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Foraminifers from the Treskelodden Formation (Carboniferous–Permian) of south Spitsbergen

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Abstract: The organodetritic, sandy limestones of the Treskelodden Formation (Late Gzhelian to Early Artinskian) investigated in outcrops at Treskelen Peninsula, Hyrnefjellet mount and Polakkfjellet mount of south Spitsbergen, contain rich foraminiferal assemblages. Fifty eight foraminiferal species of twenty three genera, including two new species (*Hemigordius hyrnefjelleti* sp. nov. and *Midiella arctica* sp. nov.) have been identified. Three foraminiferal zones have been defined, with ages of Late Asselian (Pseudofusulinella occidentalis), Sakmarian (Midiella ovata – Calcitornella heathi) and Early Artinskian (Hemigordius hyrnefjelleti – Midiella arctica). Sedimentary features and the biotic history of the studied succession records a Late Paleozoic cooling trend that stays in accordance with Pangaea's shift to the north.

Key words: Arctic, Svalbard, paleontology (foraminifers), biostratigraphy, Late Paleozoic.

Introduction

This paper documents the distribution of small foraminifers and fusulinaceans in three Upper Carboniferous–Lower Permian stratigraphic sections from south Spitsbergen. Late Paleozoic smaller foraminifers have received comparatively little attention in comparison with the fusulinaceans and do not figure prominently in correlation schemes. Sosipatrova (1967, 1969) presented the first stratigraphic scheme for the Upper Paleozoic deposits in the central Spitsbergen, and described many new species and genera of small foraminifers and fusulinaceans. The Polish Geological and Paleontological Spitsbergen Expeditions of 1957–1960 (Birkenmajer 1964) and 1974–1979 (Biernat and Szymańska 1982) brought new material from south Spitsbergen, and the foraminifers were mentioned by Liszka (1964) and Peryt and Małkowski (1976). Both papers did not contain illustrations or descriptions of the foraminifers. During the field work in 2005 the author along with A. Gaździcki collected samples from gray sandy and marly limestones forming in-

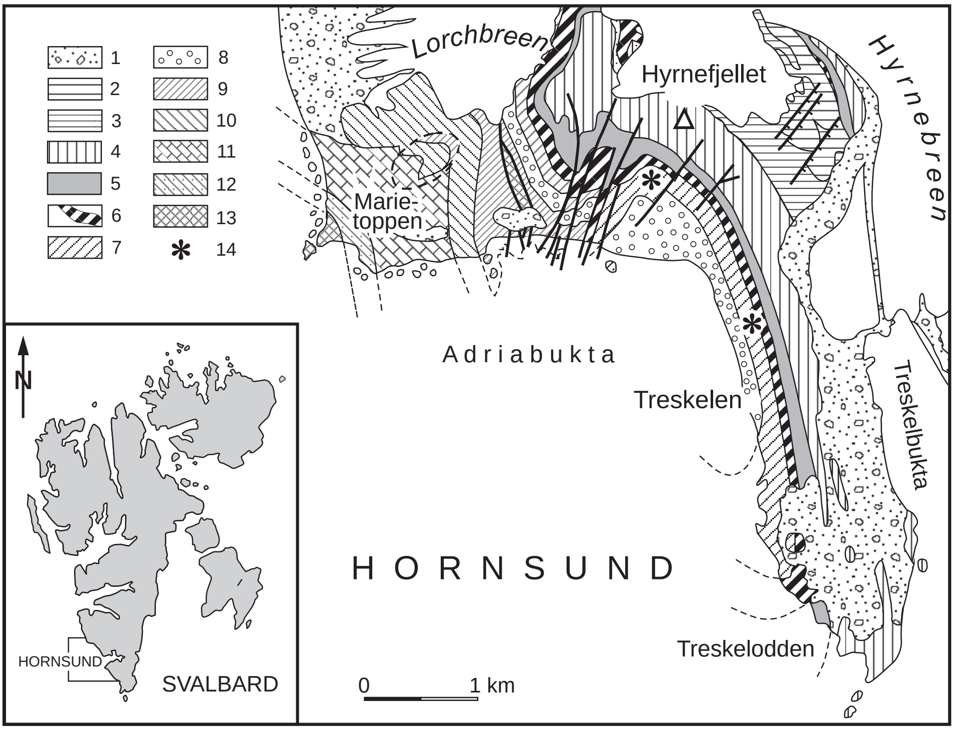


Fig. 1. Geological map of West Spitsbergen, Hornsund area (after Birkenmajer 1964), showing location of the Creek IV (Treskelen Peninsula) and Hyrnefjellet mt, where the foraminifer samples were collected. 1. Moraines, partly outwash; 2. Festningen Sandstone (Hauterivian–Barremian); Ullaberget Series (Lower Neocomian); 3. Tirolarpasset Series (Volgian–Lower Neocomian); 4. Middle and Upper Triassic; 5. Lower Triassic; 6. Brachiopod Cherty Limestone (Upper Permian); 7. Treskelodden Fm (Upper Carboniferous–lowermost Permian); 8. Hyrnefjellet Fm (Middle Carboniferous); 9. Adriabukta Series (Visean–Namurian A?); 10. Upper Marietoppen Series (Devonian); 11. Middle Marietoppen Series (Devonian); 12. Lower Marietoppen Series (Devonian); 13. Sofiebogen Fm (Eocambrian–Precambrian); 14. Asterisk shows foraminifer sampling locality.

tercalations in the Treskelodden Fm in Hornsund area (Treskelen-Hyrnefjellet region) outcrops (Figs 1–3). The studies of foraminifers were carried out using thin sections from collected samples.

The purpose of this paper is to document stratigraphic distribution and depositional environment of foraminifers from south Spitsbergen. The main theme of this paper is to discuss the stratigraphy of Late Carboniferous–Early Permian strata in the Hornsund area based on all available paleontological data. The result of this study is a significant addition to known occurrences of Carboniferous–Permian foraminifers in the High Arctic, complementing the previous studies of Sosipatrova (1967, 1969) on material from central Spitsbergen, Groves and Wahlman (1997) from the Barents Sea (offshore Arctic Norway), and Pinard and Mamet (1998) on material from the Sverdrup Basin of Canada.

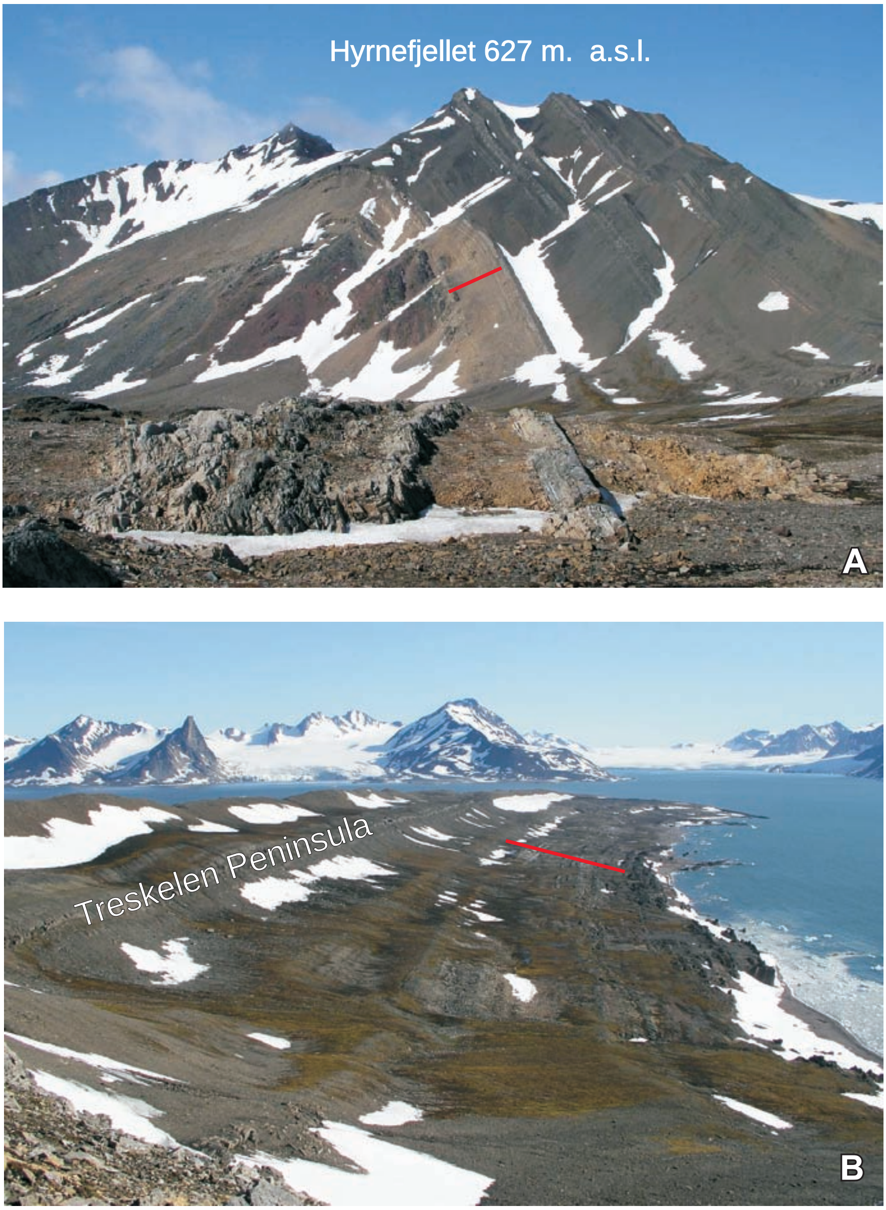


Fig. 2. Outcrops of the upper Paleozoic–lower Mesozoic sequences and measured sections Hyrnefjellet mt (**A**) and Creek IV (**B**), Hornsund. Sections shown by red lines.

Geological setting

The Svalbard Archipelago is part of the Barents Sea shelf that was uplifted in the Late Mesozoic and Cenozoic, and contains Permo–Carboniferous carbonate

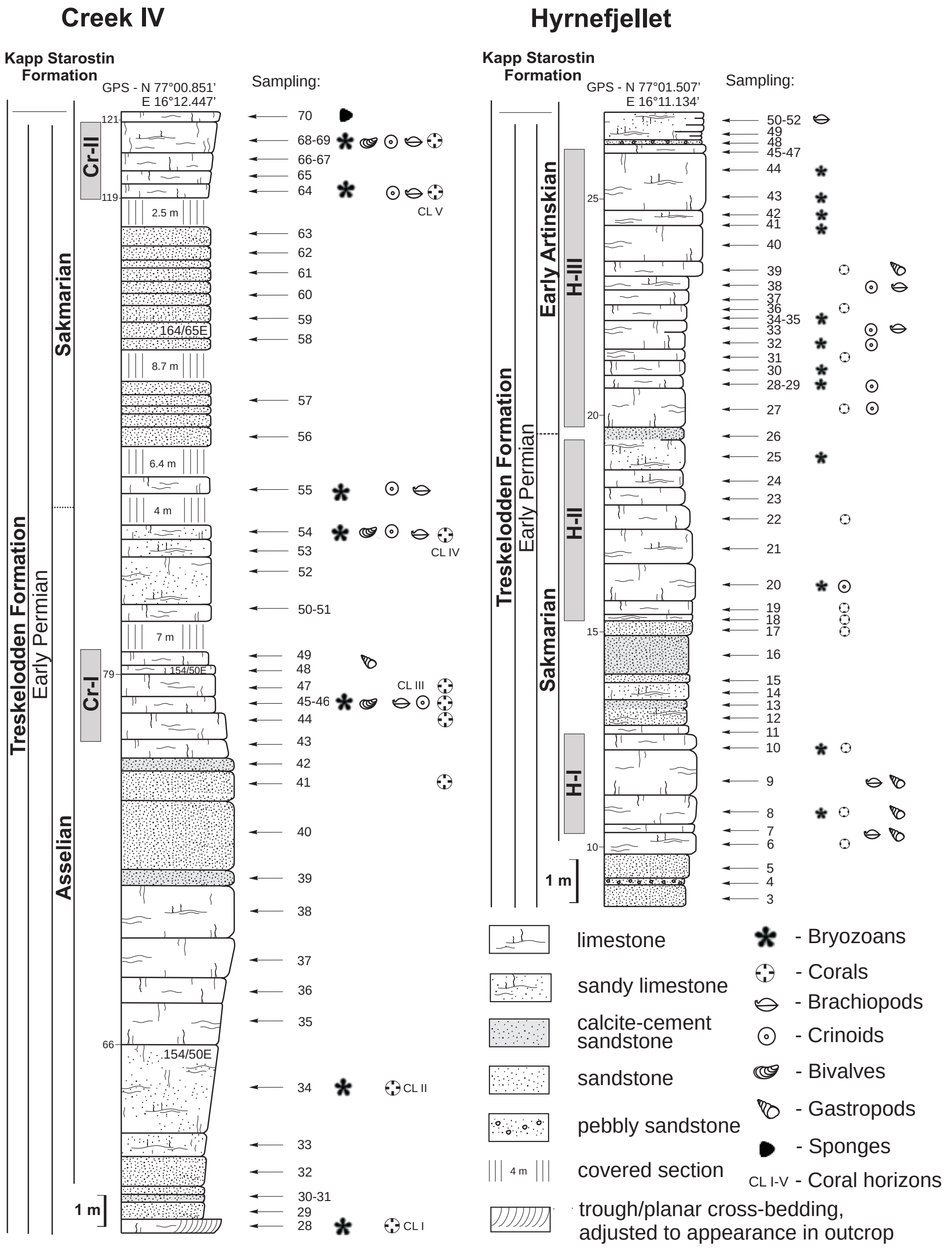


Fig. 3. Litostratigraphic sections and position of samples at the Treskelen (Creek IV) and Hyrnefjellet mt localities.

sediments deposited along the northern margins of the Pangaea supercontinent (Scotese and McKerrow 1990; Doré 1991). There are difficulties in making lithostratigraphic correlations among the various components of the carbonate platform, due to its mosaic-like structure additionally complicated by numerous horsts and troughs (Harland 1997; Stemmerik 2000).

The Upper Paleozoic rocks of southern Spitsbergen, including the Treskelodden Fm, are exposed between Hornsund and Bellsund fjords, along a 5–10 km wide NNW-SSE oriented belt. The formation consists of a sequence of fresh water and shallow marine clastic rocks having some large scale cross-bedding, and with subordinate shales and organodetritic, sandy limestone intercalations bearing well preserved fossils (Birkenmajer 1964, 1984; Birkenmajer and Fedorowski 1980; Dallmann *et al*. 1999). There is a regional low angle unconformity between the Treskelodden Fm below and the brachiopod cherty limestone of the Kapp Starostin Fm above.

