the cardinal quadrants successively shorter towards the cardinal septum	zaphrentoid throughout early ontogeny; permanently thin; inner ends of the counter quadrants are directed toward the end of the counter septum
minor septa	seen in the microstructure of the external wall only within calice	early in ontogeny not evident either in corallite lumen or in microstructure of corallite wall	in peripheral part of external wall; evident only near or within calice	sometimes seen in the microstructure of the external wall	well developed in the upper part of the calice, decrease to disappearance near its floor
tabularium		without biform morphology	calice floor elevated much more in periaxial part of counter quadrants than in cardinal quadrants	tabulae concave axially	
external wall	thick (1.0 mm) and ribbed	at early growth stages thick, smooth, with small attachment structure; later in ontogeny corallite surface deeply ribbed	at early growth stages thick, smooth or ribbed; later in ontogeny thin and ribbed or thick and smooth	bears growth lines and delicate septal furrows	delicate, shallow septal furrows
microstructure	septa trabecular 0.1mm	septa trabecular 0.03 – 0.04mm			
occurrence/age	Treskelen (Kapp Starostin Fm.), Wordian	Spitsbergen (Kapp Starostin Fm.) – Roadian (?Kungurian) or Wordian; Sverdrup Basin (Degerböls Fm.) – Wordian	Sverdrup Basin (Trold Fiord Fm.) – Wordian	Southwestern Texas (Gaptank Fm.) – Upper Carboniferous	Southwestern Texas (Lower Bone Spring Fm.) – Upper Carboniferous

Table 4. Morphologically-comparative table of species *Euryphyllum* Hill, 1938

Euryphyllum sp. A [n-C,K,A/d]	*Euryphyllum* sp. A EZAKI & KAWAMURA (1992) [n-C,K,A/d]
	$\frac{4\,\vert\,3}{3\,\vert\,3}/4.5$
$\frac{6\,\vert\,5}{2\,\vert\,2}/6.5$	$\frac{4\,\vert\,4}{4\,\vert\,4}/6.0$
$\frac{6\,\vert\,6}{2\,\vert\,2}/7.5$	$\frac{5\,\vert\,5}{4\,\vert\,4}/8.0$
$\frac{7\,\vert\,7}{2\,\vert\,2}/9.0$	
$\frac{8\,\vert\,8}{3\,\vert\,2}/11.0$	
$\frac{10\,\vert\,10}{3\,\vert\,2}/13.0$	

Table 5. The numbers of major septa (excluding the cardinal, counter and alar septa), broken down into quadrants, at various stages of the ontogeny of the Treskelen specimen and the specimen illustrated in EZAKI & KAWAMURA (1992)

?*Euryphyllum* sp. B
(Pl. 9, Fig. 3; Text-fig. 10)

MATERIAL: UAMIG.Tc-Tdn.5. Five thin sections and six acetate peels.

DESCRIPTION: The ontogenetically earliest preserved growth stage has a n/d ratio = 23/8. The corallite surface at this growth stage is substantially corroded (Text-fig. 10.1a-b). The septal furrows are shallow. The arrangement of the major septa is zaphrentoid up to the calice floor (Text-fig. 10.1a-c); the cardinal septum is about 3/4 the length of the major septa. The minor septa are not evident either in the corallite lumen or in the microstructure of the corallite wall. The external wall 0.5-0.8 mm thick and septothecal.

The mature corallite (Text-fig. 10.1c – section directly under the calice floor) is 14.0 mm in diameter, with 36, laterally contiguous major septa, meeting at the corallite axis and successively shortened in the cardinal quadrants towards the long and thin cardinal septum (Text-fig. 10.1c); the minor septa extend only slightly from the external wall. The counter septum is equal in length to the adjacent major septa. The alar septa are the longest septa in the cardinal quadrants.

In the calice floor (Text-fig. 10.1d) with n/d=37/16.5, the cardinal septum is distinctly shortened and located in a deep, narrow cardinal fossula, which reaches the inner margins of the major septa of the counter quadrants. The counter and alar septa are the longest major septa at this growth stage.

The narrow, closed, weakly developed alar pseudo-fossulae occur only in the younger growth stages. Minor septa are generally confined to the external wall, which attains a width of up to 2.0 mm. The microstructure of the septa is trabecular, with the diameter of individual trabeculae amounting to 0.1 mm (Pl. 9, Fig. 3).

