Silurian and Devonian strata on the Severnaya Zemlya and Sedov archipelagos (Russia)

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Männik P., Menner V. V., Matukhin R. G. & Kuršs V. 2002. — Silurian and Devonian strata on the Severnaya Zemlya and Sedov archipelagos (Russia). *Geodiversitas* 24 (1) : 99-122.

ABSTRACT
Silurian and Devonian strata are widely distributed on the islands of the Severnaya Zemlya and Sedov archipelagos. The Silurian is represented by fossiliferous shallow-water carbonates underlain by variegated sandstones and siltstones of Ordovician age. The Devonian consists mainly of various red sandstones, siltstones and argillites, with carbonates only in some intervals. The best sections available for study are located in the river valleys, and in the cliffs along the coastline of islands. Type sections of most of the stratigraphical units identified are located on the Matusevich River, October Revolution Island. As the Quaternary cover is poorly developed on Severnaya Zemlya, the Palaeozoic strata can be easily traced also outside the sections.

KEY WORDS
Silurian,
Devonian,
Sedov Archipelago,
Severnaya Zemlya Archipelago,
Russia,
lithostratigraphy,
biostratigraphy.

RÉSUMÉ

Les niveaux stratigraphiques silurien et dévonien des archipels de Severnaya Zemlya et de Sedov (Russie).

Sur les îles de Severnaya Zemlya et de Sedov, les niveaux du Silurien et du Dévonien sont bien représentés. Le Silurien est représenté par des carbonates fossilifères de dépôts peu profonds, recouverts par des grès et des silts d'âge ordivicien. Les niveaux dévoniens sont représentés par des grès rouges, des silts et des argilites, qui alternent parfois avec des niveaux carbonatés. Comme souvent, les meilleures coupes sont localisées dans les vallées et sur les falaises le long des côtes. Les coupes-types des unités stratigraphiques sont principalement localisées dans la vallée de la rivière Matusevich sur l'île de la Révolution d'Octobre. Sur l'archipel de Severnaya Zemlya, la couverture quaternaire est si réduite que les niveaux paléozoiques peuvent être facilement retrouvés en dehors des coupes-types.

MOTS CLÉS
Silurien,
Dévonien,
archipel de Sedov,
archipel de Severnaya Zemlya,
Russie,
lithostratigraphie,
biostratigraphie.

INTRODUCTION

The Severnaya Zemlya and Sedov archipelagos lie north of the Tajmyr Peninsula, between the Kara and Laptev seas. The Severnaya Zemlya Archipelago, with a total area of about 37 000 km^2, consists of four large islands (October Revolution, Bol'shevik, Komsomolets and Pioneer) and up to 70 smaller ones. Six islands – Srednij, Golomyannyj, Domashnij, Figurnyj, Vostochnyj and Samojlovich – form the Sedov Archipelago. About half of the Severnaya Zemlya Archipelago's territory is covered by continental glaciers (Fig. 1). Due to a very poor vegetation, the rocks are well exposed. Numerous continuous sections of highly fossiliferous Lower and Middle Palaeozoic strata put the archipelagos among the key areas for geological studies in the Circum-Arctic region. The beginning in 1996 of the IGCP Project 406 (Circum-Arctic Lower and Middle Palaeozoic Vertebrate Palaeontology and Biostratigraphy) reactivated the studies connected with Severnaya Zemlya.

The aim of the present paper is to give a general idea about the sections, lithologies and stratigraphy of the Silurian and Devonian strata on Severnaya Zemlya.

PREVIOUS STUDIES

The Severnaya Zemlya Archipelago was discovered in 1913. The first evidence of the existence of Palaeozoic strata on the Severnaya Zemlya, but also in the Sedov Archipelago, came from collections made by G. A. Ushakov and N. N. Urvantsev during the expedition in 1930-1932. In samples from Severnaya Zemlya, B. B. Chernyshev identified Silurian tabulates, similar to those known from Tajmyr and Novaya Zemlya. In 1948-1954, a group of geologists from the Scientific Research Institute of Geology of Arctic (NIIGA, St.-Petersburg), led by B. Kh. Egiazarov, studied the archipelagos and compiled a geological map on a scale of 1:1 000 000. A rich collection of fossils was studied by A. P. Bystrov, Z. G. Balashov, V. A. Vostokova, R. S. Eltysheva, M. S. Zhizhina, B. N. Nalivkin, O. I. Nikiforova, V. N. Ryabinin, Ya. D. Zekkel' and S. V. Cherkesova. The general stratigraphy of the Palaeozoic strata was published in a number of papers and monographs (Egiazarov 1957, 1959, 1970, 1973).

Modern understanding of the Lower and Middle Palaeozoic strata on Severnaya Zemlya is based mainly on the data of detailed geological mapping by V. A. Markovskij, A. A.

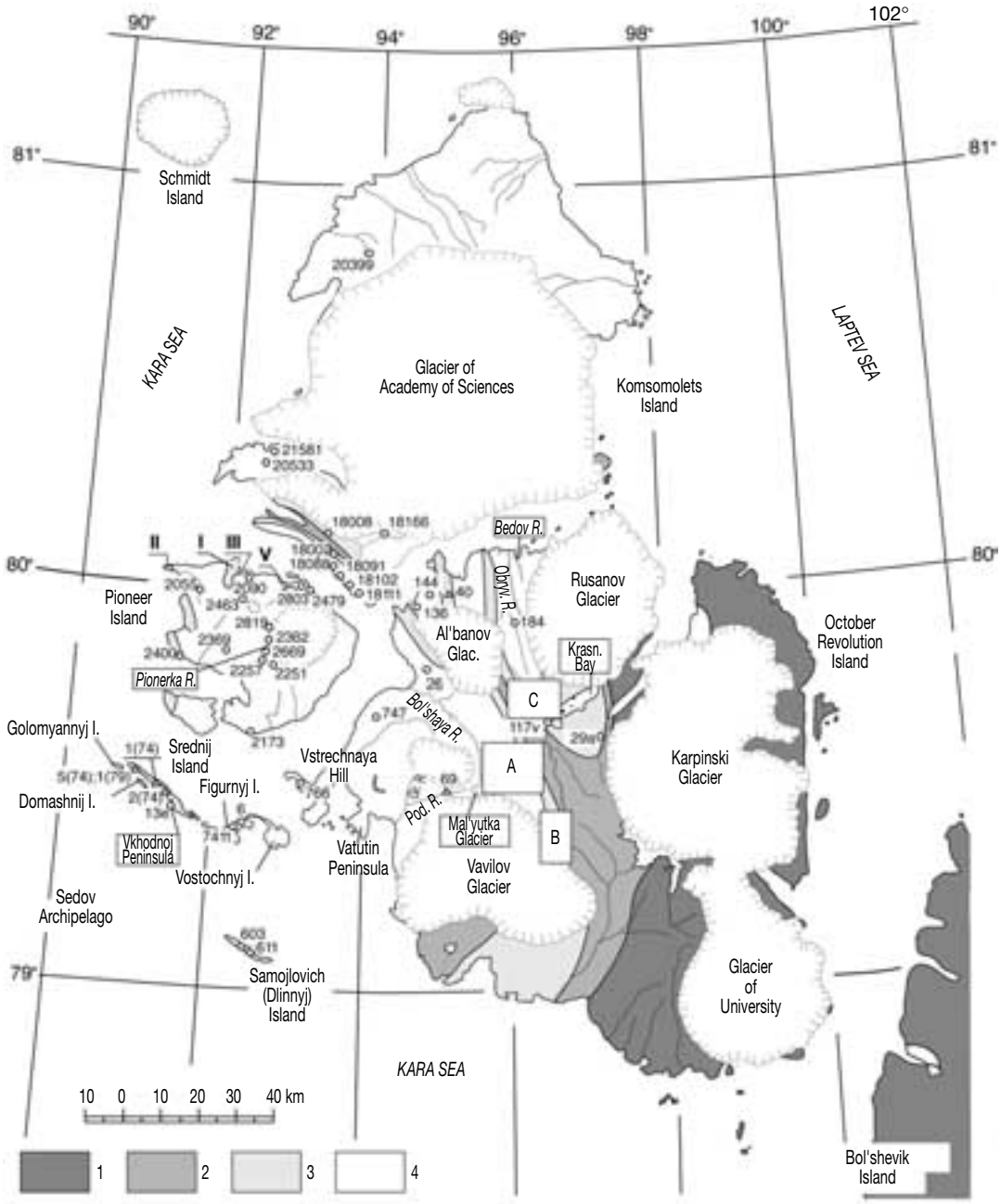

Fig. 1. — Distribution of Palaeozoic strata on Severnaya Zemlya, showing location of studied sections and spot samples (geology modified from Egiazarov 1959). Areas **A**, **B** and **C** show the location of detailed maps in Figs 2; 6; 9. Areas of Silurian outcrops studied on Pioneer Island (according to Klubov *et al*. 1980) are indicated as follows: **I**, samples 2A-4G; **III**, samples 4D-6A, 8G; **V**, sample 12. Samples 7A-7B, 8D-8G, 9E, 9Zh and 10A-10B come from areas **I** or **II** (precise location not known). **Bedov. R.**, Bedovaya River; **Obryv. R.**, Obryvistaya River; **Gr. R.**, Gremyashchaya River; **Krasn. Bay**, Krasnaya Bay; **Pod. R.**, Pod''emnaya River. **1**, Cambrian and older rocks; **2**, Ordovocian; **3**, Silurian; **4**, Devonian to Quaternary strata.

