

Permian Bryozoans from North Ellesmere Island, Canadian Arctic Archipelago

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Abstract Eighteen species of Permian bryozoans in three limestone blocks collected from North Ellesmere Island include two cystoporates, ten trepostomes, and six cryptostomes. Four species, *Goniocladia regularis*, *Tabulipora ellesmerensis*, *Araxopora? ikedai* and *Helenopora phillipsae* are new. The bryozoan fauna is typical of the Permian Arctic realm, except that fenestrates are absent.

Key words : Permian, Bryozoans, Ellesmere Island.

Introduction

After arriving at the North pole, the Nihon University North Pole Expedition Team (1978) discovered and collected some blocks of fossil-bearing limestone near Cape Joseph Henry (64°00'W, 82°44'N), North Ellesmere Island (Fig. 1). These collections including Permian bryozoans and brachiopods were reported by Hamada and Sakagami (1982), but did not involve detailed study of the material. The present article provides a systematic description of the bryozoans in the limestone blocks.

Bryozoan Assemblage

Twelve genera and 18 species, consisting of two cystoporates, ten trepostomes and six cryptostomes of Permian bryozoans were identified from the three limestone blocks (Table 1). The bryozoan assemblages in each of the three limestone blocks show differences but two species, *Tabulipora intermedia* and *Primorella tundrica*, are common to all three assemblages. Three species are common to Limestone blocks; LB-1 and LB-2, four species are common to LB-1 and LB-3, and four species are common to LB-2 and LB-3. Because the lithology of all blocks is similar, they all may have been derived from the same horizon in the rock succession.

The species *Goniocladia pulchra*, described in this study, is identical to the original description, based on material from the Artinskian of Pechora Land, North Urals. *Rhombotrypella composita* was originally described from the lower Artinskian of the South Urals by Nikiforova (1939) and later Ross and Ross (1962) described a comparable form of the species from the Wolfcampian? of Northeast Greenland. *Tabulipora arcticensis*, described originally from the Wolfcampian? of Northeast Greenland (Ross and Ross, 1962) is widely known from the Arctic Region, i.e., Spitsbergen and

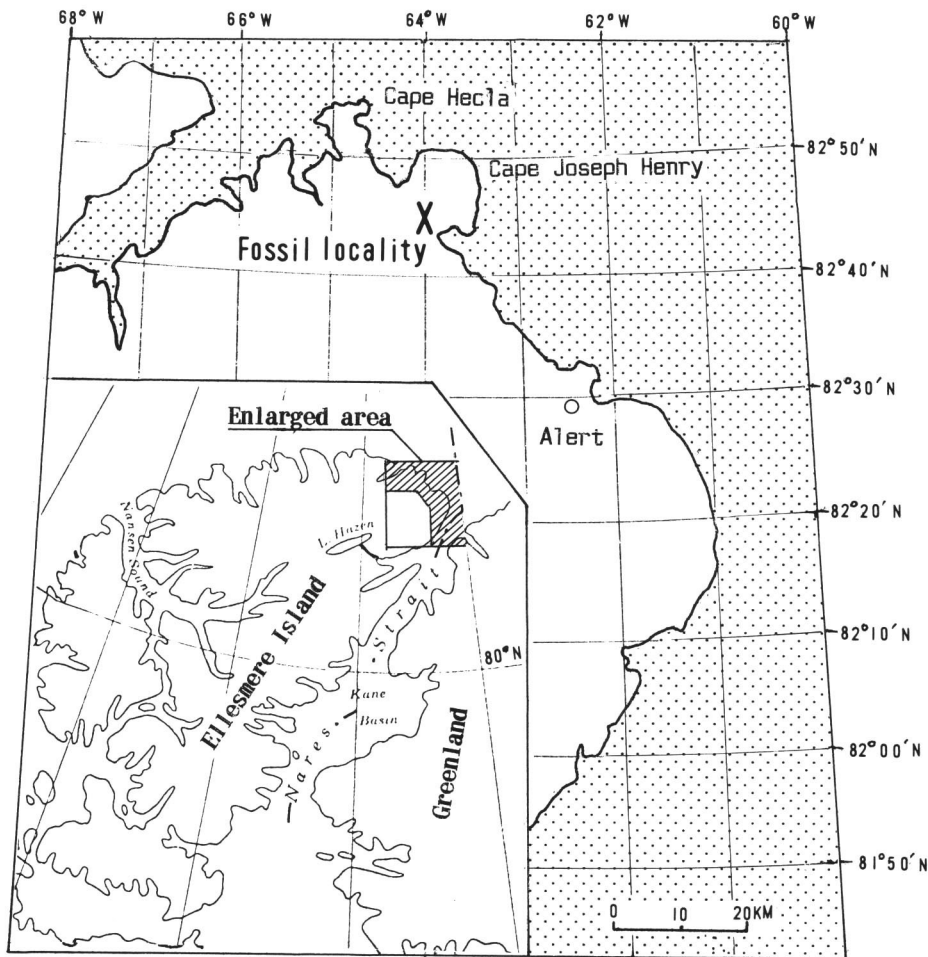


Fig. 1. Map showing the locality of the collections.

Canadian Arctic Archipelago (Morozova and Krutchinina, 1986). Two species of the genus *Dyscritella*, *D. speciosa* and *D. porosa* were both described originally from the Kazanian of Novaya Zemlya (Morozova, in Morozova and Krutchinina, 1986). *Permoheloclema merum* was described originally from the Upper Permian of Novaya Zemlya (Ozhgibesov, 1983), and later it was reported from the Artinskian of Middle Urals (Morozova and Krutchinina, 1986) and from the Kapp Starostin Formation of Spitsbergen (Sakagami, 1992; and Nakrem, 1994 a). *Primorella polita*, type species of the genus, described originally from Primorsky and Khabarovsk Krays of Siberia was reported from the Kapp Starostin Formation of Spitsbergen (Sakagami, 1992) and a comparable form (Nakrem, 1994 a). *Primorella tundrica* was originally described from the Kungurian of Timan. The original specimens of *Clausotrypa monti-*

Table 1. Distribution of the Permian bryozoans in 3 limestone blocks collected from N. Ellesmere Island.

Species	Limestone Blocks		
	LB-1	LB-2	LB-3
<i>Goniocladia pulchra</i>	○		
<i>Goniocladia regularis</i> sp. nov.		○	
<i>Rhombotrypella composita</i>		○	
<i>Tabulipora arcticensis</i>	○		
<i>Tabulipora intermedia</i> sp. nov.	○	○	○
<i>Tabulipora</i> sp. indet.	○		
<i>Stenopora</i> sp. indet.			○
<i>Dyscritella speciosa</i>		○	
<i>Dyscritella porosa</i>	○		○
<i>Pseudobotostomella</i> sp. indet.	○		
<i>Araxopora?</i> <i>ikedai</i> sp. nov.	○		
<i>Helenopora phillipsae</i> sp. nov.	○		
<i>Permoheloclema merum</i>		○	○
<i>Permoheloclema</i> sp. indet.	○		
<i>Primorella polita</i>		○	○
<i>Primorella tundrica</i>	○	○	○
<i>Clausotrypa monticola</i>	○	○	
<i>Streblascopora vulgaris</i>	○		○

cola (Eichwald, 1860) were restudied by Nikiforova (1938). The species has a wide distribution from the Artinskian to Kungurian of Timan and Canadian Arctic Archipelago (Morozova and Krutchinina, 1986), and also from the Kapp Starostin Formation of Spitsbergen (Sakagami, 1992; Nakrem, 1994 a). *Streblascopora vulgaris* was originally described from the Artinskian of the Urals (Shulga-Nesterenko, 1941). The occurrence of *Helenopora phillipsae* is notable, because the genus *Helenopora* established by Ross (1987) has been hitherto known only from the upper Mississippian of the western United States. The conspicuous absence of fenestrate bryozoans may suggest unsuitable environmental sedimentary conditions for these bryozoans.

From the species cited above, the geological age of the bryozoan fauna is most probably Late Artinskian (Early Permian).

Comparison with Other Bryozoan Faunas in the Arctic Region

Recently, the researches of Upper Paleozoic bryozoans of the Arctic region have greatly progressed by the studies by Morozova and Krutchinina (1986), Sakagami (1992), Nakrem (1988, 1991, 1994 a, 1994 b and 1994 c) and Nakrem and Spjeldnaes (1995).

Earlier, Ross and Ross (1962) studied Upper Paleozoic bryozoans from North-east Greenland, and listed 21 species from Amdrup Land (Pennsylvanian to Permian) and 11 species from Holm Land (Permian, Wolfcampian?). The Spitsbergen faunas seem to be predominantly trepostomes, such as *Rhombotrypella* and *Tabulipora*.

