Arcticoporidae Fam. Nov. (Bryozoa, Trepostomata) from the Lower Triassic of Ellesmere Island (Canada) with Remarks on some other Triassic Bryozoans

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Abstract

The type series of *Arcticopora christiei* Fritz, 1961—type species of *Arcticopora*—has been restudied and compared with recently collected material from time-equivalent beds of Ellesmere Island, Canadian Arctic. Taxonomically important characters previously not discussed include diaphragms in both endozone and exozone, irregularly shaped zooecial apertures and growth of acanthostyles. The bryozoan beds containing *A. christiei* are confirmed as Late Dienerian – Early Smithian (Early Triassic) based on new conodont data. Most Triassic species of *Paralioclema* and *Pseudobatostomella* are transferred to *Arcticopora*. A new family Arcticoporidae fam. nov. is erected, including *Arcticopora* Fritz, 1961; *Zozariella* Schäfer and Fois, 1987; *Vysokella* Zágoršek, 1993; and *Dyscritellopsis* Schäfer and Grant-Mackie, 1994.

Introduction

Bryozoans of the orders Trepostomata, Cystoporata, Cryptostomata and Fenestrata were widespread and diverse in the Permian of both Boreal and Tethyan seas. Only a few Paleozoic genera survived the Permian/Triassic boundary, and only two new genera evolved during the Early Triassic: *Arcticopora* Fritz, 1961 originally described from Ellesmere Island (Canadian Arctic) and *Dyscritellopsis* Schäfer and Grant-Mackie, 1994 originally described from New Zealand. Only six undisputed Early Triassic bryozoan species have formally been described, all from the Boreal region. This is in strong contrast to the increased diversity through the Middle and Late Triassic with a total number of more than 40 species (see review in Schäfer and Grant-Mackie 1994, Schäfer et al. 2003).

Two occurrences of supposed *Arcticopora* in younger Triassic rocks of the European Tethys have previously been synonymised with *Dyscritella zardinii* Schäfer and Fois, 1987 (*Arcticopora* sp. in Boardman 1984) and *Pseudobatostomella recubariensis* (Schauroth 1855) (*Arcticopora recubariensis* (Schauroth 1855) in Bizzarini et al. 1989). Morozova (1986) synonymised several species of Triassic *Pseudobatostomella* and *Batostomella* with *Arcticopora* – a view that is followed by us, but in the same publication she retained some species in the genus *Paralioclema* which in the current work we have placed in *Arcticopora*.

Material

In this study the type material of *Arcticopora christiei* Fritz, 1961 was re-examined, and new material from several localities in Ellesmere Island was thin sectioned and investigated. Material from the following sections was studied (all from the Lower Triassic Blind Fiord Formation) (Fig. 1): Blue Mountains (80°47′ N, 85°02′ W), Smith Creek Member (Smithian); northern shore of Otto Fiord (81°11′ N, 86°11′ W), 10 m below top of the Confederation Point Member (Late Dienerian); south of the head of Otto Fiord (80°15′ N, 84°37′ W), upper part of the Smith Creek Member (Late? Smithian); Confederation Point (80°37′ N, 87°31′ W), upper part of the Conferederation Point Member (Late Dienerian).

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Nakrem & Ernst. Figure 1.

