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The Cambrian of the Severnaya Zemlya Archipelago, Russia

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with 7 figures and 1 plate

Abstract. The Lower Palaeozoic strata belonging to the Kara Basin are extensively exposed in the Severnaya Zemlya Archipelago. During the Cambrian, thick clastic sequences are the dominating sediments on Severnaya Zemlya. The Cambrian rocks occur in the Nekrasovskaya, Maratovskaya, Universitetskaya and Kurchavinskaya formations. Short descriptions of the main lithological and faunal features of each formation are given. Based on new palaeontological data, the age of the Kurchavinskaya Formation is clarified. Successions straddling the Cambrian/Ordovician boundary show a break in the late Cambrian stratigraphy of Severnaya Zemlya, which was caused by the (?) early Ordovician unconformity. Based on faunal evidences, the best palaeolatitudional position of the Kara microplate is estimated between 30°–40° of the southern latitudes and in the vicinity of Baltica and Siberia.

Zusammenfassung. Unterpaläozoische Schichten, die zum Kara-Becken gehören, sind weit verbreitet auf dem Severnaya Zemlya-Archipel aufgeschlossen. Während des Kambrium sind mächtige klastische Serien die dominierenden Sedimente. Die kambrischen Gesteine erscheinen in der Nekrasovskaya-, Maratovskaya-, Universitetskaya- and Kurchavinskaya-Formation. Es werden die wichtigsten lithologischen und faunistischen Charakteristika einer jeden Formation dargestellt. Aufgrund neuer paläontologischer Daten ist das Alter der Kurchavinskaya-Formation präzisiert. Die Abfolgen an der Kambrium/Ordovizium-Grenze zeigen eine Unterbrechung in der oberkambrischen Stratigraphie von Severnaya Zemlya, die durch eine vermutlich frühordovizische Diskordanz bedingt ist. Aufgrund der faunistischen Gegebenheiten wird eine paläogeographische Position der Kara-Mikroplatte zwischen 30°–40° südlicher Breite, in der Nachbarschaft von Baltica und Siberia, als sehr wahrscheinlich vermutet.

1 Introduction

During the summer 1999, an expedition sponsored by the Swedish Polar Research Secretariat, examined the Palaeozoic sections of the Severnaya Zemlya Archipelago of Russia. This expedition was part of the Europrobe's Timpebar project, seeking a new understanding of the geodynamic evolution of the Eurasian high Arctic (Gee et al. 1999). On October Revolution Island of the Severnaya Zemlya Archipelago, fieldwork has been

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concentrated on structural geology, stratigraphy and palaeontology (particularly of the Cambrian, Ordovician and Silurian), magmatism and palaeomagnetism.

The Cambrian of the Severnaya Zemlya islands is characterized by thick terrigenous sequences and rich skeletal fauna.

The aim of this paper is 1) to review briefly the biostratigraphy of the Cambrian strata of Severnaya Zemlya; 2) to give new and additional biostratigraphical data for these units; and 3) to determine the geographical distributions and faunal links of the enclosed fauna.

2 Geological framework

The Severnaya Zemlya islands, formerly known as Nicholas II Land, have a surface area of 360.000 km^2. They lie north of the Taimyr Peninsula, central Siberia (Fig. 1), and glaciers cover about 50 per cent of the territory.

Although consisting of a large territory which is close to the mainland, Severnaya Zemlya's geology is poorly known. One reason for this may be that Nicholas II Land was firstly discovered in 1913, and the inner territory of the archipelago was not studied until 1930, when the first expeditions by the Research Institute of Arctic Geology in Leningrad were organised to carry out topographical and glaciological work (Urvantsev 1933). Most of the information about the geological structure of the Severnaya Zemlya Archipelago was obtained during the geological mapping in 1950–70s and is summarised by Egiazarov (1957; 1959; 1970).

With respect to tectonics, Severnaya Zemlya, together with North Taimyr, belongs to the Kara plate (Bogdanov et al. 1998), the palaeogeographical position of which is controversial: it may have been thought to be a part of the separate microcontinent Arctida (Zonenshain et al. 1991) or contiguous with Siberia, Laurentia or Baltica (Ziegler 1990; Pickering & Smith 1995; Gee 1996; Nikishin et al. 1996). Bogdanov et al. (1998) recognised two structural zones within the Kara plate: 1) a deformed passive margin, which is exposed in the northern part of the Taimyr Peninsula, in the Bol'shevik Island, and in the eastern areas of the October Revolution and Komsomolets islands. All these areas are composed of the Upper Riphean – Cambrian turbidite complex; and 2) the central part of the plate, i.e. the central part of the Severnaya Zemlya Archipelago (the October Revolution, the Pioner and Komsomolets islands) and the Sedov Archipelago that are composed of Palaeozoic strata. The boundary between these zones can be traced in the eastern part of the October Revolution Island and is developed as a belt of dislocations sutured with magmatic bodies of variable lithology and age. In the eastern areas of the October Revolution and Komsomolets islands, this belt is characterised by a submeridional strike which changes from westerly directions towards the south.

3 Stratigraphy

Cambrian rocks of the Severnaya Zemlya Archipelago are widely exposed in the central and eastern areas of the October Revolution Island and in the south-eastern part of the Komsomolets Island (Fig. 2). More recent progress in their knowledge has been made during the years of geological mapping, when the data obtained were published in a series