Morozova and Krutchinina (1986) compiled the Permian bryozoans of Arctic region including Timan and Malozemel'sky tundra, South Novaya Zemlya, Spitsbergen (including Bear Island) and the Canadian Arctic Archipelago. They listed 24 species of bryozoans including 2 cystoporates, 5 trepostomes, 3 cryptostomes and 14 fenestrates from the Canadian Arctic Archipelago. Only 2 species, *Tabulipora arcticensis* and *Clausotrypa monticola*, are common in the present collections. Morozova and Krutchinina listed 30 species from Spitsbergen and Bear Island but mainly from Bear Island. Only one common species, *Tabulipora arcticensis*, is included.

Sakagami's (1992) biostratigraphic study listed 25 genera and 41 species of bryozoans from the Kapp Starostin Formation, Spitsbergen. Nakrem (1994 b, 1994 c) in his comprehensive studies on Upper Paleozoic bryozoans from Spitsbergen identified in total 41 species from the Kapp Starostin Formation. Six species are common to Sakagami and Nakrem's reports; namely *Tabulipora arcticensis*, *Dyscritella speciosa*, *Dyscritella porosa*, *Permoheloclema merum*, *Primorella polita* and *Clausotrypa monticola*.

Systematic Paleontology

All specimens in this study are deposited and registered in the Collections of the National Science Museum (NSM), Tokyo, Japan.

Order Cystoporida

Suborder Fistuliporina Astrova, 1964

Family Goniocladidae Nikiforova, 1938

Genus *Goniocladia* Etheridge, 1876

Goniocladia pulchra Shulga-Nesterenko, 1933

(Figs. 2–1, 2)

Goniocladia pulchra Shulga-Nesterenko, 1933, p. 18–21, 51, 52, pl. 2, figs. 10, 11, pl. 3, figs. 1–4, 6, 7, text-figs. 9–11; Shulga-Nesterenko, 1941, p. 189–192, pl. 50, figs. 4–7, pl. 51, figs. 1–4.

Material: Limestone Block 1, NSM PA14042a, NSM PA14047a.

Description: Zoarium bifoliate, with anastomosing branches. Fenestrules rhomboidal to polygonal with rounded corners in outline. Fenestrule varies in width

Fig. 2. 1, 2. *Goniocladia pulchra* Shulga-Nesterenko, 1: tangential section, $\times 10$, NSM PA14047a, 2: enlarged part of Fig. 1, $\times 20$. 3, 4. *Goniocladia regularis* sp. nov., 3: tangential section, $\times 10$, NSM PA14060a (holotype), 4: enlarged part of Fig. 3, $\times 20$.



from 1.3 to 1.9 mm and length about 4.0 mm. Number of fenestrules in 10 mm along length about 2 and across colony 3 to 4. Width of branch ranges from 0.64 to 0.80 mm. Zooecial tubes circular in tangential section near the surface, diameter about 0.13 mm; parallel to mesotheca for some distance, and curved sharply upward and outward. Diaphragms absent. Interzooecial tissue consists of vesicles in endozone and dark fibrous material 0.16 to 0.26 mm thick in exozone.

Remarks: The original specimens of *Goniocladia pulchra* were described from the Lower Permian (P_1^{ta} and P_1^{tb} horizon) of Pechorsky Ural. The present form is closely similar to the type specimen in zoarial form, zoarial and zooecial measurements and other characters.

***Goniocladia regularis* sp. nov.**

(Figs. 2–3, 4)

Material: Limestone Block 2, NSM PA14057a, NSM PA14059a, NSM PA14060 (holotype).

Description: Zoarium bifoliate, with anastomosing branches. Fenestrules regularly arranged, oval, hexagonal, or rhomboidal with rounded corners in outline. Width of fenestrule varies from 1.3 to 2.4 mm and length from 3.2 to 4.1 mm. Number of fenestrules in 10 mm along length about 2 and across colony 3.5 to 4. Width of branch ranges from 0.64 to 0.96 mm. Zooecial tubes circular in tangential section near surface, diameter from 0.13 to 0.19 mm, parallel to mesotheca for a short distance, and curved sharply upward and outward. Diaphragm absent. Interzooecial tissue consists of vesicles in endozone, and thick, dark fibrous material, 0.26 to 0.32 mm thick, in exozone.

Remarks: *Goniocladia regularis* is characterized by regularly arranged oval fenestrules and is not closely comparable with any previously described species. The new species is distinguished from *Goniocladia pulchra* by the wider branch diameter and thicker fibrous material in exozone.

The specific name is derived from the regular arrangement of fenestrules.

Order Trepostomida

Family Stenoporidae Waagen and Wentzel, 1886

Genus *Rhombotrypella* Nikiforova, 1933

***Rhombotrypella composita* Nikiforova, 1939**

(Figs. 3–1~4)

Rhombotrypella composita Nikiforova, 1939, p. 80, 81, pl. 2, figs. 10, 11, pl. 3, figs. 1–6.

Rhombotrypella cf. *R. composita* Nikiforova, Ross and Ross, 1962, p. 30, 31, pl. 3, fig. 3, pl. 4, fig. 4, pl. 5, fig. 2.

Material: Limestone Block 2, NSM PA14056a, b, NSM PA14057b, NSM

PA14058a, NSM PA14059b, NSM PA14063a.

Description: Zoarium thick with cylindrical ramose branches but branching pattern is unknown, 6.0 to 7.0 mm in diameter.

In longitudinal section, zooecial tubes straight, parallel to longitudinal direction in inner part of endozone and gradually curve outward at base of exozone. Diameter of endozone ranges from 5.0 to 6.0 mm and width of exozone narrow, ranges from 0.40 to 0.50 mm. Zooecial walls thin and straight in endozone, and showing progressive bifurcations which occur at definite curved levels forming arcuate rows of monilae across zoaria and become rapidly thickened, composed of finely laminated fibrous tissue in exozone. Centrally perforated diaphragms located usually at just proximal side of monilae forming arcuate row and also at outermost part of endozone in a tube. Diaphragms are thin and usually straight, but in some cases, inner edges of perforated diaphragms swollen and extending proximally.

In typical transverse section, zooecial tubes thin walled, regularly arranged, quadrate in central part, and encompassed by a rhombic or polygonal pattern in outer part of endozone.

In tangential section of exozone, zooecial tubes elliptical, regularly arranged in longitudinal and diagonal directions. Usually 4 zooecia per 2 mm longitudinally, and 5 per 2 mm diagonally. Longer diameter ranges from 0.23 to 0.26 mm, shorter diameter ranges from 0.12 to 0.15 mm. Mesozooecia rarely present, circular to subcircular, diameter ranges from 0.06 to 0.08 mm. Well developed megacanthostyles having concentric laminate fibrous calcite, outside diameter ranges from 0.10 to 0.14 mm. Micracanthostyles in a single series between megacanthostyles, outside diameter is about 0.03 mm.

Remarks: The present form is identical with *Rhombotrypella composita* which was originally described from the lower part of the Artinskian of the South Ural Mountains (Nikiforova, 1939). Ross and Ross (1962) described and illustrated this species as a comparable form from the Wolfcampian? of Northeast Greenland.

Genus *Tabulipora* Young, 1883

Tabulipora arcticensis Ross and Ross, 1962

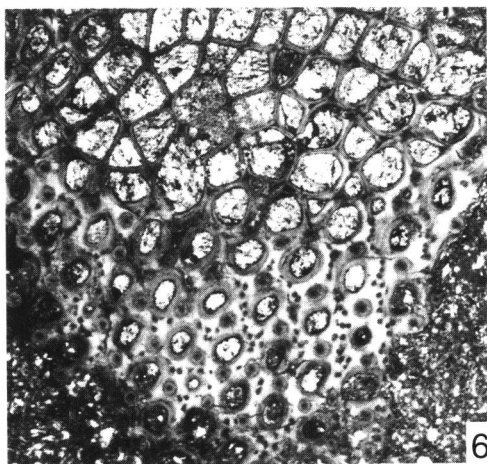
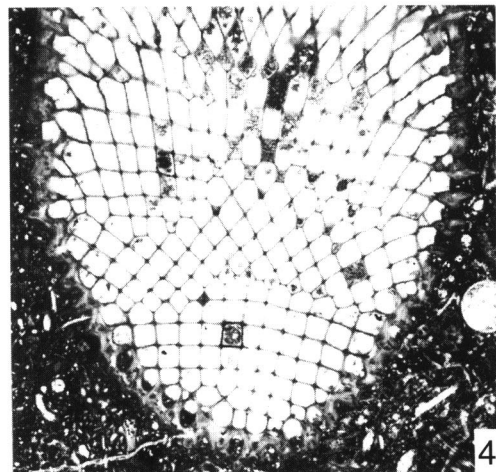
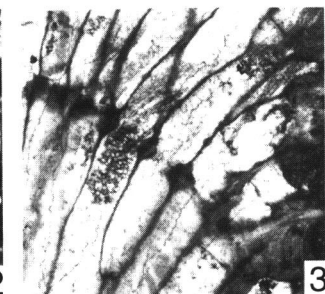
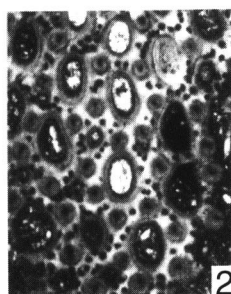
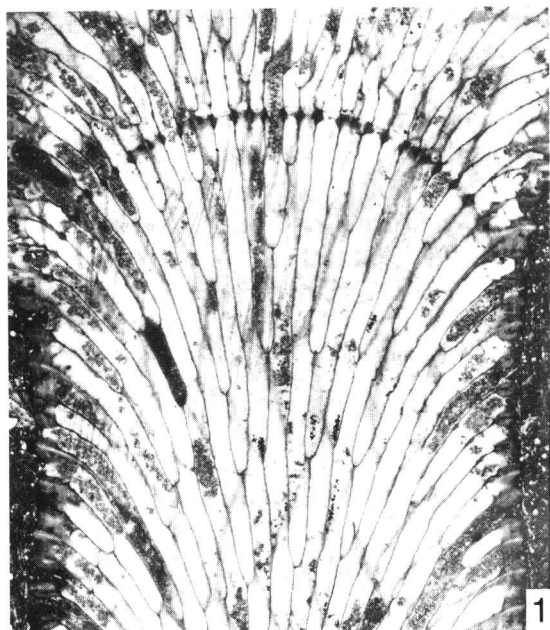
(Figs. 4–1, 2)