In the Hornsund region the lowermost part of the Treskelodden Fm lacks fossils or contains scarce conifer branches (Birkenmajer 1964, 1984), whereas the upper part contains an abundant fauna with numerous foraminifers, rugose and tabulate corals which occur in organodetritic limestone and clastic coral-bearing conglomerate. An interesting phenomenon is the presence of up to five coral horizons on Treskelen Peninsula outcrops (Birkenmajer 1964). Both colonial and solitary rugose (Fedorowski 1964, 1965, 1967; Birkenmajer 1979) and tabulate corals (Nowiński 1982) occur as well as calcareous algae (Nowiński 1990), bryozoans (Nakrem *et al.* 2009), brachiopods (Czarniecki 1966, 1969), gastropods (Karczewski 1982), trilobite fragments (Osmólska 1968), bivalves and crinoids of which many have been described.

Birkenmajer (1964, 1984) and Siedlecka (1968) pointed out a distinct cyclictity of the succession of the Treskelodden Fm. Birkenmajer (1964) interpreted such changes as being caused by glaciation and deglaciation in the Southern Hemisphere. Except for the lower alluvial cycle, the facies pass repeatedly from shallow marine to lagoonal and alluvial environments (Birkenmajer 1984). Czarnecki (1966, 1969) regarded the Treskelodden Fm as entirely of marine origin. Fedorowski (1982) pointed out at redeposited nature of the corals, considering that tectonic factors were responsible for the observed faunal and sedimentological variations more than the global climatological mechanisms, as was proposed by Birkenmajer (1964).

Material and methods

The studied material was selected from a large collection of over 400 samples, taken for laboratory examination and was chosen with attention to the density and preservation of the foraminifers. Field observations and descriptions of three outcrop localities represent approximately 300 m of strata. Stratigraphic placement of samples is indicated in Fig. 3 (lithostratigraphic logs for the Creek IV and Hyrnefjellet mt sections); these sample numbers are also used in the systematic description of individual taxa. The Creek IV and Hyrnefjellet mt sections were sampled

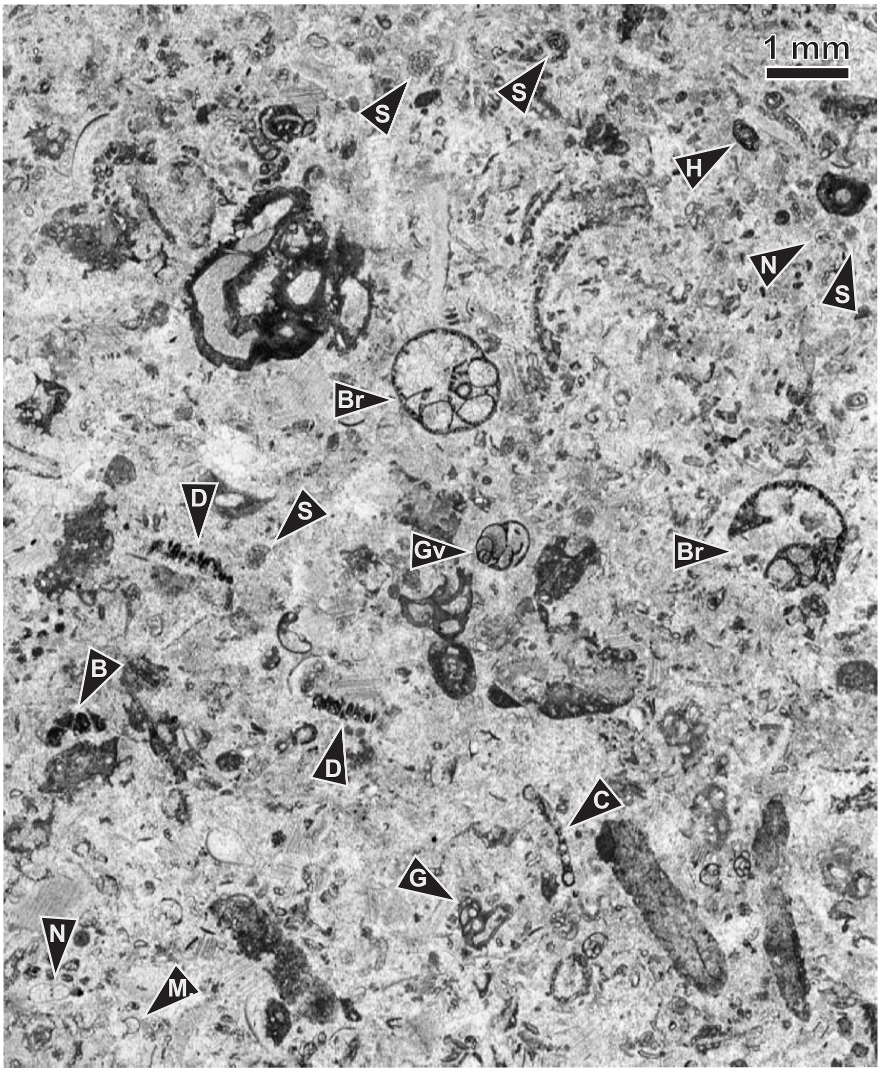


Fig. 4. Microfacies of the upper part of the Treskelodden Fm (section Creek IV, sample Cr67). Sakmarian (Permian): south Spitsbergen. Bioclastic packstone with algal (D) and bryozoans (B) fragments, and small foraminifers: S – *Schubertella*, H – *Hemigordius*, N – *Nodosinelloides*, Br – *Bradyinelloides*, Gv – *Globivalvulina*, C – *Calcitornella*, M – *Mendipsia* and G – Hemigordiopsida indet.

bed by bed, and a total number of 950 thin sections have been examined. Part of the material used for presenting grain association types (Chloroforam and Bryonoderm-extended) of warm water and cool water shelf carbonates was described using terminology and the classification of Beauchamp (1994). The biostratigraphic meaning of smaller foraminifers encountered in this study has been determined relative to an independently established regional fusulinacean biochronology (Konovalova 1991; Nilsson 1993, 1994). The thin sections containing foraminifers were placed under a transmitted light microscope, photographed and studied using standard methods of microfacies analysis.

Biostratigraphic distribution of the foraminifers

Stratigraphic occurrences of recognizable small foraminifers and their abundance in each sample at the Creek IV and Hyrnefjellet mt sections are shown in Tables 1 and 2. The list of all species found in the studied samples is given in Appendix.

Creek IV section (Treskelen Peninsula)

The Creek IV section (Figs 2B, 3) is the stratotype for the Treskelodden Fm (Birkenmajer 1964). In this section foraminifers appear in carbonate beds intercalated with packages of clastic rocks that do not contain foraminifers. In the studied section two foraminiferal assemblages are distinguished: lower (Cr-I) and upper (Cr-II).

The oldest bed of carbonate with a preserved foraminiferal fauna is exposed 61 m above the base of the section (Fig. 3, Table 1). They occur as carbonate lithofacies intercalations within clastic series. The first scarce foraminifers *Pseudofusulinella* sp. were found in sample Cr28.

Above the mentioned bed, a 2 m thick package appears, consisting of marly claystone that lacks foraminifers, and passes upward into a sequence of carbonate rock (sample Cr33–Cr38), in which one specimen of ?*Glomospira* sp. was identified (sample Cr34) (Fig. 3, Table 1, Fig. 5: 1). Above the sequence, no foraminifers were found in a 3 m thick package of clastic rocks (sample Cr39–Cr42).

Lower foraminiferal assemblage (Cr-I). — Organodetritic, sandy limestones are exposed between 77 m and 80 m above the base of the section (samples Cr43–Cr49) where a coral fauna determining the III coral horizon (Fig. 3) was found (Birkenmajer 1964, 1979; Fedorowski 1982). Besides the coral fauna, also bryozoans, mollusks, brachiopods and crinoid columnals are present (Czarniecki 1969; Karczewski 1982; Nakrem *et al*. 2009).

In these limestone beds abundant foraminifers were distinguished as the lower foraminiferal assemblage of the Creek IV section (Cr-I). The assemblage contains 13 species, including one single specimen of *Nodosinelloides* sp. A (Fig. 9: 4), belonging to 8 genera, with the most significant percentage of the representatives of the Class Fusulinata (approx. 98 % of the assemblage, Table 1).

The species *Pseudofusulinella occidentalis* (Thompson and Wheeler in Thompson *et al.,* 1946) deserves special attention for being a stratigraphic indicator (Table 1, Fig. 14: 7). This species was described from the Late Asselian Wordiekammen Fm (Tyrrellfjellet Mb) of central Spitsbergen (Nilsson 1988, 1993), as well as from the Urals and Timan-Pechora oil- and gas-bearing provinces of the Late Asselian age (Grozdilova and Lebedeva 1961; Konovalova

Table 1

Stratigraphic occurrences of foraminifer taxa at Creek IV section

Age	Lithostratigraphy	Sample	Meters above base of section	*Nodosariata* indet.	*Nodosinelloides longissima*	*Nodosinelloides aequiampla*	*Nodosinelloides potievskayae*	*Nodosinelloides* aff. *camerata*	*Nodosinelloides* aff. *netschajewi*	*Nodosinelloides* spp.	*Nodosinelloides* sp. A	*Geinitzina postcarbonica*	*Earlandia* ex gr. *elegans*	*Tetrataxis* sp.	*Mendipsia* spp.	*Endothyra* aff. *pseudobradyi*	*Endothyra* sp.	*Globivalvulina bulloides*	*Globivalvulina nassichuki*	*Globivalvulina graeca*	*Globivalvulina* cf. *graeca*	*Globivalvulina* cf. *sikhanensis*	*Globivalvulina syzranica*
Sakmarian	Treskelodden Formation	70	121.40																				
		69	120.80												1			3	1			1	
		68	120.50	1					1	1			1					2	2	2	1		1
		67	120.35	2		1		1		2		?		1	2			2	2	1			
		66	120.10			1							2		1				1	2		1	
		65	119.20									1				1		1	5				
		64	118.95		1		1											1					1
		63	116.05																				
		62	115.50																				
		61	114.80																				
		60	113.90																				
		59	113.10																				
		58	112.30																				
		57	103.00																				
		56	101.60																				
		55	94.70																				
Asselian		54	90.10																				
		53	89.90																				
		52	89.00																				
		51	86.80																				
		50	86.30																				
		49	80.10												2				2				
		48	79.80																				
		47	79.00															2					
		46	78.90								1							2		1			
		45	78.50												1		1		2				
		44	78.20	1															1				
		43	77.40																				
		42	76.80																				
		41	76.10																				
		40	74.60																				
		39	73.10																				
		38	72.05																				
		37	70.30																				
		36	69.20																				
		35	68.40																				
		34	66.00																				
		33	64.10																				
		32	63.30																				
		31	62.70																				
		30	62.50																				
		29	61.90																				
		28	61.60																				

1991). The species *P. occidentalis* is considered as an index fossil for the Late Asselian (Nilsson 1993). During Late Paleozoic, the regions mentioned above (Nikiforova 1938; Morozova and Kruchinina 1986) together with the Sverdrup

Table 1 – *continued*.

Globivalvulina spp.	*Pseudobradyina* sp.	*Bradyinelloides* spp.	*Palaeotextularia* sp.	*Schubertella* spp.	*Schubertella spherica*	*Eoschubertella* spp.	Schwagerinidae indet.	*Pseudofusulinella occidentalis*	*Pseudofusulinella* spp.	Hemigordiopsida indet.	*Hemigordius* spp.	*Midiella ovata*	? *Pseudoglomospira* sp.	*Calcitornella heathi*	*Baryshnikovia* sp.	? *Glomospira* sp.	Foraminiferal assemblage	Assemblage zone
2		1		3	1					2		6	1	2			Cr-II	Midiella ovata - Calcitornella heathi
2		3		4	2	2				1	1			2				
5		3		2	3		1				1	2	1	1				
4				3	2		2				?							
4				2			3				?	2	2					
1				2											1			
																		barren interzone
	1																	
																	Cr-I	Pseudofusulinella occidentalis
2				4	1											1		
				2				1	2									
4		?		1	3				8									
1			2	2				1	9									
																1		
								2									

Basin (Morozova and Kruchinina 1986) and the Wandel Sea Basin (Madsen and Håkansson 1989) were forming expanded carbonate platform that was included within the Franklinian Shelf (Ross 1981; Ross and Ross 1990).