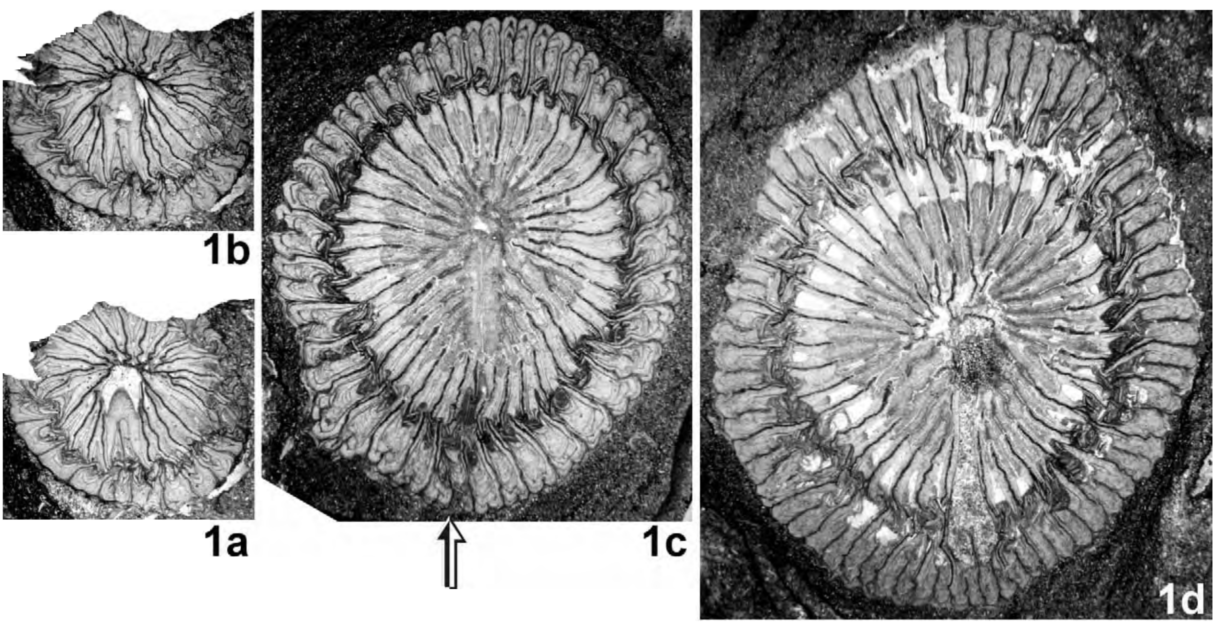

Fig. 10. ?*Euryphyllum* sp. B, UAMIG.Tc-Tdn.5, all transverse sections, 1a-d × 4; arrow in 1c shows position of cardinal septum

DISCUSSION: The identification of this specimen as ?*Euryphyllum* is doubtful, because the poor preservation of the specimen makes it impossible to determine if the tabularium is uniform or biform, which seems to be the most significant diagnostic characteristic distinguishing the species of the genera *Euryphyllum* and *Allotropiochisma*.

The specimen has been eventually identified as *Euryphyllum* by possessing: 1) long septa major, reaching the corallite axis, and arranged pinnately along the long, closed cardinal fossula and radially in the counter quadrants (Text-fig. 10.1a-d); 2) longer counter and alar septa than the remaining major septa; 3) an axial area free from septa; 4) a distinct, compact stereocolumn, extending up to the calice floor (Text-fig. 10.1d).

Characteristics of the specimen that are typical of *Allotropiochisma*, are: 1) cardinal septum shortened slightly in the early growth stages (Text-fig. 10.1a-b); 2) trabeculae up to 0.1 mm in diameter *vs*. 0.03-0.04 mm in *Euryphyllum*; 3) indistinct alar fossulae; 4) numbers of septa in quadrants

$$\left(\frac{5}{3}\Big|\frac{6}{3}/8,\ \frac{9}{5}\Big|\frac{9}{5}/14,\ \frac{10}{5}\Big|\frac{11}{5}/16{,}5\right)$$

compatible with these in *A. euryphylloides* sp. nov.

The specimen in question shows a mixture of characteristics, with those of *Euryphyllum* prevailing. Also, it resembles *Euryphyllum* sp. A in the diameter of the trabeculae and in the early shortening of the cardinal septum. Therefore, its identification as *Euryphyllum* is more likely.