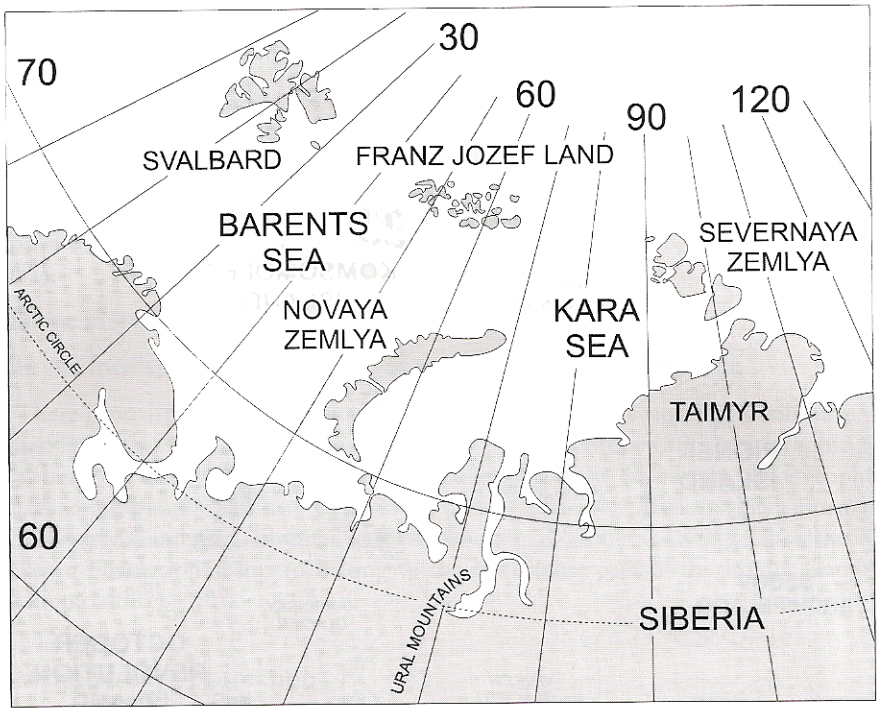


Fig. 1. Geographic location of the studied area.

of articles by LAZARENKO, MAKAR'EVA, MAKAR'EV & ROGOZOV (1981–1982). The Cambrian deposits are up to 2.700 m thick and are composed mostly by turbidites. Sandstone, shale and limestone interbeds are also present. Carbonate concretions and lenses contain trilobites of almost all the Cambrian stages.

The Lower Cambrian is represented by a turbidite alternation of light grey sandstones and dark siltstones. Higher in the succession, polymictic sandstone beds with lenses and interbeds (up to 1.5 m thick) of gritstone and small-pebble conglomerate become more abundant. The upper part of the Lower Cambrian sequence is composed of foliated dark grey to black claystones with siltstone interbeds. Limestone concretions (up to 0.5 m across) with trilobites are present in the upper part.

The Middle Cambrian is represented by a rhythmical alternation of light siltstone and sandstone beds. The lower part of the sequence includes rare limestone lenses with trilobites. Sometimes, there are sandstones with numerous ripple-marks, cross bedding, algae, and ichnofauna.

The Upper Cambrian is composed of alternating grey siltstones and black claystones containing concretions with rich faunal remains. The upper horizons include limestone interbeds and concretions. Trace fossils are numerous and diverse.

The Cambrian of Severnaya Zemlya is subdivided into four formations (Fig. 3): the Nekrasovskaya and Maratovskaya formations of the Lower Cambrian, the Universitets-

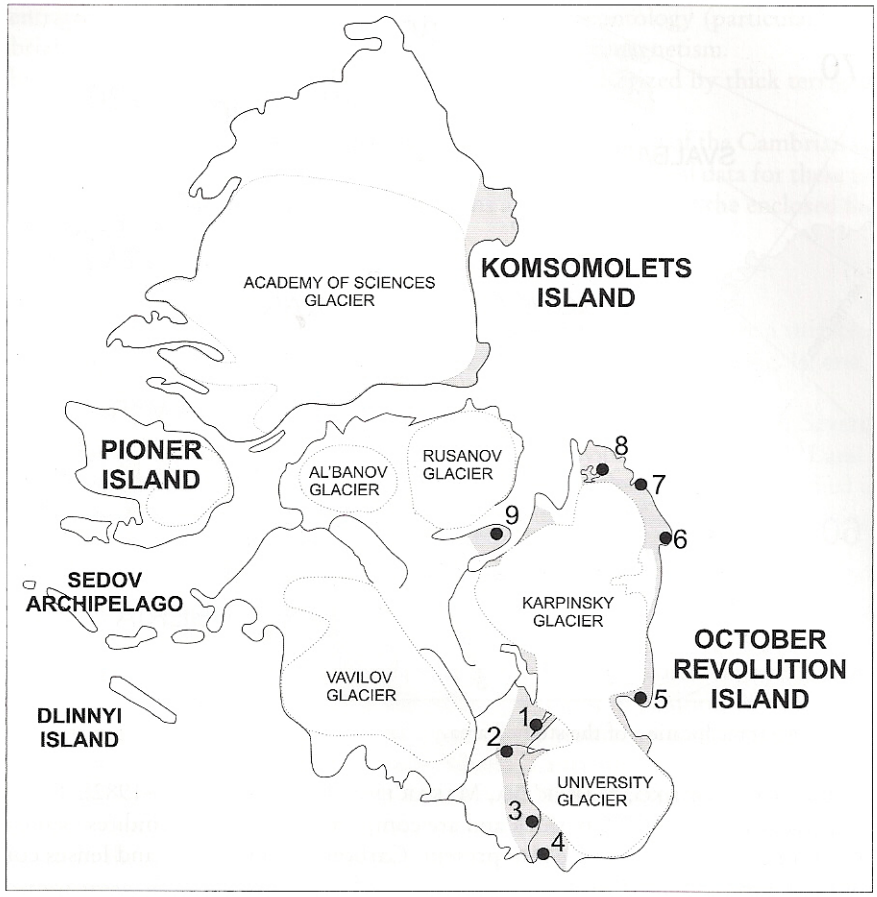


Fig. 2. A map of Severnaya Zemlya (Nicholas II Land) showing areas with Cambrian outcrops. 1 – Kruzhilikha River; 2 – Ostroe Lake; 3 – Kurchavaya River; 4 – Snezhnaya Bay; 5 – Marat Bay; 6 – Kamen' Point; 7 – Lagernyi Point; 8 – Spokojnoe Lake; 9 – Bazarnaya Mountain.

kaya Formation of the Middle Cambrian, and the Kurchavinskaya Formation of the Upper Cambrian (Makar'ev et al. 1981; Krasnov et al. 1983).

The Nekrasovskaya Formation

The name is derived from the Nekrasov Bay, where these strata are widely exposed.

Distribution: The Nekrasovskaya strata are exposed along the eastern coast of the October Revolution Island (Fig. 2).

Type section: At the Otdykha Bay, on the north-eastern coast of the October Revolution Island (MAKAR'EV et al. 1981).

Boundaries: A lower boundary of the Nekrasovskaya Formation is not exposed. It is supposed to have a conformable contact to the underlying Vendian strata (KABAN'KOV et al. 1982).