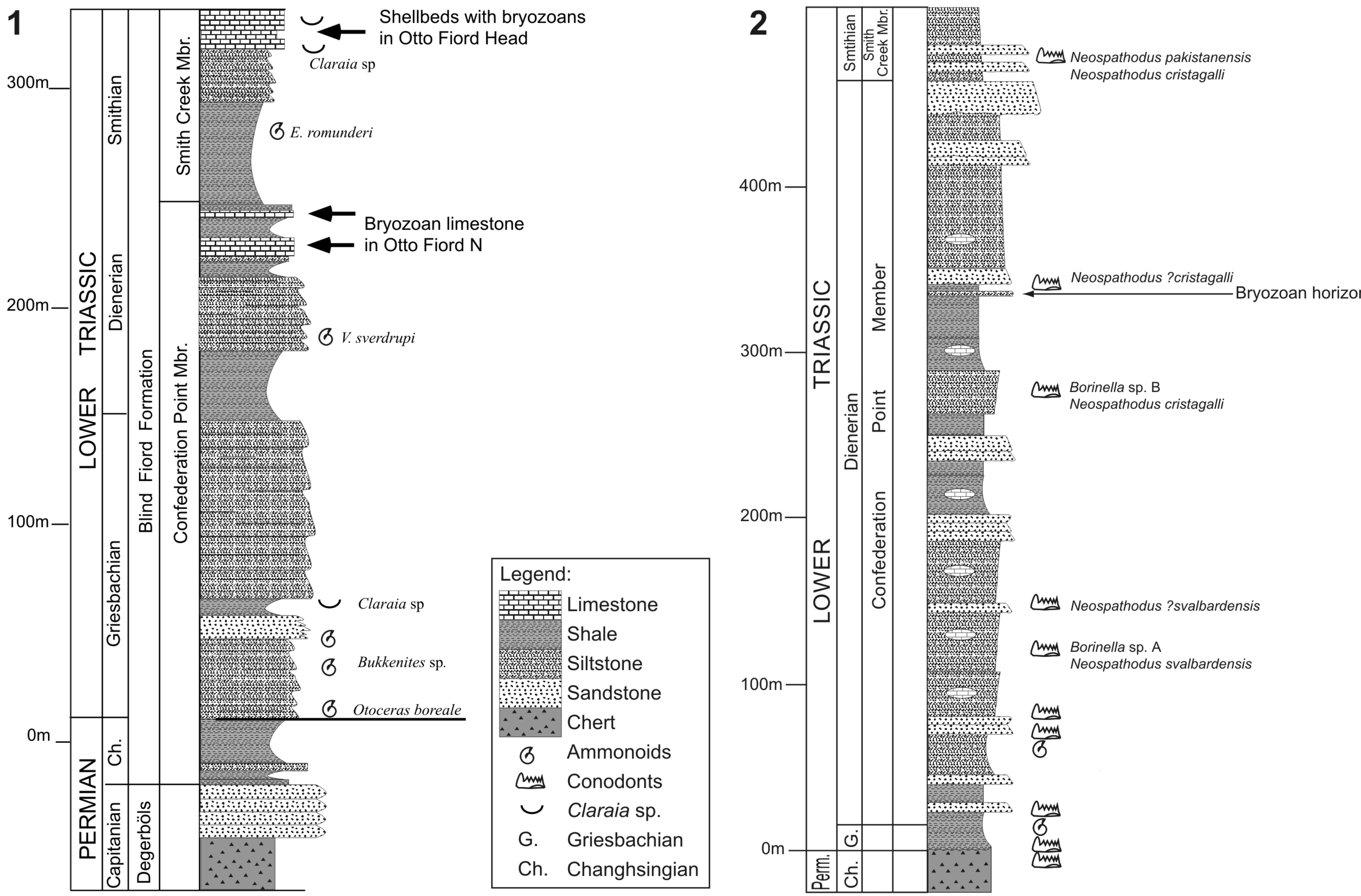

Figure 1. Lithologic section from the Lower Triassic Blind Fiord Formation of Ellesmere Island. (1) Otto Fiord section indicating two bryozoan beds and associated ammonoids. (2) Confederation Point section, indicating a single bryozoan bed and associated conodonts.

The bryozoan material published by Fritz (1961) was collected by the Canadian Geological Survey (samples GSC 10783-87) from the north shore of Lake Hazen (northeast Ellesmere Island) of Dienerian-Smithian age. An additional occurrence of *Arcticopora christiei* was reported by Bolton (1961) from the northwestern side of Van Hauen Pass (northwest Ellesmere Island) 450 m above the base of the Blind Fiord Formation, Dienerian-Smithian age (sample GSC 10789, a-c).

The thin sections illustrated in this study are housed in the Geological Survey of Canada, Ottawa, Canada (GSC), the National Museum of Natural History, Smithsonian Institution, Washington, DC, USA (USNM) and in the Natural History Museum, University of Oslo, Norway (PMO).

Systematic Paleontology

Phylum Bryozoa Ehrenberg, 1831
Class Stenolaemata Borg, 1926
Order Trepostomata Ulrich, 1882
Family Arcticoporidae fam. nov.