Makar'ev, Yu. G. Rogozov, B. N. Batuev, A. F. Khapilin and others in 1973-1979. A proper stratigraphical framework for the mapping was provided by special sedimentological and biostratigraphical studies. During field-work in 1974, 1976, 1978 and 1979, many sections in different parts of the archipelagos were described in detail and fossils collected. Yu. G. Samojlovich, D. K. Patrunov and A. A. Egorova (St.-Petersburg, Russia), V. Karatajūtė-Talimaa and J. Valiukevičius (Lithuania), E. Mark-Kurik and P. Männik (Estonia), V. Kuršs (Latvia), R. G. Matukhin (Novosibirsk, Russia), V. Vl. Menner (Moscow, Russia), and B. A. Klubov and E. I. Kachanov (Magadan, Russia) participated in the expeditions. The collections were studied and described by A. Abushik (ostracodes), O. Afanassieva (vertebrates), A. Blieck (vertebrates), S. Cherkesova (brachiopods), D. Drygant (conodonts), I. Evdokimova (ostracodes), V. Karatajūtė-Talimaa (vertebrates), E. Levitski (trilobites), E. Lukševičs (vertebrates), Z. Maximova (trilobites), E. Mark-Kurik (vertebrates), T. Modzalevskaya (brachiopods), P. Männik (conodonts), T. Märss (vertebrates), L. Nekhorosheva (bryozoans), H. Nestor (stromatoporoids), M. Shurygina (rugose corals), M. Smirnova (tabulate corals), N. Sobolev (conodonts), G. Stukalina (crinoids), V. Sytova (rugose corals), G. Vaitiekūnienė (miospores), and J. Valiukevičius (vertebrates).
A special meeting devoted to the stratigraphy of Severnaya Zemlya was held in Vilnius, Lithuania, in 1980, and several papers were published later (e.g., Kurik *et al.* 1982; Matukhin *et al.* 1982; Markovskij & Smirnova 1982). Also in 1980, during a meeting in Novosibirsk, an official stratigraphic scheme of the Silurian and Devonian systems of Severnaya Zemlya was ratified (Gurari & Krasilov 1982).

GENERAL GEOLOGY AND STRATIGRAPHY

The sequence of sedimentary rocks on Severnaya Zemlya ranges from the Upper Proterozoic on Bol'shevik Island (Kaban'kov *et al.* 1982) to the Upper Palaeozoic (small oucrops of Carboniferous and Permian rocks on Bol'shevik, October Revolution and Komsomolets islands; Dibner 1982) (Fig. 1). Large areas on northern Komsomolets Island are covered with Cenozoic sediments. The oldest Palaeozoic strata (Cambrian) are exposed in the eastern part of October Revolution Island.
The Cambrian-Devonian sediments in the middle and eastern parts of October Revolution Island are folded, with the Silurian and Devonian outcrops situated on the limbs of a north-west south-east trending anticline. This structure extends to the southwesternmost Komsomolets Island. The core of the anticline is formed of Ordovician rocks. On western October Revolution Island and on Pioneer Island, the Palaeozoic strata are less deformed.

SILURIAN

The best Silurian sections available for study are located in the river valleys, perpendicular to the outcrop belts in the central part of October Revolution Island, and in the cliffs along the coastline of the Sedov Archipelago islands. Over 40 years ago, Egiazarov (1959) noted that the most complete sequence of Ordovician, Silurian and Devonian strata is exposed on the Matusevich River (Figs 1; 2). Later, this section has been studied in detail by many geologists, and the type sections of most of the Silurian formations are located there (see below). Almost complete, but not studied in detail, Silurian sequences are known from the southwestern part of Komsomolets Island (Fig. 1), and from some areas on western and northern Pioneer Island. In general, the Silurian strata on Severnaya Zemlya are represented by fossiliferous shallow-water carbonates, underlain by variegated sandstones and siltstones of Ordovician age, and overlain by mainly red terrigenous sediments of Devonian age. All Silurian formations were erected and described during field-work in 1978 by a team (included V. Karatajūtė-Talimaa, V. Kuršs, V. Markovskij, R. Matukhin, V. Menner, Yu. Samojlovich and J. Valiukevičius)

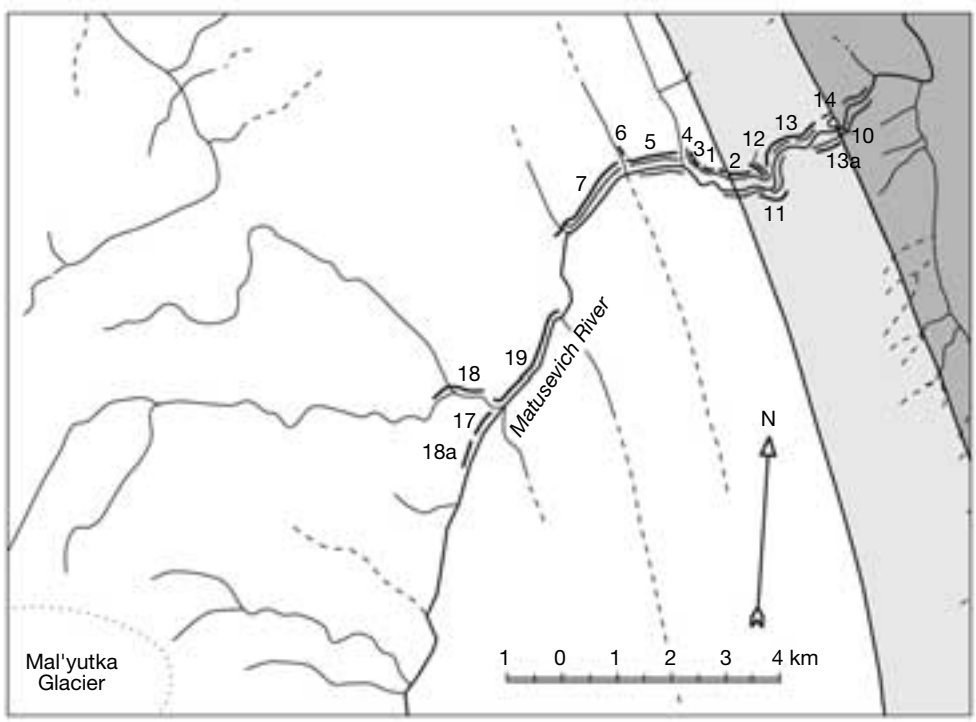

FIG. 2. — Localities on the Matusevich River (= A on Fig. 1). For legend refer to Fig. 1. Numbers along river correspond to outcrops as shown on logs in Figs 4 and 12.

led by V. Menner. The Ust'-Spokojnaya Formation was originally described as Izluchina Formation, and was renamed later (see below).

Llandovery and Wenlock

Vodopad Formation. The Vodopad Formation is the lowermost Silurian unit on Severnaya Zemlya (Fig. 3). It is named after the waterfall (in Russian, "vodopad") on the Matusevich River, October Revolution Island, where the type section of the formation is located (outcrops 14 and 13a; outcrop 13, beds 87-141; Figs 2; 4; 5) (Menner *et al.* 1979). The lower boundary of the Vodopad Formation corresponds to the level where variegated mainly terrigenous rocks of the Strojnaya Formation (Upper Ordovician) are replaced by dark grey limestones and dolostones.

The formation has highly variable lithologies, formed in open-shelf conditions during the first major early Silurian transgression in the Severnaya Zemlya region. It is dominated by grey to dark grey fine- to coarse-grained biodetrital and dolomitic limestones. Tabulate and rugose corals, stromatoporoids, brachiopods, ostracodes and echinoderms are abundant, particularly in the upper part of the formation. The lowermost and uppermost strata are rich in pentamerid brachiopods. At some levels pentamerid coquinas occur. In the lower pentamerid interval, *Borealis* Boucot, Johnson & Rubel, 1971 has been identified (T. Modzalevskaya pers. comm.). An interval of thin-bedded argillaceous limestones, rich in stromatolites but almost lacking other fossils, divides the Vodopad Formation into two parts, the upper one containing large colonies of tabulate corals and siliceous nodules.

On October Revolution Island the thickness of the Vodopad Formation varies within 240-280 m

SYSTEM	SERIES	STAGE	FORMATION
DEVONIAN	Upper	Famennian	Mal'yutka
		Frasnian	Vavilov
			Matusevich
	Middle	Givetian	Gremyashchaya
			Vatutin
		–?–	Vstrechnaya
		Eifelian	
	Lower	Emsian	Al'banov
			Rusanov
		Pragian	Spokojnaya
		Lochkovian	Pod''emnaya
			Severnaya Zemlya
SILURIAN	Přidoli		Krasnaya Bukhta
	Ludlow	Ludfordian/ Gorstian	Ust'-Spokojnaya
	Wenlock	Homerian/ Sheinwoodian	Samojlovich
	Llando-very	Telychian	Srednij
		Aeronian	Golomyannyj
		Rhuddanian	Vodopad

FIG. 3. — The sequence of Silurian and Devonian formations of Severnaya Zemlya and its probable correlation with the international subdivisions of the Silurian and Devonian Periods.

in the Ushakov and Matusevich River sections, but reaches up to 360 m in the Krasnaya Bay region. On the Sedov Archipelago islands, only the uppermost part of the formation is exposed. The Vodopad Formation can be recognized also on the southwestern Komsomolets Island.

FIG. 4. — Limestones in the lower part of the Vodopad Formation. Matusevich River, outcrops 13a and 13. Photo by P. Männik.

The assemblages of stromatoporoids (including *Clathrodictyon boreale* Riabinin, 1951, *C. variolare* (Rosen, 1867), *Ecclimadictyon microvesiculosum* Riabinin, 1951; H. Nestor pers. comm.), rugose corals (Shurygina & Sytova 1999), tabulate corals (Markovskij & Smirnova 1982), ostracodes (Abushik 1999, in press) and brachiopods (Modzalevskaya 1999, in press) indicate a Llandovery age for the Vodopad Formation. The assemblages of conodonts and crinoids occurring in this formation allow us to correlate it with the upper Rhuddanian and lower Aeronian (Männik 1997, 2002; Stukalina 1999) (Fig. 3).