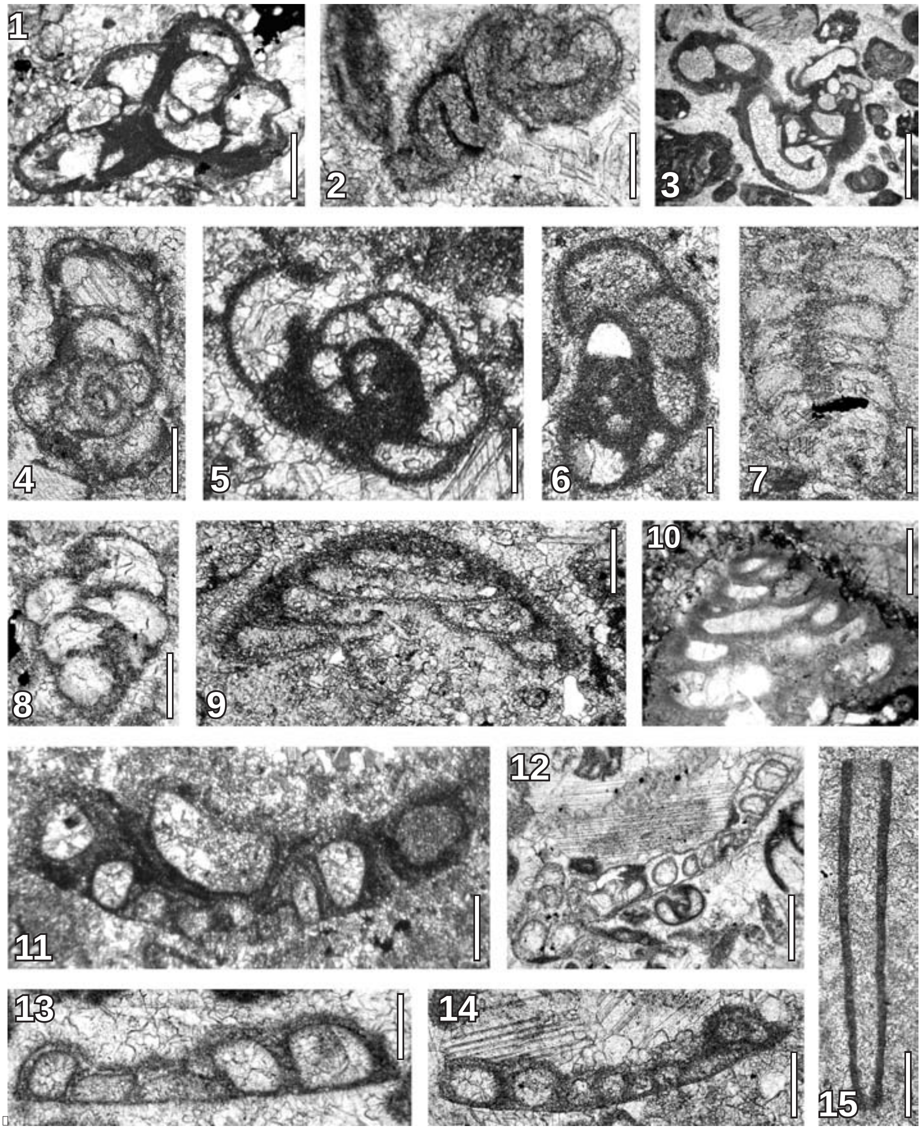


Fig. 5. **1**, **4**. ?*Glomospira* sp., oblique sections; **1**. (ZPAL F.53/Cr34.35); **4**. (ZPAL F.53/Cr47.19). **2**. *Calcivertella adherens* Cushman and Waters, 1928, close to axial section (ZPAL F.53/H42.80). **3**. ?*Glomospira ishimbarica* Lipina, 1949, horizontal section (ZPAL F.53/H41.97). **5**. *Endothyra* sp., transverse section (ZPAL F.53/Cr45.67). **6**. *Endothyra* aff. *pseudobradyi* Brazhnikova, 1956, transverse section (ZPAL F.53/Cr65.63). **7**–**8**. *Palaeotextularia* sp., close to axial sections; **7**. (ZPAL F.53/Cr44.49); **8**. (ZPAL F.53/Cr44.48); **9**–**10**. *Tetrataxis* sp., close to axial sections; **9**. (ZPAL F.53/H8.63); **10**. (ZPAL F.53/Cr67.77). **11**–**13**. *Calcitornella heathi* Cushman and Waters, 1928, close to axial sections; **11**. (ZPAL F.53/Cr64.83). **12**. (ZPAL F.53/Cr68.84); **13**. (ZPAL F.53/H21.86). **14**. *Calcitornella* sp., close to axial section (ZPAL F.53/H20.53). **15**. *Earlandia* ex gr. *elegans* (Rauser-Chernousova and Reitlinger *in* Rauser-Chernousova and Fursenko, 1959), axial section (ZPAL F.53/Cr68.3). Scale bars 0.1 mm. Treskelodden Fm; Creek IV (Cr) and Hyrnefjellet mt (H) sections, Hornsund, Lower Permian.

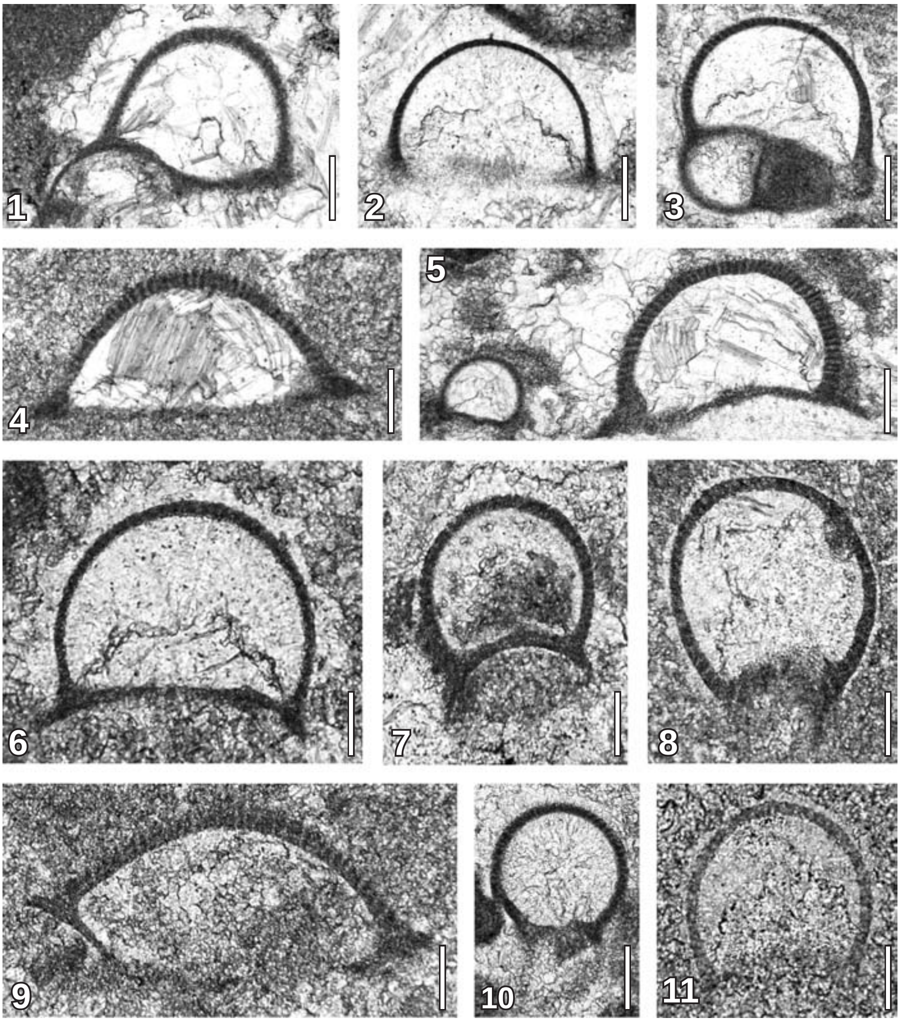


Fig. 6. **1**, **4–5**, **7–10**. *Mendipsia* sp., longitudinal sections; **1**. (ZPAL F.53/Cr49.50); **4**. (ZPAL F.53/Cr49.51); **5**. (ZPAL F.53/Cr69.53); **7**. (ZPAL F.53/H7.83); **8**. (ZPAL F.53/H42.85); **9**. (ZPAL F.53/H40.86); **10**. (ZPAL F.53/Cr45.81). **2–3**, **6**. *Tuberitina maljavkini* Mikhailov, 1939, longitudinal sections; **2**. (ZPAL F.53/H35.57); **3**. (ZPAL F.53/H38.58); **6**. (ZPAL F.53/H38.59). **11**. *Tuberitina* sp. longitudinal section (ZPAL F.53/H7.25). Scale bars 0.1 mm. Treskelodden Fm; Creek IV (Cr) and Hyrnefjellet mt (H) sections, Hornsund, Lower Permian.

Taking into account the documented appearance (Nilsson 1993) of *P. occidentalis* within Asselian strata in adjacent areas, its presence in the lower beds of the Treskelodden Fm in the Creek IV section should be considered an argument for the Late Asselian age of these strata.

Above the carbonate interval containing foraminifers of the lower foraminiferal assemblage (Cr-I) there is a 7 m of covered section that makes impossible any detailed investigation of lithology. Above it at the distance of 86 m to 90 m from

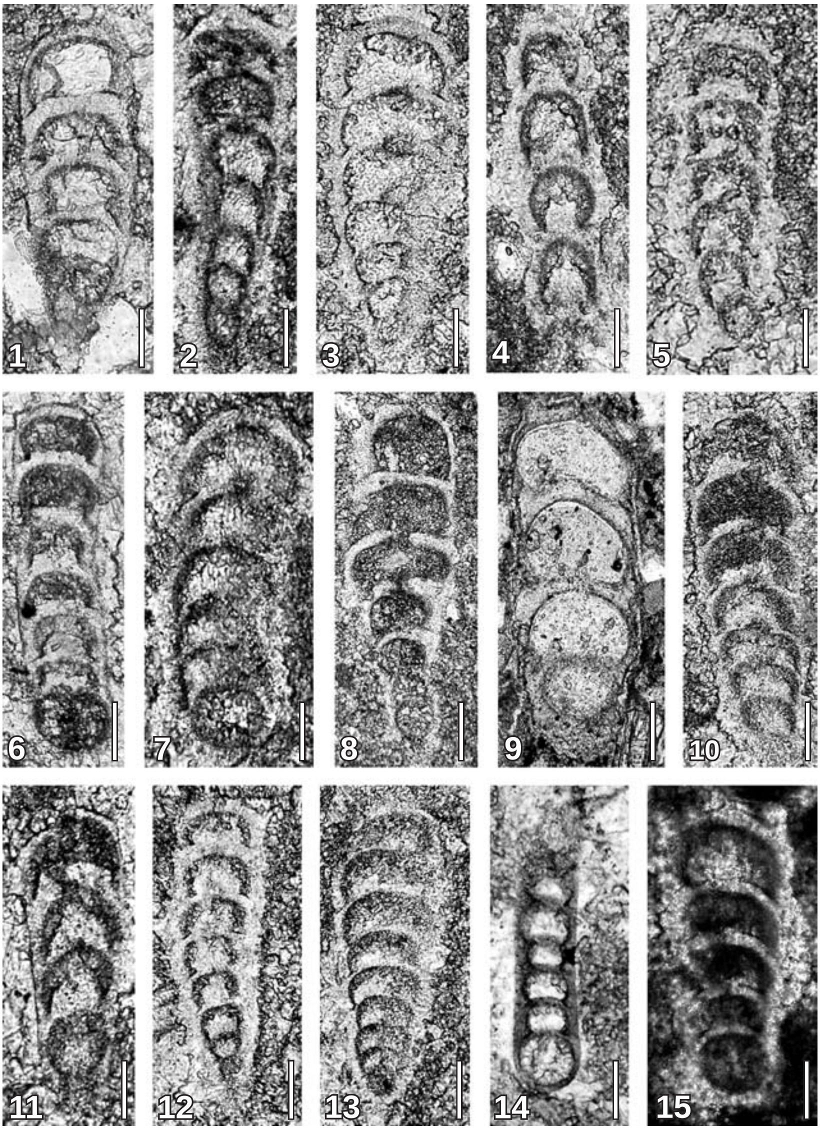


Fig. 7. **1**–**2**. *Nodosinelloides* aff. *netschajewi* (Cherdyntsev, 1914); **1**. Oblique axial section (ZPAL F.53/Cr68.1); **2**. Axial section (ZPAL F.53/H33.2). **3**, **5**, **10**. *Nodosinelloides* sp., close to axial sections; **3**. (ZPAL F.53/Cr68.2); **5**. (ZPAL F.53/H38.5); **10**. (ZPAL F.53/H7.3). **4**. *Nodosinelloides* cf. *longa* (Lipina, 1949), longitudinal section (ZPAL F.53/H43.1). **6**–**7**. *Nodosinelloides aequiampla* (Zolotova *in* Zolotova and Baryshnikov 1980), close to axial sections; **6**. (ZPAL F.53/Cr67.1); **7**. (ZPAL F.53/Cr66.7). **8**–**9**, **13**. Nodosariata indet.; **8**. Tangential section (ZPAL F.53/Cr67.5); **9**. Oblique axial section (ZPAL F.53/Cr68.4); **13**. Oblique axial section (ZPAL F.53/H40.1). **11**. *Nodosinelloides mirabilis* (Lipina, 1949), tangential section (ZPAL F.53/H30.2). **12**. ?*Nodosinelloides* sp., axial section (ZPAL F.53/H33.3). **14**. *Nodosinelloides potievskayae* Mamet and Pinard, 1996, tangential section (ZPAL F.53/Cr64.2). **15**. *Nodosinelloides* aff. *camerata* (Miklukho-Maklay, 1954), axial section (ZPAL F.53/Cr67.8). Scale bars 0.1 mm. Treskelodden Fm; Creek IV (Cr) and Hyrnefjellet mt (H) sections, Hornsund, Lower Permian.

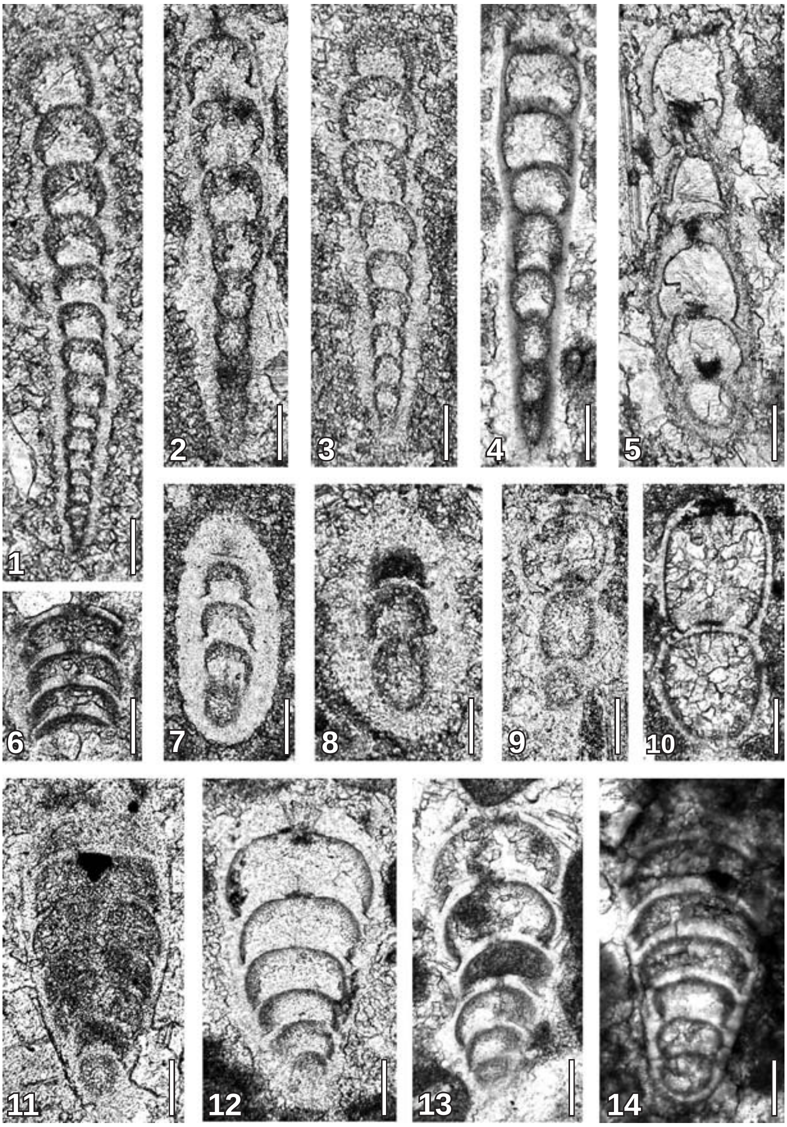


Fig. 8. **1**–**3**. *Nodosinelloides longissima* (Suleimanov, 1949), longitudinal sections; **1**. (ZPAL F.53/H36.30); **2**. (ZPAL F.53/Cr64.1); **3**. (ZPAL F.53/H7.6). **4**. *Nodosinelloides* cf. *longissima* (Suleimanov, 1949), longitudinal section (ZPAL F.53/H7.7). **5**. *Nodosinelloides spitzbergiana* (Sosipatrova, 1969), axial section (ZPAL F.53/H38.4). **6**, **12**. *Geinitzina frondiculariformis* Sosipatrova, 1969; **6**. (ZPAL F.53/H42.8), axial section of broken specimen; **12**. (ZPAL F.53/H39.1), oblique axial section. **7**–**8**. *Langella seminula* Zolotova, 1980, oblique sections; **7**. (ZPAL F.53/H19.1); **8**. (ZPAL F.53/H7.1). **9**. *Protonodosaria* cf. *globifrondina* Sellier de Civrieux and Dessauvagie, 1965, oblique section (ZPAL F.53/H36.1). **10**, **13**. Nodosariata indet.; **10**. Longitudinal? section (ZPAL F.53/Cr67.6); **13**. Close to axial section (ZPAL F.53/H41.2). **11**. *Geinitzina postcarbonica* Spandel, 1901, close to axial section (ZPAL F.53/Cr65.1). **14**. ?*Geinitzina postcarbonica* Spandel, 1901, tangential section (ZPAL F.53/Cr67.2). Scale bars 0.1 mm. Treskelodden Fm; Creek IV (Cr) and Hyrnefjellet mt (H) sections, Hornsund, Lower Permian.