Tabulipora arcticensis Ross and Ross, 1962, p. 37, pl. 9, fig. 5, pl. 10, fig. 3, 4, pl. 17, fig. 6; Morozova and Krutchinina, 1986, p. 45, 46, pl. 11, fig. 1.

Material: Limestone Block 1, NSM PA14042b, NSM PA14044a, NSM PA14045a, NSM PA 14050a.

Description: Zoarium thick, cylindrical ramose branches, 9.0 to 9.5 mm in diameter; in some specimens two to three lamellate zoaria encrust a branch.

Longitudinal section was not observed; transverse section suggests that zooecial tubes are parallel to longitudinal direction in inner part, gradually curve outward in



outer part of endozone, and are perpendicular to surface in exozone. Diameter of endozone from 6.5 to 7.5 mm and width of exozone narrow, 0.64 to 0.96 mm. In transverse section, zooecial walls thin, usually irregularly arranged, polygonal, but in some sections regularly arranged quadrate in central part. Zooecial walls in exozone thickened and moniliform. Centrally perforate diaphragms present; one located at the outer part of endozone and 2 to 3 visible in exozone but may commonly be absent. Diaphragms straight or more usually slightly concave.

In tangential section, zooecial tubes subcircular to oval, irregularly arranged, longer diameter from 0.18 to 0.22 mm, and shorter diameter from 0.13 to 0.19 mm. Mesozooecia circular and commonly present, diameter from 0.05 to 0.10 mm. Prominently developed megacanthostyles surrounded by dark concentric laminate fibers; located at the junctions of zooecial walls, but in some sections, megacanthostyles are replaced by mesozooecia. Outside diameter of megacanthostyles from 0.09 to 0.15 mm and inner diameter is exceedingly small. A single series of micracanthostyles in outer part of zooecial walls.

Remarks: The present taxon is characterized by a thick cylindrical zoarium, and very narrow exozone. It can be easily identified with *Tabulipora arcticensis* which was described from the Upper Marine Group (Wolfcampian?) of Amdrup Land, Northeast Greenland (Ross and Ross, 1962), but the zoarium is slightly thinner than that of the originally described specimen. This species has been also reported from Ellesmere Island and Spitsbergen (Morozova and Krutchinina, 1986).

***Tabulipora ellesmerensis* sp. nov.**

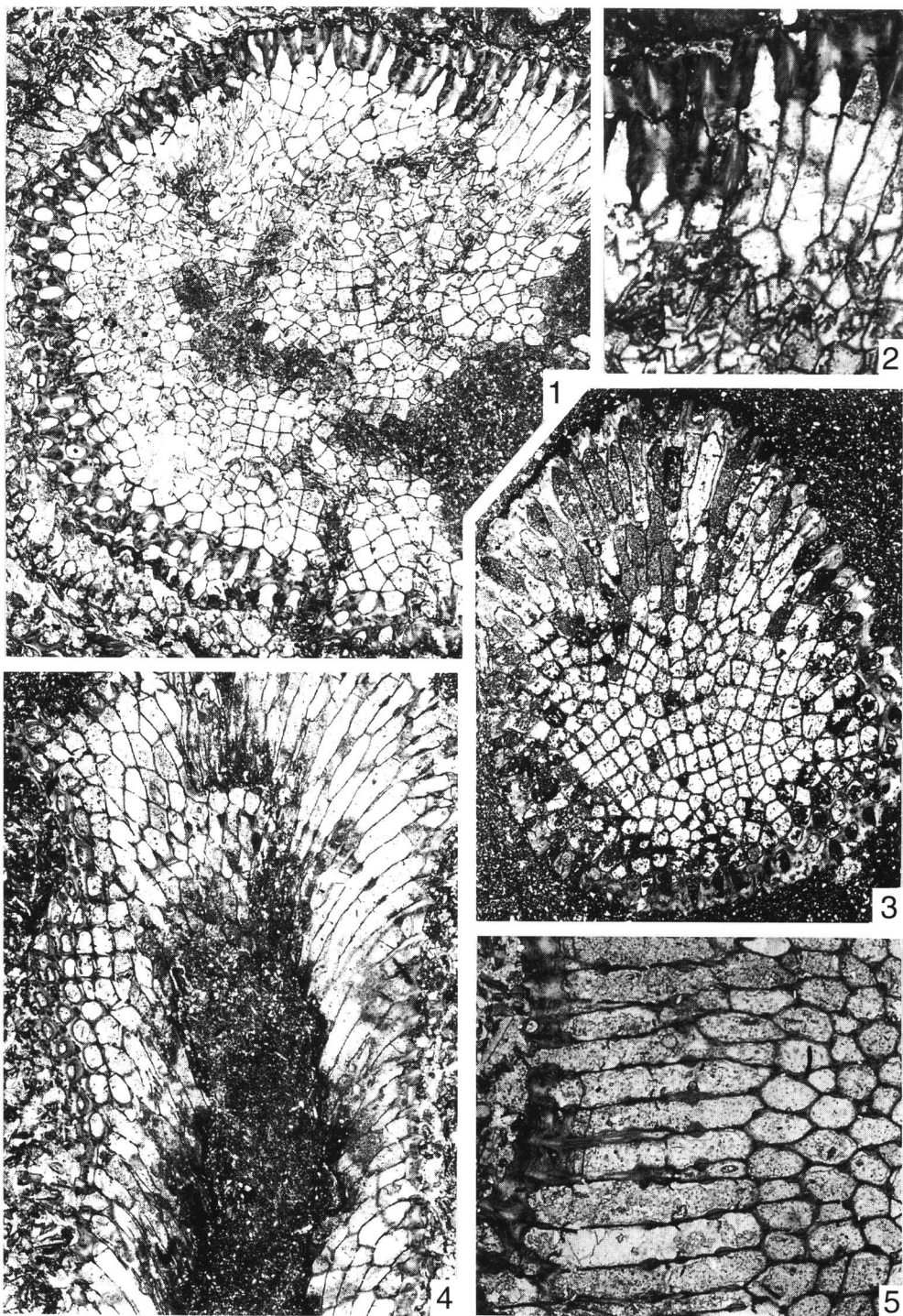
(Fig. 3–6; Figs. 4–3~5)

Material: Limestone Block 1, NSM PA14043(holotype), NSM14046a, NSM PA14052a, NSM PA14054a; Limestone Block 2, NSM PA14064a; Limestone Block 3, NSM PA14069a, NSM PA14070a, NSM PA14071a, NSM PA14073, NSM PA14074a.

Description: Zoarium cylindrical, ramose branches. Secondary branch is divided from main branch and at about a right angle with the same thickness. Branching interval is not known. Diameter of zoarium 5.1 to 6.4 mm.

In longitudinal section, zooecial tubes parallel to longitudinal direction in inner part, gradually curve outward in outer part of endozone, and are short and straight, and nearly perpendicular to surface in exozone. Diameter of endozone 4.0 to 4.8 mm;

Fig. 3. 1–4. *Rhombotrypella composita* Nikiforova, 1: longitudinal section, $\times 10$, NSM PA14056a, 2: tangential section, $\times 20$, NSM PA14059b, 3: enlarged part of Fig. 1, $\times 20$, 4: obliquely transverse section, $\times 10$, SM PA14056b. 5. *Tabulipora?* sp. indet., longitudinal section, $\times 20$, NSM PA14055a. 6. *Tabulipora ellesmerensis* sp. nov., tangential part of oblique section, $\times 20$, NSM PA14073 (paratype).



width of exozone 0.40 to 0.64 mm. Zooecial walls thin, straight, forming arcuate rows of monilae in endozone. One perforated diaphragm usually at the base of exozone of zooecium, but may absent; occasionally one in endozone of zooecium. Diaphragms thin and straight in endozone, but thick and slightly concave in exozone.