Lithology: The Nekrasovskaya Formation is composed of coarse-grained sandstones and siltstones with many interlayers and lenses of gritstones and conglomerates (MAKAR'EV et al. 1981).

Thickness: at least 870 m in its type area.

Fossils: No fossils have been yet found in the Nekrasovskaya Formation.

Age: There is no direct evidence for the age of the formation, because no fossils have been obtained from this unit. An early Cambrian age is assumed due to its stratigraphic position above the Upper Proterozoic Kasatkinskaya Formation which yields Riphean-Vendian acritarchs (KABAN'KOV et al. 1982) and beneath the Maratovskaya Formation with mid-early Cambrian trilobites in its lower part (LAZARENKO 1982). Thus, the Nekrasovskaya Formation seems to belong to the lowermost part of the Lower Cambrian (LAZARENKO 1982).

The Maratovskaya Formation

The name is derived from the Marat Bay, where sections of the Maratovskaya Formation were first described by MAKAR'EV et al. (1981).

Distribution: The Maratovskaya Formation crops out from the Marat Bay to the Lagernyi Point (Fig. 2).

Type section: At the Marat Bay (Fig. 2), on the eastern part of the October Revolution Island.

Boundaries: The lower boundary is drawn with the appearance of dark-grey and dark to black, thin-laminated claystones (MAKAR'EV et al. 1981).

Lithology: The Maratovskaya Formation is a succession of predominantly foliated shales, dark-grey to dark, with interlayers of siltstones and numerous nodules of limestone with trilobites (MAKAR'EV et al. 1981).

Thickness: 440 m in the type section (MAKAR'EV et al. 1981).

Fossils: Trilobites were obtained from several horizons of the section, which allow a dating of the sediments and a tentative correlation to the North European and North American zonations (LAZARENKO 1982). These are Ellipsocephalidae, *Fallotaspis* (*?*) sp., *Galahetes* sp., *Hebediscus* (*?*) sp., *Nevadella* sp., *Pagetiellus* cf. *lenaicus* and *Palaeolenus* sp.

Age: Early Cambrian (LAZARENKO 1982), probably Atdabanian – Toyonian (ROZANOV & ZHURALEV 1992).

The Universitetskaya Formation

The name is after the University Glacier, southwestwards from which the type section is situated.

Distribution: On the south-eastern part of the Komsomolets Island and on the October Revolution Island: 1) along the eastern edge of the Karpinsky Glacier from the Marat Bay to the Lednikovaya Bay; 2) within the Sobachii Bay and the Bazarnaya Mountain on the north-eastern part of the island; and 3) within the Snezhnaya Bay on the south-eastern part of the island (Fig. 2).

Type section: At the Lagernaya-Bezymyannaya Rivers, within the basin of the Kurchavaya River (Fig. 2), on the southern part of the October Revolution Island (Makar'ev et al. 1981).

Boundaries: The lower boundary is placed at the level marked by a change from black to green-grey siltstone. In many sections the boundary is also marked by the change in trilobite associations. The topmost part of the formation contains a 10 m thick limestone bed (Makar'ev et al. 1981).

Lithology: The Universitetskaya Formation is characterized by fine-grained green-grey sandstones, claystones and siltstones with limestone nodules. As a whole, the formation is characterized by the green-grey colour and the fine-grained composition of the sediments (Makar'ev et al. 1981).

Thickness: The thickness of the formation varies between 240 m and 560 m (Makar'ev et al. 1981).

Fossils: Trilobites and numerous brachiopods (*?Nisusia* sp.) were found in the type section and in the sections along the Kurchavaya River (Makar'ev et al. 1981). The follow-

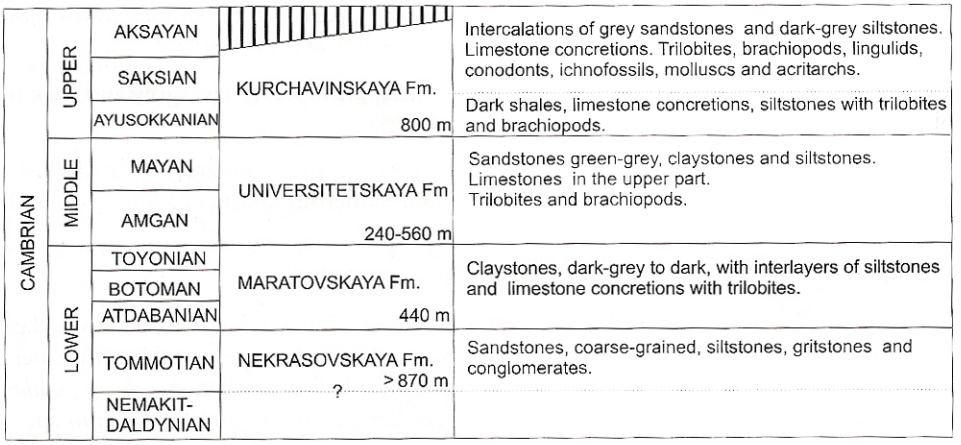


Fig. 3. Nomenclature and proposed ages of the Cambrian units in Severnaya Zemlya (after Makar'ev et al. 1981).

ing trilobites were identified by LAZARENKO (1982): *Anomocarina* (?) sp., *Chondragraulos* (*Ant.*) sp., *Chondranomocare* sp., *Diplagnostus* (?) sp., *Ellipsocephalus* sp., *Oidalagnostus* cf. *trispinifer*, *Paradoxides* (cf. *P.* (*Acadoparadoxides*) sp., *Peronopsis* (?) sp., *Phalagnostus* ex gr. *glandiformis*, *Proceratopyge* sp., *Pseudanomocarina* sp., *Solenopleura* sp. and *Xystridura* sp.

Age: Middle Cambrian (LAZARENKO 1982), probably Amgan – Mayan (ROZANOV et al. 1992)

The Kurchavinskaya Formation

The name is derived from the Kurchavaya River, where the type section has been described by MAKAR'EV et al. (1981)

Distribution: The Kurchavinskaya strata are developed on the south-eastern part of the October Revolution Island between the Vavilov and University Glaciers, from the mouth of the Kurchavaya River in the south to the Ostroe Lake in the north, on the north-eastern part of the island, where these rocks were exposed in a narrow belt between the Krutaya River, the Lednikovaya Bay and the Kamen' Point (Fig. 2), and also in a small tectonic block within the Ordovician rocks southwards from the Razdol'e Bay.