Golomyannyj Formation. This formation is named after Golomyannyj Island in the Sedov Archipelago (Menner *et al.* 1979) (Fig. 1). However, the type section of the formation is located on the Matusevich River, October Revolution Island (outcrop 13, beds 34-86; Figs 2; 5). The lower boundary of the formation is taken just above the uppermost bed with pentamerid brachiopods.

Sedimentological and palaeontological data suggest that the strata of the Golomyannyj Formation were formed in the conditions of a major marine regression. The formation is built up of thin-bedded argillaceous limestones with interbeds of sandstone, stromatolitic limestone, and dolostone at some levels. Mud-cracks are common in many intervals. Ostracodes, gas-

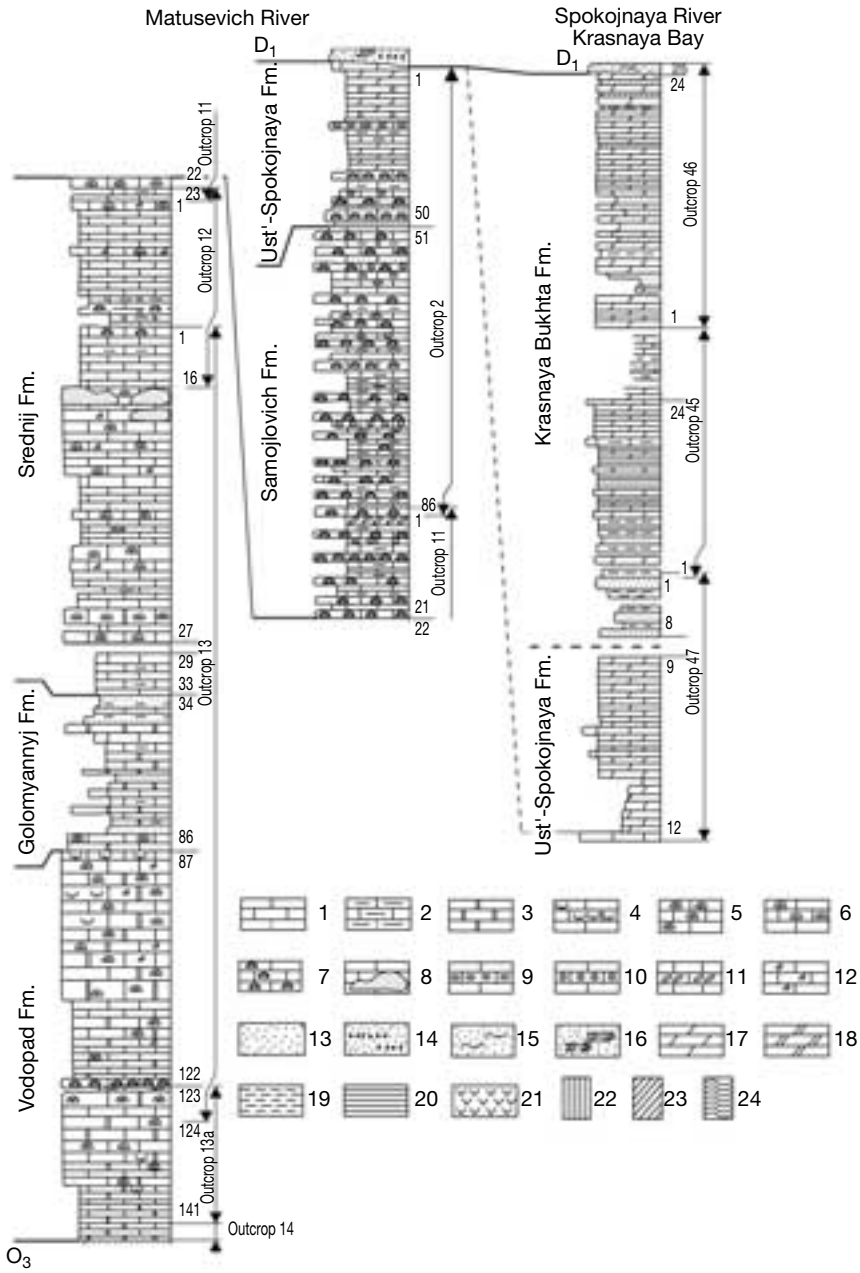

Fig. 5. — Silurian section on the Matusevich River, and in the Spokojnaya River-Krasnaya Bay region (for location of outcrops see Figs 1; 2; 9). To the right of the lithological log are shown the numbers of the beds described, and the extent of the outcrops studied. The interval above bed 24 in outcrop 45 was not logged in detail. **1**, limestone; **2**, argillaceous limestone; **3**, dolomitized limestone; **4**, limestone with pentamerids; **5**, limestone with tabulate corals; **6**, limestone with stromatoporoids; **7**, limestone with stromatolites; **8**, coral-stromatoporoid biostromes and bioherms; **9**, oolithic limestone; **10**, oncolitic limestone; **11**, carbonate conglomerates; **12**, silicified limestone; **13**, sandstone; **14**, conglomeratic sandstone; **15**, fine cross-bedding in sandstone; **16**, coarse cross-bedding in sandstone; **17**, marlstone; **18**, dolomitized marlstone; **19**, siltstone; **20**, argillite; **21**, gypsum. Colour of rock for Fig. 12: **22**, grey; **23**, red; **24**, variegated.

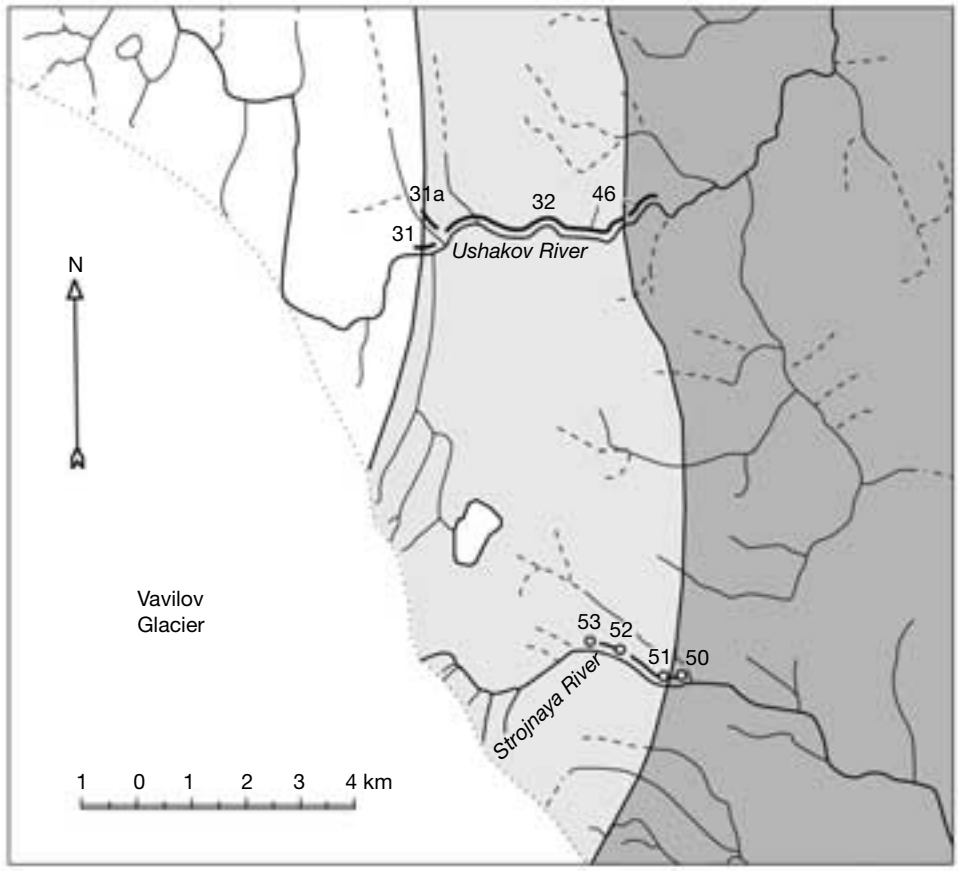

FIG. 6. — Localities on the Ushakov and Strojnaya rivers. For legend refer to Fig. 1. Numbers correspond to outcrop numbers.

tropods, small brachiopods and fragments of echinoderms are abundant in the argillaceous limestones, whereas rugose corals, tabulate corals and stromatoporoids are very rare. The best sections of the Golomyannyj Formation, up to 100-120 m thick, are located on the Matusevich and Ushakov rivers (Figs 2; 5; 6). In the sections of the Sedov Archipelago the thickness of the formation does not exceed 60-70 m.

Poor faunas from the Golomyannyj Formation, including among others the tabulate corals *Palaeofavosites schmidti* Sokolov, 1951, *Mesofavosites fleximurinus* Sokolov, 1951 and *Favosites gothlandicus* Lamarck, 1816, ostracodes *Hogmochilina orientalis* Abushik, 1975 and *Tollitia navicula* Abushik in press, brachiopods *Dubaria tenera* Nikiforova & T. Modzalevskaya, 1968 and conodonts *Pranognathus tenuis* (Aldridge, 1972) and *Icriodella* aff. *inconstans* Aldridge, 1972, indicate an Aeronian age (Nikiforova & Modzalevskaya 1968; Markovskij & Smirnova 1982; Johnson *et al.* 1997; Männik 1997, 2002; Abushik 1999, in press; Modzalevskaya 1999, in press) (Fig. 3).

In the paper by Markovskij & Smirnova (1982) the Vodopad and Golomyannyj formations are dealt with as the lower and upper subformations of the Snezhinka Formation.