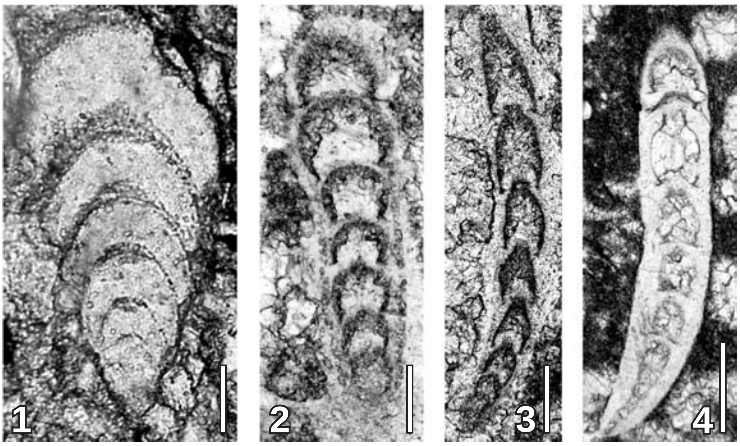


Fig. 9. **1**. *Howchinella semiovalis* (Zolotova and Sosipatrova *in* Sosipatrova, 1969), close to axial section (ZPAL F.53/H27.1). **2**. *Nodosinelloides* sp., longitudinal section (ZPAL F.53/H29.4). **3**. *Vervilleina bradyi* (Spandel, 1901), axial section (ZPAL F.53/H33.1). **4**. *Nodosinelloides* sp. A, axial section (ZPAL F.53/Cr46.1). Scale bars 0.2 mm. Treskelodden Fm; Creek IV (Cr) and Hyrnefjellet mt (H) sections, Hornsund, Lower Permian.

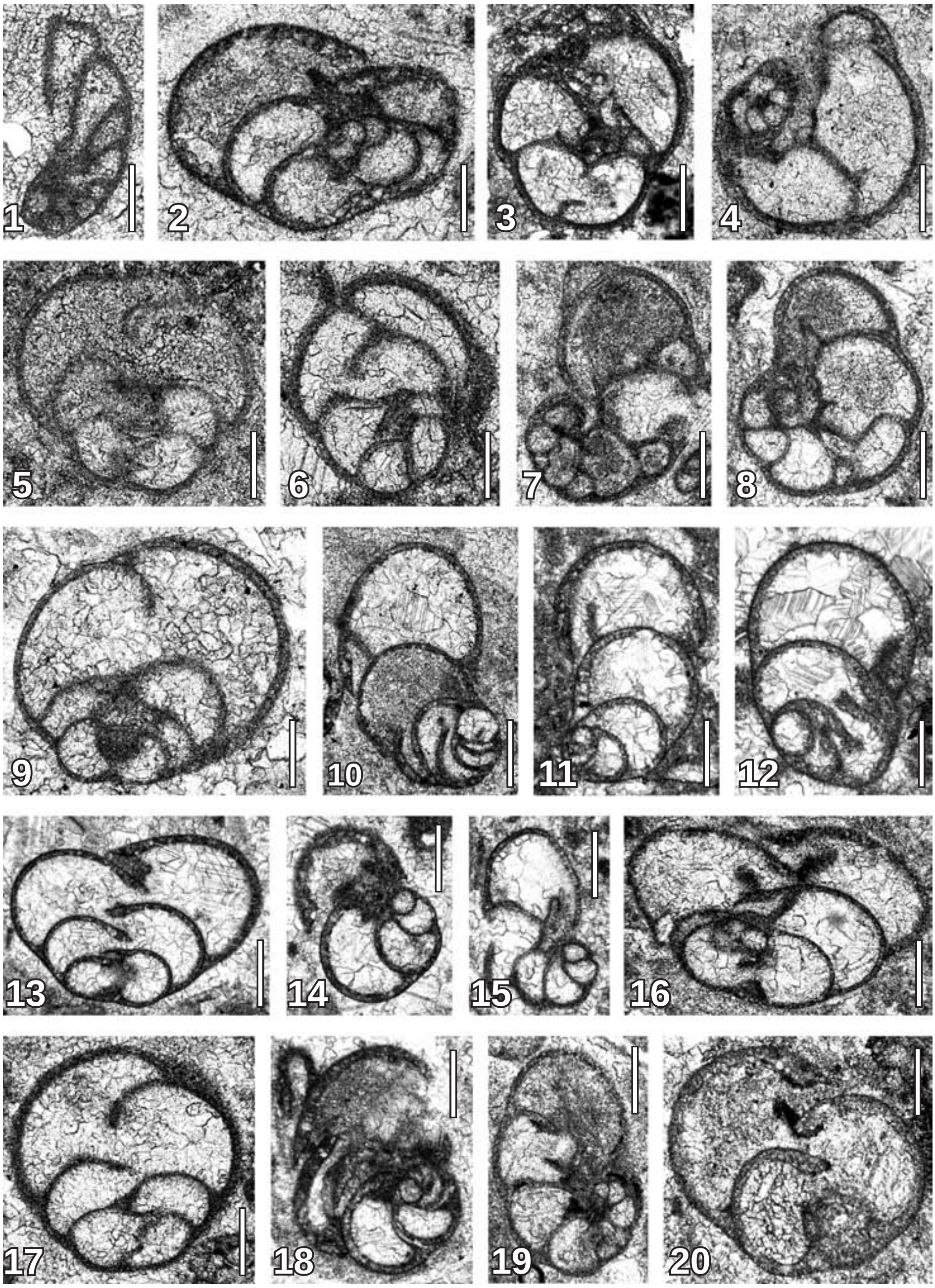
the base of the section, another package of carbonate rock is exposed (samples Cr50–Cr54). Only one specimen of the genus *Pseudobradyina* Reitlinger, 1950 was found in sample Cr54. The corals in this part of the section (Fig. 3) define the IV coral horizon (Birkenmajer 1964). Bivalves, bryozoans, brachiopods, crinoid remains and rare spherical colonies of calcareous algae are also present in this horizon.

The successive 11 m interval of the section is covered, excluding a 50 cm thick bed at 95 m above the section base, where biogenic limestone is exposed (sample Cr55). In this bed no foraminifers were found. On the contrary, there are abundant crinoid remains, and less common bivalves and brachiopods.

Above the covered interval, a 2 m thick sequence of sandstone and calcareous sandstone is exposed (sample Cr56 and Cr57). Upward the section, a 8.7 m thick interval is covered up to 102 m above the base of the section. Still higher up, a package of thick-bedded clastic rocks with thickness of 3.5 m is exposed (sample from Cr58 to Cr63).

Upper foraminiferal assemblage (Cr-II). — Above of previous package, there is 2.5 m thick part of covered interval located 116 to 119 m above the section base.

Fig. 10. **1**. *Globivalvulina* cf. *sikhanensis* Morozova, 1949, transverse section (ZPAL F.53/Cr66.3). **2**. *Globivalvulina pergrata* Konovalova, 1962, oblique section (ZPAL F.53/H42.31). **3**. *Globivalvulina syzranica* Reitlinger, 1950, tangential axial section (ZPAL F.53/Cr64.4). **4–5**. *Globivalvulina graeca* Reichel, 1945; **4**. Oblique section (ZPAL F.53/Cr68.9); **5**. Oblique axial section (ZPAL F.53/Cr68.10). **6–9**. *Globivalvulina* cf. *graeca* Reichel, 1945; **6**. Close to axial section (ZPAL F.53/Cr68.15); **7**. Transverse section (ZPAL F.53/H40.10); **8**. Transverse section (ZPAL F.53/H43.37); **9**. Oblique axial section (ZPAL F.53/H43.33). **10–16**, **18**. *Globivalvulina nassichuki* Pinard and Mamet, 1998; **10**. Oblique transverse section (ZPAL F.53/Cr69.1); **11**. Transverse section (ZPAL F.53/H42.4); →



12. Oblique transverse section (ZPAL F.53/H42.5); **13**. Axial section (ZPAL F.53/H42.8); **14**. Oblique transverse section (ZPAL F.53/H42.9); **15**. Transverse section (ZPAL F.53/H42.10); **16**. Oblique section (ZPAL F.53/H40.6); **18**. Oblique transverse section (ZPAL F.53/H32.40). **17**. *Globivalvulina* sp., axial section (ZPAL F.53/H42.29). **19–20**. *Globivalvulina bulloides* (Brady, 1876); **19**. Transverse section (ZPAL F.53/H39.5); **20**. Oblique section (ZPAL F.53/H36.3). Scale bars 0.1 mm. Treskelodden Fm; Creek IV (Cr) and Hyrnefjellet mt (H) sections, Hornsund, Lower Permian.

Then follows gray organodetritic limestone with lenses and intercalations of calcareous sandstone (samples Cr64–Cr69), there the upper foraminiferal assemblage was distinguished (Fig. 4, Table 1). It contains twenty eight species of foraminifers representing 16 genera and is much more taxonomically diversified than the lower foraminiferal assemblage (Cr-I).

Gray organodetritic limestone of V coral horizon (Birkenmajer 1964, 1979) yielded also dasycladacean algae and corals (Fig. 3).

The upper foraminiferal assemblage (Cr-II) lacks a few species occurring in the lower foraminiferal assemblage (e.g. *Nodosinelloides* sp. A, *Palaeotextularia* sp., *Pseudofusulinella occidentalis*, *Pseudofusulinella* spp., and ?*Glomospira* sp.), but many other species appear (Table 1). In contrast to the lower foraminiferal assemblage, the percentage of the representatives of the Class Nodosariata (*Nodosinelloides* Mamet and Pinard, 1992 and *Geinitzina* Spandel, 1901) is greater (13%). Representatives of the Class Miliolata are identified here for the first time in the section, making 19% of the assemblage. Besides foraminifers, also solitary rugose and tabulate corals, bryozoans, bivalves, brachiopods, crinoids and phosphatized sponges were found in the section (Fig. 3).

The upper foraminiferal assemblage (Cr-II) is considered to be of Sakmarian age because some taxa are known from Late Sakmarian strata, e.g. *Midiella ovata* (Grozdilova, 1956) (Fig. 16: 6–11). *Pseudofusulinella occidentalis* that is typical for the Asselian strata, known from the lower foraminiferal assemblage (Cr-I) is no longer present. Moreover, there are no taxa whose stratigraphical range begins in the Artinskian.

Hyrnefjellet mount section

In the section exposed at Hyrnefjellet mt (Figs 2A, 3), foraminifers occur only in the carbonate rock and they are similar to those of the Creek IV section. Three assemblages of foraminifers were distinguished: lower (H-I), middle (H-II), and upper (H-III), see Fig. 3 and Table 2.

Lower foraminiferal assemblage (H-I). — The first 10 m of the Hyrnefjellet mt section are composed of clastic rocks, mostly quartzitic sandstone (samples H1 to H5). Above this package, from 9.90 to 12.80 m above the base of the section, the sequence of carbonate rock is exposed (samples H6 to H10, Fig. 3). An abundant foraminiferal fauna is present at the base of the sequence. Foraminifers are represented by three classes: Fusulinata, Spirillinata and Nodosariata and 17 species of 11 genera of foraminifers were identified. The representatives of the Class Fusulinata make 57% of the total species in the assemblage, the Spirillinata and Nodosariata – respectively 23% and 20%. Besides the foraminifers, also corals, brachiopods and bivalves were found (Fig. 3, Table 2).