Type section: At the Kurchavaya River, 6 km up from its mouth (MAKAR'EV et al. 1981).

Boundaries: The lower boundary is defined by the transition from grey limestone of the topmost part of the Universitetskaya Formation to black claystones and grey siltstones of the Kurchavinskaya Formation. The upper contact of the formation is exposed heterogeneously, and this has resulted in conflicting opinions (EGIAZAROV 1957; AGEEV 1979; MARKOVSKY & MAKAR'EV 1982; PROSKURNIN 1999). Our field observations in the middle reaches of the Kruzhilikha River (Section BG99–37) (Fig. 4) have shown that the overlying strata of the ?Lower Ordovician Kruzhilikhinskaya Formation lie on the Upper Cambrian Kurchavinskaya rocks with an angular unconformity (Fig. 5). With the new findings of fossils (e.g. acritarchs, trilobites, helcionelloid molluscs and brachiopods), a discussion on the magnitude of the unconformity will be possible.

Lithology: The lower part of the formation consists of dark foliated shales, rhythmically interbedded by thin interbeds of dark-grey siltstones. Numerous brown to dark-grey nodules of limestones with a "mosaic" texture and carbonaceous fossiliferous siltstones are very typical for this part of the formation. The upper part of the formation is characterised by intercalations of grey, graded sandstones with cross lamination and trace fossils, dark-grey siltstones and dark claystones. Limestone concretions are also present, their abundance is increasing up-section.

Thickness: 800 m in the type section (MAKAR'EV et al. 1981).

Fossils: As the Kurchavinskaya Formation is divided into two parts, the list of fossils is given according to this subdivision. The lower part of the formation yields the trilobites *Agnostus* sp., *Aspidagnostus* sp., *Cedarellus felix*, *Glyptagnostus* sp., *Irvingella* sp., *Oida-*

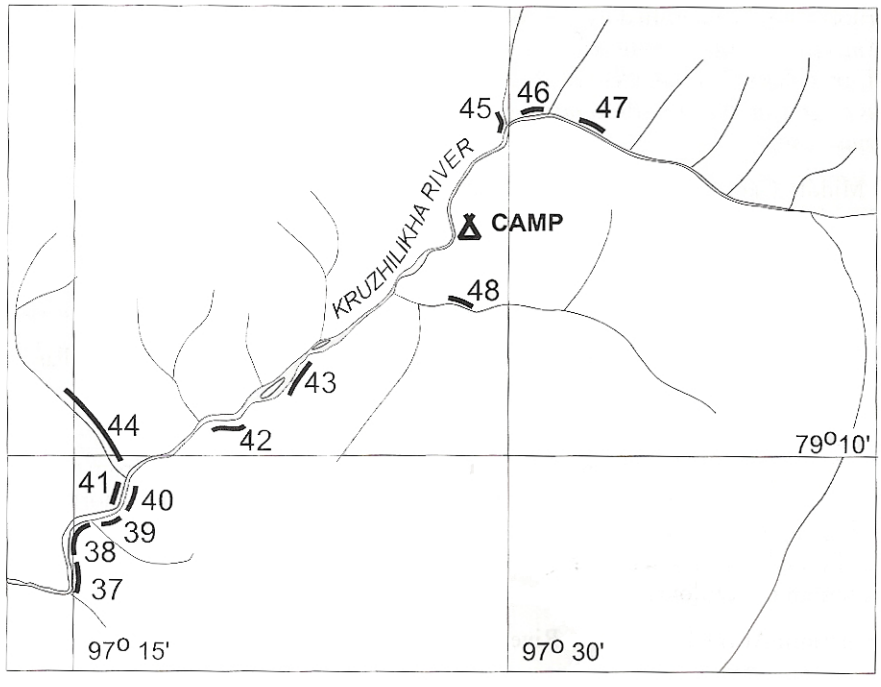


Fig. 4. The basin of the Kruzhilikha River with the location of sections (BG99– 37 – BG99–48).

lagnostus sp., *Olenaspella* sp., *Palaeodotes florenz*, *Proagnostus* (?) sp., *Proceratopyge* sp., *Pseudagnostus* (?) sp., *Protopeltura* sp., and the brachiopods *Apheorthis* aff. *khantaiskiensis* and *Eoorthis* (?) *wichitaensis*. The upper part of the formation yields the trilobites *Agnostotes* sp., *Agnostus* sp., *Cedarellus felix*, *Geragnostus* sp., *Irvingella* sp., *Kujandaspis* (?) sp, *Parabolina* sp., *Parabolinites* sp., *Protopeltura* sp., *Pseudagnostus* sp., the articulate brachiopods *Apheorthis* aff. *khantaiskiensis*, *Billingsella* sp., *Eoorthis* (?) *wichitaensis*, the inarticulate brachiopods *Ectenoglossa* sp., *Leptembolon* sp., *Lingulella* sp., *Obolus* sp., the conodonts *Proconodontus* cf. *savitzkey*, the problematic fossil *Torellella* sp., crinoid debris and gastropods (MAKAR'EV et al. 1981).

New fossil data: The new fossil material originates from sections exposed in the middle reaches of the Kruzhilikha River in the southern part of the October Revolution Island (Fig. 4). Here a sequence of grey siltstones and dark claystones with limestone concretions, intercalated with grey sandstones, has been studied by two of the authors (OKB and APG). Collected fossils include trilobites (*Kujandaspis ketiensis*, *Maladiodella* aff. *abdita*, *Protopeltura holdtedahli*, olenid sp. indet.; A.W.A. RUSHTON & R.A. FORTEY, pers. comm., June 2000), abundant articulate brachiopods (*Billingsella* sp., huenellid gen. indet, eoorthids (Fig. 6D), *Finkelnburgia* (?) sp.; L.R.M. COCKS, pers. comm., June 2000),

lingulids, helcionelloid molluscs, "eocrinoid columnals", and trace fossils. Organic-walled microfossils have been recorded in these strata for the first time.