Srednij Formation. The Srednij Formation is named after Srednij Island in the Sedov Archipelago (Menner *et al.* 1979) (Fig. 1). The lower boundary of this formation corresponds

to the contact between the uppermost bed of sandstone in the Golomyannyj Formation and the overlying fossiliferous limestones. Alike to the Vodopad Formation, the Srednij Formation also formed during an extensive transgression. However, the sedimentological and palaeontological data suggest that the sea was shallower, and the environmental conditions more variable than in early Llandovery. In its type section on the Matusevich River (outcrop 13, beds 1-33; outcrop 12; and beds 22-23 of outcrop 11; Figs 2; 5), the Srednij Formation consists of cyclic intercalations of horizontal-bedded, sometimes silicified, tabulate-stromatoporoid limestones with tabulate-stromatoporoid (less with algal) biostromes and bioherms, and thick layers of brownish-grey limestones containing ostracodes, gastropods, echinoderms, cephalopods and rare tabulate corals. The coral-stromatoporoid biostromes and bioherms (Fig. 7) occur more frequently in the middle and upper parts of the formation. Interbeds of greenish-grey thin-bedded dolomitic limestones are poor in fauna, dominated mainly by ostracodes. In these intervals, stromatolitic limestones and mud-crack structures may occur.

The thickness of the Srednij Formation on October Revolution Island varies from 290 to 350 m in the sections on the Matusevich and Ushakov rivers, and reaches up to 500 m in the Krasnaya Bay region. In the latter region the lithology of the formation changes considerably: its lower part (200 m) is represented by dark grey biodetrital limestones, the middle part (150 m) consists of intercalated grey limestones and black marlstones with rare fauna, and the upper part (100-150 m) is characterized by coral-stromatoporoid biostromes and bioherms in biodetrital limestones.

The Srednij Formation can be recognized also on southwestern Komsomolets Island and, probably, on Pioneer Island. In the Sedov Archipelago its thickness evidently does not exceed 130 m, although the rocks are very similar lithologically to those in the type locality on the Matusevich River. According to Yu. G. Samojlovich, on Samojlovich Island the Srednij

FIG. 7. — Reef in the upper part of the Srednij Formation. Srednij Island, outcrop 1(79). Photo by P. Männik.

Formation is about 300 m thick. Here, three distinct intervals with coral-stromatoporoid biostromes and bioherms are recognized, and the upper strata of the formation are considerably more argillaceous than the lower ones.

Although the associations of stromatoporoids, tabulate corals, and rugose corals allow precise correlation with coeval strata in Siberia, in the Timan-Urals region, and Novaya Zemlya, correlation of the Srednij Formation with the international Silurian standard has for a long time been unclear, because different groups of fossils have given inconsistent ages. The assemblages of stromatoporoids (including *Vikingia tenuis* (Nestor, 1966), *Ecclimadictyon robustum* Nestor, 1966, *Simplexodictyon validum* (Nestor, 1966, etc.) and tabulate corals, indicate a Wenlock age for the Srednij Formation (Markovskij & Smirnova 1982; H. Nestor pers. comm.). However, the ostracodes *Hogmochilina maackii* (Schmidt, 1873), *Noviportia* aff. *silurica* (Sarv, 1962) and some new taxa (Abushik in press), the brachiopod *Meristina norilica* (Nikiforova, 1961), and conodonts *Apsidognathus* sp. and some others, correlate these strata with the Telychian (Männik 1997, 2002; Abushik 1999, in press; Modzalevskaya 1999, in press). It is this solution which is adopted here (Fig. 3).

Samojlovich Formation. The Samojlovich Formation (with its type section on the

FIG. 8. — Stromatolites in the middle part of the Samojlovich Formation. The length of the hammers handle is about 80 cm. Ushakov River, outcrop 32. Photo by P. Männik.

Matusevich River: outcrop 11, beds 1-21, and outcrop 2, beds 51-86; Figs 2; 5) is named after Samojlovich (Dlinnyj) Island in the Sedov Archipelago (Menner *et al.* 1979) (Fig. 1). The boundary with the underlying Srednij Formation is placed at the top of the uppermost, 2-3 m thick bed of limestone with abundant stromatoporoids. The Samojlovich Formation shows rhythmic intercalation of highly variable limestones (grey stromatolitic, oolitic and oncolitic limestones; greenish-grey thin-bedded argillaceous limestones with numerous gastropods, brachiopods, ostracodes and trilobites), with almost unfossiliferous dolomitic limestones and argillaceous dolostones. In the dolomitic rocks mud-cracks are quite common. Characteristically, the Samojlovich Formation almost totally lacks beds with tabulates and stromatoporoids, but contains abundant stromatolitic structures (including stromatolitic biostromes; Fig. 8). With the stromatolitic strata are connected numerous lens-like interbeds of carbonate conglomerates. In most of these interbeds the pebbles are inclined. Tabulate, and also rugose corals, have only been recorded from some beds in the upper Samojlovich Formation. In the uppermost strata of the formation the number and taxonomic variation of fossils decrease rapidly, and the content of sandy material increases. Sedimentological features in the Samojlovich Formation indicate that these strata were formed in shallow-water rimmed-shelf environments, under conditions of continuous shallowing of the basin.

In the sections on the Ushakov and Matusevich rivers the formation thickness is 240-280 m, increasing to 400 m in the Krasnaya Bay region, as does also the content of clay in the rocks. The formation has been recorded also on southwestern Komsomolets Island (150-180 m thick), in several regions on Pioneer Island, and in the Sedov Archipelago (Srednij and Samojlovich islands; Fig. 1).

The age of the Samojlovich Formation is still under discussion. Traditionally, based on the assemblages of stromatoporoids, tabulate corals, ostracodes and brachiopods, the lower Samojlovich Formation has been considered of late Wenlock age, and the upper part of Ludlow age (Abushik 1982; Smirnova 1982; Markovskij & Smirnova 1982; Matukhin *et al.* 1982; Kurik *et al.* 1982). However, the occurrence of an *Apsidognathus*-fauna in the lower Samojlovich Formation suggests a Telychian age for these strata, whereas the conodonts *Ozarkodina confluens bucerus* (Viira, 1983) and *Kockelella* cf. *ortus* (Walliser, 1964), and the vertebrate *Loganellia grossi* Fredholm, 1990 indicate middle to late Wenlock age for the upper part of the formation (Männik 1997, 2002; Märss & Karatajūtē-Talimaa in press) (Fig. 3).

Ust'-Spokojnaya Formation. This stratigraphic unit was originally described as the Izluchina Formation (Menner *et al.* 1979), but was later renamed the Ust'-Spokojnaya Formation (Menner *et al.* 1982). The new name is derived from the Spokojnaya River, as the most complete sections of this formation occur close to the river mouth (Fig. 9). However, the type section of the Ust'-Spokojnaya Formation is located on the Matusevich River (outcrop 2, beds 1-50; Figs 2; 5). The lower boundary of this formation corresponds to the base of the lowermost distinctive sandstone bed. On the Matusevich and Ushakov rivers the upper part of the formation has been eroded before Devonian sedimentation started, and its upper

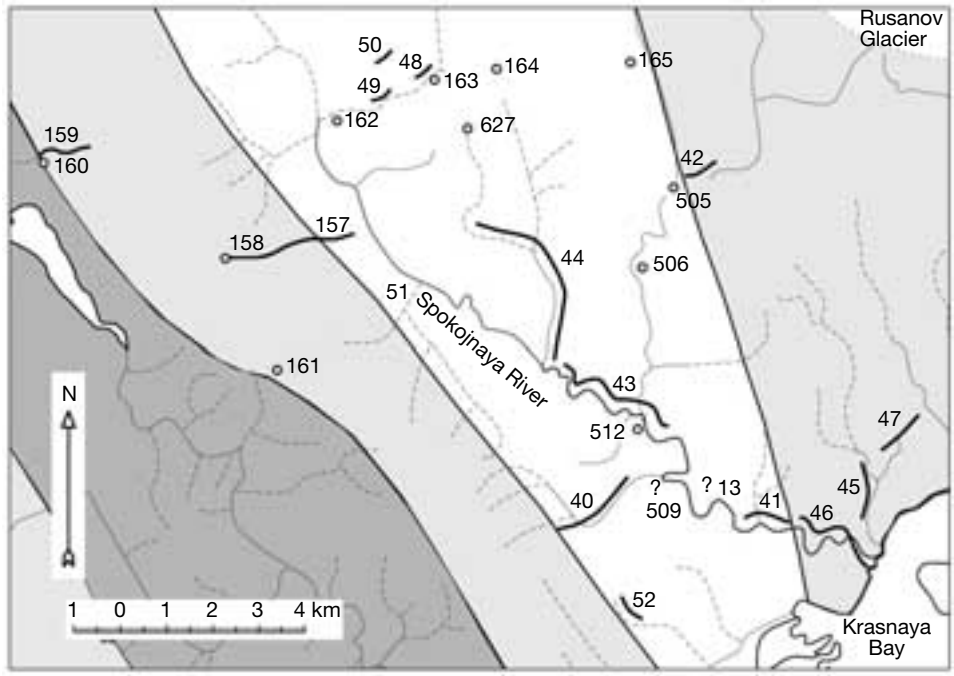

FIG. 9. — Localities in the Spokojnaya River region. For legend refer to Fig. 1. Numbers correspond to outcrops.

boundary corresponds to the erosional surface at the base of the Severnaya Zemlya Formation of early Devonian age (Figs 5; 10). The upper part of the formation is available for study only in the Krasnaya Bay region, near the mouth of the Spokojnaya River (section 47, beds 9-12; Figs 5; 9). Here, the upper boundary of the Ust'-Spokojnaya Formation corresponds to the transition from variegated marlstones with ostracodes to the red sandstones and argillites of the overlying Krasnaya Bukhta Formation.