The assemblage of foraminifers is represented mostly by cosmopolitic species (excluding *Midiella ovata* (Grozdilova, 1956), *Calcitornella heathi* Cushman and

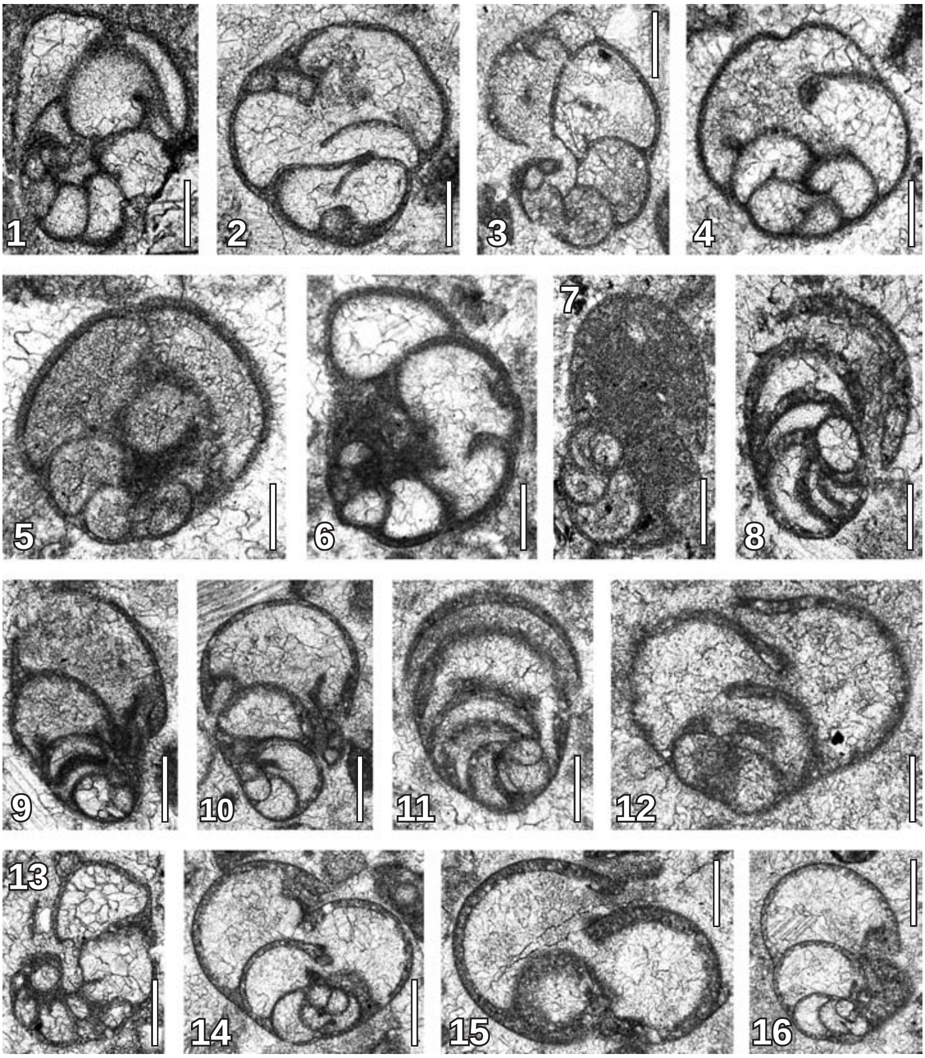


Fig. 11. **1**–**6**. *Globivalvulina bulloides* (Brady, 1876); **1**. Slightly oblique transverse section (ZPAL F.53/H36.21); **2**. Colse to axial section (ZPAL F.53/H38.40); **3**. Transverse section (ZPAL F.53/H34.40); **4**. Close to axial section (ZPAL F.53/H36.40); **5**. Close to axial section (ZPAL F.53/H40.42); **6**. Transverse section (ZPAL F.53/H8.40). **7**. *Globivalvulina nassichuki* Pinard and Mamet 1998, oblique transverse section (ZPAL F.53/Cr65.4). **8–16**. *Globivalvulina pergrata* Konovalova, 1962; **8**. Oblique transverse section (ZPAL F.53/H18.21); **9**. Oblique transverse section (ZPAL F.53/H41.23); **10**. Oblique transverse section (ZPAL F.53/H43.35); **11**. Oblique transverse section (ZPAL F.53/H38.30); **12**. Oblique section (ZPAL F.53/H38.34); **13**. Transverse section (ZPAL F.53/H43.40); **14**. Oblique axial section (ZPAL F.53/H43.41); **15**. Oblique section (ZPAL F.53/H42.31); **16**. Oblique section (ZPAL F.53/H43.38). Scale bars 0.1 mm. Treskelodden Fm; Creek IV (Cr) and Hyrnefjellet mt (H) sections, Hornsund, Lower Permian.

Waters, 1928 and *Langella seminula* Zolotova *in* Zolotova and Baryshnikov, 1980) of wide stratigraphic range and usually poorly preserved. The occurrence of *Calci-*

Table 2

Stratigraphic occurrences of foraminifer taxa at Hyrnefjellet section

Age	Lithostratigraphy	Sample	Meters above base of section	Nodosariata indet.	*Vervilleina bradyi*	*Nodosinelloides mirabilis*	*Nodosinelloides longissima*	*Nodosinelloides* cf. *longissima*	*Nodosinelloides* cf. *longa*	*Nodosinelloides* aff. *netschajewi*	*Nodosinelloides spitzbergiana*	*Nodosinelloides* spp.	*Protonodosaria* cf. *globifrondina*	*Geinitzina frondiculariformis*	*Geinitzina* sp.	*Howchinella semiovalis*	*Langella seminula*	*Mendipsia* spp.	*Tetrataxis* sp.	*Tuberitina maljavkini*	*Tuberitina* sp.	*Globivalvulina bulloides*	*Globivalvulina nassichuki*	*Globivalvulina pergrata*	*Globivalvulina* cf. *graeca*	*Globivalvulina* spp.
Early Artinskian	Treskelodden Formation	52	26.90																							
		51	26.75																			1				1
		50	26.60																							
		49	26.40																							
		48	26.35																							
		47	26.25																							
		46	26.20																							
		45	26.05																							
		44	25.60	1																						
		43	25.00						1													1		6	2	
		42	24.65	1										1				1		1	1	3	7	2	1	2
		41	24.50	1											1							3	3	1		
		40	24.00	1								1						1		2		1	2		2	2
		39	23.45											1								2		1		
		38	22.95								1	2							1	2		7		3		
		37	22.85																			1	1		1	
		36	22.55	1			2						1									2		1		
		35	22.40																	1			3			
		34	22.15																			?	2			
		33	22.00	1	1					1		?														1
		32	21.80	1																			2			
		31	21.10	1																						
		30	20.90	1		1						4			1								1			6
		29	20.60									3			1									2		
		28	20.40																							1
		27	20.05													1										
Sakmarian		26	19.50																							
		25	19.00																							1
		24	18.15																							
		23	17.90																							
		22	17.40																							
		21	16.80																							
		20	16.00																							
		19	15.50														1									
		18	15.40																				1	1		
		17	15.00																							
		16	14.55																							
		15	13.95																							
		14	13.60																							
		13	13.00																							
		12	12.65																							
		11	12.50																							
		10	12.25	1								1							1			4	1			
		9	11.10																							
		8	10.60																1			2				2
		7	10.20				2	1				3					1	1		1	2	2				
		6	9.95																							

tornella heathi known from the Virgilian (Pennsylvanian) to the Middle Permian (Cushman and Waters 1928; Crespin 1958; Palmieri in Foster *et al.*, 1985; Palmieri 1994; Scheibnerová 1982), and *Midiella ovata* (Vachard and Krainer 2001; Vachard

Table 2 – *continued*.

Bradyinelloides lucida	*Bradyinelloides shikhanica*	*Bradyinelloides omrica*	*Bradyinelloides major*	*Bradyinelloides* spp.	*Schubertella* spp.	*Schubertella spherica*	Schwagerinidae indet.	*Pseudofusulinella* spp.	*Pseudoreichelina darvasica*	Hemigordiopsida indet.	*Hemigordius* spp.	*Hemigordius hyrnefjelleti* sp. nov.	*Midiella ovata*	*Midiella glomospiroidalis*	*Midiella arctica* sp. nov.	*Midiella* sp.	? *Glomospira ishimbarica*	*Calcitornella* spp.	*Calcivertella adherens*	*Calcitornella heathi*	Foraminiferal assemblage	Assemblage zone
		1	2		1																H-III	Hemigordius hyrnefjelleti – Midiella arctica
					3		4	1														
	2				6	9	2	1		1			3		2				1			
				1	3	2			1	4	1		1		2		1					
				3	5	3		1		1	1			1		1						
				1	1					2	1											
1			1	4	6		2	4		1	3											
2				1				2				1										
			3	1						1		2			2							
								1														
2						2																
					2	4							2									
						2	1				1											
													2									
													1									
																						barren interzone
							1														H-II	Midiella ovata - Calcitornella heathi
							1													1		
					1								1					1		1		
					2																	
																						barren intrazone
							1															
								1					6			1					H-I	Midiella ovata - Calcitornella heathi
							1											1		1		
					1		3															

et al. 1993), as well as the lack of taxa typical for the Artinskian, should be considered as indicators of Sakmarian (or even Late Sakmarian) age for the lower foraminiferal assemblage (H-I).

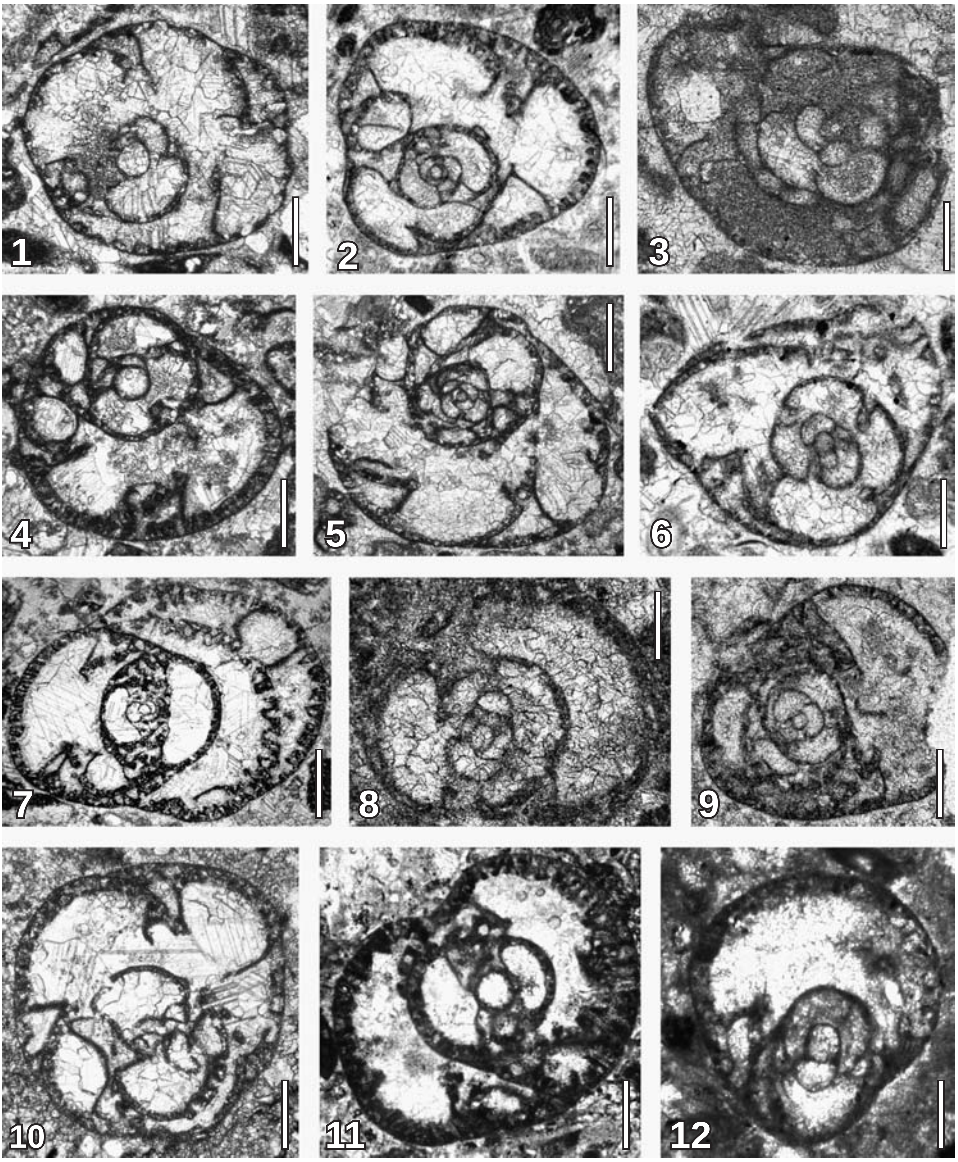


Fig. 12. **1**–**3**. *Bradyinelloides* sp.; **1**. Oblique section (ZPAL F.53/Cr69.72); **2**. Axial section (ZPAL F.53/H38.70); **3**. Transverse section (ZPAL F.53/H38.78). **4**. *Bradyinelloides omrica* (Konovalova, 1962), transverse section (ZPAL F.53/H44.84). **5**–**6**. *Bradyinelloides shikhanica* Morozova, 1949 *sensu* Korolyuk and Rauser-Chernousova, 1977, transverse sections; **5**. (ZPAL F.53/H42.80); **6**. (ZPAL F.53/H42.80). **7**–**11**. *Bradyinelloides major* (Morozova, 1949); **7**. Axial section (ZPAL F.53/H38.80); **8**. Close to axial section (ZPAL F.53/H36.72); **9**. Axial section (ZPAL F.53/H36.71); **10**. Transverse section (ZPAL F.53/H44.81); **11**. Axial section (ZPAL F.53/H44.82). **12**. *Bradyinelloides lucida* Morozova, 1949 *sensu* Korolyuk and Rauser-Chernousova, 1977, axial section (ZPAL F.53/H37.85). Scale bars 0.1 mm. Treskelodden Fm; Creek IV (Cr) and Hyrnefjellet mt (H) sections, Hornsund, Lower Permian.

Above the strata with the lower foraminiferal assemblage (H-I), more than 12.80 m above the base of the section, foraminifers became less frequent (samples H11). From 13 m to 15.40 m above the base, another package of clastic rocks is exposed (samples H12–H17). These are mostly fine-grained sandstone and calcareous sandstone devoid of where foraminifers (Fig. 3, Table 2). A sequence of carbonate rock (samples H18–H25), defining the middle foraminiferal assemblage (H-II) appears higher up.

Middle foraminiferal assemblage (H-II). — A middle foraminiferal assemblage is distinguished within the carbonate rock (samples H18 to H25) between 15.40 m and 19.50 m above the base of the section (Fig. 3, Table 2). In the assemblage taxonomic diversification of foraminifers is similar to that of the lower foraminiferal assemblage (H-I). Eight species of five genera of small foraminifers, and two species on family level (Schwagerinidae, Fusulinata) were identified (H-II, Table 2). Each species is represented by a single specimen. The middle foraminiferal assemblage (H-II) is dominated by representatives of the Class Fusulinata (61%), whereas Spirillinata and Nodosariata make up 31% and 8%, respectively. Besides foraminifers, also corals, crinoid remains (sample H20) and bryozoans (sample H24) were found.

Considering the documented existence of taxa in Sakmarian strata in the adjacent areas, as well as the taxonomic diversification and composition of the lower (H-I) and middle (H-II) foraminiferal assemblages, the same age – Sakmarian – of both assemblages is supported.

Approximately 19.50 m above the base of the section (sample H26), no foraminifers were found in the 0.4 m thick bed of calcareous fine grained sandstone (Fig. 3, Table 2).

Upper foraminiferal assemblage (H-III). — Above the calcareous fine grained sandstone, there is a sequence of carbonate rock with a thickness of 6 meters (samples H27 to H44). Within this sequence, the upper foraminiferal assemblage (H-III) of the Hyrnefjellet mt section (Fig. 3) was defined.