In tangential section of exozone, zooecial tubes circular to subcircular, longer diameter from 0.19 to 0.28 mm and shorter diameter ranges from 0.12 to 0.15 mm. Mesozooecia circular, small and rare; diameter 0.05 to 0.08 mm. Well developed megacanthostyles surrounded by dark, concentric laminate fibers, located at junctions of zooecial walls, outside diameter 0.08 to 0.13 mm and inner diameter very small, less than 0.003 mm. A single series of micracanthostyles in outer part of zooecial walls; outside diameter 0.03 to 0.05 mm.

Remarks: This new species resembles *Tabulipora arcticensis* in some essential characters, especially in the extremely thin exozone and seems to be quite similar to *Tabulipora* sp. A described from the Wolfcampian? of Northeast Greenland (Ross and Ross, 1962) in the size of branch, thin exozone, but it differs by fewer diaphragms in each zooecial tube.

Tabulipora? sp. indet.

(Fig. 3–5)

Material: Limestone Block 1, NSM PA14055a.

Description: A single longitudinal section of a cylindrical ramose zoarial stem; branching pattern is unknown, diameter about 2.4 mm.

Zooecial tubes parallel to longitudinal direction in central part and gradually curve outward to be at nearly a right angle. Thickness of zooecial walls thin in central part but gradually thickened and consisting of fine laminated fibers in exozone. Several perforated diaphragms at regular intervals throughout the zooecial tube in exozone. Perforation in diaphragms is large.

In tangential part of section, zooecial tubes elliptical, longer diameter 0.19 to 0.26 mm, and shorter diameter 0.13 to 0.17 mm. Mesozooecia present but small and rare, diameter 0.03 to 0.05 mm. Acanthostyles located at intersection of zooecial walls, outside diameter about 0.05 mm and inner diameter 0.003 to 0.01 mm.

Remarks: This unique species is characterized by very long exozone for zoarial diameter and regularly spaced diaphragms with many large perforation. This taxon is tentatively placed in the genus *Tabulipora*, but it has some characteristics of the Carboniferous genus *Nikiforopora*. The specific identification can not be made until

Fig. 4. 1, 2. *Tabulipora arcticensis* Ross and Ross, 1: transverse section, $\times 10$, NSM PA14042b, 2: enlarged part of Fig. 1, $\times 20$. 3–5. *Tabulipora ellesmerensis* sp. nov., 3: transverse section, $\times 10$, NSM PA14070a (paratype), 4: longitudinal section, $\times 10$, NSM PA14043 (holotype), 5: enlarged part of holotype, $\times 20$.

more specimens are available.

Genus *Stenopora* Lonsdale, 1844

Stenopora sp. indet.

(Fig. 5-1)

Material: Limestone Block 3, NSM PA14072.

Remarks: The present taxon, assigned to *Stenopora*, is about 3 mm in zoarial diameter and is characterized by well developed monilae in zooecial walls. Because of only one obliquely transverse section, detailed measurements and comparison with previously described species are not possible but this taxon is clearly distinguished from others in the collections.

Family Dyscritellidae Dunaeva and Morozova, 1967

Genus *Dyscritella* Girty, 1911

Dyscritella speciosa Morozova, 1986

(Figs. 5-5, 6)

Dyscritella speciosa Morozova in Morozova and Krutchinina, 1986, p. 53, pl. 15, fig. 1; Sakagami, 1992, pl. 1, figs. 3, 4.

Material: Limestone Block 2, NSM PA14060b, NSM PA14062.

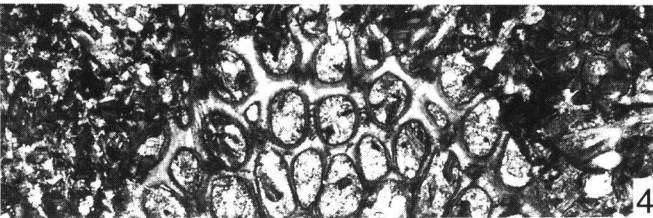
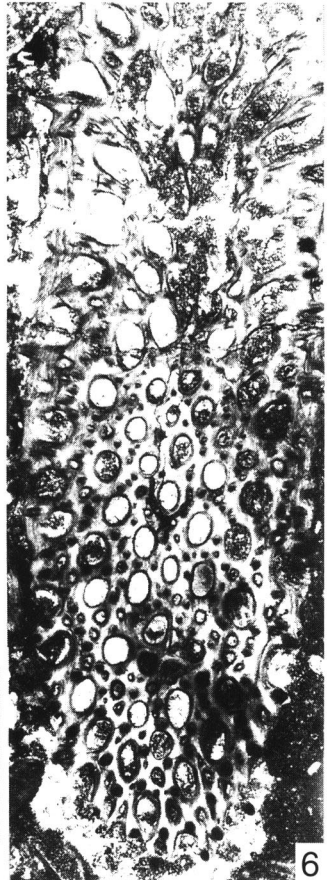
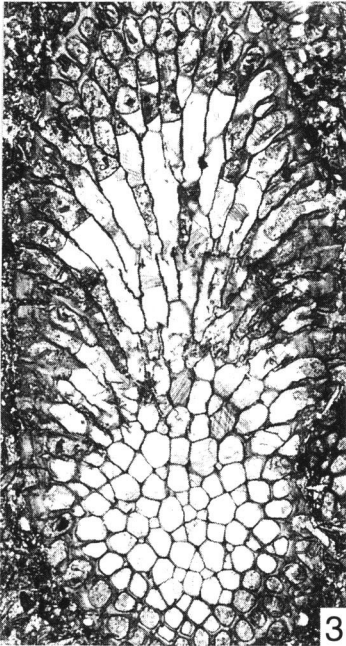
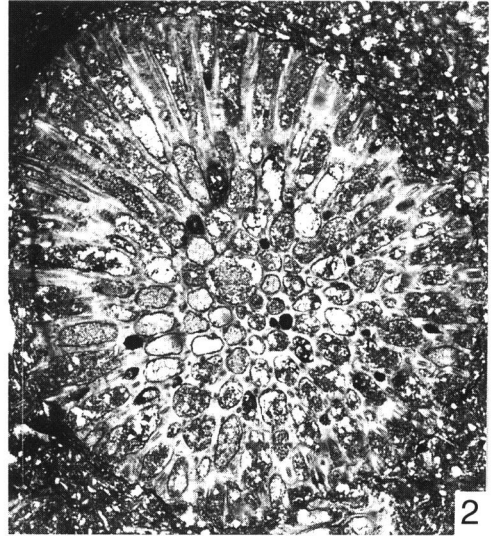
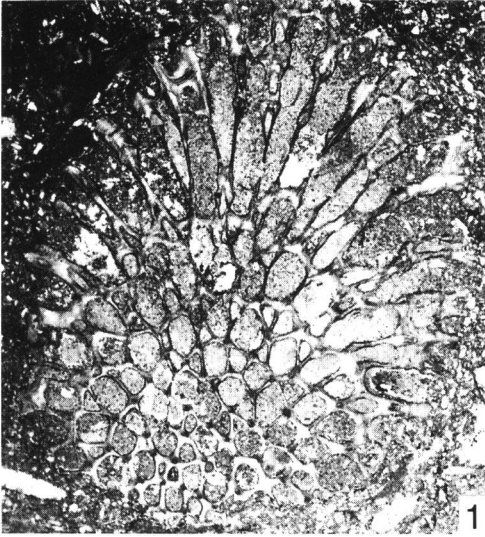
Description: Two longitudinal and partly tangential sections were examined. Zoarium cylindrical ramose branches, diameter 2.0 and 2.1 mm. Zooecial apertures near the surface do not have any special pattern in either longitudinal or diagonal directions.

In longitudinal section, zooecial tubes parallel to longitudinal direction of zoarium in inner part of endozone, and gradually curve outward to meet outer surface of zoarium at an angle of about 90°. Zooecial walls nearly straight, thin and in exozone becoming gradually thickened and finely laminated fibers. Diaphragm absent.

In tangential section of exozone, zooecia circular to oval, longer diameter 0.13 to 0.19 mm and shorter diameter ranges from 0.12 to 0.14 mm. Mesozooecia circular and rare, from 0.06 to 0.12 mm. Well developed acanthostyles usually located at intersection of zooecial walls, surrounded by concentric dark dense fibers, outside diameter 0.06 to 0.10 mm.

Remarks: The present taxon is similar to *Dyscritella speciosa* Morozova (in

Fig. 5. 1. *Stenopora* sp. indet., obliquely transverse section, $\times 20$, NSM PA14072, 2. *Dyscritella porosa* Morozova, obliquely transverse section, $\times 20$, NSM PA14065a. 3, 4. *Pseudobatosmella* sp. indet., 3: oblique section, $\times 10$, NSM PA14044b. 4: enlarged part of 3, $\times 20$. 5, 6. *Dyscritella speciosa* Morozova, 5: longitudinal section, $\times 20$, NSM PA14060b. 6: longitudinal and partly tangential section, $\times 20$, NSM PA14062.