The Ust'-Spokojnaya Formation consists mainly of brownish-red, violet-grey and greenish-grey marlstones with thin lens-like interbeds of argillaceous limestone containing ostracodes, bivalves, gastropods, and vertebrate remains (Fig. 11). Interbeds of grey, greenish-grey and dark grey fine-grained and oolitic limestones containing bivalves, ostracodes, cephalopods, stromatolites and oncolites, characterize the lowermost part of the formation. Stromatoporoids, rugose and tabulate corals, and echinoderms have not been found. The lowermost part of the formation contains interbeds of sandstone, and thin beds of dolostone are common.

The lithology of the Ust'-Spokojnaya Formation indicates the continuous shallowing of the sedimentary basin, and an increasing input of red terrigeneous material from neighbouring land areas.

The thickness of the Ust'-Spokojnaya Formation is highly variable: from 60-100 m in the central part of October Revolution Island (where the upper strata of the formation are missing) to 270-340 m in the Kasnaya Bay region. Strata on Komsomolets Island, probably corresponding to this formation are 180 m thick. The Ust'-Spokojnaya Formation can be recognized also on Pioneer Island, and probably also in the eastern part of the Sedov Archipelago (Figurnyj and Vostochnyj islands; Fig. 1).

The Ust'-Spokojnaya Formation is of Ludlow age based on the occurrence of the vertebrates *Trematapis obruchevi* Afanassieva & Karatajūtē-Talimaa, 1998, *Paralogania martinssoni* (Gross,

FIG. 10. — The Silurian-Devonian boundary between argillaceous limestones below and conglomeratic sandstones above. The hammer lies on the upper surface of the Silurian strata. Matusevich River, contact between sections 2 (below) and 1 (above). Photo by P. Männik.

FIG. 11. — Dolomitic marlstones and argillaceous dolostones of the Ust'-Spokojnaya Formation. Matusevich River, outcrop 2. Photo by P. Männik.

1967), *Phlebolepis elegans* Pander, 1856, and *Andreolepis* sp., and also on the ostracodes *Eukloedenella posterioalta* Abushik, 1980, *Herrmannina nana* Abushik, 1960, *H. hebes* Abushik, 1980, *Tollitina minuta* (Abushik, 1980) (Märss *et al.* 1995; Abushik & Evdokimova 1999; Abushik 1999, in press; Karatajūtē-Talimaa & Märss in press) (Fig. 3).

Krasnaya Bukhta Formation. The Krasnaya Bukhta Formation is named after Krasnaya Bay (in Russian "bukhta"), October Revolution Island (Menner *et al.* 1982) (Fig. 1). Its type section lies close to the northern coast of this bay, about 0.5 km east from the mouth of the Spokojnaya River (outcrop 47, beds 1-8; outcrop 45; and beds 1-24 of outcrop 46; Figs 5; 9).

The Krasnaya Bukhta Formation represents the youngest part of the Silurian sequence on Severnaya Zemlya. It contains brownish-red siltstones, argillites, marlstones and sandstones with rare interbeds of greenish-grey marlstones and argillaceous limestones. In the carbonate interbeds ostracodes, bivalves, vertebrates and charophytes (algae) have been found. At the lower boundary of the Krasnaya Bukhta Formation variegated marlstones, characteristic of the underlying Ust'-Spokojnaya Formation, are replaced by red sandstones (Fig. 5). The sediments of the Krasnaya Bukhta Formation were evidently deposited in shallow-water restricted marine environments during a continuing regression of sea. Most common in the poor fauna of this formation are micro- and macroremains of vertebrates, but some beds also contain ostracodes and charophytes occur.

The total thickness of the Krasnaya Bukhta Formation in the region just north from Krasnaya Bay is about 350-400 m. To the west the thickness of the formation decreases rapidly due to the pre-Devonian denudation of upper Silurian strata. It does not exceed 100-150 m in the outcrops to the west of the Spokojnaya River. Further to the north from Krasnaya Bay, in the Bedovaya River region, the thickness of the formation increases to 600-700 m. Beside the northeastern part of October Revolution Island, the Krasnaya Bukhta Formation can probably be recognized only on southwestern Komsomolets Island, and on Pioneer Island.

Thelodonts *Paralogania* cf. *borealis* (Karatajūtē-Talimaa, 1978), *Loganellia cuneata* (Gross, 1947), *Gonioporus alatus* (Gross, 1947) and the

osteostracan *Hemicyclaspis* sp. correlate the Krasnaya Bukhta Formation with the Přidoli (Märss & Karatajūtē-Talimaa in press) (Fig. 3). Acanthodians, represented by the *Poracanthodes punctatus* Zone assemblage (Valiukevičius 1999, in press), and ostracodes are also indicative of a Přidoli age (Abushik & Evdokimova 1999; Abushik 1999, in press).

DEVONIAN

On October Revolution Island, but particularly on Komsomolets and Pioneer islands, the Devonian strata are more widely distributed than the Silurian sediments. In the Sedov Archipelago, the Devonian is known only from Figurnyj and Vostochnyj islands (Fig. 1). Eleven formations, most of them recognized all over the archipelago, are identified in the almost complete Devonian sequence on Severnaya Zemlya, and all standard Devonian stages are represented by deposits (Fig. 3). Most of the formations were originally defined and described in the continuous Devonian section on the Matusevich River, October Revolution Island (Menner *et al*. 1979). However, later it appeared that in several sections on Pioneer and Komsomolets islands some intervals of the Devonian sequence are more completely represented than along the Matusevich River.

Lower Devonian

Severnaya Zemlya Formation. The Severnaya Zemlya Formation was originally described in 1978 (Menner *et al.* 1979). Its lower boundary corresponds to the base of coarse-grained conglomeratic sandstones unconformably overlying the rocks of the Krasnaya Bukhta or Ust'-Spokojnaya formations (Fig. 10). The type section of the Severnaya Zemlya Formation is located on the Matusevich River (outcrop 1, beds 21-28; Figs 2; 12).

The Severnaya Zemlya Formation can be subdivided into lower and upper parts. On October Revolution Island, in the sections on the Matusevich, Ushakov and Spokojnaya rivers (Figs 2; 6; 9; 12), the basal strata of the lower Severnaya Zemlya Formation are represented by greenish-grey coarse-grained sandstones which contain numerous lenses or interbeds of conglomerates with pebbles of different Silurian rocks. Higher in the sequence, these sediments are replaced by variegated siltstones and argillites.

The upper part of the Severnaya Zemlya Formation consists of dark grey slate-like limestones, marlstones and argillites with numerous flat nodules holding well-preserved (often complete) fish remains, eurypterids, ostracodes and algae (Fig. 13). The thickness of the lower part of the formation varies between 17 and 70 m, and of the upper part between 20 and 30 m. The total thickness of the Severnaya Zemlya Formation on October Revolution Island is 30-100 m, and on Komsomolets Island it is also up to 100 m thick. The formation has also been identified on Pioneer Island but its thickness there is not known.

The association of heterostracans, represented by the genera *Anglaspis* Jaekel, 1926, *Corvaspis* Woodward, 1934, *Ctenaspis* Kiaer, 1930, *Lepidaspis* Dineley & Loeffler, 1976, *Phialaspis* Wills, 1935, *Protopteraspis* Leriche, 1924, *Tesseraspis* Wills, 1935 and *Unarkaspis*? Elliott, 1983, indicates a Lockhovian age for the Severnaya Zemlya Formation (Karatajūtē-Talimaa & Blieck 1999) (Fig. 3). The Lockhovian age is also evidenced by acanthodians, represented here by the assemblage of the *Poracanthodes menneri* Subzone (lower part of the *Nostolepis minima* Zone; Valiukevičius in press), and the ostracode *Herrmannina convexa* Abushik, 1980 (Abushik & Evdokimova 1999; Evdokimova & Abushik in press).

At the end of the Silurian, sedimentation terminated in several areas on Severnaya Zemlya and the uppermost Silurian strata were denudated. The early Lochkovian time was characterized by a new transgression in this region but even the uppermost strata of the Severnaya Zemlya Formation formed still in extremely shallow-water conditions, in an environment closest to lagoonal.