In this assemblage, the number of species significantly increases relatively to assemblages (H-I) and (H-II), Moreover, the upper foraminiferal assemblage (H-III) contains many specimens of the genera *Nodosinelloides*, *Globivalvulina*, *Bradyinelloides*, *Schubertella*, *Hemigordius* and *Midiella* (Table 2). In the assemblage 39 species belonging to 24 genera were identified, of which two species are new: *Hemigordius hyrnefjelleti* sp. nov. (Fig. 16: 15–16) and *Midiella arctica* sp. nov. (Fig. 16: 1–5). The percentage of representatives of the below mentioned classes in the assemblage is: Fusulinata (70%), Spirillinata (16%) and Nodosariata (14%).

The foraminiferal assemblage (H-III) lacks a few species characteristic for the Sakmarian strata, e.g. *Calcitornella heathi* (Fig. 5: 13), *Langella seminula* (Fig. 8: 7–8), but contains several new stratigraphically important taxa e.g. *Vervilleina bradyi* (Fig. 9: 3), *Geinitzina frondiculariformis* (Fig. 8: 6, 12) and

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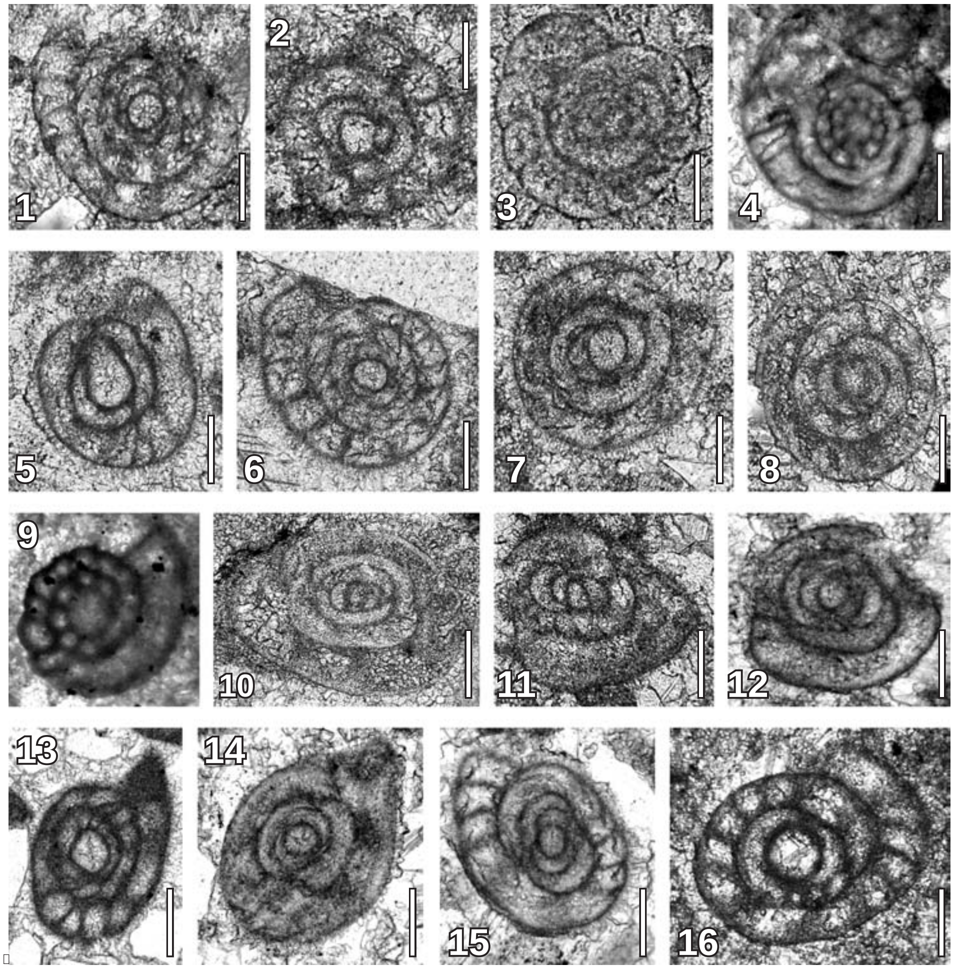


Fig. 13. **1–2**, **4–9**. *Schubertella sphaerica* Suleimanov, 1946, sagittal sections; **1**. (ZPAL F.53/Cr45.80); **2**. (ZPAL F.53/Cr67.86); **4**. (ZPAL F.53/H33.93); **5**. (ZPAL F.53/H42.101); **6**. (ZPAL F.53/H42.102); **7**. (ZPAL F.53/H42.107); **8**. (ZPAL F.53/Cr66.110); **9**. (ZPAL F.53/Cr68.111). **3**, **10–16**. *Schubertella* sp.; **3**. Sagittal section (ZPAL F.53/H41.95); **10**. Axial section (ZPAL F.53/Cr66.171); **11**. Oblique section (ZPAL F.53/Cr65.122); **12**. Axial section (ZPAL F.53/H7.140); **13**. Sagittal section (ZPAL F.53/H38.145); **14**. Axial section (ZPAL F.53/H38.146); **15**. Sagittal section (ZPAL F.53/H38.172); **16**. Sagittal section (ZPAL F.53/H38.170). Scale bars 0.1 mm. Treskelodden Fm; Creek IV (Cr) and Hyrnefjellet mt (H) sections, Hornsund, Lower Permian.

Pseudoreichelina darvasica (Fig. 14: 15). The genus *Pseudoreichelina* Leven, 1970, whose stratigraphical range is from the Sakmarian to the Artinskian (Lower Permian, Cisuralian) is represented by a single specimen belonging to *P. darvasica* Leven, 1970. This species is known from the Artinskian of Koryak terrane in the northeastern Russia (Davydov *et al.* 1996), southern Abukuma Mountains of northeast Japan (Ueno 1992), and Ban Phi Chngwat Loei in the northeastern Thailand (Igo *et al*. 1993). The occurrence of *P. darvasica* known

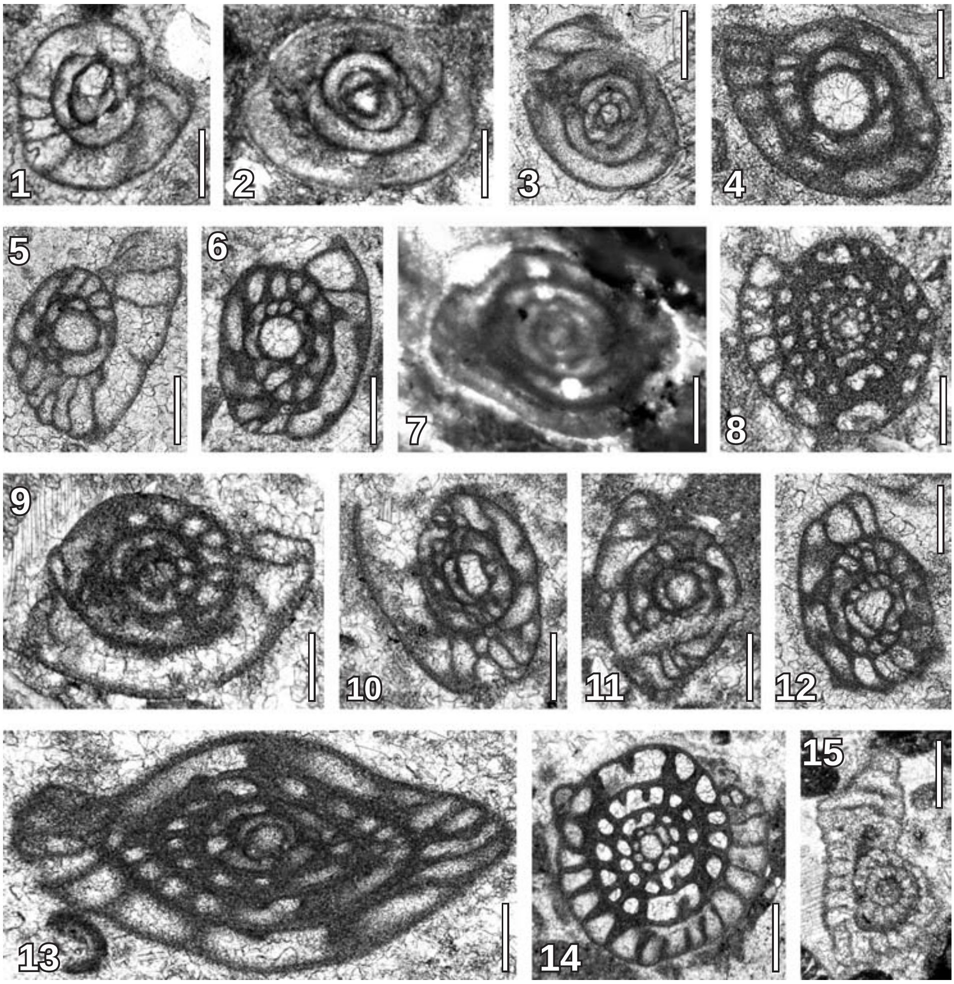


Fig. 14. **1–3**. *Schubertella* sp.; **1**. Sagittal section (ZPAL F.53/H40.170); **2**. Axial section (ZPAL F.53/H38.174); **3**. Close to axial section (ZPAL F.53/H42.155). **4**. *Eoschubertella* sp., oblique axial section (ZPAL F.53/Cr68.181). **5–6**. Schwagerinidae indet.; **5**. Oblique equatorial section (ZPAL F.53/Cr65.131); **6**. Oblique equatorial section (ZPAL F.53/H38.123). **7**. *Pseudofusulinella occidentalis* (Thompson and Wheeler, 1946), axial section (ZPAL F.53/Cr44.160). **8**, **10–14**. *Pseudofusulinella* sp.; **8**. Sagittal section (ZPAL F.53/Cr45.155); **10**. Oblique equatorial section (ZPAL F.53/H35.151); **11**. Oblique equatorial section (ZPAL F.53/Cr46.152); **12**. Oblique equatorial section (ZPAL F.53/H38.160); **13**. Oblique axial section (ZPAL F.53/H43.169); **14**. Sagittal section (ZPAL F.53/H38.170). **9**. ?*Pseudofusulinella* sp.; oblique axial section (ZPAL F.53/Cr45.157); **15**. *Pseudoreichelina darvasica* Leven, 1970, equatorial section (ZPAL F.53/H41. 193). Scale bars 0.1 mm. Treskelodden Fm; Creek IV (Cr) and Hyrnefjellet mt (H) sections, Hornsund, Lower Permian.

from Artinskian in the uppermost part of the Hyrnefjellet mt section should be considered as an age indicator of the upper foraminiferal assemblage. Another species probably defining the age of the assemblage is ?*G. ishimbarica* Lipina, 1949 (Fig. 5: 3) described from Artinskian– Kungurian strata from the buried

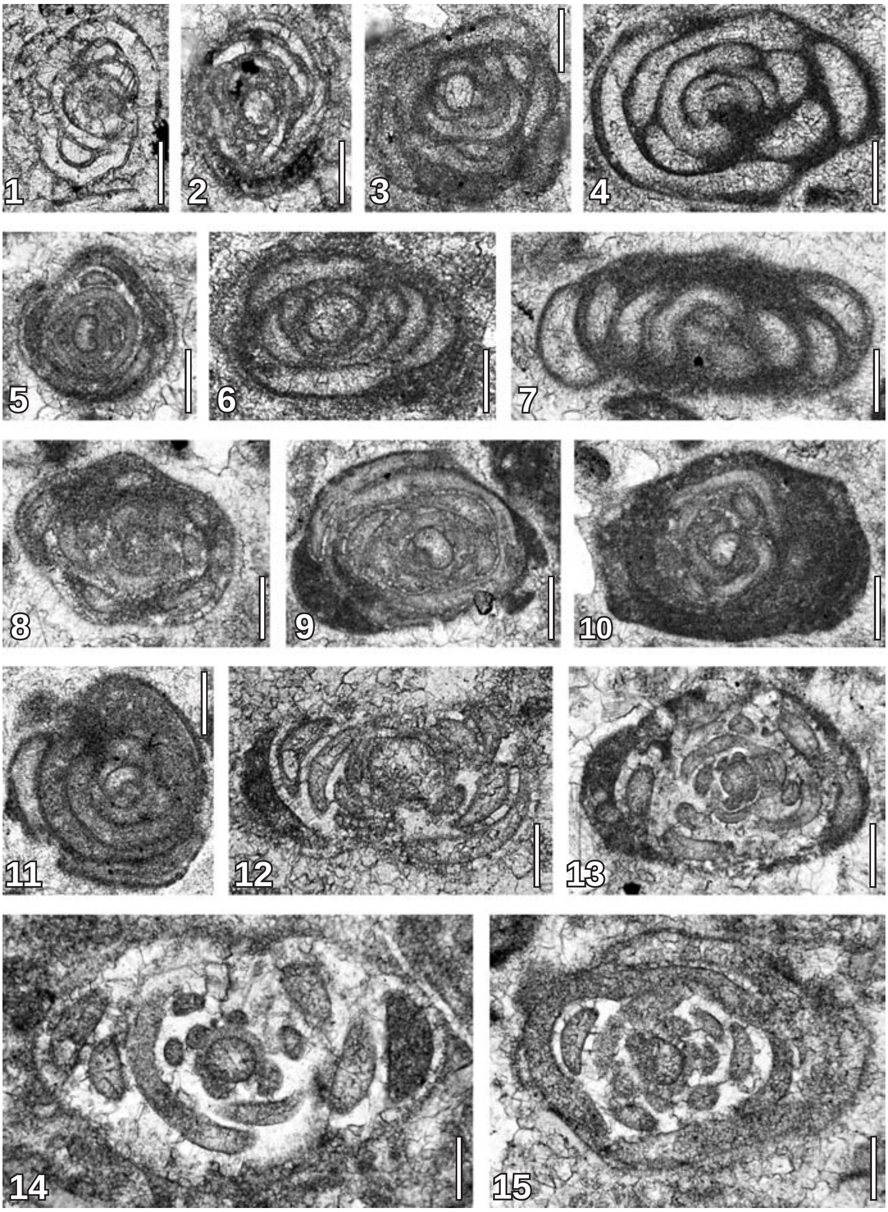


Fig. 15. **1–2**. ?*Pseudoglomospira* sp.; **1**. Axial section (ZPAL F.53/Cr65.40); **2**. Axial section (ZPAL F.53/Cr65.41). **3**, **4**, **6**, **13–15**. Hemigordiopsida indet.; **3**. Axial section (ZPAL F.53/Cr68.40); **4**. Transverse section (ZPAL F.53/H40.44); **6**. Axial? section (ZPAL F.53/H40.44); **13**. Axial sections (ZPAL F.53/Cr69.40); **14**. Axial sections (ZPAL F.53/H41.61); **15**. Axial sections (ZPAL F.53/H38.63). **5**, **7**. ?*Hemigordius* sp.; **5**. Transverse section (ZPAL F.53/Cr65.40); **7**. Oblique axial section (ZPAL F.53/Cr66.40). **8–12**. *Hemigordius* sp.; **8**. Axial section (ZPAL F.53/H30.45); **9**. Transverse section (ZPAL F.53/H38.46); **10**. Axial section (ZPAL F.53/H38.47); **11**. Transverse section (ZPAL F.53/H41.45); **12**. Axial section (ZPAL F.53/H40.60). Scale bars 0.1 mm. Treskelodden Fm; Creek IV (Cr) and Hyrnefjellet mt (H) section, Hornsund, Lower Permian.

massifs of Bashkiria, Russia (Lipina 1949). The presence of these taxa supports the assumption that the age of the entire upper foraminiferal (H-III) assemblage is Late Cisuralian, Artinskian. Besides the foraminifers, also brachiopods, bivalves and very large coral colonies were found. The abundant coral fauna consists of rare massive colonies of Tabulata (Nowiński 1982) and common branching and massive colonies of Rugosa (Fedorowski 1964, 1965, 1967).