Morozova and Krutchinina, 1986) which was described from the Upper Permian, Novaya Zemlya, in all characters except for a slightly thinner zoarial branch. This species has been reported also from the Kapp Starostin Formation of Spitsbergen (Sakagami, 1992).

***Dyscritella porosa* Morozova, 1986**

(Fig. 5–2)

Dyscritella porosa Morozova in Morozova and Krutchinina, 1986, p. 54, pl. 15, fig. 3; Sakagami 1992, figs. 5, 6.

Material: Limestone Block 1, NSM PA14048, NSM PA14049a, NSM PA14055b; Limestone Block 3, NSM PA14065a, NSM PA14069b.

Description: Zoarium cylindrical ramose branches, diameter 3.0 to 6.5 mm. Based on a tangential section near the surface, zooecial apertures do not show any special pattern in either longitudinal and diagonal directions.

In longitudinal section, zooecial tubes parallel to longitudinal direction of zoarium in inner part of endozone, but gradually curve outward to meet outer surface of zoarium at an angle of 90°. Zooecial walls straight, thin and become gradually thickened with finely laminated fibers in exozone. Length of zooecial tubes in exozone ranges from 1.0 to 1.3 mm. Diaphragms absent.

In transverse section, zooecial tubes thin walled, polygonal in central part of endozone.

In a tangential section of the exozone, zooecia circular to oval, longer diameter ranges from 0.19 to 0.31 mm; shorter diameter ranges from 0.13 to 0.23 mm. Mesozooecia circular and very common, diameter from 0.04 to 0.13 mm. Well developed acanthostyles usually located at intersection of zooecial walls, surrounded by concentric dark dense fibers, outside diameter ranges from 0.08 to 0.10 mm and inside diameter is less than 0.005 mm.

Remarks: This taxon is characterized by well developed mesozooecia and is readily identified measurements in essential characters as *Dyscritella porosa* Morozova (in Morozova and Krutchinina, 1986), described from the Upper Permian of Novaya Zemlya. This species is known also from the Kapp Starostin Formation, Spitsbergen (Sakagami, 1992).

Genus *Pseudobatostomella* Morozova, 1960

***Pseudobatostomella* sp. indet.**

(Figs. 5–3, 4; Fig. 6–5)

Material: Limestone Block 1, NSM PA14044b, NSM PA14050b.

Description: Two oblique sections probably from the same zoarium were examined. Zoarium is a cylindrical ramose branch, about 4.5mm in diameter.

In the longitudinal part of a section, zooecial tubes are parallel to longitudinal direction of zoarium in endozone, and curve gradually outward to meet outer surface at an angle of about 90° . Zooecial walls thin and crenulate in endozone, then becoming rapidly thickened with finely laminated fibers in exozone. Length of zooecial tubes in exozone about 0.8 to 0.9 mm. Usually one straight or slightly concave diaphragm located at outer part of endozone of zooecial tube, but may be absent in exozone of zooecial tubes.

In transverse section, zooecial tubes thin-walled, irregularly arranged polygons in central part of endozone.

In tangential section near the surface, zooecial tubes circular to oval and irregularly arranged; longer diameter ranges from 0.32 to 0.35 mm, shorter diameter 0.19 to 0.24 mm. Mesozooecia sporadic; diameter ranges from 0.06 to 0.13 mm. Acanthostyles usually located at the junction of zooecial walls; outside diameter ranges from 0.06 to 0.08 mm and inner diameter is very small, less than 0.003 mm.

Remarks: This taxon is characterized by a large zooecial diameter, typical of *Pseudobatostomella*, and only one diaphragm located at the outer part of endozone of the zooecial tubes. It is distinguished from other described species, but the specific identification must be postponed because of poorly oriented thin sections of zoarium.

Genus *Araxopora* Morozova, 1965

Araxopora? ikedai sp. nov.

(Figs. 6-1~4)

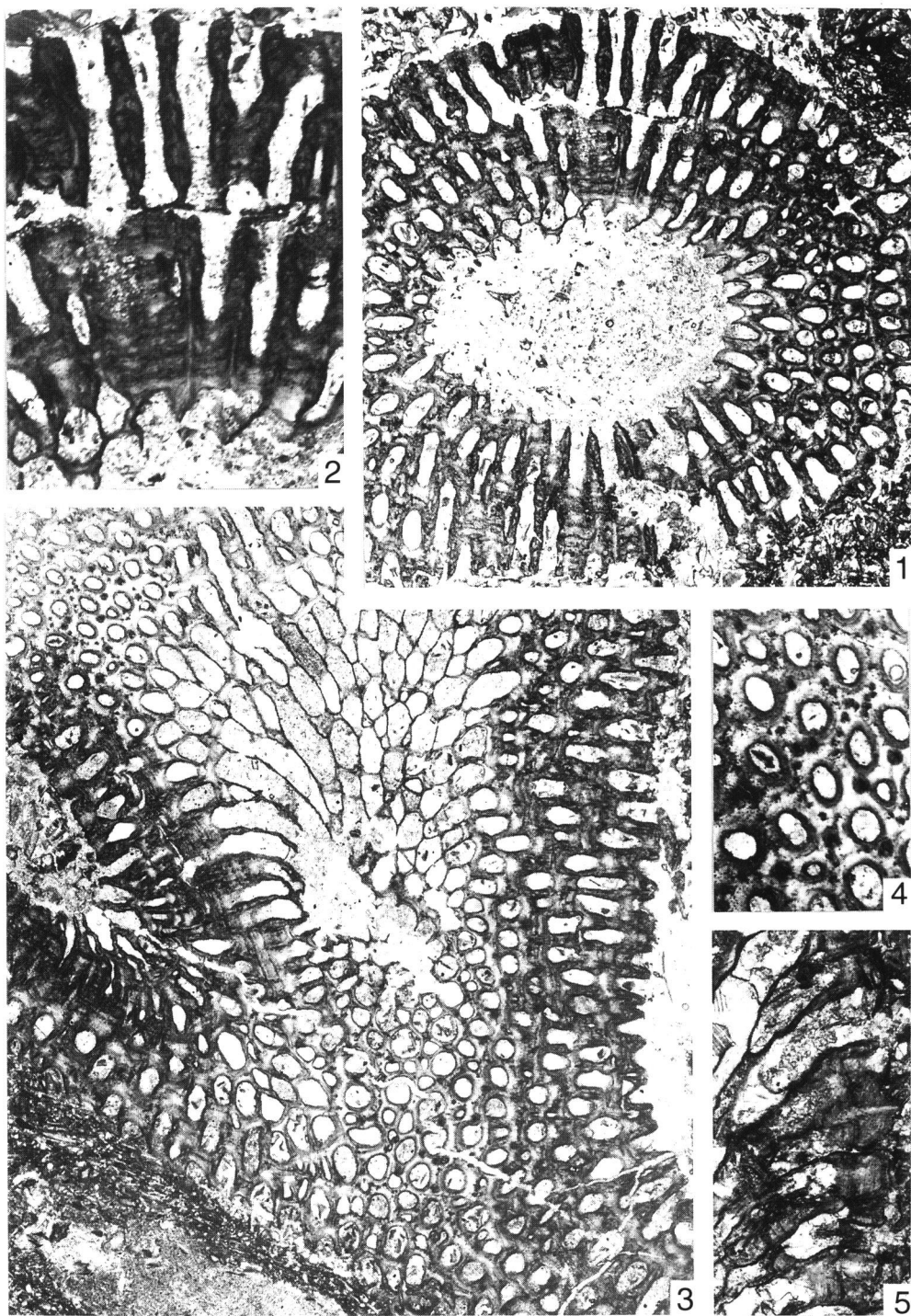
Material: Limestone Block 1, NSM PA14051a, NSM PA14053 (holotype), NSM PA14054b.

Description: Zoarium cylindrical ramose branches, diameter 7.5 to 8.5 mm.

In longitudinal section, zooecial tubes trend parallel to longitudinal direction of zoarium in inner part of endozone, curve gradually outward, rapidly bend outward at the inner edges of exozone, and are straight throughout exozone reaching the surface at an angle of 90° . Length of zooecial tubes in exozone ranges from 2.2 to 2.9 mm. Zooecial walls very thin in endozone, occasionally the inner part is obliterated by diagenesis; walls in exozone rapidly thickened, consisting of dark, laminated fibers. Straight or slightly concave, thick, non-perforated diaphragm occasionally present but very rare in either endozone or exozone.

A typical transverse section commonly lacks in the inner region because of the secondary diagenesis. The characters of exozone are the same as those of the longitudinal section.