Our material contains trilobites, which appear to originate from a limited stratigraphical interval. The genus *Kujandaspis* has been described for the first time from the Upper Cambrian Kujandinskaya Formation of Central Kazakhstan (IVSHIN 1956) and below the level with *Irvingella*-bearing strata. The Kujandinskaya Formation was correlated with the lower part of the Franconian of the North American succession (IVSHIN 1956; 1962) and is equivalent to the *reticulatus-evansi* Zone (lower Saksian) in Siberia (ROZANOV et al. 1992). However, the recorded stratigraphic range of *Kujandaspis kujandensis* IVSHIN and *K. ketiensis* LAZARENKO in Siberia appears to embrace the upper part of the middle Upper Cambrian Saksian Horizon and the uppermost Upper Cambrian Aksayan Horizon (ROZANOV et al. 1992). *Protopeltura holtedahli* HENNINGSMOEN has been recorded in the *Protopeltura praecursor* Zone of Norway (HENNINGSMOEN 1957), which may correspond to the middle part of the Franconian of North America and to the Saksian Horizon of Siberia. *Cedarellus felix* LAZARENKO (= *Maladiodella abdita* (SALTER) according to RUSHTON & HUGHES 1996) has previously been recorded from the *Irvingella* and *Cedarellus felix* zones, the two upper zones of the middle Upper Cambrian Saksian Horizon of Siberia (ROZANOV et al. 1992). Occurrences of *Cedarellus felix* (Fig. 6A) in the Severnaya Zemlya sections have been assigned to the middle part of the Upper Cambrian (MAKAR'EV et al. 1981). Its occurrence with *Irvingella* is also noteworthy. On the base of trilobites, the age of this part of the sequence (Sections BG99–43, BG99–44/5–10 and BG99–45) can thus be defined to between the *Agnostus pisiformis* - *Acerocare* zones of the late

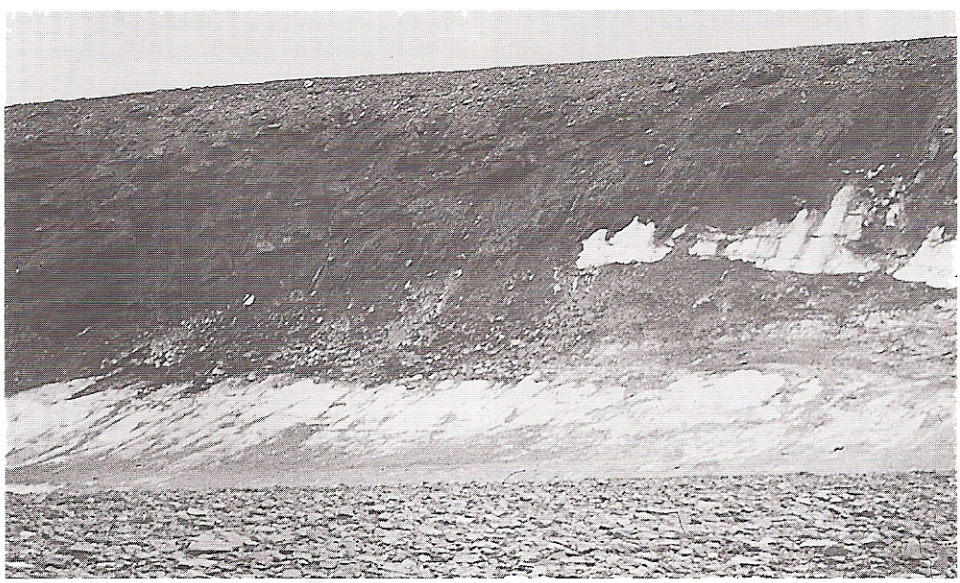
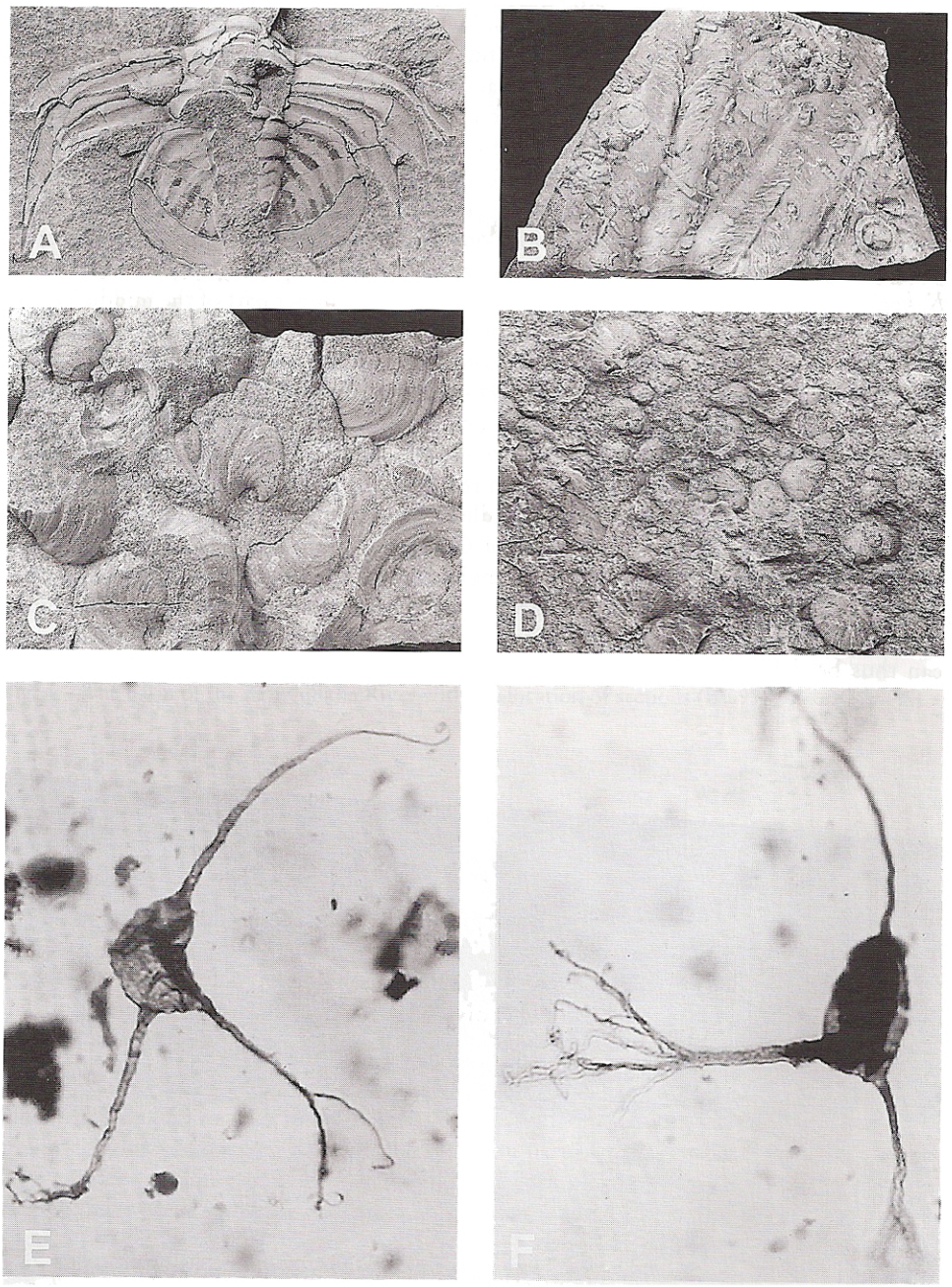