OCCURRENCE: Spitsbergen, Hornsund, Treskelen Peninsula, Kapp Starostin Formation, Wordian (Text-fig. 4, Tdn.5 locality).

Gen. and sp. indet.
(Pl. 8, Fig. 1; Pl. 9, Fig. 5)

MATERIAL: UAMIG.Tc-Tdn.20 (35 mm long). 12 thin sections and 4 acetate peels were available for the study.

DESCRIPTION: A horn-shaped, non-dissepimented solitary coral, with a partly preserved calice 20 mm deep. The ontogenetically earliest preserved growth stage with n/d ratio 14/2 (Pl. 8, Fig. 1a) possesses major septa that are thin, zaphrentoidally arranged, two per quadrant. The cardinal and the counter septa connect to form the axial septum. No minor septa. The external wall, 0.2 mm thick, is almost smooth. The curved structure was probably an attachment to a rounded object.

Three mm above the previous section with n/d ratio 14/3 (Pl. 8, Fig. 1b), the thin major septa are diagenetically broken in the corallite axis. The 0.2 mm thick external wall penetrated by the peripheral parts of the major septa, bears distinct septal furrows corresponding to major and minor septa but the latter are not recognisable in the wall structure.

In subsequent, somewhat oblique sections, cut every 2 mm with n/d ratio 16/3.5-4.0 respectively (Pl. 8, Figs 1c-d), the major septa withdraw from the corallite axis, leaving an oval, aulos-like structure. The cardinal septum is almost as long as the other major septa (Pl. 8, Fig. 1d, arrow) and is located in a distinct cardinal fossula.

In a transverse section cut 5 mm beneath the calice floor (Pl. 8, Fig. 1e), with n/d index 18/4, all the major septa are strongly thickened. They form the septotheca at the periphery and are laterally contiguous around the inner part of the deep cardinal fossula delimited by the successively shortened major septa of the cardinal quadrants and the axial ends of the septa of the counter quadrants. The cardinal septum remains long (Pl. 8, Fig. 1e, arrow), and equal in thickness to the remaining major septa.

In the transverse section cut partly below the calice floor (n/d=24/7.5; Pl. 8, Fig. 1g), the major septa are thick and vary in length. In the periaxial part they touch one another laterally, forming an aulos-like structure. The thin inner margins of the longest septa extend to the corallite axis. The cardinal septum remains long and straight, slightly flaring at the periphery but the cardinal fossula lost its earlier shape, being marked only by additional section of tabulae and shortening of the last pairs of major septa. The 0.6 mm thick external wall remains clearly ribbed. Major septa are absent from its thickness. One side of the corallite was abraded from this stage up, making further description incomplete.

Immediately under the calice floor (n/d=26/11.5; Pl. 8, Fig. 1h), 7.0 mm above the previous section, the major septa are long, almost radially arranged, but do not meet at the corallite axis, leaving an open axial area 1.5 mm wide. Their inner halves join laterally around the axial part of the corallite; the resulting ring of major septa opens only at the axial margin of the cardinal fossula, which is deep and triangular. The cardinal septum is shortened, reaching less than 1/2 of the length of the adjacent major septa. The counter septum is somewhat longer than the other major septa.

In the middle of the calice height (n/d = 26/13; Pl. 8, Fig. 1i), the major septa remain long and radially arranged. They remain slightly thickened in the periaxial part, but do not touch one another laterally. The open axial area reaches 2.5 mm in diameter. The cardinal septum (Pl. 8, Fig. 1i, arrow) remains shortened to less than 1/2 of the length of the major septa. The minor septa, noticeable only at this level, are 0.3-0.5 mm long.

In a longitudinal section (Pl. 8, Fig. 1j) cut along the C–K line, the tabularium is domed, with almost flat tabulae in the axial part, corresponding to the aulos-like structure, and peripheral parts declined steeply toward the external wall. The section reaches the calice floor in its upper part, documenting the very deep cardinal fossula (Pl. 8, Fig. 1j, right).

The septal microstructure is trabecular, with individual trabeculae 0.1 mm in diameter (Pl. 9, Fig. 5).

DISCUSSION: The specimen described here has been partly damaged and diagenetically changed, but shows several features in common with *Allotropiochisma* and *Euryphyllum*.