In tangential section of exozone, zooecial tubes circular or oval and irregularly arranged, longer diameter ranges from 0.23 to 0.26 mm; shorter diameter ranges from 0.15 to 0.23 mm. Zooecial apertures arranged longitudinally but not so regularly, about 4 to 4.5 per 2 mm of longitudinally. Mesozooecia commonly present and circu-



lar, 0.04 to 0.08 mm in diameter. Megacanthostyles usually located at intersection of zooecial walls, surrounded by dark, dense fibers, outside and inner diameters ranging from 0.10 to 0.12 mm and less than 0.005 mm, respectively. Micracanthostyles are also visible and irregularly arranged between the megacanthostyles in the outer part of exozone. In addition, very small granules are developed in interzooecial tissue near the surface.

Remarks: There is some doubt as to the assignment of this species to the genus *Araxopora* based on wall structure and shape of zooecia and mesozooecia in tangential section. *Araxopora? ikedai* also has some characteristics of *Arcticopora*, *Gilmoropora* and *Hinganella*, but it is readily distinguished from described species of those genera. This species is not unlike *Gilmoropora unica*, but it differs in having a thicker exozone, more delicate granules in the fibrous material of exozone and rare diaphragms.

The specific name is dedicated to Mr. Kaneshige Ikeda, the leader of the Nihon University North Pole Expedition Team (1978) to commemorate the arrival at the North Pole.

Family Helenoporidae Ross, 1987

Genus *Helenopora* Ross, 1987

***Helenopora phillipsae* sp. nov.**

(Figs. 7-1~3)

Material: Limestone Block 1, NSM PA14045b (holotype), NSM PA14051b, NSM PA14054c.

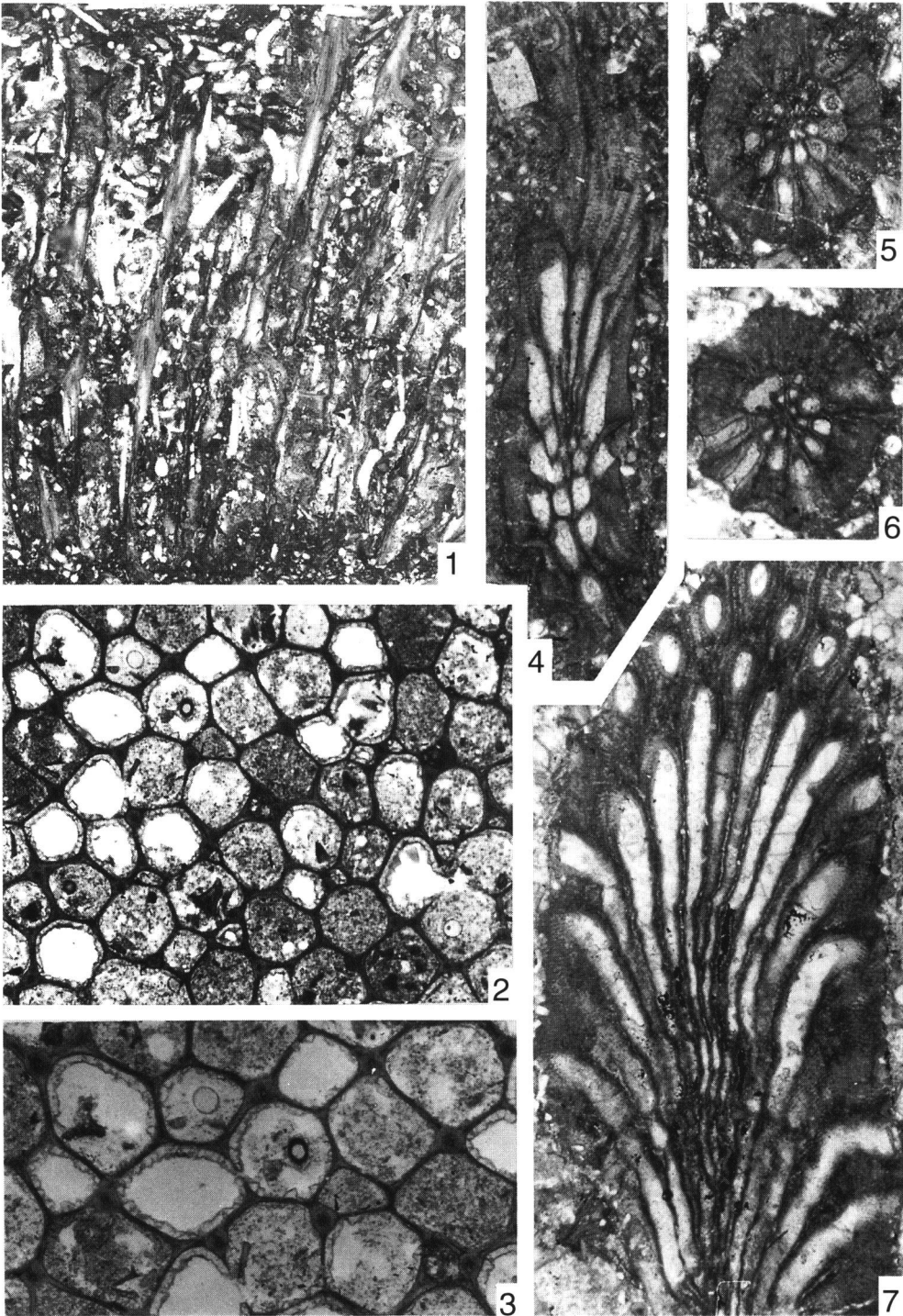
Description: Incrusting zoarium may have been attached to *Tabulipora arcticensis* but coenelasma is indistinct.. Thickness of zoarium about 5 mm.

In longitudinal section, zooecial tubes straight, and diaphragms rarely present but may be missing in many cases because they are very thin and weak. Zooecial walls thin and delicately crenulate in endozone region, but gradually thickened and having steep wall laminae in exozone region.

In tangential section, zooecial tubes polygonal to subpolygonal, diameter ranges from 0.39 to 0.51 mm. Mesozooecial tubes small and polygonal; rare and scattered among the zooecia, diameter ranges from 0.15 to 0.23 mm. Acanthoforms, located at junctions of zooecial walls, fill the zooecial walls, and are surrounded by dark dense fibers. Acanthoform diameter ranges from 0.10 to 0.15 mm.

Remarks: The type species of *Helenopora*, *H. duncanae* was described from

Fig. 6. 1-4. *Araxopora? ikedai* sp. nov., 1: transverse section, $\times 10$, NSM PA14054b (paratype). 2: enlarged part of 1, $\times 20$. 3: obliquely longitudinal section, $\times 10$, NSM PA14053 (holotype). 4: enlarged part of 3, $\times 20$. 5. *Pseudobatosomella* sp. indet., enlarged part of Fig. 5-3, $\times 20$, NSM PA14044b.



the Late Mississippian of the western United States. The present new species is consistent with the generic diagnosis of *Helenopora* (Ross, 1987) in all essential characters, but is quite different from *Helenopora duncanæ* in the thinner zoarium, and larger zooecial diameter.

This species is named in honour of Professor June R. Phillips Ross of Western Washington University (USA) who established the genus *Helenopora*.

Order Cryptostomida

Suborder Rhabdomesina Astrova and Morozova, 1956

Family Arthrostylidae Ulrich, 1882

Genus *Permoheloclema* Ozhgibesov, 1983

***Permoheloclema merum* Ozhgibesov, 1983**

(Figs. 7–4~6)

Permoheloclema merum Ozhgibesov, 1983, p. 98, figs. 1 a–d; Goryunova, 1985, p. 94, pl. 5, figs. 3 a–c; Morozova and Krutchinina, 1986, p. 71, pl. 24, figs. 1 a–f; Sakagami, 1992, pl. 4, figs. 3–5; Nakrem, 1994 c, p. 25, pl. 8, figs. C, H.

Material: Limestone Block 2, NSM PA14057c, NSM PA14058a, NSM PA14059c, NSM PA14061a, NSM PA14063b, NSM PA14064b; Limestone Block 3, NSM PA14075a.

Description: Zoarium consists of nearly straight, thin cylindrical ramose branches, diameter varies from 0.6 to 1.2 mm. 10 to 12 zooecial rows around zoarial stem.

In longitudinal section, zooecial tubes parallel the longitudinal direction of growth, arise from zoarial axis in helicoid pattern curving gradually outward, then bend rapidly at posterior end the exozone. One diaphragm present and occasionally visible near the base of a zooecial tube in exozone. Diameter of endozone ranges from 0.64 to 0.90 mm and width of exozone ranges from 0.32 to 0.40 mm.

In transverse section, zooecial tubes show a helical pattern from zoarial axis in endozone.

In tangential section of exozone, zooecial tubes elliptical, longer diameter ranges from 0.15 to 0.17 mm, shorter diameter ranges from 0.06 to 0.09 mm, regularly arranged, about 5 zooecia per 2 mm longitudinally and 7 per 2 mm diagonally. Zooecial walls consist of dark, coarser fibrous striations with fine granules. Metapores not observed.