Type genus: *Arcticopora* Fritz, 1961 from the Early Triassic (Late Dienerian – Early Smithian) of Ellesmere Island, Canada.

Diagnosis: Zoaria cylindrical, branching and encrusting. Endozone and exozone separation indistinct to significantly distinct. Endozone thin-walled, autozooecia polygonal in transverse section; budding pattern of autozooecia acyclical in zooecial corners (interzooecial). Exozone of variable width. Basal diaphragms rare to absent in endozone, rare to abundant in exozone, usually abundant in transition between endozone and exozone. Autozooecia long in endozone, almost parallel to zoarial growth direction, more or less rapidly bending outward in endozone, meeting colony surface at high angles. Autozooecial apertures irregularly rounded to oval in shallowest tangential section, often indented by acanthostyles, more angular in slightly deeper tangential section, arranged randomly on colony surface. Zooecial walls moderately thickened in exozone, non-beaded. Distinctly convex lamellar wall microstructure, zooecial boundaries amalgamated. Heterozooecia (mesopores in Boardman and Buttler 2005) usually abundant, originating in the inner exozone, containing rare to abundant basal diaphragms. Distinct difference in diameter between autozooecia and smaller heterozooecia. Acanthostyles common to abundant, moderately thick, of one size, originating in endozone or exozone.

Included genera: *Arcticopora* Fritz, 1961; *Zozariella* Schäfer and Fois, 1987; *Vysokella* Zágoršek, 1993; *Dyscritellopsis* Schäfer and Grant-Mackie, 1994.

Comparison: Arcticoporidae fam. nov. differs from the most similar family Dyscritellidae Dunaeva and Morozova, 1967 in having acanthostyles of one size and usually more abundant basal diaphragms, both in autozooecia and heterozooecia. The new family differs from the family Heterotrypidae Ulrich, 1890 in having lamellar wall structure instead of amalgamated in the latter family. Furthermore, heterozooecia of Heterotrypidae contain consistently abundant diaphragms, whereas the number of diaphragms in heterozooecia of Arcticoporidae is highly variable. Zozariellidae Zágoršek, 1993 partly embraces Arcticoporidae fam nov. and is included in the latter family, the indistinct boundary between the endozone and the exozone (Zágoršek 1993, 51) is herein considered a less important character (see discussion under *Arcticopora*). Generic characters of both *Vysokella* (considered herein as synonym of *Zozariella*) and *Zozariella* fall well within the broader definition of Arcticoporidae.

Occurrence and age: Representatives of the family Arcticoporidae fam. nov. are restricted to the Triassic (Griesbachian – Norian), recorded from North America, Europe, Siberia, New Zealand, Japan and the Arctic region.

Genus *Arcticopora* Fritz, 1961

Arcticopora Fritz, 1961:53; Bolton, 1961:55; Astrova, 1978:146; Morozova, 1986:71; Schäfer and Fois, 1987:177; Bizzarini et al., 1989:92.

Batostomella (pars) Lazutkina, 1963:126.

Pseudobatostomella (pars) Morozova, 1969:54; Sakagami, 1972:275.

Paralioclema (pars) Morozova, 1969:51; Morozova, 1986:68; Nakrem and Mørk, 1991:135.

Type species: *Arcticopora christiei* Fritz 1961 from the Early Triassic (Late Dienerian – Early Smithian) of Ellesmere Island, Canada.

Revised diagnosis: emended from Fritz (1961), Astrova (1978) and Schäfer and Fois (1987):

Zoaria cylindrical, branching and encrusting. Significant distinction between endozone and exozone. Endozone thin-walled, autozooecia polygonal in transverse section; budding pattern of autozooecia acyclical in zooecial corners (interzooecial). Autozooecia long in endozone, almost parallel to zoarial growth direction, rapidly bending outward in endozone, meeting colony surface at 90° angles. Basal diaphragms locally present, more common in transition between endozone and exozones. Autozooecial apertures irregularly rounded to oval in shallowest tangential section, indented by acanthostyles, more angular in slightly deeper tangential section, arranged randomly on colony surface. Basal diaphragms common in exozones. Zooecial walls moderately thickened in exozone,