Characteristics which resemble *Euryphyllum* are: the underdevelopment of the minor septa, a similar kind of reduction in the thickness of the major septa, their similar stereoplasmic junction around a corallite axis, the well marked interseptal ridges, the late appearance of the short minor septa, and the morphology of the normal tabularium, which does not show an axial depression in the cardinal-counter septal plan in some specimens (FEDOROWSKI 1987). The main characteristics associated with *Allotropiochisma* are: the diameter of the trabeculae, reaching 0.1 mm, the early withdrawal of the major septa from the axial part of the corallite, and the absence of a clear and permanent alar fossula (one is visible only in Pl. 8, Fig. 1g). Whilst the small size of the specimen (n/d = 26/13 in the middle of the calice height) may be explained by its immature growth compared to both genera, the simultaneous occurrence of such features as the non-septothecal external wall, the late appearance of very short but free minor septa, and the narrow stereocolumn, resembling an aulos rather than the structure present in *Allotropiochisma* or *Euryphyllum*, preclude the identification of the specimen under discussion as either of these genera.

OCCURRENCE: Spitsbergen, Hornsund, Treskelen Peninsula, Kapp Starostin Formation, Wordian (Text-fig. 4, Tdn.20 locality).

Suborder Plerophyllina SOKOLOV, 1960
Family Polycoeliidae DE FROMENTEL, 1861
Genus *Calophyllum* DANA, 1846

TYPE SPECIES: *Turbinolia donatiana* KING, 1848.

EMENDED DIAGNOSIS: See FEDOROWSKI & BAMBER 2001, p.53.

Calophyllum columnare (SCHLOTHEIM, 1813)
(Pl. 6, Figs. 1, 2; Pl. 7, Figs 1, 2; Pl. 8, Fig. 2; Pl. 9, Figs 6-9)

DIAGNOSIS: See FEDOROWSKI & BAMBER 2001, p. 54.

MATERIAL: UAMIG.Tc-Tdn.6, UAMIG.Tc-Tdn.13, UAMIG.Tc-Tdn.14, UAMIG.Tc-Tdn.21, UAMIG.Tc-Tdn.22. 30 thin section and 15 acetate peels.

DESCRIPTION: Variation in size and n/d values are shown in Text-fig. 11. The major septa are 0.2–0.8 mm thick (Pl. 6, Figs 1, 2; Pl. 7, Figs 1, 2; Pl. 8, Fig. 2) and trabecular. The trabeculae are 0.03 mm in diameter and arranged in a single row (Pl. 9, Figs 6-9). The cardinal, counter and alar septa are the longest septa and join at the axis of the corallite in the early growth stages. The other major septa vary in length. The numbers of septa in the cardinal and counter quadrants are either similar, mostly five per quadrant (Pl. 6, Figs 1, 2; Pl. 7, Fig. 2), or dominate slightly in the counter quadrants (6 *vs*. 4; Pl. 7, Fig. 1; Pl. 8, Fig. 2). The external wall is between 1.2 mm (Pl. 7, Fig. 1e) and 0.4 mm (Pl. 6, Fig. 1f) thick, with distinct septal furrows corresponding to both major and minor septa, although minor ones are not recognisable in the wall structure. The tabulae are complete, markedly convex, with somewhat asymmetrically elevated surfaces in the periaxial part of the K-quadrants (Pl. 6, Fig. 1h). The distances between tabulae are considerable (1 every 5 mm), as is evident from both the longitudinal section (Pl. 6, Fig. 1h) and the transverse sections, which only occasionally cut them (Pl. 6; Pl. 7; Pl. 8, Fig. 2).

DISCUSSION: FEDOROWSKI (1982b) discussed the species in detail (and synonymy see FEDOROWSKI & BAMBER 2001, pp 53-54). He substantially reduced the number of taxa, including several new ones introduced by FLÜGEL 1973. FEDOROWSKI (1982b) considers that the morphological differences observed resulted from the intraspecific variability. Almost twenty years later, and despite the opinion of WEYER (1984), FEDOROWSKI & BAMBER (2001) expressed the same opinion.