Pod''emnaya Formation. The Pod''emnaya Formation is named after the Pod''emnaya

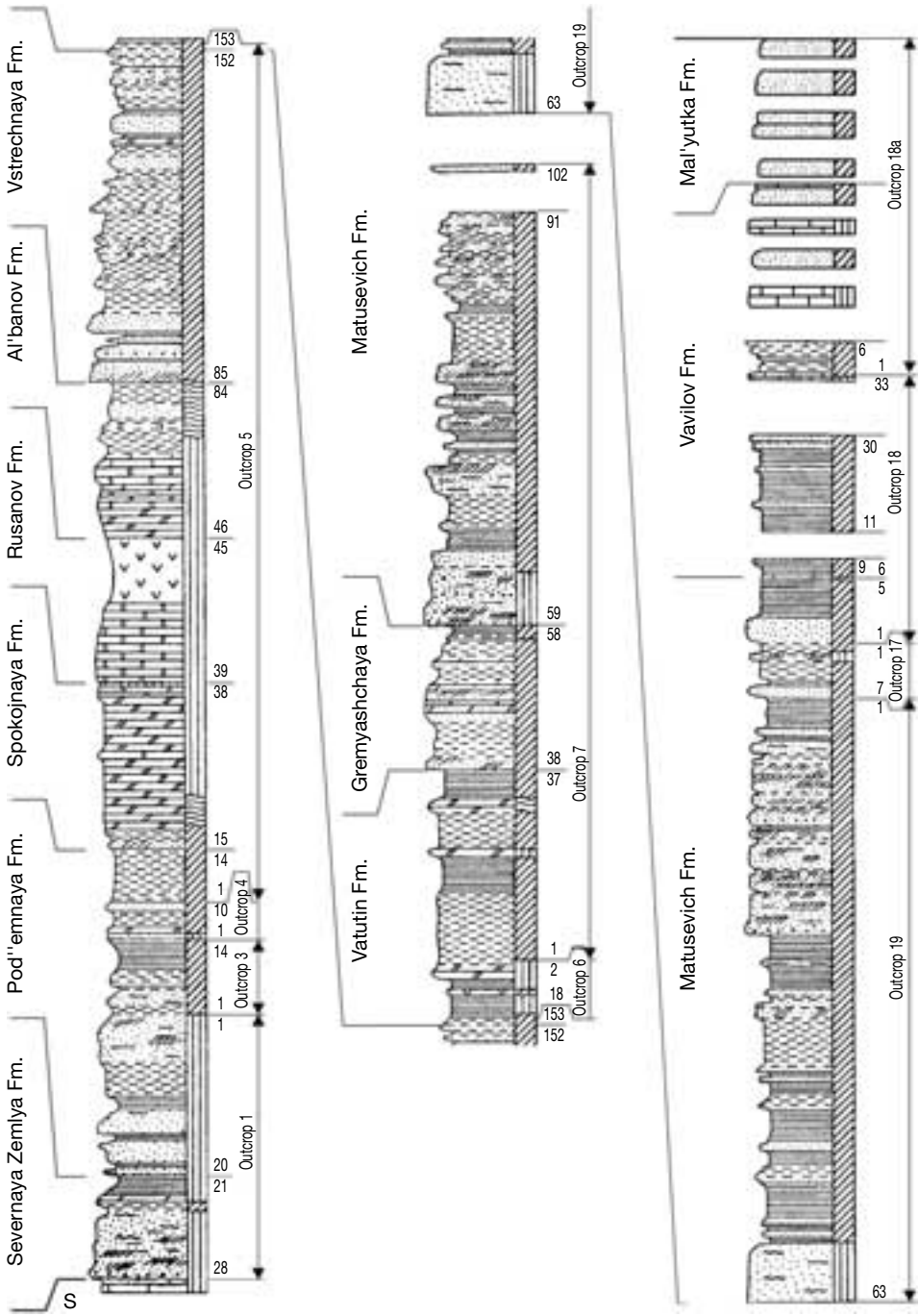

FIG. 12. — Devonian section on the Matusevich River (for location of outcrops see Figs 1 and 2; for legend refer to Fig. 5). To the right of the lithological log are shown the rock colour, the numbers of the beds described, and the extent of the outcrops studied. The interval above bed 6 in outcrop 18a was not described in detail. Abbreviation: **S**, top of Silurian strata (Ust'-Spokojnaya Formation).

River (western October Revolution Island), where a section yielding the richest assemblages of vertebrates was described (Menner *et al.* 1979). The type section is located on the Matusevich River (outcrop 1, beds 1-20; outcrops 3 and 4; outcrop 5, beds 1-14; Figs 2; 12). The lower boundary of the Pod''emnaya Formation corresponds to the upper surface of the dark grey carbonate argillites of the underlying Severnaya Zemlya Formation, and its upper boundary to the base of the variegated sandstones of the overlying Spokojnaya Formation.

On October Revolution Island the Pod''emnaya Formation was differentiated into two parts. The lower part comprises grey siltstones and quartz-feldspar sandstones with interbeds of argillites, and contains plant fossils and rare vertebrates. The upper part consists of a rhythmic intercalation of reddish-brown and greenish-grey sandstones, siltstones, and argillites with interbeds of variegated argillaceous dolostones yielding concretions of celestite. Flat nodules of gypsum are common. Ostracodes and fish remains occur in abundance in dolostones.

The lower part of the Pod''emnaya Fomation is 50-90 m thick, and the upper part is 80-190 m thick. The total thickness of the formation on October Revolution Island varies from 160 m (Pod''emnaya River) to 280 m (Spokojnaya River). The Pod''emnaya Formation is also well exposed on Komsomolets and Pioneer islands.

The age of the Pod''emnaya Formation, based on the associations of ostracodes (*Leperditia* cf. *marinae* Abushik, 1980, *Herrmannina* aff. *orbiculata* Abushik, 1980, *Hogmochilina isochilinoides* (Jones, 1883) and *H. teres* Solle, 1935), and heterostracans (identical to those in the Severnaya Zemlya Formation; see above), is Lochkovian (Abushik & Evdokimova 1997, 1999; Evdokimova & Abushik in press; Karatajūtē-Talimaa & Blieck 1999). The acanthodians, represented by the *Diplacanthus poltingi* Subzone (upper part of the *Nostolepis minima* Zone) fauna, correlate the Pod''emnaya Formation with the upper Lochkovian (Valiukevičius in press) (Fig. 3).

FIG. 13. — Severnaya Zemlya Formation. In the centre of the figure (cliff), argillaceous limestones and argillites of the upper part of the formation are exposed. Spokojnaya River, outcrop 41(?). Photo by V. Menner.

FIG. 14. — Spokojnaya Formation. Spokojnaya River, outcrop 43. Photo by V. Menner.

Spokojnaya Formation. The Spokojnaya Formation is named after the Spokojnaya River, at the middle course of which one of the most complete sections of this formation is located (Menner *et al.* 1979) (Fig. 14). The type section of this formation is located on the Matusevich River (outcrop 5, beds 15-38; Figs 2; 12). Its lower boundary corresponds to the base of variegated sandstones and siltstones, and its upper boundary to the base of grey dolostones or limestones of the overlying Rusanov Formation. The lower part of the Spokojnaya Formation (1-151 m thick) is represented by red and variegated quartz-feldspar sandstones, siltstones and argillites. In some sections also intervals of variegated marlstones occur. Fossils in the lower

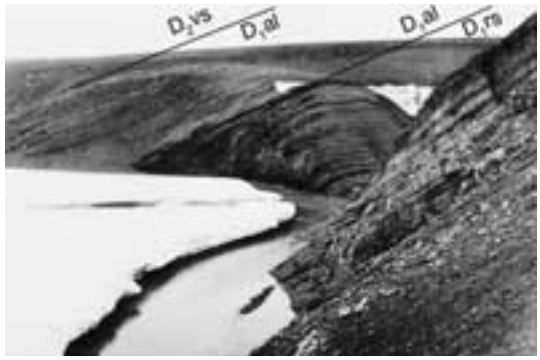

FIG. 15. — Rusanov and Al'banov formations, and the lowermost part of the Vstrechnaya Formation. Boundaries between formations are indicated by lines. Abbreviations: **D_1rs**, Rusanov Formation; **D_1al**, Al'banov Formation; **D_2vs**, Vstrechnaya Formation. Matusevich River, outcrop 5. Photo by V. Menner.

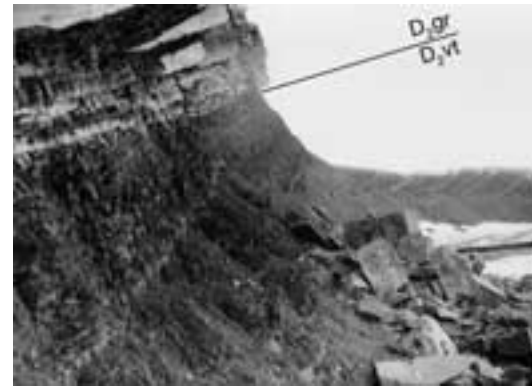

FIG. 16. — The contact between the argillites of the Vatutin Formation (**D_2vt**) and coarse-grained sandstones of the Gremyashchij Formation (**D_2gr**). Matusevich River, outcrop 7. Photo by P. Männik.

Spokojnaya Formation are mainly represented by vertebrates.

Higher in the sequence, variegated terrigenous sediments are gradually replaced by grey argillaceous carbonate rocks indicative of the developing Early Devonian transgression in the Severnaya Zemlya region. The upper part of the formation (50-145 m thick) consists of grey, and some greenish-grey, dolomitic marlstones with interbeds of grey argillaceous dolostones and siltstones. In the sections where the formation is thicker, numerous interbeds of gypsum occur in the dolomitic marlstones. Fossils in the upper Spokojnaya Formation are represented by rare ostracodes, bivalves, stromatolites and vertebrates.

On October Revolution Island the thickness of the formation varies widely, from 25 m on the Pod''emnaya River up to 300 m on the Spokojnaya River. In the Matusevich and Ushakov rivers' sections it is about 80-90 m thick, and on Komsomolets and Pioneer islands up to 100 m thick.

The comparison of the vertebrate assemblages from the Spokojnaya Formation with those from Spitsbergen and other regions has revealed that this formation, most probably, corresponds to the boundary beds of the Lochkovian and Pragian stages (Afanassieva & Karatajūtē-Talimaa 1999; Karatajūtē-Talimaa & Blieck 1999; Mark-Kurik 1999). However, considering the ages of the underlying Pod''emnaya Formation (see above), and the overlying Rusanov Formation (see below), the Spokojnaya Formation is correlated with the Pragian (Fig. 3).

Rusanov Formation. The Rusanov Formation was originally described by Egiazarov (1959) on Pioneer Island, in the valley of the Pionerka River. The name was given in the honour of V. A. Rusanov, an Arctic explorer. Later, in 1972-1979, during the geological mapping of Severnaya Zemlya and special stratigraphical studies, a new type section for this formation was selected and described on the Matusevich River, about 3 km upstream from the waterfalls (Menner *et al.* 1979; outcrop 5, beds 39-45; Figs 2; 12; 15). Here, the lower boundary of the Rusanov Formation corresponds to the base of grey limestones or dolostones containing a rich assemblage of marine invertebrates.

The Rusanov Formation is known from October Revolution, Komsomolets and Pioneer islands in Severnaya Zemlya, and from Figurnyj Island in the Sedov Archipelago. In all known sequences a carbonaceous lower member and a gypsum-rich upper member are distinguished in this formation. A rich association of fossils in the lower member allows detailed correlation of

these strata with the sequences on Tajmyr and Novaya Zemlya, but also with the international Devonian standard.