Fig. 5. The ?early Ordovician unconformity, Kruzhilikha River (BG99–37), general view.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Cambrian in Scandinavia (SHERGOLD 1997) and to the interval attributed to the Saksian and Aksayan Horizons in Siberia (ROZANOV et al. 1992).

Cambrian "small shelly fossils" have been recorded for the first time in the Severnaya Zemlya sequences. Abundant well preserved helcionelloid molluscs, tentatively identified by one of the authors (APG) as *Helcionella ?* sp. (Fig. 6C), were found at the Sections BG99–37, 38, 45, 46 and 48 (Fig. 4) at the same stratigraphic level with trilobites mentioned above.

Trace fossils dealt with and illustrated partly in this paper were recovered from rocks mapped as part of the Upper Cambrian Kurchavinskaya Formation at the Sections BG99–37, 38, 42, 46 and 47 (Fig. 4). At certain clastic horizons there are surfaces and beds abundant of straight, meandering, cylindrical, non branching and branching burrows and of the trilobite-type trace fossil *Cruziana semiplicata* (Fig. 6B). An association between the trilobite *Maladiodella* cf. *colcheni* SHERGOLD and the trace fossil *Cruziana semiplicata* SALTER, recorded in the Upper Cambrian Andam Formation of Oman, has been suggested recently by FORTEY & SEILACHER (1997). However, the referred part of the Kurchavinskaya Formation we have studied in the basin of the Kruzhilikha River does not have trace and body fossils in close association. There is one locality, where the *Maladiodella* type trilobites occur, but *Cruziana semiplicata* has not been found. No study has yet been undertaken of the trace fossils from Severnaya Zemlya; this work is in preparation now by JENSEN et al.

Hitherto, Cambrian acritarchs were unknown from Severnaya Zemlya. Four samples derived from the upper part of the Kurchavinskaya Formation, just below the unconformity (Fig. 5), were studied by one of the authors (EGR). One sample (BG99–37/5) yielded poorly preserved acritarchs. In all, the assemblage comprises 21 taxa: *Acanthodiacrodium commune* TIMOFEEV, *A. partiale* TIMOFEEV, *A. perspicuum* TIMOFEEV, *A. spinutisum* TIMOFEEV, *A. unigerminum* DOWNIE et SERJEANT, *Baltisphaeridium* sp., *Cymatiogalea* sp., *Cristallinium* sp., *Goniosphaeridium* sp., *Impluviculus multiangularis* VOLKOVA, *I.* aff. *I. villosiusculus* VOLKOVA, *Leiofusa stoumoensis* VANGUESTAINE, *Leiosphaeridia* sp., *Lusatia* aff. *L. dendroidea* BURMANN, *L. dramatica* RIBECAI & TONGIORGI (Fig. 6E, F), *Lusatia* sp. *1*, *Micrhystridium shinetonense* DOWNIE, *Micrhystridium* sp. *1*, *Pirea* sp., *?Timofeevia* sp. and *Veryhachium dumontii* VANGUESTAINE. This assemblage includes numerous age-diagnostic taxa. The acritarchs *Acanthodiacrodium commune*, *A. partiale*, *A. perspicuum* and *A. unigerminum* have been recorded from the Upper Cambrian of north-western Russia (TIMOFEEV 1959). The species *Impluviculus muntiangularis* and *I.* aff. *vellosiusculus* have been described by VOLKOVA (1990) from the uppermost Cambrian deposits of the Leningrad region and Estonia. *Leiofusa stoumonensis* is known from the Upper Cambrian of north-western Russia (VOLKOVA 1990), Estonia (PAALITS 1992), eastern Newfoundland (MARTIN 1982), and central Sardinia (DI MILIA 1991). The

Fig. 6. Fossils from the Kurchavinskaya Formation, Upper Cambrian, Severnaya Zemlya. A. Trilobites, *Maladiodella* cf. *abdita* (SALTER), × 1.2; B. Trace fossils *Cruziana ? semiplicata* SALTER, × 0.3; C. Helcionelloid molluscs *Helcionella ?*sp., × 0.75; D. Eoorthid brachiopods, × 0.2; E-F. Acritarchs, *Lusatia dramatica* RIBECAI et TONGIOTGI, E – slide D/3, England Finder coordinates: M33/4, × 600; F – slide D/2, EFc: K29/4, × 500.

species *Veryhachium dumontii* has been reported from the uppermost Cambrian (*Peltura* Zone) of north-western Russia (Volkova 1990), Estonia (Paalits 1992; 1995), eastern Newfoundland (Martin & Dean 1981; Martin 1982), Belgium and northern France (Vanguestaine 1973; Ribecai & Vanguestaine 1993), and Algerian Sahara (Vecoli 1996). *Lusatia dramatica* is a good stratigraphic marker for the Upper Cambrian. This species was originally described from the upper Cambrian beds (*Peltura scarabaeoides* Zone) of the Degerhamn Quarry Road section in southern Öland of Sweden (Ribecai & Tongiorgi 1997). These data narrow the age for the studied strata interval indicating a level between the *Olenus – Agnostus besus* to the *Peltura scarabaeoides* zones in Baltica (Shergold 1997).

Age: Late Cambrian (*Agnostus – Peltura* zones).