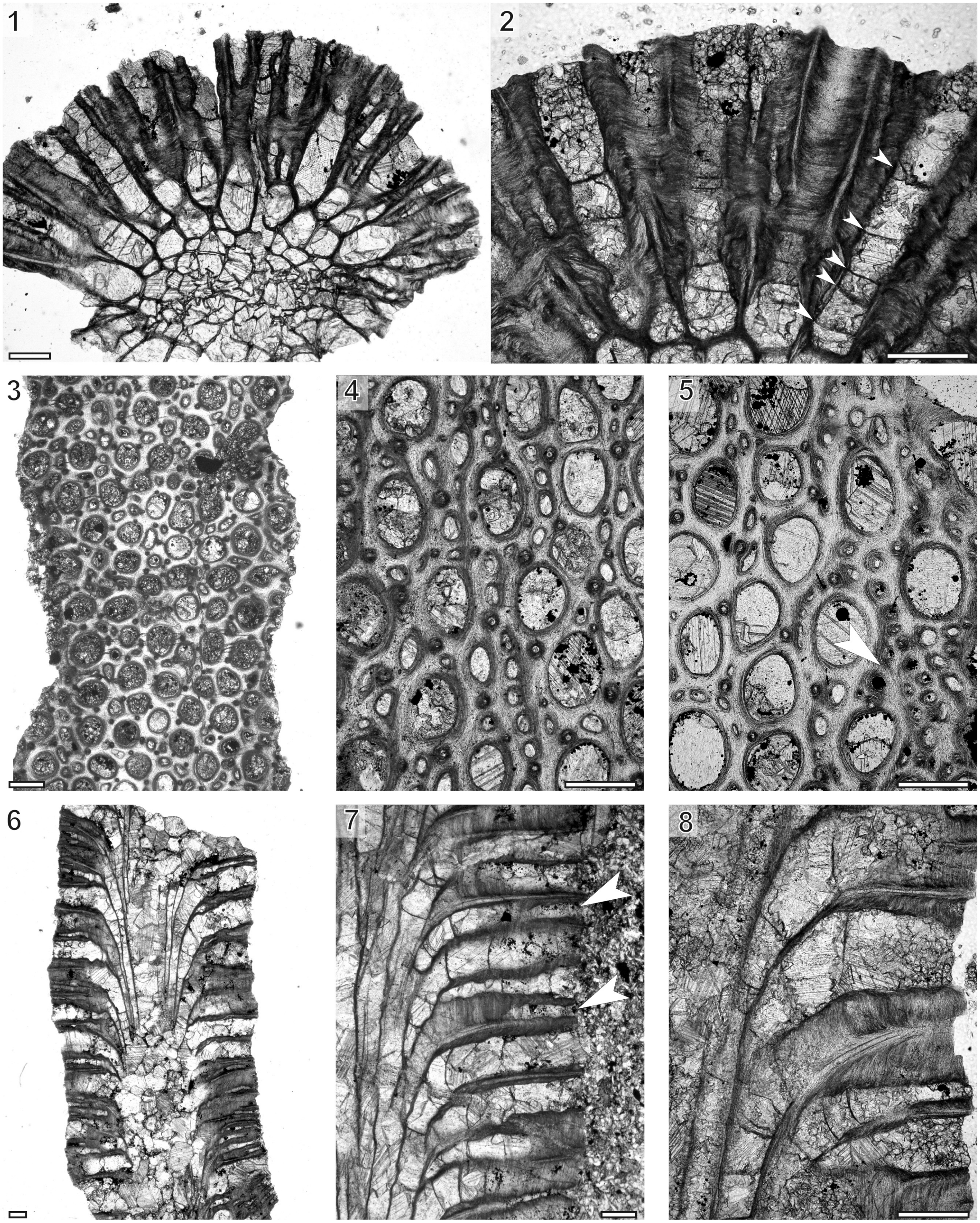

Figure 2. Fritz' syntypes of *Arcticopora christiei*. All scale bars = 0.2 mm. 1. Transverse section, CGS 10783. 2. Transverse section, arrows pointing at basal diaphragms, lectotype, CGS 10786. 3. Tangential section, lectotype, CGS 10786. 4. Tangential section, CGS 10785. 5. Tangential section, arrow points at maculum with abundant heterozooecia and few autozooecia, CGS 10785. 6. Axial longitudinal section, CGS 10784. 7. Axial longitudinal section, arrows point at heterozooecia, CGS 10784. 8. Longitudinal section, lectotype, CGS 10786.