The lower member of the Rusanov Formation on October Revolution Island (17-50 m thick) is represented by grey dolomitized limestones (Fig. 15). In the middle of this interval a number of interbeds rich in stromatoporoids, tabulate and rugose corals, brachiopods, bivalves, ostracodes, trilobites, echinoderms and vertebrates occur. In some beds stromatoporoids form small bioherms. Dolomitization of these limestones is probably connected with a stratigraphical gap between the lower and upper parts of the Rusanov Formation. The upper member of the Rusanov Formation (20-50 m thick) consists of grey gypsum interbedded with dolostones.

In southwestern Komsomolets Island, and on Pioneer Island, the limestones of the lower Rusanov Formation are less dolomitized than on October Revolution Island. Here, an interval rich in stromatoporoids, tabulate and rugose corals, brachiopods, echinoderms, trilobites and conodonts occurs in the lower part of these strata. Higher in the sequence is an interval of limestones and dolostones, not known in the sections of the Rusanov Formation on October Revolution Island. In this interval stromatoporoids and corals are missing, but brachiopods, trilobites and vertebrates are common. The thickness of the lower member of the Rusanov Formation in this region is 85-110 m, and the upper member is 50-135 m thick.

The lower strata of the Rusanov Formation were formed during the maximum transgression of the Early Devonian in the Severnaya Zemlya basin. This is the only interval in the Devonian sequence on Severnaya Zemlya containing rich and variable invertebrate faunas. The late Rusanov time was characterized by a rapid regression which resulted in deposition of evaporites.

According to Valiukevičius (1999), the upper part of the lower member of the Rusanov Formation corresponds to the lower part of his "Beds with *Watsonacanthus costatus*". Based on the co-occurrence in these strata of acanthodians and conodonts (*Pandorinellina exiqua exiqua* (Philip, 1966), *P. expansa* Uyeno & Mason, 1975, etc.), the "Beds with *W. costatus*" correlate with the *dehiscens-inversus* conodont zones (lower-middle Emsian; Valiukevičius in press). The Emsian age of the upper part of the lower member is also supported by the contained ostracodes (Abushik & Evdokimova 1997; Evdokimova & Abushik in press). However, the occurrence of the ostracode *Eomoelleritia kondiaini* Abushik, 1972 in the lower part of this member indicates a Pragian age. The upper Pragian-Emsian age of the Rusanov Formation is evidenced also by other marine invertebrates (Khapilin 1982; Kurik *et al*. 1982; Menner *et al.* 1982) (Fig. 3).

Al'banov Formation. The Al'banov Formation was originally described by Egiazarov (1959) in the sections on the Pionerka and Burnaya rivers, Pioneer Island. The formation was named in honour of V. I. Al'banov, an Arctic explorer. In 1979 a new type section for the Al'banov Formation was described on the Matusevich River, October Revolution Island (Menner *et al*. 1979; outcrop 5, beds 46-84; Figs 2; 12; 15). The distribution of the Al'banov Formation coincides with that of the Rusanov Formation. The lower boundary of the Al'banov Formation is marked by the disappearance of gypsum, which is characteristic of the upper member of the Rusanov Formation.

In the section on the Matusevich River, two members (respectively 48 m and 34 m in thickness) were recognized in the Al'banov Formation. The basal beds of the lower Al'banov Formation consist of grey dolomitic marlstones and dolostones followed by an intercalation of grey dolostones, limestones and greenish-grey argillaceous limestones containing fish remains, large ostracodes, eurypterids and bivalves. The upper member of the Al'banov Formation is represented by an intercalation of light variegated siltstones, sandstones and argillites rich in aggregates of siderite, and containing interbeds of oolitic goethite ore and breccia. In several sections a big stratigraphical gap has been identified between the lower and upper members of the Al'banov Formation.

In the Pod''emnaya River region the upper carbonate interval of the lower part of the lower member of the Al'banov Formation is mostly missing. Here the total thickness of the formation is only *c.* 36 m. On Komsomolets and Pioneer islands the lithology of the lower member of the Al'banov Formation is similar to that on the Matusevich River, and its upper part is represented by grey and red argillites. These are missing from the October Revolution Island sequence, either due to a stratigraphical gap or to facies changes.

The strata of the Al'banov Formation were formed during alternating short-term transgressions and regressions in a generally shallowing basin, which was evidently still connected with the marine basins in northern Europe and Siberia. Egiazarov (1957) considered the Al'banov Formation to be of Givetian age. However, later palaeontological studies have revealed a considerably older age, with acanthodians characteristic of the "Beds with *Watsonacanthus costatus*" indicating an Emsian age (Valiukevičius 1999) (Fig. 3). The Emsian age is supported by the occurrence of a rich and diverse assemblage of placoderms, several representatives of which (*Wijdeaspis* Obruchev, 1964, early heterostiids, buchanosteids, etc.) have a global distribution (Mark-Kurik 1991, 1998). The fauna of ostracodes in this formation, almost identical to that in the upper part of the lower member of the Rusanov Formation, is also Emsian in age (see above; Evdokimova & Abushik in press).

Middle Devonian

Three formations – Vstrechnaya, Vatutin and Gremyashchaya – have been established in the Middle Devonian sequence in the central and western parts of the Severnaya Zemlya Archipelago (Fig. 3). Type sections of all these formations are located on the Matusevich River. Quite probably the basal strata of the overlying Matusevich Formation are also of Middle Devonian age (see below).

The sediment sequence in the Vstrechnaya and Vatutin formations indicates a gradual deepening of the sea in the Severnaya Zemlya region after an extensive regression in late Emsian (the upper Al'banov Formation; see above). The strata of the upper Gremyashchaya Formation were deposited in conditions of a new regression. On the geological map of Severnaya Zemlya, compiled by V. Markovskij, the strata corresponding to the Vstrechnaya, Vatutin and Gremyashchaya formations are indicated as a single unit – the Geographers Formation with its type section on Komsomolets Island (Gurari & Krasilov 1982).

Vstrechnaya Formation. The formation is named after hill Vstrechnaya in the western part of October Revolution Island (Fig. 1) (Menner *et al.* 1979). The type section of the formation is located on the Matusevich River (outcrop 5, beds 85-152; Figs 2; 12). The lower boundary of the Vstrechnaya Formation corresponds to the base of the coarse-grained sandstones containing Middle Devonian vertebrates. In the sections on the Matusevich, Ushakov and Pod''emnaya rivers, and close to the northern coast of October Revolution Island, the Vstrechnaya Formation consists of rhythmically intercalating brownish-red terrigenous sediments. The basal parts of the cycles are composed of coarse-grained cross-bedded sandstones with lenses or lens-like interbeds of conglomerates, haematitic pebbles and bone-breccias. Higher in the cycles the grain size in sandstones decreases, and their upper parts are represented by siltstones and argillites. Commonly, the bases of the cycles exhibit erosional surfaces. Ostracodes, inarticulate brachiopods and plant remains are found in the siltstones and argillites. In the western part of the Severnaya Zemlya Archipelago, on Komsomolets and Pioneer islands, red sandstones of the lower Vstrechnaya Formation are replaced by light-grey and yellowish-grey ones.

The thickness of the Vstrechnaya Formation on October Revolution Island varies between 70 and 160 m, except in the north, in the Obryvistaya River region, where its thickness may reach some 400 m.

The association of Psammosteidae in the Vstrechnaya Formation is typical of the Middle Devonian (Karatajūtē-Talimaa pers. comm.).

The assemblages of placoderms indicate an Eifelian to Givetian age (Mark-Kurik 1998, pers. comm.). Acanthodians of the *Diplacanthus solidus* Assemblage from the upper part of the formation also indicate an Eifelian-Givetian age (Valiukevičius 1999, in press) (Fig. 3).

Vatutin Formation. This formation is named after the Vatutin Peninsula on western October Revolution Island, where it is well exposed (Fig. 1) (Menner *et al.* 1979). The best sections of the Vatutin Formation are located on the Matusevich and Pod''emnaya rivers, and close to Vstrechnaya hill. The type section of the formation is located on the Matusevich River (outcrop 5, bed 153; outcrop 6, and outcrop 7, beds 1-37; Figs 2; 12; 16). The lower boundary of the Vatutin Formation corresponds to the upper surface of the sandstones of the underlying Vstrechnaya Formation, and its upper boundary to the base of the basal sandstones of the overlying Gremyashchaya Formation.

The 100-130 m thick Vatutin Formation consists mainly of rhythmically intercalating reddish-brown siltstones and argillites with rare thin interbeds of greenish-grey dolomitic marlstones. Sandstones are missing. The basal part of the formation includes beds of grey argillites containing nodules of gypsum, shells of *Lingula* Bruguière, 1797, and ostracodes. Plant remains are also quite common.

The age of the Vatutin Formation is problematic, but rare psammosteid heterostracans (*Psammolepis* Agassiz, 1844, *Tartuosteus*? Obruchev, 1961, *Psammosteus* Agassiz, 1844) suggest Givetian age (Mark-Kurik pers. comm.) (Fig. 3).

Gremyashchaya Formation. The Gremyashchaya Formation is named after the Gremyashchaya River, a tributary of the Pod''emnaya River in the western part of October Revolution Island (Fig. 1) (Menner *et al.* 1979). Its type section is located on the Matusevich River (outcrop 7, beds 38-58; Figs 2; 12). The Gremyashchaya Formation consists of yellowish and violet coarse- to fine-grained quartz sandstones with rare interbeds of conglomerates, red siltstones, argillites and marlstones. Thin interbeds of oolitic or nodular limestones occur at some levels. In the coarse-grained sandstones large fragments of fossil plants occur, and ostracodes and stromatolites are common in the argillites and marlstones. The formation is characterized by abundant and well-preserved vertebrate remains. The lower boundary of the Gremyashchaya Formation is marked by the appearance of coarse-grained sandstones above the fine-grained sediments of the Vatutin Formation (Fig. 16).