The present author agrees with the opinion of FEDOROWSKI (1982b) and FEDOROWSKI & BAMBER (2001), suggesting that only a single species of *Calophyllum* is present in the Guadalupian/Wuchiapingian strata of the Cordilleran-Arctic-Uralian Realm and included specimens from the Kapp Starostin Formation in Treskelen in *C. columnare*. Specimens from Treskelen do not differ significantly in n/d index from other representatives of this species (FEDOROWSKI & BAMBER 2001, fig. 10). One specimen (UAMIG.Tc-Tdn. 13; Pl. 6, Fig. 1) has a similar number of septa in younger growth stages to that shown in FEDOROWSKI & BAMBER (2001, fig. 10), but the diameters of the specimen described are smaller. The other specimen (UAMIG.Tc-Tdn. 6; Pl. 6, Fig. 2) has markedly fewer septa in the older growth stages than the specimens measured by the authors cited. This resulted from a total reduction of most septa near the calice end. Such specimens, formerly identified as *Tetralasma* SCHINDEWOLF, 1942, were recently synonymised with *Calophyllum* by WEYER (2005, fig. 2), who included them in *C. columnare*.

OCCURRENCE: Central European Basin (WEYER 1979, 1984) – Wordian or Early Capitanian; East European Platform (ILINA 1984, IVANOVSKY 1989) – Lower Kazanian, Wordian; Spitsbergen, Kapp Starostin Formation from Isfjorden (EZAKI & KAWAMURA 1992) – Wordian or Capitanian – according to FEDOROWSKI & BAMBER 2001; East Greenland, Kapp Stosch and Jameson Land, Foldvik Creek Group, Wegener Halvø Formation (FLÜGEL 1973, FEDOROWSKI 1982b) – Wordian or Early Capitanian; Sverdrup Basin, Degerbols and Trold Fiord Formations (FEDOROWSKI & BAMBER 2001) – Wordian; Spitsbergen, Kapp Starostin Formation from Treskelen – Wordian.

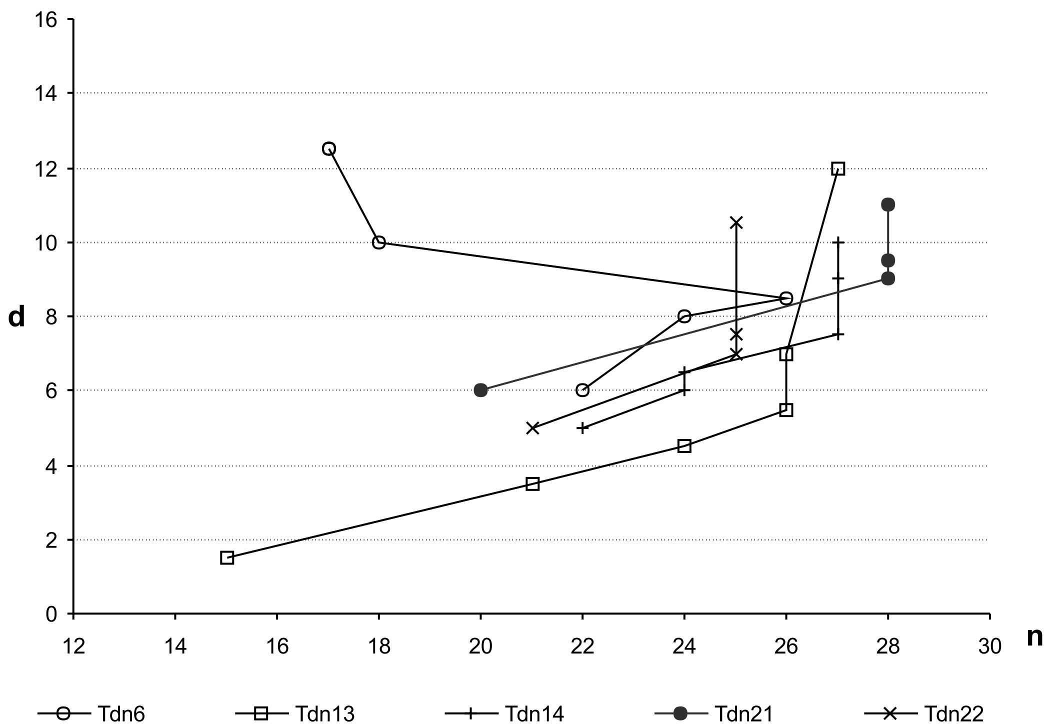

Fig. 11. *Calophyllum columnare* (SCHLOTHEIM, 1813), number of major septa *vs*. diameter; n – number of major septa, d – diameter (mm); symbols joined by lines represent values taken from individual specimens