4 Palaeogeographic implications

Geological, geophysical and geochemical data presented in various publications during the last decades (Pogrebitsky 1971; Zonenshain & Natapov 1987; Bogolepov et al. 1991; Zonenshain et al. 1991; Vernikovsky 1992; Bogdanov et al. 1998) gave evidence of an independent history of the Kara plate prior to a collision with Siberia in the Late Carboniferous - Permian. As far as the earliest history is concerned, the presence of Neoproterozoic ophiolites within the Central Taimyr accretionary belt suggests that the Siberian and Kara palaeocontinents were separated by an oceanic-type crust in the late Precambrian time (Verniskovsky 1997). Due to the absence of palaeomagnetic data for Severnaya Zemlya and North Taimyr, it is difficult to determine accurately a palaeogeographic position of the Kara block during the Palaeozoic. However, an attempt is made to use the biogeographically relevant lithic and fossil data in providing a clue to palaeogeography.

During the Cambrian, terrigenous sediments were deposited in Severnaya Zemlya, such as conglomerates, sandstones, siltstones with limestone lenses, and interbeds. The composition of the heavy grain size fraction (zircons, tourmaline, garnet) from the Cambrian terrigenous rocks has been analysed by Makar'eva (1982). She noticed that in the middle Cambrian (in the central and in the eastern part of October Revolution Island) and in the late Cambrian the detrital sediments were supplied from one source area, which consisted of basic igneous rocks. Further investigations on inherited zircons from the clastic sequences of Severnaya Zemlya could define this source area in more detail.

The Cambrian fossil assemblage consists of trilobites, inarticulate and articulate brachiopods, helcionelloid molluscs, conodonts, problematics and acritarchs; only a small part has been studied yet.

According to Lazarenko (1982), who did a detailed study on the Cambrian trilobites from Severnaya Zemlya, there is a significant similarity between the trilobite faunas from the October Revolution Island and those faunas in Novaya Zemlya (i. e. the northeastern margin of Baltica). She concluded that since the end of the early Cambrian to the middle late Cambrian these areas were parts of a single basin.

Palaeogeographical distributions of trilobites from Severnaya Zemlya are summarised in Table 1. Data for the Lower Cambrian trilobites from Severnaya Zemlya are sparse and

Table 1 Biogeographical distribution of trilobite genera (G) and species (S) reported from the Cambrian of Severnaya Zemlya (based on data of LAZARENKO 1966; BEZZUBTSEV et al. 1979; MAKAR'EV et al. 1981; LAZARENKO 1982; CAGE reports, and own data).

A. Lower Cambrian

Severnaya Zemlya	Siberia	China	Baltica	Peri Gondwana	N. America		
Ellipsocephalus sp.			G				
Fallotaspis (?) sp.				G			
Hebediscus (?) sp.	G	G	G	G	G		
Nevadella sp.					G		
Pagetiellus cf. *lenaicus*	S						
Palaeolenus sp.	G	G					

B. Middle Cambrian

Severnaya Zemlya	Siberia	China	Baltica	Peri-Gondwana	N. America	N. Greenland	Australia
Anomocarina sp.	G		G				
Chondragraulos sp.	G		G				
Diplagnostus (?) sp.	G		G	G	G		G
Ellipsocephalus sp.			G	G	G		G
Oidalagnostus cf. *trispinifer.*			S				
Paradoxides sp.	G		G	G	G		G
Peronopsis (?) sp.	G	G	G	G	G		G
Phalagnostus ex gr. *glandiformis*	S		S		G		G
Proceratopyge sp.	G	G	G	G			G
Solenopleura sp.	G	G	G	G	G	G	
Xystridura sp.			G				G

C. Upper Cambrian

Severnaya Zemlya	Siberia	China	Baltica	Peri-Gondwana	N. America	Kazakhstan	Australia
Agnostus sp.	G	G	G		G	G	
Aspidagnostus sp.							G
Geragnostus sp.		G	G	G	G	G	
Glyptagnostus sp.	G		G	G	G		G
Homagnostus sp.	G	G	G	G	G		G
Irvingella sp.	G	G	G	G	G	G	
Kujandaspis ketiensis	S					G	
Maladiodella aff. *abdita*	S	G		S			G
Parabolina sp.			G	G	G		
Parabolinites sp.				G	G		
Proceratopyge sp.		G	G				G
Protopeltura holtedahli	S		S				
Pseudagnostus (?) sp.	G	G	G	G	G	G	G

far from being sufficient (Tab. 1A). Trilobites, which have been identified only to a genus level, have a Siberian, China (*Palaeolenus*) or Baltica (*Ellipsocephalus*) biogeographic aspect and are known from the peri-Gondwana areas (*Fallotaspis*) and North America (*Nevadella*), or have widespread distributions (*Hebediscus*). Of the remaining trilobites, only one species, *Pagetiellus* cf. *lenaicus*, is known from central Taimyr (BEZZUBTSEV et al. 1979) and Siberia (REPINA et al. 1974).

Nearly all trilobite genera from the Middle Cambrian of Severnaya Zemlya (*Diplagnostus*, *Paradoxides*, *Peronopsis*, *Phalagnostus*, *Proceratopyge*, and *Solenopleura*) are wide-

spread (Tab. 1B). Others exhibit an affinity to Baltica and Siberia (*Anomocarina*, *Chondragraulos*) and to Baltica and Australia (*Xystridura*). At the species level, Baltica and Severnaya Zemlya have some elements in common, for example, the agnostid trilobites *Oidalagnostus* cf. *trispinifer* and *Phalagnostus* ex gr. *glandiformis*, which occur in central Taimyr (BEZZUBTSEV et al. 1979) and Siberia (ROZANOV et al. 1992) as well.

Fourteen trilobite taxa are identified from the Upper Cambrian strata of Severnaya Zemlya (Tab. 1C). Most of them show a broad geographic distribution (*Geragnostus*, *Glyptagnostus*, *Irvingella*, *Homagnostus*, *Maladiodella*, *Parabolina*, *Proceratopyge*, and *Pseudagnostus*). The olenid trilobites *Parabolina* and *Parabolinites* occur in Baltica, Kara and North America, *Protopeltura holtedahli* is common for Siberia, Baltica and Kara, while Siberia and Kara share the occurrence of *Kujandaspis ketiensis* and *Maladiodella* aff. *abdita*. The species *Maladiodella abdita* shows a widespread peri-Gondwanan distribution as well and occurs in a wide range of lithofacies (RUSHTON & HUGHES 1996). However, no Laurentian occurrences of *Maladiodella* are recorded. Species of the genus *Kujandaspis* occur in Kazakhstan (IVSHIN 1962).