The thickness of the Gremyashchaya Formation on October Revolution Island varies from 15 m on the Pod''emnaya River, 70 m on the Matusevich River, to up to 150 m on the Obryvistaya River.

The association of vertebrates indicates a correlation of the Gremyashchaya Formation with the middle Givetian Abava Regional Substage in the Baltic sequence (Mark-Kurik 1998).

Upper Devonian

Matusevich, Vavilov and Mal'yutka formations correspond to the Upper Devonian on Severnaya Zemlya (Fig. 3). However, it is quite possible that the basal strata of the Matusevich Formation are still of Middle Devonian in age (see below). Type sections of all these formations are located on the Matusevich River. The Matusevich and Vavilov formations have been recognized on October Revolution and Komsomolets island, the Mal'yutka Formation only in the central part of the October Revolution Island.

Lithological changes in the Matusevich Formation reflect the cyclic development of the Frasnian transgression, the sediments of the Vavilov Formation formed in time when the sea level reached its highest position in late Frasnian, and those of the Mal'yutka Formation already in conditions of the Famennian regression.

Matusevich Formation. The formation was erected by Egiazarov (1957) and named after the Matusevich River, October Revolution Island. Later, the boundaries of the formation have been revised (Menner *et al.* 1979). The type

section of the Matusevich Formation is located on the Matusevich River (outcrop 7, beds 59-102; outcrops 19, 17, and beds 1-5 of outcrop 18; Figs 2; 12). Its lower boundary corresponds to the base of a very distinctive bed of coarse-grained conglomeratic sandstones.

The strata of the Matusevich Formation are exposed on October Revolution and Komsomolets islands. The formation shows a rhythmic intercalation of variegated and red quartz sandstones, siltstones and argillites formed in a gradually deepening basin. The lower parts of the cycles are represented by reddish-brown cross-bedded coarse-grained sandstones replaced upwards by interbedding fine-grained sandstones, siltstones and argillites. Particularly characteristic of the Matusevich Formation, but also of the overlying strata, are reddish-brown thin-bedded fine-grained sandstones and siltstones. Interbeds of greenish-grey sediments are rare in this interval. The strata of the Matusevich Formation are rich in plant fossils and vertebrates.

In the type section on the Matusevich River five units have been described in the sequence of the Matusevich Formation, viz., from bottom to top:

1) grey coarse-grained sandstones, 35 m;
2) intercalation of red sandstones (dominating), siltstones and argillites, 240 m;
3) red argillites and siltstones with rare interbeds of sandstones, 150 m;
4) red sandstones, 90 m;
5) intercalation of sandstones, siltstones and argillites (dominating), 65 m.

In the neighbouring regions (Ushakov, Pod''emnaya, Bol'shaya rivers) only some intervals of this sequence are represented. On Komsomolets Island, the Matusevich Formation is well exposed in many regions, and may reach 470 m in thickness.

The heterostracan *Psammosteus* cf. *maeandrinus* Agassiz, 1844, and placoderms *Asterolepis* cf. *maxima* Agassiz, 1844, *Bothriolepis* cf. *obrutschevi* Gross, 1942, *B.* cf. *trautscholdi* Jaekel, 1927 and *B.* cf. *maxima* Gross, 1933, indicate a Frasnian age for this formation (Lukševičs 1997, 1999) (Fig. 3). However, in the type section on the Matusevich River the typical Frasnian fauna appears only in bed 2 (see above), so it is possible that the lowermost part of the formation is of late Givetian age (Lukševičs 1999). *Bothriolepis* cf. *obrutschevi* from the lower part of the formation correlates these strata with the upper Givetian or lower Frasnian Amata Formation of the Baltic (Mark-Kurik 1998).

Vavilov Formation. The Vavilov Formation, first identified by Egiazarov (1957), was named after the Vavilov Glacier (southwestern October Revolution Island). Its type section is located on the Matusevich River and on its tributaries (outcrop 18, beds 6-33, and outcrop 18a, lower part; Figs 2; 12).

The lower boundary of the Vavilov Formation corresponds to the base of the lowermost bed of limestones. Characteristic of this formation is the dominance of fine-grained sediments – mainly red to variegated siltstones and argillites with interbeds of fine-grained sandstone. Rare interbeds of grey limestones with abundant plant remains are up to 2.7 m thick. The limestones are rich in vertebrate remains, and thin-walled ostracodes are common. The Vavilov Formation was formed during the maximum of the Late Devonian transgression.

The thickness of the Vavilov Formation reaches up to 200-300 m on October Revolution Island, and varies between 150 and 290 m on Komsomolets Island.

A poor vertebrate fauna in the Vavilov Formation does not allow its precise age-dating. However, considering the ages of the underlying Matusevich Formation (see above), and the overlying Mal'yutka Formation (see below), the Vavilov Formation is correlated with the Frasnian (Fig. 3; see also Lukševičs 1999).

Mal'yutka Formation. The Mal'yutka Formation is named after a tiny glacier just north of the Vavilov Glacier, on the upper reaches of the Matusevich River (Fig. 1) (Menner *et al.* 1979). This is the only region where the strata of the Mal'yutka Formation are known to be exposed. The type section of this

formation is located on the Matusevich River (outcrop 18a, upper part; Figs 2; 12).

The lower boundary of the Mal'yutka Formation corresponds to the upper surface of the last limestone bed in the underlying Vavilov Formation. In comparison with the underlying Vavilov Formation, the amount of sandstone increases considerably and limestones are missing in the Mal'yutka Formation. The formation consists of an intercalation of red and variegated sandstones with interbeds of conglomerates, siltstones and argillites. At some levels flat nodules of pink gypsum are common. Vertebrate and plant remains are the only fossils. The sediments of the Mal'yutka Formation were formed in gradually shallowing basin. On the Matusevich River, where the Upper Devonian sequence is most complete in the region, the Mal'yutka Formation is at least 300 m thick.

A new subspecies of the placoderm *Bothriolepis leptocheira* Traquair, 1893, occurring in the upper part of the Mal'yutka Formation, suggests Famennian age for these strata (Lukševičs 1999) (Fig. 3). The age of the lower part of this formation is not known but is assumed to be Frasnian.

CONCLUSIONS

The development of the Silurian and Devonian sedimentation in the Severnaya Zemlya region was affected by both, global eustatic events and regional tectonics in northern Europe, Urals, and Central Siberia.

Rhuddanian-early Aeronian normal marine carbonates (Vodopad Formation) formed during the major early Llandovery transgression. Assemblages of stromatoporoids, corals, crinoids, and ostracodes from the Vodopad Formation indicate not only to the open-shelf environment of sedimentation but also to the good connections of the sea in the Severnaya Zemlya region with the Siberian and Timan-Urals but also Baltic basins.

In late Aeronian (Golomyannyj Formation), in conditions of a global regression, common elements with Baltic faunas became rare or disappeared. During the major late Llandovery (Telychian) transgression (Srednij Formation), in shallow-shelf environments biostromes and bioherms flourished in the Severnaya Zemlya region. Starting from the end of Llandovery, the general tendency of the development of sedimentation in Severnaya Zemlya and Sedov archipelagos was regressive, with transgressive oscillations in some periods. Carbonates were replaced by variegated and red terrigenous sediments in Ludlow to Přidoli time (Ust'-Spokojnaya and Krasnaya Bukhta formations). In the late Samojlovich time, Severnaya Zemlya evidently became semi-isolated also from the Siberian basin (common taxa are found only among ostracodes and vertebrates), and starting from the Ust'-Spokojnaya Formation some faunal similarities are noticed only between the Severnaya Zemlya and Svalbard sequences (Markovskij & Smirnova 1982). At the end of the Silurian, sedimentation terminated in several areas in the Severnaya Zemlya basin and the uppermost Silurian strata were lost to erosion. In some regions both the entire Přidoli and the upper Ludlow are missing.

Unlike the Silurian, Devonian strata are dominated by variegated terrigenous rocks. Three main periods, related to the global eustatic cyclicity, can be recognized in the Devonian sedimentation on Severnaya Zemlya:

1) after a considerable gap, and denudation of the late Silurian sediments, the sedimentation started again in Lochkovian. During the initial stage of the Early Devonian transgression mainly terrigeneous sediments accumulated (Severnaya Zemlya, Pod''emnaya and Spokojnaya formations);

2) the transgression reached its maximum in the late Pragian-early Emsian (Rusanov and early Al'banov) time (the lower Rusanov Formation is the only interval in the Devonian sequence on Severnaya Zemlya containing rich and variable open marine invertebrate faunas). Based on vertebrates, in early Lochkovian the Severnaya Zemlya region had some connections only with the northern Europe. In late Lochkovian, the developing transgression re-opened migrational ways, and in late Pragian-early Emsian faunas

became similar in Severnaya Zemlya, Tajmyr, Central Siberia, Timan-Urals region, Novaya Zemlya, and Svalbard;

3) the main part of the Devonian sequence, starting from the upper Al'banov Formation, is mainly represented by variegated or red terrigeneous sediments formed in an extremely shallow-water epicontinental basin with abnormal salinity. Rare thin interbeds of carbonate rocks are found only at some levels. The vertebrate associations in these strata possess some similarity to those from Baltic.

Acknowledgements

The authors are grateful to A. Abushik, I. Evdokimova, V. Karatajūtė-Talimaa, E. Lukševičs, E. Mark-Kurik, T. Modzalevskaya, T. Märss, H. Nestor and J. Valiukevičius for valuable comments on biostratigraphy. A. Noor made linguistic improvements to the manuscript and O. Hints assisted in scanning the figures. The manuscript was much improved following the comments of referees A. Blieck and G. C. Young. The study by P. Männik was supported by grant No. 3749 of the Estonian Science Foundation and by governmental research grant No. 0330360s98.

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Submitted on 13 April 1999;
accepted on 30 October 2001.