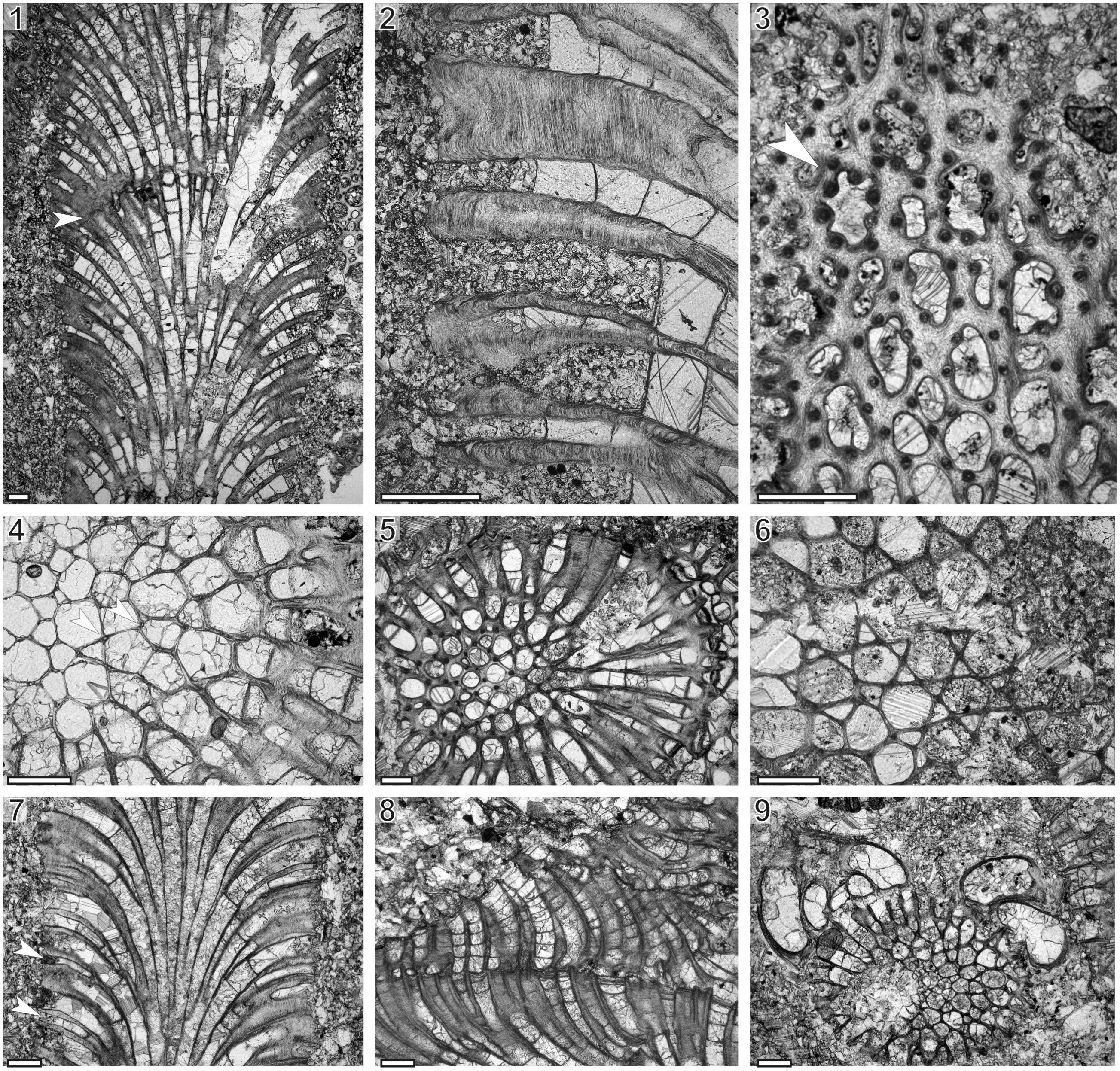

Figure 3. *Arcticopora christiei*. All scale bars = 0.2 mm. 1. Off-axial longitudinal section with zone of regeneration (arrow), northern shore of Otto Fiord, PMO 207.894. 2. Exozone, longitudinal section showing diaphragms blocking sediment influx into zooecia, northern shore of Otto Fiord, PMO 207.890. 3. Shallow tangential section showing irregular outline zooecial apertures due to projecting acanthostyles (arrow), Blue Mountains, PMO 138.112. 4. Transverse section showing acanthostyles originating in inner endozone (arrows), northern shore of Otto Fiord, PMO 170.795. 5. Transverse section close to zone of regeneration giving the impression of thick-walled endozone, northern shore of Otto Fiord, PMO 207.895. 6. Transverse section, endozone, showing star shaped budding pattern (proximal triangular to more distal hexagonal zooecia), northern shore of Otto Fiord, PMO 207.890. 7. Axial longitudinal section, northern shore of Otto Fiord, PMO 207.894. 8. Intrazoarial overgrowth, longitudinal section, with up to 14 diaphragms in exozone, northern shore of Otto Fiord, PMO 170.796. 9. Transverse section of zoarium with two microconchid tubeworms or foraminifers attached, Blue Mountains, PMO 138.109.

non-beaded. Distinctly convex lamellar wall microstructure, zooecial boundaries amalgamated. Heterozooecia abundant, originating in the inner exozone, basal diaphragms present or absent. Distinct difference in diameter between autozooecia and smaller heterozooecia. Acanthostyles common but irregularly scattered, moderately thick, of one size, originating in endozone or exozone.

Comparison: *Arcticopora* is similar to *Pseudobatostomella*, but distinguished from the latter by a less regular budding pattern arrangement of autozooecial apertures and more abundant diaphragms (Astrova 1978). *Pseudobatostomella* also lacks diaphragms in the smaller heterozooecia. Furthermore, *Pseudobatostomella* is known only as a branching form, whereas *Arcticopora* can also develop encrusting sheets.