Fig. 7. 1–3. *Helenopora phillipsae* sp. nov., 1: longitudinal section, $\times 20$, NSM PA14045b (holotype). 2: tangential section, $\times 20$, NSM PA14054c (paratype). 3: enlarged part of 2, $\times 30$. 4–6. *Permoheloclema merum* Ozhgibesov, 4: obliquely longitudinal section, $\times 30$, NSM PA14058a. 5, 6: transverse section, $\times 30$, NSM PA14063b and 14064b, respectively. 7. *Permoheloclema* sp. indet., longitudinal section, $\times 30$, NSM PA14052b.

Remarks: This taxon is identical in all essential characters with *Permoheloclema merum* originally described from the Lower Permian of Novaya Zemlya (Ozhgibesov, 1983). Metapores discussed by Nakrem (1994 c) are not recognized in these Ellesmere specimens.

***Permoheloclema* sp. indet.**

(Fig. 7–7)

Material: Limestone Block 1, NSM PA14052b.

Remarks: Only one longitudinal section of a zoarium was examined. This taxon can be distinguished from *Permoheloclema merum* in having a much thicker zoarium, about 1.6mm in diameter. It seems to be similar to *Permoheloclema porifera* which Fritz (1932) originally assigned to the genus *Rhombopora* from the Permian, Vancouver Island, in zoarial diameter and other essential characters. Detailed comparison cannot be made because of only one thin section of zoarium is to hand.

Family Rhomboporidae Simpson, 1895

Genus *Primorella* Romantchuk and Kiseleva, 1968

***Primorella polita* Romantchuk and Kiseleva, 1968**

(Fig. 8–1)

Primorella polita Romantchuk and Kiseleva, 1968, p. 57, fig. 2; Sakagami, 1992, pl. 4, figs. 9, 10.

Primorella cf. *P. polita* Romantchuk and Kiseleva, Nakrem, 1994 c, p. 23, pl. 8, figs. A, D, F.

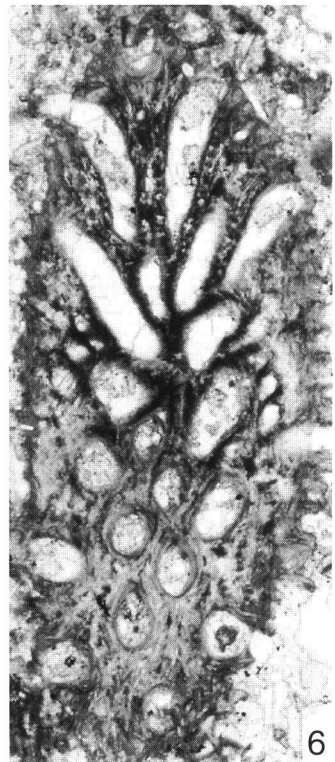
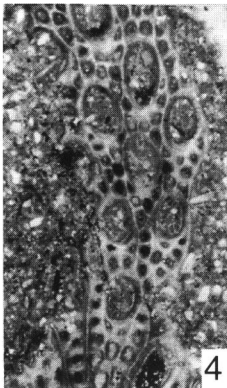
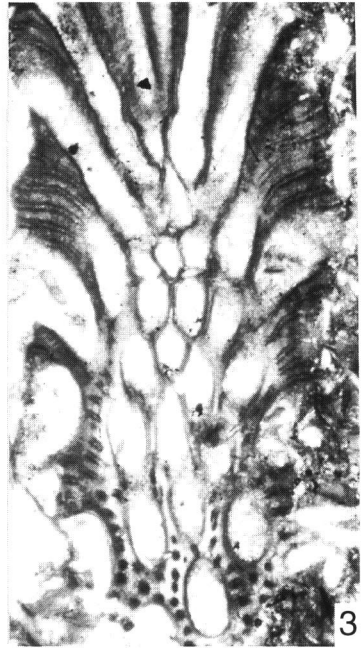
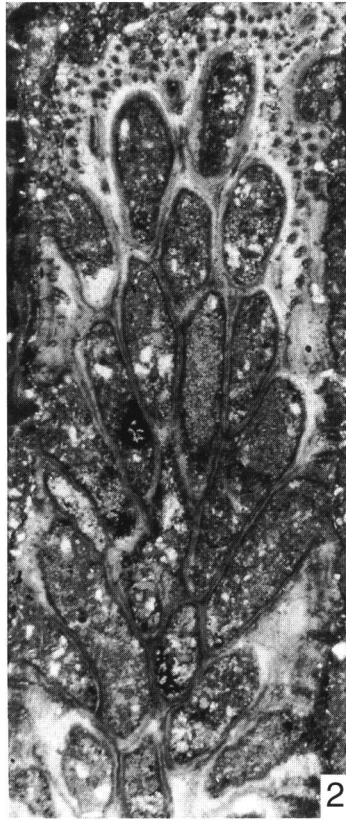
Material: Limestone Block 2, NSM PA14057d, NSM PA14058b; Limestone Block 3, NSM PA14066a, NSM PA14067.

Description: From fragmentary zoaria, four thin sections were examined.

In longitudinal section, axial region consists of a nearly straight axis, and zooecial tubes make a small angle from longitudinal direction in endozone; then bend outward at posterior end of exozone. Diameter of endozone ranges from 0.5 to 0.7 mm and width of exozone ranges from 0.20 to 0.30 mm.

In tangential section of exozone, zooecia elliptical, longer diameter ranges from 0.29 to 0.36 mm, shorter diameter ranges from 0.17 to 0.19 mm, zooecia alternate and in a regular pattern, usually 3.5 zooecia per 2 mm longitudinally. Zooecial walls thin in endozone, but sharply thickened in exozone. One kind of acanthostyle

Fig. 8. 1. *Primorella polita* Romantchuk and Kiseleva, longitudinal section, $\times 30$, NSM PA14058b. 2, 3. *Primorella tundrica* Krutchinina, 2: longitudinal section, $\times 30$, NSM PA14069c. 3: obliquely longitudinal section, $\times 30$, NSM PA14051c. 4, 5. *Streblascopora vulgaris* Shulga-Nesterenko, 4: transverse section, $\times 30$, NSM PA14068a. 5: longitudinal section, $\times 30$, NSM PA 14068b. 6. *Clausotrypa monticola* (Eichwald), obliquely longitudinal section, $\times 30$, NSM PA14042c.



arranged regularly in one, occasionally two or three rows, ranges; 0.03 to 0.05 mm in outside diameter.

Remarks: This taxon is identical in all essential characters and measurements with *Primorella polita*, originally described from the Upper Permian, Maritime Territory, Russia, by Romantchuk and Kiseleva (1968).

***Primorella tundrica* Krutchinina, 1986**

(Figs. 8–2, 3)

Primorella tundrica Krutchinina in Morozova and Krutchinina, 1986, p. 54, pl. 20, fig. 2.

Material: Limestone Block 1, NSM PA14051c; Limestone Block 2, NSM PA14056c, NSM PA14059d, NSM PA14060c; Limestone Block 3, NSM PA14069c, NSM PA14071b.

Description: This description is based on six thin sections selected from many fragments. Zoarium thin, straight cylindrical ramose branches, diameter ranges from 1.3 to 1.6 mm.

In longitudinal section, axial region has a nearly straight axis; zooecial tubes make a small angle with longitudinal direction in endozone, and bend outward at posterior end of exozone. Diameter of endozone ranges from 0.6 to 0.7 mm, width of exozone 0.40 to 0.45 mm.

In tangential section of exozone, zooecia elliptical, longer diameter ranges from 0.26 to 0.38 mm, shorter diameter ranges from 0.15 to 0.19 mm, may be arranged regularly in longitudinal and diagonal patterns. Zooecial walls thin in endozone, but sharply thickened in exozone. One kind of acanthostyle arranged regularly in one to two rows in interzooecial spaces. Outside diameter of acanthostyles ranges from 0.03 to 0.04 mm.

Remarks: The present form is similar to *Primorella polita* in the essential characters, but it can be distinguished by the greater diameter of zoarium.

Family Nematotrypidae Spjeldnaes, 1984

Genus *Clausotrypa* Bassler, 1929

***Clausotrypa monticola* (Eichwald, 1860)**

(Fig. 8–6)

Myriolithes monticola Eichwald, 1860, p. 452, pl. 25, figs. 6 a, c.

Clausotrypa monticola (Eichwald), Nikiforova, 1938, p. 181 [267, 268], pl. 64, figs. 4–7, pl. 65, figs. 7–10; Shulga-Nesterenko, 1941, p. 219, pl. 13, figs. 3–6; Goryunova, 1985, p. 99, pl. 13, figs. 4, text-fig. 33; Morozova and Krutchinina, 1986, p. 67, pl. 20, figs. 3 a, b, pl. 4, figs. 4 a–c; Sakagami, 1992, pl. 3, figs. 6, 7; Nakrem, 1994 c, p. 23, 24, pl. 8, figs. B, E, G.