As regards the brachiopods, little is presently known. All brachiopod genera identified in the Cambrian of Severnaya Zemlya (*Apheorthis*, *Billingsella*, *Eoorthis*, *Finkelnburgia*, *Ectenoglosa* and *Lingulella*) have a wide geographic distribution.

Abundant well-preserved helcionelloid molluscs have been recorded in the Upper Cambrian Kurchavinskaya Formation of Severnaya Zemlya. The available late Cambrian record of helcionelloids is very poor. Only two poorly preserved specimens defined as *Latouchella* ? sp. have been found in the Minaret Formation in West Antarctica (WEBERS et al. 1992).

The problematic fossil *Torellella*, known from the Upper Cambrian of Severnaya Zemlya (MAKAR'EV et al. 1982), has been described before from the Lower Cambrian of Sweden (HOLM 1893), France (COBBOLD 1935), Siberia (ROZANOV & MISSARZHEVSKY 1966) as well as from the Lower Cambrian of Germany (ELICKI 1994), and it is also mentioned in the Upper Cambrian strata of Baltica (MENS et al. 1987).

So far, only a single occurrence of the conodont genus *Proconodontus* has been recorded in the Upper Cambrian strata of Severnaya Zemlya (MAKAR'EV et al. 1982). This genus has a widespread distribution throughout North America, Siberia and Australia.

The acritarch association from Severnaya Zemlya strongly resembles in taxonomic composition the assemblage previously reported from Baltica. Affinities to Siberia are not regarded, because no information is available on the late Cambrian acritarch distributions in Siberia.

In terms of biogeographic relationships, a comparison between these fossil groups is difficult to assess. The preliminary character of this estimation should be taken into consideration, as some of the listed taxa, especially from previous trilobite and brachiopod collections from Severnaya Zemlya, ought to be restudied in detail. However, we believe that the Cambrian faunas from the Kara basin, in particular the trilobites, show stronger affinities to both Baltica and Siberia than to the other areas, even though the faunas of the two regions are marked by their difference and endemism. These data support the geological evidence for the Kara microplate having an independent history during the Cambrian.

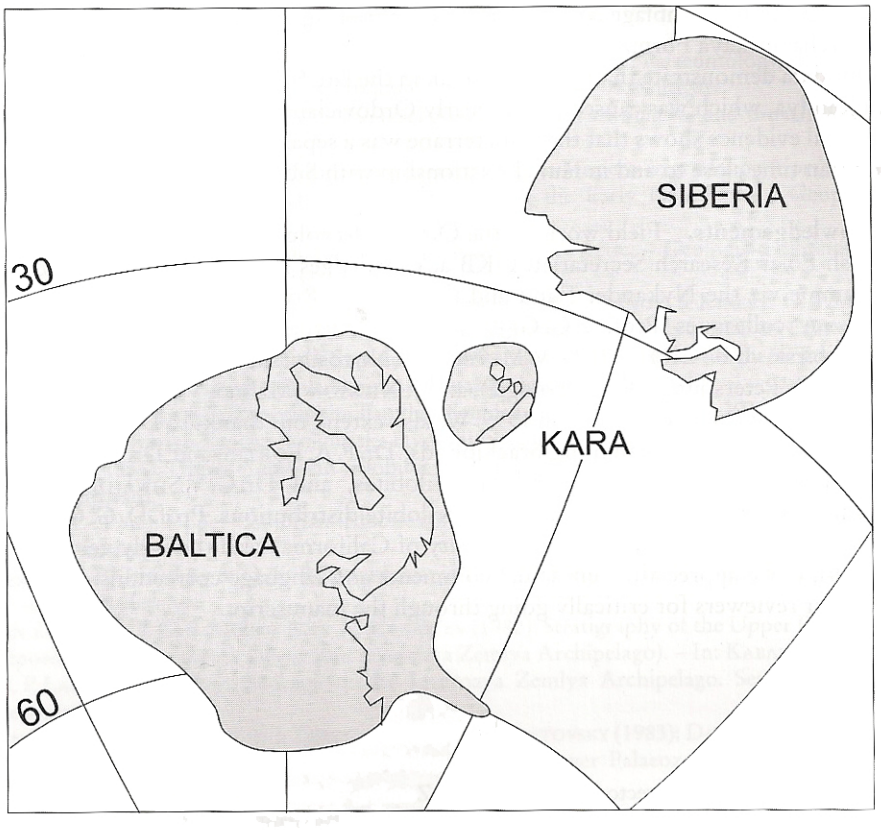

Fig. 7. Palaeogeographic reconstruction of the Kara terrane during Cambrian times. The position of Baltica is according to Torsvik & Rehnström (in press), that of Siberia according to Gallet & Pavlov (1996).

Our suggestion for the palaeolatitudional position of the Kara block during the Cambrian is illustrated on Figure 7. This plate configuration, based on the available faunal data from Severnaya Zemlya and supported by the palaeomagnetic data from Siberia (0–30°S, based on Gallet & Pavlov 1996; Pisarevsky et al. 1998) and from Baltica (30–60°S, according to Torsvik & Rehnström, in press), demonstrates that the Kara terrane was located in low southerly latitudes, probably between 30° and 40°S, and in the vicinity of Baltica and Siberia.

5 Conclusions

During the Cambrian, thick clastic sequences are the dominating sediments on Severnaya Zemlya. Fossils are rich and diverse, consisting of trilobites, inarticulate and articulate brachiopods, helcionelloid molluscs, conodonts, acritarchs, and problematica.

The acritarch assemblage confirms a late Cambrian age (*Agnostus – Peltura* zones) for the Kurchavinskaya Formation.

Our data demonstrate that there is a break in the late Cambrian stratigraphy of Severnaya Zemlya, which was caused by the ?early Ordovician unconformity.

Faunal evidence shows that the Kara terrane was a separate microcontinent during the Cambrian time close to and in faunal relationship with Siberia and Baltica.

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