Arcticopora is distinguished from *Dyscritella* by the lack of diaphragms in the latter genus – "diaphragms absent in autozooecia and exilazooecia" (Schäfer and Fois 1987, 177). Diaphragms have rarely been reported in Paleozoic species of *Dyscritella*, and we consider this character to be an important distinguishing feature. Therefore Triassic species of *Dyscritella* with common to abundant diaphragms should be transferred to *Arcticopora*, but this is considered outside the scope of the present work. We follow the views expressed in Astrova (1978) that *Paralioclema* should remain a Devonian genus, and that subsequently Triassic forms originally described as *Paralioclema* should be transferred to *Arcticopora* (Table 1). The major difference between Devonian *Paralioclema* and Triassic *Arcticopora* is the type of heterozooecia. Heterozooecia of *Paralioclema* always have abundant basal diaphragms, whereas basal diaphragms in heterozooecia of *Arcticopora* occur only sporadically. Additionally, acanthostyle diameter in *Paralioclema* can vary markedly even within the same colony.

Vysokella Zágoršek, 1993 and *Zozariella* Schäfer and Fois, 1987 are similar to *Articopora* but are distinguished by the indistinct transition between endozone and exozone in the former two genera. Defining this transition is somewhat problematic as it changes according to orientation of thin sections (see discussion below). *Vysokella* is generally distinguished from *Zozariella* by a stellar budding pattern in the former genus (Zágoršek 1993). However, this character is difficult to distinguish in the original description and illustrations (Zágoršek 1993), therefore this character should not be used to separate these two genera. In *Zozariella* the heterozooecia are distributed in a starlike pattern around acanthostyles (Schäfer and Fois 1987), but we agree with Zágoršek (1993) that this pattern is probably a specific rather than a generic character. *Vysokella* is thus considered a junior synonym of *Zozariella*.

Emended description *Arcticopora christiei* Fritz, 1961 Figs. 2, 3

Arcticopora christiei Fritz, 1961:53, pl. 1, figs. 1-2, pl.2, figs. 1-2, pl. 3, figs. 1-2; Bolton, 1961:55; Astrova, 1978:146, pl. 37, fig. 1a-b; Schäfer and Fois, 1987:177, pl.1, figs. 7-9.