Clausotrypa monticola Shulga-Nesterenko, Goryunova, 1996, pl. 30, fig. 1.

Material: Limestone Block 1, NSM PA14042c, NSM PA14046b, NSM

PA14047b, NSM PA14049b, NSM PA14050c; Limestone Block 2, NSM PA 14060d, NSM PA14061b, NSM PA14064c.

Description: Zoarium thin, sometimes straight, slightly curved; cylindrical branches, but branching pattern is unknown, diameter 1.1 to 1.4 mm.

In longitudinal section, zooecial tubes arise from central axis at angle of about 30°, then gradually curve outward to surface. Diameter of endozone ranges from 0.5 to 0.8 mm and width of exozone ranges from 0.20 to 0.40 mm. Diaphragms absent.

In transverse section, zooecial tubes radiate from central axis.

In tangential section of exozone, zooecia elliptical, longer diameter ranges from 0.17 to 0.22 mm, shorter diameter ranges from 0.12 to 0.15 mm. About 3 zooecial apertures per 2 mm longitudinally and about 5 per 2 mm diagonally. Circular or angular metapores sporadically present, about 0.05 mm in diameter; acanthostyles irregularly arranged in zooecial walls. Small stylets pierce the exozone producing a striated appearance in tangential section.

Remarks: The holotype of this species established by Eichwald (1860) was restudied by Nikiforova (1938). The present taxon is identical in all essential characters and measurements with the holotype and is quite similar to the specimens which Shulga-Nesterenko (1941) described from Chusovskie Gorodki, P₁¹, Urals. This taxon also seems to be similar to *Clausotrypa spinosa* which Fritz (1932) described from the Permian of Vancouver Island.

Family Hyphasmoporidae Vine, 1886

Genus *Streblascopora* Bassler, 1952

Streblascopora vulgaris Shulga-Nesterenko, 1940

(Figs. 8–4, 5)

Streblotrypa vulgaris Shulga-Nesterenko, 1941, p. 220, 221, [242], pl. 64, figs. 1, 2.

Material: Limestone Block 3, NSM PA14065b, NSM PA14066b, NSM PA14068a, b, NSM PA14070b, NSM PA14071c, NSM PA14074b, NSM PA14075b.

Description: Zoarium thin, cylindrical ramose branches, varying from 1.1 to 1.4 mm in diameter.

In longitudinal section, diameter of central bundle of zooecia ranges from 0.3 to 0.4 mm; ratio of zoarial diameter to central bundle ranging from 3.3 : 1 to 4.3 : 1, and 3 to 4 zooecial tubes in central bundle. Width of exozone ranges from 0.26 to 0.30 mm. Zooecial tubes arise from central bundle at an angle of about 20°, straight in endozone and bending outward rapidly at inner edge of exozone. Metapores arise from base of exozone, approximately parallel to endozone walls for a very short distance, then curving outward and parallel to zooecial tubes in exozone. Superior and inferior hemisepta present but not prominent.

In tangential section of exozone, zooecia oval, longer diameter ranges from 0.17

to 0.21 mm and shorter diameter ranges from 0.10 to 0.13 mm. Zooecial apertures arranged regularly in longitudinal rows. Number of zooecia 5 to 6 per 2 mm longitudinally. Metapores circular and regular in shape and size, diameter ranging from 0.03 to 0.05 mm, usually two or three rows with 2 to 4 per mm in each row longitudinally. Total number of metapores disposed between zooecial tubes in one series usually 7 to 9, occasionally 10.

In transverse section, about 20 to 25 tubes in central bundle.

Remarks: Although several species of *Streblascopora* are known from the Arctic region, the present taxon in essential characters and microscopic measurements is nearest to *Streblascopora vulgaris* which was originally described from the Lower Permian of the Urals (Shulga-Nesterenko, 1941).

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References Cited

- Eichwald, E., 1860. Lethaea Rossica. Ancienne Period. Bryozoa. p. 355-494, Stuttgart. (not seen)
- Goryunova, R. V., 1985. Morfologiya, sistema i filogeniya mashanok (otryad Rhabdomesida). [Morphology, systematics and phylogeny of Bryozoa (Order Rhabdomesida)]. *Trudy Paleont. Inst. SSSR*, (208), 152 p., 16 pls.
- Goryunova, R. V., 1996. Filogeniya paleozoiskikh mshanok. [Phylogeny of the Paleozoic bryozoans]. *Trudy Paleont. Inst. SSSR*, (267), 165 p., 48 pls.
- Hamada, T. and Sakagami, S., 1982. A preliminary report on some Upper Paleozoic fossils collected by the Nihon University North Pole Expedition Team. In A report of the Nihon University North Pole Expedition Team, 1978. p. 89-93. (in Japanese)
- Morozova, I. P. and Krutchinina, O. N., 1986. Permskie mshanki Arktiki (Zapadnyi Sektor). [The Permian bryozoans of the Arctic region (Western Sector)]. Akad. Nauk SSSR, "Nauka", Moscow, 144 p., 48 pls.
- Nakrem, H. A., 1988. Permian bryozoans from southern Spitsbergen and Bjornoya. A review of bryozoans described by J. Malecki (1968, 1977). *Polar Res.* (6): 113-121.
- Nakrem, H. A., 1991. Distribution of bryozoans in the Permian succession of Svalbard (Preliminary data). In Bigey, F. P. (edit): Bryozoaires actuels et fossiles: Bryozoa living and fossil. *Bull. Soc. Sci. Nat. l'Ouest France, Mém. HS I*. Nantes, France. p. 291-298.
- Nakrem, H. A., 1994a. Middle Carboniferous to Early Permian bryozoans from Spitsbergen. *Acta Palaeont. Polonica*, **39** (1): 45-116.
- Nakrem, H. A., 1994b. Environmental distribution of bryozoans in the Permian of Spitsbergen. In Hayward, P. J., Ryland, J. S. and Taylor, P. D. (edit.): *Biology and Palaeobiology of Bryozoans*. Olsen & Olsen, Fredensborg. p. 133-137.

- Nakrem, H. A., 1994 c. Bryozoans from the Lower Permian Voringen member (Kapp Starostin Formation), Spitsbergen, Svalbard. *Norsk Polarinst., Skrifter* (196), 93 p. (incl. 16 pls.)
- Nakrem, H. A. and Spjeldnaes, N., 1995. *Ramipora hochstetteri* Toulou, 1875 (Bryozoa, Cystoporata), from the Permian of Svalbard. *Jour. Paleont.*, **69** (5): 831–838.
- Nikiforova, A. I., 1938. Types of Carboniferous Bryozoa from the European part of the USSR. *Acad. Sci. USSR, Inst. Paleont.*, **4**, pt. 5, Fasc. 1, 290 p., 55 pls. (in Russian with English summary)
- Nikiforova, A. I. 1939. New species of Upper Paleozoic Bryozoa from the Bashkirian Urals (The Families Fenestellidae and Acanthocladiidae). *Trans. Geol. Oil Inst., Ser. A, Fasc. 115*, p. 70–102. (in Russian with English abstract)
- Ozhgibesov, V. P., 1983. *Permoheloclema*—novyi rod mshanok otryada Rhabdomesonida [*Permoheloclema*—new bryozoan genus of the Order Rhabdomesonida]. *Paleont. Zhur.* (4): 96–98.
- Romantchuk, T. V. and Kiseleva, A. V., 1968. Novye pozdne-permskiye mshanki Dalnego Vostoka [New Late Permian bryozoans from the Soviet Far East]. *Paleont. Zhur.* (4): 55–60.
- Ross, J. R. P., 1987. New chaetetiform trepostome Bryozoa from the Upper Mississippian of the western United States. *Palaeontology*, **31** (2): 551–566, pls. 46–51.
- Ross, J. R. P. and Ross, C. A., 1962. Faunas and correlation of the Late Paleozoic rocks of northeast Greenland. Part IV Bryozoa. *Medd. om Grønland*, **167** (7): 1–65, pls. 1–18.
- Sakagami, S., 1992. Notes on the Permian bryozoans from the Kapp Starostin Formation at Festningen route, Spitsbergen. In Nakamura, K. (edit.): Investigations on the Upper Carboniferous–Upper Permian succession of West Spitsbergen 1989–1991. Hokkaido Univ., Sapporo. p. 39–57 (incl. 6 pls.).
- Shulga-Nesterenko, M. I., 1933. Bryozoa from the coal-bearing and the subjacent series of Pechora Land, *Goniocladia* Etheridge and *Ramipora* Toulou, Carboniferous and Permian representatives of the Family Cystodictyonidae. *Trans. United Geol. & Prosp. Serv. USSR*, Fasc. 259, p. 1–64, pls. 1–8. (in Russian with English abstract)
- Shulga-Nesterenko, M. I., 1941. Lower Permian Bryozoa of the Urals. *Paleontology of USSR*, vol. V, Pt. 5, Fasc. 1, p. 1–276, pls. 1–67. *Acad. Sci. USSR*. (in Russian with English abstract)