The foraminiferal assemblage above 26 m of the investigated field section visibly diminishes. Many recrystallized and poorly preserved tests of foraminifers are seen (samples H45 and H46). In the uppermost part of the section (thickness of 0.5 m, samples H48–H52), only two foraminiferal species *Globivalvulina bulloides* and *Globivalvulina* sp. were identified (Table 2).

Foraminifer biostratigraphy

Among the foraminiferal assemblages distinguished within the Treskelodden Fm many species have a wide stratigraphical range, but there are also species that may be regarded as index fossils.

Three assemblage zones were defined, in ascending order: Pseudofusulinella occidentalis, Midiella ovata – Calcitornella heathi and Hemigordius hyrnefjelleti – Midiella arctica (Tables 1, 2).

The Pseudofusulinella occidentalis Assemblage Zone (Late Asselian). This zone is based on the co-occurrence of taxa characterizing the relatively poorly diversified lower foraminiferal assemblage (Cr-I) in the Creek IV section. The name of the zone derives from the name of zonal taxon – *Pseudofusulinella occidentalis* (Thompson and Wheeler in Thompson *et al.*, 1946). The most characteristic taxa, except for *P. occidentalis*, are *Pseudofusulinella* sp. and *Nodosinelloides* sp. A. The lower boundary of the zone is defined at 78.20 m above the Creek IV section base by the change from clastic to carbonate sedimentation and first appearance of foraminifers. The upper boundary of the zone is defined at 80.10 m above the base of the section by change of sedimentation pattern and disappearance of the foraminiferal fauna. Above it a barren interzone appears that underlies the Midiella ovata – Calcitornella heathi Assemblage Zone.

The Midiella ovata – Calcitornella heathi Assemblage Zone (Sakmarian). This zone is based on co-occurrence of two taxa: *Midiella ovata* (Grozdilova, 1956) and *Calcitornella heathi* Cushman and Waters, 1928, which characterize the upper foraminiferal assemblage (Cr-II) in the Creek IV section, and the lower (H-I) and middle (H-II) foraminiferal assemblages in the Hyrnefjellet mt section (Tables 1, 2). At Creek IV section, the zone occurs between 118.95 m and 120.80 m above the base of the section. At the Hyrnefjellet mt section, the zone occurs between 10.20 m and 19.0 m above the base of the section. Between 12.50–15.00 m there is a barren intrazone (Table 2). The lower and upper boundaries of the zone are defined by the appearance and disappearance of foraminiferal assemblage.

The Hemigordius hyrnefjelleti – Midiella arctica Assemblage Zone (Early Artinskian) was established on the basis of the co-occurrence of taxa *Hemigordius hyrnefjelleti* sp. nov. and *Midiella arctica* sp. nov., together with a much diversified taxonomically and quantitatively upper foraminiferal assemblage (H-III) of the Hyrnefjellet mt section. The stratigraphical range of this zone starts with the lower- and ends with the upper boundary of upper foraminiferal assemblage (H-III), simultaneously with changes in sedimentation patterns at 20.05 m to 25.60 m above the base of section. Below there is a barren interzone (Table 2) including strata which separate the Hemigordius hyrnefjelleti – Midiella arctica Assemblage Zone from the younger Midiella ovata – Calcitornella heathi Assemblage Zone.

Selected systematic descriptions

The present author uses the system of higher foraminiferal taxa (on the class level) proposed by Mikhalevich (1998) for descriptions of new species. Within this framework, the author uses the definitions of several different workers' for the scopes of the following orders Nodosariida of Karavaeva and Nestell (2007), Hemigordiopsida of Pronina (1994) and Nestell and Nestell (2006). The method of Gerke (1967) was used for the description of new species of Nodosariids. For descriptions of the hemigordiopsids the present author uses some terminology (*e.g.* pseudoinvolute test and pseudotubular chamber) proposed by Dain (*in* Rauser-Chernousova and Fursenko 1959), and Pronina-Nestell and Nestell (2001). The studied foraminifers belong to the Fusulinata, Spirillinata and Nodosariata classes. All illustrated specimens are housed at the Institute of Paleobiology, Polish Academy of Sciences, Warszawa, Poland (abbreviated ZPAL F.53).

Family Nodosariidae Ehrenberg, 1838

Genus *Nodosinelloides* Mamet and Pinard, 1992

Type species: *Nodosinelloides potievskayae* Mamet and Pinard, 1996 (for *Nodosaria gracilis* Potievskaya, 1962 preoccupied).

Nodosinelloides sp. A

(Fig. 9: 4)

Description. — Test is small and curved, egg-shaped lanceolate, with 12 postproloculus chambers. Proloculus is small, rounded, with internal diameter 16 μm. Following chambers are high. Chambers are cask-shaped, sometimes slightly asymmetrical to the axis. Wall is calcareous, ortho-monolamellar, radial and very thick, its thickness in the initial part is from 9 μm to 48 μm, in the terminal part about 25 μm. Septa are of the same thickness as the wall, small rim-shaped thickenings are located near the apertural borders of the septa. Aperture is not seen. Dimensions: test length (L) 955 μm, width (W) 55–172 μm, ratio of L/W 6.5.

Remarks. — *Nodosinelloides* sp. A is characterized by its medium size, relatively thick wall, and high, subquadratic chambers.

Occurrence. — Only one specimen was found in the Treskelodden Fm (Creek IV section, sample 46; Asselian).

Family Hemigordiopsidae Nikitina, 1969
emend. Brönnimann, Whittaker and Zaninetti, 1978

Subfamily Hemigordiinae Reitlinger in Vdovenko *et al*., 1993
[nomen translatum Pronina 1994 ex Hemigordiidae Reitlinger in Vdovenko *et al*., 1993]

Genus *Hemigordius* Schubert, 1908
[= *Discospirella* Okimura and Ishii 1981, = *Okimuraites* Reitlinger in Vdovenko *et al*., 1993]

Type species: *Cornuspira schlumbergeri* Howchin, 1895.

Hemigordius hyrnefjelleti sp. nov.
(Fig. 16: 15–16)

Holotype: The specimen illustrated on Fig. 16: 15 is designated as the holotype (ZPAL F.53/H36.51).

Type horizon: Treskelodden Fm.

Type locality: Hyrnefjellet mt section, Hornsund (south Spitsbergen).

Derivation of the name: After Hyrnefjellet mt.

Type level: Early Artinskian, Hemigordius hyrnefjelleti – Midiella arctica Assemblage Zone.

Material. — Three sections.

Description. — The test is large, disk-shaped, bichambered, elongate in axial section, pseudoinvolute, slightly concave on both sides. Proloculus is large, spherical, with diameter 98–102 μm. The second pseudotubular chamber forms 6 volutions. The height of the first volution is 13–28 μm, of fourth volution 55 μm. Wall is calcareous, microgranular and thin (thickness 2–9 μm). Aperture is probably simple, terminal, at the end of the pseudotubular chamber.

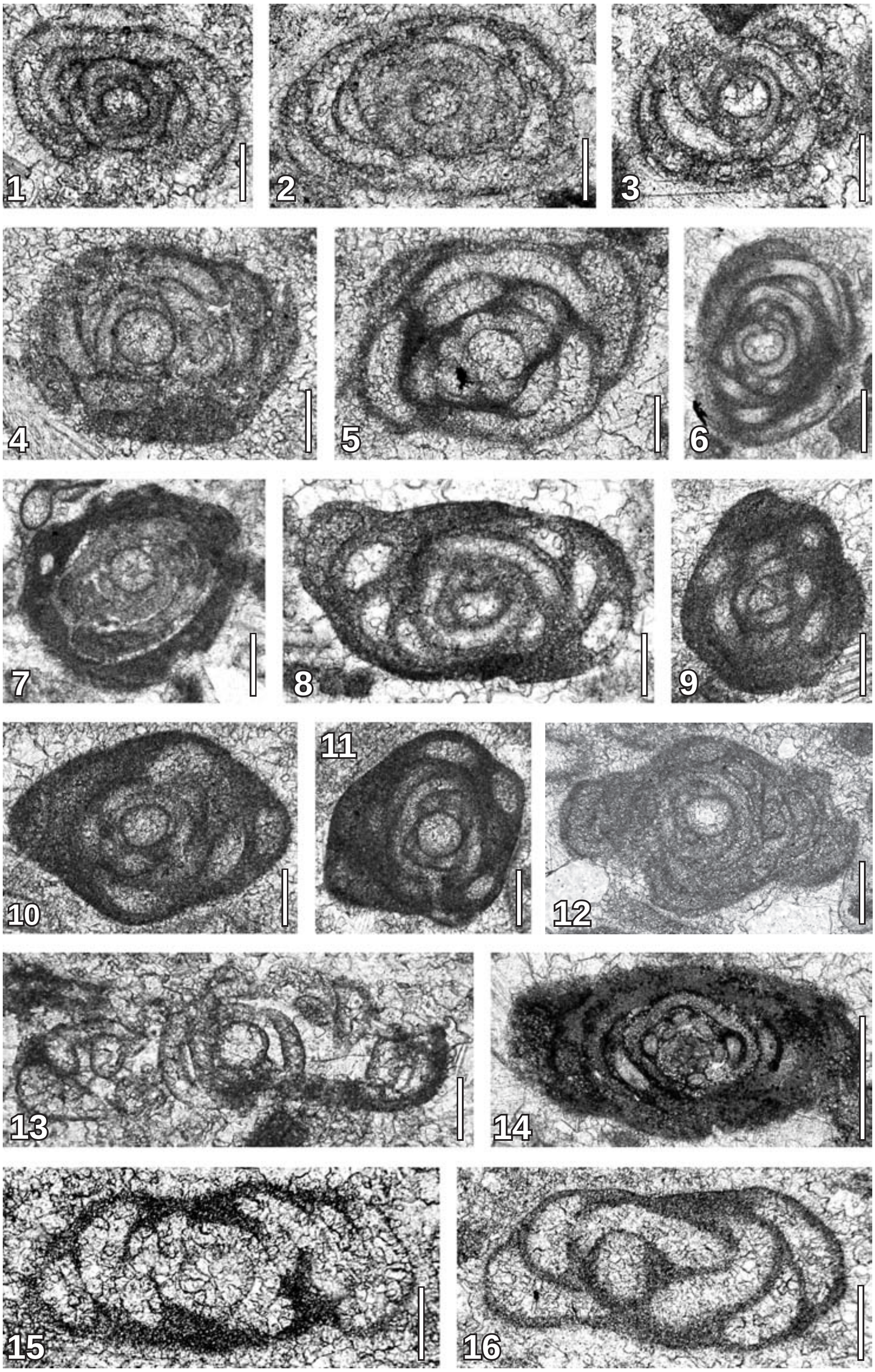
Dimensions. — Test diameter (D) = 485–510 μm, width (W) = 180–215 μm, the ratio D/W = 2.2–2.8, in the holotype the corresponding dimensions are 510 μm, 215 μm and 2.8.

Remarks. — Because of the disk-shaped test, *H. hyrnefjelleti* sp. nov. is similar to *H.*? *gracilis* (Vdovenko 2001; pl. 28, figs 48–50), but it differs in type of coiling, size and larger ratio D/W.

Occurrence. — Confidently identifiable specimens are very rare in the Treskelodden Fm (Hyrnefjellet mt section, samples H36 and H37; Artinskian).

Genus *Midiella* Pronina, 1988
[nomen translatum Pronina 1990 ex subgenus *Midiella* Pronina 1988]

Type species: *Hemigordius broennimanni* Altiner, 1978.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Midiella arctica sp. nov.
(Fig. 16: 1–5)

Holotype: The specimen illustrated on Fig. 16: 5 is designated as the holotype (ZPAL F.53/H41.53).

Type horizon: Treskelodden Fm.

Type locality: Hyrnefjellet mt section, Hornsund (south Spitsbergen).

Derivation of the name: After the Arctic.

Type level: Early Artinskian, Hemigordius hyrnefjelleti – Midiella arctica Assemblage Zone.

Material. — Six sections.

Description. — The test is small of ovate shape in axial and round in transverse sections, bichambered, pseudoinvolute. Proloculus is spherical, large, diameter 65–90 μm. The second pseudotubular chamber forms 5–6 volutions. Coiling is weakly sigmoidal, volutions evenly increase in height and width. The height of the first volution is 12–25 μm and width 21–26 μm; of the fifth volution correspondingly 54–61 μm and 68–71 μm. Wall is calcareous, microgranular and thin (thickness 2–12 μm).

Dimensions. — Test diameter (D) = 310–510 μm, width (W) = 280–390 μm, the ratio D/W = 2.4–2.5, in the holotype the corresponding dimensions are 445 μm, 340 μm and 2.5.

Occurrence. — Six specimens found in the Treskelodden Formation (Hyrnefjellet mt section, samples H36 and H41–H42; Artinskian).