Material examined: Types series (syntypes): GSC10783-87 and USNM 168367-1F, 1H, 1I. Bolton (1961) material: GSC10789. Additional material studied: From Blue Mountains (6 thin sections, PMO 138.109-114); northern shore of Otto Fiord (17 thin sections, PMO 170.791-798, and 207.890-896); south of the head of Otto Fiord (3 thin sections, PMO 170.787-789); Confederation Point (2 thin sections, PMO 170.799-800). Specimen GSC10786, from Fritz' syntype series, is herein selected as lectotype, Figs. 2.2, 2.3, and 2.8.

Diagnosis: As for genus.

Revised description: Zoaria form slender, frequently branching, cylindrical stems, sometimes branching from an encrusting base. Growth irregularities are indicated by regeneration and self-encrustrations. The endozone – exozone transition is distinct as observed in axial longitudinal section (Figs. 2.6 and 2.7). In off-axial longitudinal section (Fig. 3.1) this transition may seem indistinct.

Endozonal walls are thin. Autozooecia are proximally triangular and distally more rounded to polygonal, infrequently forming a proximal star-shaped pattern (Fig. 3.6). Basal diaphragms are commonly developed in the transition between endozone and exozone but sometimes also developed in the proximal part of the zooecia (Figs. 2.7 and 3.7). The distance between diaphragms decreases towards the surface of the colony.

Acanthostyles are positioned in zooecial corners (Fig. 3.4) and originate in the endozone. Acanthostyles are prominent, projecting as blunt spines above the surface of the zoarium (Fig. 3.2), with a narrow light core and a dark corona.
Heterozooecia originating in exozone occur in varying number. Distribution of basal diaphragms is much the same as in autozooecia. Locally maculae are developed with heterozooecia forming clusters but with few autozooecia.

Autozooecial apertures commonly have an irregular outline due to projecting acanthostyles into autozooecial lumina in shallowest tangential section. Slightly deeper the apertures are rounded or oval, becoming more angular in even deeper section. The syntypes are generally ground too deep to reveal this irregular outline.

Measurements: See Table 2.

Discussion: Regenerated growth and self-encrustations often trap biological particles, and in some cases the zoaria form a substrate for encrusting microconchid tubeworms or foraminiferans (Fig. 3.9). Irregular growth may be result of rapidly changing and/or infavorable living conditions or substrate competition.

Thin sections made close to regenerated zoaria tips sometimes form less typical endozonal patterns (i.e. displaying superficially thicker endozonal walls (Figs. 3.1 and 3.5)).

Diaphragms are irregularly scattered in the endozone and exozone of both autozooecia and heterozooecia; they are usually more crowded in the exozone near the surface of the colony. It is thus not possible statistically to state an average number in a certain distance or per zooecium. The Bolton (1961) thin sections are prepared rather obliquely, and they have not provided additional information in the current study.

Distribution: In the original description Fritz (1961) referred to the additional material of *A. christiei* published by Bolton (1961) and assigned an Early Triassic age to the bryozoan beds. The additional material studied herein is well dated by conodonts and ammonoids (Baud and Beauchamp 2006, Baud et al., in press) confirming a Late Dienerian age for most beds, although bryozoans are also studied from an Early Smithian collection. *A. christiei* is known only from Ellesmere Island, Canada.

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Table 1. Species assigned to *Arcticopora* Fritz (sorted stratigraphically).

Species		Age	Locality
Paralioclema formosum Morozova, 1969	Late Triassic	Norian	NW Caucasus
Paralioclema abnorme Morozova, 1969		Carnian	NW Caucasus
Paralioclema dagysi Morozova, 1969		Carnian	NW Caucasus
Pseudobatostomella kobayashi Sakagami, 1972		Carnian	Japan
Pseudobatostomella morbosa Morozova, 1969		Carnian-Norian	Jakutzk, Primor Region, Pamir
Pseudobatostomella delibis Morozova, 1969		Ladinian-Carnian	Primor Region
Paralioclema amurense Morozova, 1969	Middle Triassic	Anisian	Primor Region
Pseudobatostomella sparsa Morozova, 1969		Anisian	NW Caucasus
Chaetetes recubariensis Schauroth, 1855		Anisian	Italy
Batostomella jakutica Lazutkina, 1963	Early Triassic	Griesbachian-Dienerian	Jakutzk (Siberia)
Paralioclema winsnesi Nakrem & Mørk, 1991		Dienerian-Smithian	Spitsbergen
Arcticopora christiei Fritz, 1961		Dienerian-Smithian	Ellesmere Island