CONCLUSIONS

The rugose corals described by TOULA (1875) and HERITSCH (1939), were perhaps derived from the Kapp Starostin Formation, but their stratigraphic position remains uncertain. All of them were lost during the Second Word War. In the latest study (EZAKI & KAWAMURA 1992) only a few specimens are illustrated. The rugose corals described in the present paper represent the first, fully described collection of these anthozoans from the Kapp Starostin Formation appearing in Treskelen. The Rugosa encountered in the uppermost strata of this formation are predominantly large (with diameters of approximately 2 cm and heights of 5-10 cm), solitary, non-dissepimented corallites identified as *Allotropiochisma*, *Euryphyllum* and *Calophyllum*, which are generally considered to be cold-water genera, in accordance with the suggestions of EZAKI (1997) and KEILEN (1992). Similarly, the studies of foraminifers (chloroforam), chlorosponges and of bryozoans (bryonoderm), by BEAUCHAMP (1994) and BEAUCHAMP & BAUD (2002), also showed that already by Asselian and Sakmarian times, sedimentation of shallow water carbonates on the northern bank of Pangea was taking place in cool waters. Progressive cooling of the climate in the Cisuralian (connected with the drift of the northerly landmass) led in the late Artinskian and Kungurian to the extinction of both colonial rugose corals and fusulinaceans (FEDOROWSKI & *al*. 2007). Consequently, in the Guadalupian the cold-water fauna dominates. Therefore, the fact that the rugose coral fauna from the Kapp Starostin Formation on Treskelen is of low diversity, characterized by non-dissepimented types and lacks colonial forms, qualifies it as a cold-water fauna.

The slight abrasion of the external walls of the corals indicates relatively insignificant transport, whereas the arrangement of specimens parallel to each other that can be observed on the upper surfaces of particular beds, suggests wave transport.

Unlike the coral fauna of the Cordilleran-Arctic-Uralian Realm, of which Spitsbergen was a part, the age of the corals of the Kapp Starostin Formation (in Treskelen) may be considered as, at their youngest, Wordian. Evidence of this is the concurrence of species of the genera *Euryphyllum* and *Allotropiochisma*, dated to Roadian–Wordian, and *Calophyllum*, dated to Wordian–Capitanian.

The corals studied by the present author differ markedly from those of the lower-lying upper strata of the Treskelodden Formation (the counterpart of the Tyrrellfjellet Member of the Wordiekammen Formation in Isfjorden), which are considered by SOMERVILLE (1997) to record tropical and/or subtropical conditions. These tropical fauna are dominated by large caniniids and colonial rugosans (SOMERVILLE 1997). FEDOROWSKI & *al*. (2007) suggest an Early Sakmarian (Testubian) age for the Upper Treskelodden Formation. This, in turn, means that in the southern Treskelen Peninsula, from where the corals described come, the stratigraphic gap includes the stages from Upper Sakmarian through Artinskian to Roadian (the Gipshuken Formation, and the Svenskeegga and Voringen Members, encountered in the area of the Isfjorden). To support this hypothesis, it is important to note that *Tschussovskenia minor* FEDOROWSKI, 1965, a species known only from the Lower Asselian (Ural–Timan) and the Lower Sakmarian (Spitsbergen), occurs in the uppermost part of the Treskelodden Formation, available in the lithostratigraphic scheme studied by the present author (Text-fig. 4, sample Tdn.24). This fact lends further support to the hypothesis that during Late Sakmarian–Roadian times, the Treskelen area was uplifted and that is why the erosion here reached deeper. After levelling (planation) in Wordian time, a shallow cool sea covered the area, as suggested by the absence of dissepimented and colonial forms and the presence of small non-dissepimented horn-shaped corals.

Hopefully, the present study of the corals of the Kapp Starostin Formation in Spitsbergen will complement the earlier accounts of the coeval (according to FEDOROWSKI & BAMBER 2001) fauna of the Sverdrup Basin in the Canadian Arctic Archipelago, the very scarce Zechstein coral fauna of the Central European Basin, and the probably richest fauna of the short-lasting marine transgression which extended from Pechora to the region of the Volga in the Guadalupian, the latter described by NECHAEV (1894), SOSHKINA (1925, 1928, 1932) and SOSHKINA & *al*. (1941), as well as offer further support to the palaeogeographic reconstructions of that time (Text-fig. 1) and enhance the stratigraphic correlation.

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