Conclusions

- The studied foraminiferal assemblages consisting of 23 genera and 58 species, including two new species *Hemigordius hyrnefjelleti* sp. nov. and *Midiella arctica* sp. nov., were recognized in the Treskelodden Fm. Three biostratigraphical assemblage zones: Pseudofusulinella occidentalis (Late Asselian), Midiella ovata – Calcitornella heathi (Sakmarian), and Hemigordius hyrnefjelleti – Midiella arctica (Early Artinskian) were erected for regional correlation.
- The age of the Treskelodden Fm was one of the most important questions since it was established. First, it was considered to be Middle or Upper Carboniferous

← Fig. 16. **1–5**. *Midiella arctica* sp. nov.; **1**. Axial section (ZPAL F.53/H36.50); **2**. Axial section (ZPAL F.53/H36.53); **3**. Tangential section (ZPAL F.53/H41.51); **4**. Axial section (ZPAL F.53/H41.52); **5**. Holotype, axial section (ZPAL F.53/H41.53). **6–11**. *Midiella ovata* (Grozdilova, 1956); **6**. Axial section (ZPAL F.53/Cr65.42); **7**. Axial section (ZPAL F.53/Cr67.43); **8**. Close to axial section (ZPAL F.53/Cr67.44); **9**. Transverse section (ZPAL F.53/Cr69.41); **10**. Longitudinal section (ZPAL F.53/Cr69.43); **11**. Transverse section (ZPAL F.53/Cr69.44); **12**. *Midiella glomospiroidalis* (Sosipatrova, 1969), axial section (ZPAL F.53/H40.40). **13–14**. *Hemigordius* sp.; **13**. Oblique axial section (ZPAL F.53/H38.56); **14**. Axial section (ZPAL F.53/H39.48). **15–16**. *Hemigordius hyrnefjelleti* sp. nov.; **15**. Holotype, axial section (ZPAL F.53/H36.51); **16**. Oblique section (ZPAL F.53/H36.52). Scale bars 0.1 mm. Treskelodden Fm; Creek IV (Cr) and Hyrnefjellet mt (H) sections, Hornsund, Lower Permian.

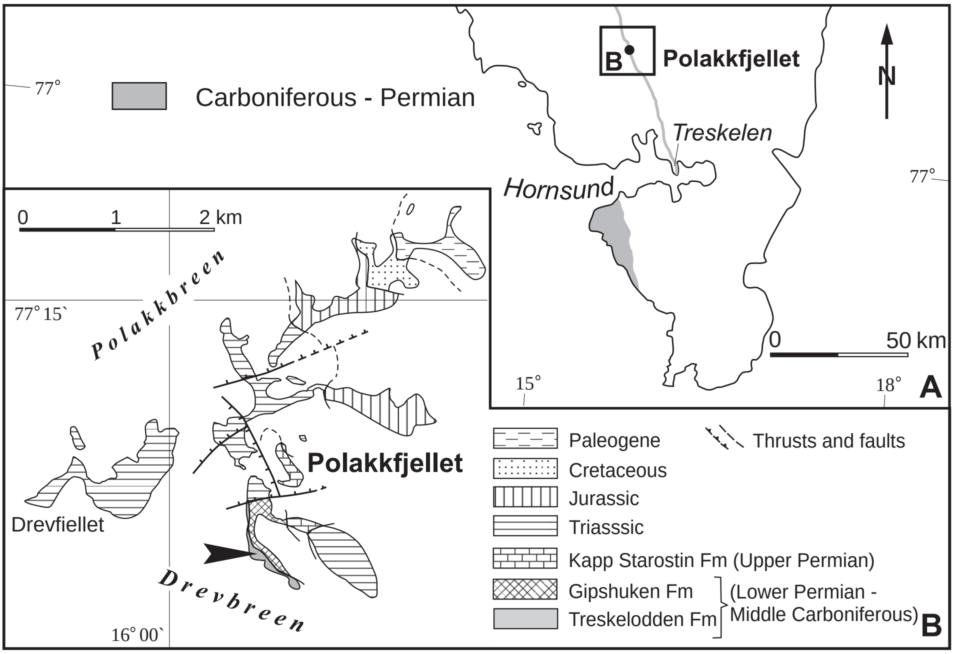

Fig. 17. **A**. Sketch map of the southern and central parts of Spitsbergen showing outcrops of Carboniferous and Permian rocks after Harland (1997). **B**. Geological map of the Polakkfjellet area after Biernat and Birkenmajer (1981). Location of the investigated section of the Treskelodden Fm is marked by arrow.

(Birkenmajer 1964), but this age was based on the poorly documented fauna, and mostly on lithological correlation. Czarniecki (1966, 1969) considered that the age of the formation is Late Carboniferous on the basis of brachiopods. Waterhouse (1977) questioned some of Czarniecki's systematic designations, and based on the species of corals (Fedorowski 1967) and foraminifers (Liszka 1964) reassigned the Treskelodden Fm to the Lower Permian. Nysæther (1977) pointed out the existence of the coral-bearing equivalents for the Treskelodden Fm in the central part of the Torrell Land in the Polakkfjellet mt area, and questioned, on the basis of foraminifers (unrecognized fusulinaceans), a middle Permian age of the formation in the Hornsund region. This statement was rejected by Fedorowski (1982). The investigations of foraminifers allowed partial confirmation of the age assignments of both Nysæther (1977) and Fedorowski (1982). The lowermost part of the formation outcropping at Polakkfjellet mt (Fig. 17) is of youngest Carboniferous (Upper Gzhelian) age, documented by occurrence of the fusulinacean species *Schellwienia arctica* (Błażejowski *et al.* 2006, fig. 4; Błażejowski 2008). The Lower Permian age of the Treskelodden Fm in the Hornsund region is established based on the small foraminifers (e.g. *Nodosinelloides* cf. *longa* (Lipina, 1949), *N. mirabilis* (Lipina, 1949), *Pseudofusulinella occidentalis* (Thompson and Wheeler in Thompson *et al.*, 1946),

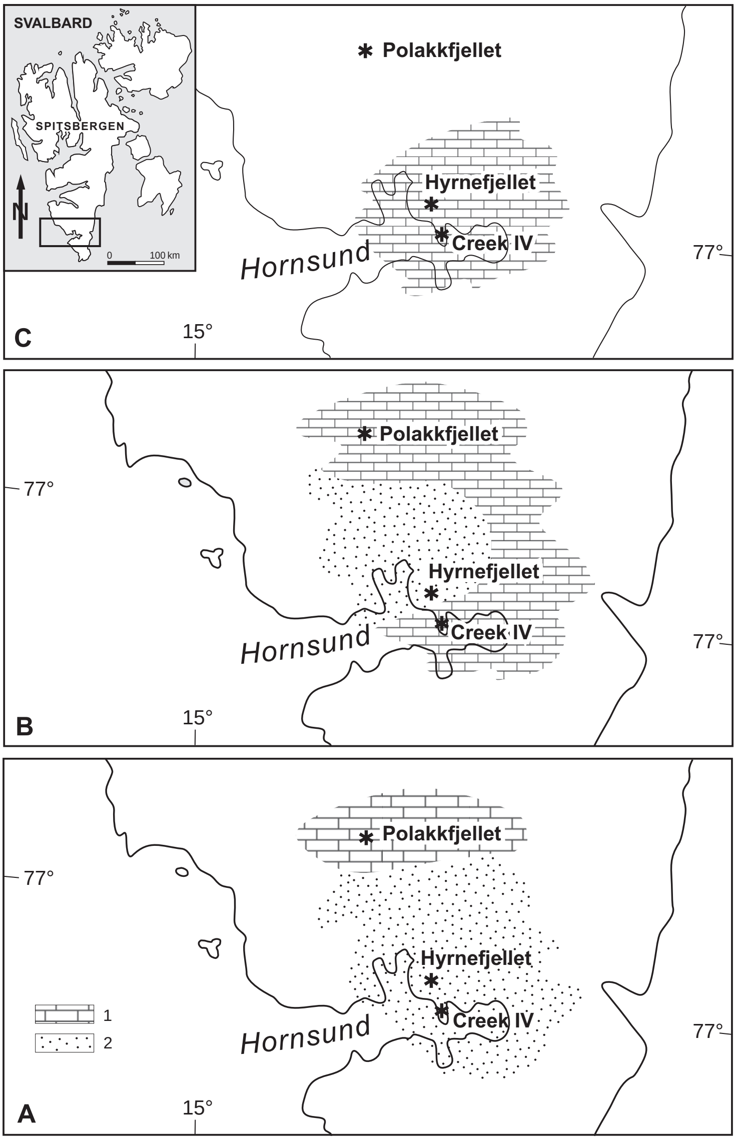

Fig. 18. Generalized paleofacies maps of the Hornsund region. **A**. Gzhelian–Early Asselian tropical water setting. **B**. Late Asselian–Early Sakmarian warm water setting. **C**. Late Sakmarian–Early Artinskian temperate-warm water setting. 1 – open marine platform carbonates; 2 – shallow marine sandstone.

Midiella ovata (Grozdilova, 1956), and *Calcitornella heathi* Cushman and Waters, 1928). In the outcrops of the Treskelodden Fm, the large fusulinaceans appear only in the Polakkfjellet mt section. In the Hornsund region (Creek IV and Hyrnefjellet mt sections) only small forms of *Pseudofusulinella* were found. The differentiation in the expansion of fusulinaceans and small foraminifers from the Gzhelian to the Asselian was caused probably by development of carbonate sedimentation that occurred in the area of Polakkfjellet mt, whereas on the south (Hornsund region) terrigenous sedimentation took place (Fig. 18). Gradual disappearance of fusulinaceans in the Treskelodden Fm in the Carboniferous–Permian transition is presumably also related to climate change. The fusulinaceans provide an independent time framework for evaluating stratigraphic occurrences of the associated smaller foraminifers. Deductions from above presented study were compiled with results of previous investigations to produce the small foraminiferal biostratigraphic model for the High Arctic (*e.g.* Groves and Wahlman 1997; Pinard and Mamet 1998).

- Environmental change took place at that time, and highly diversified, tropical-like associations of biota were dominated by calcareous algae and foraminifers (Chloroform) that were common in the Late Gzhelian to Sakmarian, gave the way to temperate-like associations dominated by bryozoans and brachiopods that characterized the Early Artinskian (Bryonoderm-extended) interval (Beauchamp 1994; Beauchamp and Desrochers 1997; Beauchamp and Baud 2002).

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Appendix

List of species mentioned in this paper, arranged alphabetically by the genus.

Bradyinelloides lucida Morozova, 1949 *sensu* Korolyuk and Rauser-Chernousova, 1977, Fig. 12: 12.
Bradyinelloides major (Morozova, 1949), Fig. 12: 7–11.
Bradyinelloides omrica (Konovalova, 1962), Fig. 12: 4.
Bradyinelloides shikhanica Morozova, 1949 *sensu* Korolyuk and Rauser-Chernousova, 1977, Fig. 12: 5–6.
Bradyinelloides sp., Fig. 12: 1–3.
Calcitornella heathi Cushman and Waters, 1928, Fig. 5: 11–13.
Calcitornella sp., Fig. 5: 14.
Calcivertella adherens Cushman and Waters, 1928, Fig. 5: 2.
Earlandia ex gr. *elegans* (Rauser-Chernousova and Reitlinger in Rauser-Chernousova and Fursenko, 1959), Fig. 5: 15.

Endothyra aff. *pseudobradyi* Brazhnikova, 1956, Fig. 5: 6.
Endothyra sp., Fig. 5: 5.
Eoschubertella sp., Fig. 14: 4.
Geinitzina frondiculariformis Sosipatrova, 1969, Fig. 8: 6, 12.
Geinitzina postcarbonica Spandel, 1901, Fig. 8: 11.
?*Geinitzina postcarbonica* Spandel, 1901, Fig. 8: 14.
Globivalvulina bulloides (Brady, 1876), Figs 10: 19–20; 11: 1–6.
Globivalvulina graeca Reichel, 1945, Fig. 10: 4–5.
Globivalvulina cf. *graeca* Reichel, 1945, Fig. 10: 6–9.
Globivalvulina nassichuki Pinard and Mamet, 1998, Figs 10; 10–16, 18; 11: 7.
Globivalvulina pergrata Konovalova, 1962, Figs 10: 2; 11: 8–16.
Globivalvulina cf. *sikhanensi* Morozova, 1949, Fig. 10: 1.
Globivalvulina syzranica Reitlinger, 1950, Fig. 10: 3.
Globivalvulina sp., Fig. 10: 17.
?*Glomospira ishimbarica* Lipina, 1949, Fig. 5: 3.
?*Glomospira* sp. Fig. 5: 1, 4.
Hemigordius hyrnefjelleti sp. nov., Fig. 16: 15–16.
Hemigordius sp., Figs 15: 8–12; 16: 14; 17: 13.
?*Hemigordius* sp., Fig. 15: 5–7.
Howchinella semiovalis (Zolotova and Sosipatrova in Sosipatrova, 1969), Fig. 9: 1.
Langella seminula Zolotova in Zolotova and Baryshnikov, 1980, Fig. 8: 7–8.
Mendipsia sp., Fig. 6: 1, 4–5, 7–10.
Midiella arctica sp. nov., Fig. 16: 1–5.
Midiella glomospiroidalis (Sosipatrova, 1969), Fig. 16: 12.
Midiella ovata (Grozdilova, 1956), Fig. 16: 6–11.
Nodosinelloides aequiampla (Zolotova in Zolotova and Baryshnikov, 1980), Fig. 7: 6–7.
Nodosinelloides aff. *camerata* (Miklukho-Maklay, 1954), Fig. 7: 15.
Nodosinelloides cf. *longa* (Lipina, 1949), Fig. 7: 4.
Nodosinelloides longissima (Suleimanov, 1949), Fig. 8: 1–3.
Nodosinelloides cf. *longissima* (Suleimanov, 1949), Fig. 8: 4.
Nodosinelloides mirabilis (Lipina, 1949), Fig. 7: 11.
Nodosinelloides aff. *netschajewi* (Cherdyntsev, 1914), Fig. 7: 1–2.
Nodosinelloides potievskayae Mamet and Pinard, 1996, Fig. 7: 14.
Nodosinelloides spitzbergiana (Sosipatrova, 1969), Fig. 8: 5.
Nodosinelloides sp. A, Fig. 9: 4.
Nodosinelloides sp., Figs 7: 3, 5, 10; 9: 2.
Palaeotextularia sp., Fig. 5: 7–8.
Protonodosaria cf. *globifrondina* Sellier de Civrieux and Dessauvagie, 1965, Fig. 8: 9.
Pseudofusulinella occidentalis (Thompson and Wheeler, 1946), Fig. 14: 7.
Pseudofusulinella sp., Fig. 14: 8, 10–14.
?*Pseudofusulinella* sp., Fig. 14: 9.
?*Pseudoglomospira* sp., Fig. 15: 1–2.
Pseudoreichelina darvasica Leven, 1970, Fig. 14: 15.
Schubertella sphaerica Suleimanov, 1949, Fig. 13: 1–2, 4–9.
Schubertella sp., Figs 13: 3, 10–16; 15: 1–3.
Tetrataxis sp., Fig. 5: 9–10.
Tuberitina maljavkini Mikhailov, 1939, Fig. 6: 2–3, 6.
Tuberitina sp., Fig. 6: 11.
Vervilleina bradyi (Spandel, 1901), Fig. 9: 3.