Table 2. Measurements of *A. christiei* Fritz (1961) syntypes including new designated lectotype and new material (see text for details). Abbreviations (all dimensions in mm except Ac/Ap): N = Number, X = Mean, SD = Standard deviation, CV = Coefficient of variation, Min = Minimum value, Max = Maximum value, ZD = Zoarium diameter, ExW = Exozone width (tangential section), AW = Aperture width, ADB = Distance between aperture centers, HzW = Heterozooecia width (tangential section), AC = Acanthostyle diameter, Ac/Ap = No. of acanthostyles per autozooecium.

Syntypes, GSC						
		X	SD	CV	Min	Max
ZD	3	2.373	0.095	3.982	2.30	2.48
ExW	7	0.914	0.190	20.780	0.76	1.25
AW		0.119	0.010	8.094	0.09	0.13
ADB		0.289	0.031	10.787	0.24	0.36
HzW		0.029	0.007	24.736	0.02	0.05
AC		0.042	0.008	18.357	0.03	0.05
Ac/Ap		4.2	0.632	15.058	3	5
Syntypes, USNM						
		X	SD	CV	Min	Max
ZD	2	3.130	0.028	0.904	3.11	3.15
ExW	2	0.895	0.035	3.950	0.87	0.92
AW		0.127	0.009	7.277	0.11	0.15
ADB		0.242	0.044	18.215	0.17	0.31
HzW		0.023	0.008	34.960	0.01	0.03
AC		0.032	0.004	11.418	0.03	0.04
Ac/Ap		4.1	0.876	21.356	3	5
Blue Mountain sample, PMO						
		X	SD	CV	Min	Max
ZD		1.380	0.323	23.394	1.14	2.19
ExW		0.468	0.082	17.586	0.33	0.57
AW		0.091	0.007	8.108	0.08	0.10
ADB		0.234	0.039	16.833	0.19	0.31
HzW		0.031	0.008	26.605	0.02	0.05
Ac		0.037	0.004	9.514	0.03	0.04
Ac/Ap		5.7	0.704	12.274	5	7

Table 2 continued

Confederation Point locality, PMO						
		X	SD	CV	Min	Max
ZD	6	1.523	0.080	5.246	1.43	1.62
ExW	6	0.545	0.060	11.055	0.48	0.65
AW		0.124	0.019	15.009	0.10	0.16
ADB		0.276	0.042	15.200	0.19	0.35
HzW		0.060	0.009	15.677	0.04	0.07
AC		0.027	0.002	8.399	0.02	0.03
Ac/Ap		5.7	1.073	18.937	4	8

Northern shore of Otto Fiord sample 1, PMO						
		X	SD	CV	Min	Max
ZD	6	1.833	0.418	22.820	1.10	2.27
ExW	6	0.673	0.029	4.372	0.64	0.72
AW		0.126	0.007	5.313	0.12	0.14
ADB		0.240	0.016	6.804	0.22	0.26
HzW		0.044	0.010	22.744	0.03	0.06
AC		0.032	0.005	17.018	0.03	0.04
Ac/Ap		5.4	0.966	17.891	4	7

Northern shore of Otto Fiord sample 2, PMO						
		X	SD	CV	Min	Max
ZD	7	2.079	0.185	8.877	1.80	2.25
ExW	5	0.690	0.152	21.979	0.50	0.90
AW		0.146	0.008	5.776	0.13	0.16
ADB		0.249	0.009	3.613	0.24	0.26
HzW		0.055	0.010	18.182	0.04	0.07
AC		0.031	0.007	23.720	0.02	0.04
Ac/Ap	6	4.5	0.548	12.172	4	5

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