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ON THE UPPER PROTEROZOIC GEOLOGY OF THE
VARANGER PENINSULA, RYBACHI AND SREDNI
PENINSULAS, KILDIN ISLAND, BOLSHOI AYN OV
AND MALYI AYN OV ISLANDS. REPORT FROM THE
JOINT FIELDWORK ON THE NORWEGIAN AND
RUSSIAN SIDES OF THE NATIONAL BORDER
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Sammendrag: <p>Stratigraphic sections and key localities were examined on both sides of the national border during this first season of the international collaboration. During fieldwork on Varanger Peninsula the Russian workers concentrated on conglomerates, diagenetic concretions and palaeoclimatic indicators as tools useful for correlation. The Norwegian participants examined sections mainly on Rybachi, Sredni and Kildin Island in terms of sedimentary facies interpretation and studied tectonic deformation and low-grade metamorphism. They concluded that there is a good evidence for an extension of the Trollfjorden — Komagelva Fault Zone from the Varanger Peninsula towards the isthmus between the Sredni and Rybachi Peninsulas.</p> <p>Alternative preliminary lithostratigraphic correlations were proposed by the Norwegian and the Russian authors.</p>				
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THE RUSSIAN-NORWEGIAN PROJECT 'NORTH REGION'

Scientific Research Exchange Programme on the Upper Proterozoic Geology of the Varanger Peninsula, Rybachi and Sredni Peninsulas, Kildin Island, Bolshoi Aynov and Malyi Aynov Islands

REPORT

FROM THE JOINT FIELDWORK ON THE NORWEGIAN AND RUSSIAN SIDES OF THE NATIONAL BORDER, AUGUST 1 - 17, 1990.

Murmansk

August 16-17, 1990

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RESULTS OF OBSERVATIONS, PRELIMINARY INTERPRETATIONS AND CONCLUSIONS

Introduction

The planned joint investigations of Upper Proterozoic sedimentary rocks on the Varanger Peninsula, Sredni and Rybachi Peninsulas, the Kildin Island and the Bolshøy Aynov and Malyi Aynov Islands are aimed at correlation of stratigraphic sections and interpretation of the sedimentary basin development in Late Proterozoic time, and subsequent deformation and metamorphism. This will help us to acquire a better understanding of the general stratigraphy of the Upper Proterozoic rocks along the northern limits of the East-European Platform, which is a basis for assessing the crucial problems of Riphean and Vendian evolution along the northern margin of the European continent, and for prospecting for potential mineral deposits.

The first stage of the planned investigation included joint fieldwork on the Norwegian and Russian sides of the national border. On August 1-8, V. Lyubtsov and V. Negrutsa, under the guidance of A. Siedlecka and D. Roberts, examined the rock types and prominent sedimentary and tectonic features of the main formations belonging to the Vadsø, Tanafjorden, Vestertana, Barents Sea and Løkvikfjellet Groups on Varanger Peninsula. On August 9-16, A. Siedlecka and D. Roberts together with V. Lyubtsov, V. Negrutsa and A. Predovsky examined formations of the Kildin Group in sections on Kildin Island and Sredni Peninsula, the lower contact of the Volokov Group and typical exposures and sections of the Motovsk, Lonsk, Perevalnaya, Maiskaya, Zubovskaya, Tsypnavolok and Skarbeyevskaya Formations of the Einov and Bargout Groups from the Rybachi Peninsula. Fieldwork was accompanied by discussions on interpretative models for the petrographic sedimentological and tectonic characteristics of the rocks. Similarities and differences between Riphean and Vendian deposits occurring in Norway and in the northwestern part of the Kola Peninsula were also discussed, as well as aspects of terminology and geological nomenclature. Detailed guidebooks prepared by both sides and an exchange of publications contributed considerably to a better understanding of the available information. Collections of samples were taken for further studies which will help in analysing the field observations and modifying the preliminary conclusions and interpretations presented below.

Upper Proterozoic sedimentary rocks on the Varanger Peninsula V. Lyubtsov & V. Negrutsa

Following the Excursion Guide written by A. Siedlecka with contributions by D. Roberts, we examined exposures of typical rocks and took samples in the following lithostratigraphic units.

1. **Tanafjorden - Varangerfjorden region.**
The Veinesbotn, Klubbnasen, Fugleberget, Golneselva and Ekkerøya Formations of the Vadsø Group; the Grønneset, Gamassfjellet, Vagge and Hanglecærro Formations of the Tanafjorden Group; and the Smalfjord, Nyborg, Mortensnes and Stappogiedde Formations of the Vestertana Group;
2. **Barents Sea Region.**
The Kongsfjord, Båsnæring and Båtsfjord Formations of the Barents Sea Group; the Sandfjord, Styret, Skjærgardneset and Stordalselva Formations of the Løkvikfjellet Group; and the Berlevåg Formation.

We believe that the following points should be mentioned in connection with the general correlation of the sections:

Upper Proterozoic sedimentary rocks of the Varanger Peninsula belong to two different tectonic-facies zones separated by a large tectonic suture, the Trollfjord-Komagelv Fault Zone. The fault was probably developed during sedimentation and repeatedly rejuvenated at post-sedimentary evolutionary stages of the observed tectonic structure. Tectonic features and some of the rock types of the southern Tanafjorden-Varangerfjorden Region are similar to those of the Terski and Kildin Regions of the Kola Peninsula. The degree of tectonic dislocation, metamorphism and sedimentary features of some formations composing the northern part of the Barents Sea Region (Kongsfjord and Sandfjord Formations, Berlevåg Formation) indicate that it is similar to the Rybachi Region of the Kola Peninsula. The degree of deformation, diagenesis and metamorphism of the sediments is evidently increasing from SSE to NNW on both the Varanger and the Kola Peninsulas. The minimum age of deformation has been determined by K-Ar dating of dolerite dykes (c. 350 Ma) which cut the lithified and folded sedimentary rocks on Varanger Peninsula. According to D. Roberts, the deformation is referred to Late Silurian time.

Although the history of the entire region from Vendian to Early Silurian is not known in detail, there are aspects of the geological development which can be traced from area to area:

- (1) Among the Upper Proterozoic sedimentary rocks of the Varanger Peninsula, the Rybachi and Sredni Peninsulas and Kildin Island there are lithological analogues accumulated in sedimentary environments of land, sea coast, continental shelf and submarine fans of turbiditic origin. Sediments of three climatic types can be distinguished: glacial (including typical tillites), arid (redstones and related meta-evaporites) and humid (monomict and oligomict quartz psammites and psephites). In conjunction with other evidence, they can serve as stratigraphic references for correlating the sections of the Varanger and Kola Peninsulas which differ considerably

from each other in facial composition of the rocks and in types of organic relics. The observed climatic succession and the three major stages of late Proterozoic evolution (Late Riphean, Early and Late Vendian) of the Varanger area reflected in the sequences of sediments of different ages can be fairly well correlated with the stratigraphic sequence of the combined section of the Sredni and Rybachi Peninsulas. The Vadsø Group, of Late Riphean age, may be correlated with the Kildin Group; the Vestertana Group and its age counterpart, the Løkvikfjellet Group, may in our view possibly be correlated with the Bargout Group of the Rybachi Peninsula. The Tanafjorden Group and the part of the Barents Sea Group of the same age, and the breaks separating them from underlying and overlying strata, may be correlated in terms of time of accumulation with the Volokov and Einov Groups of the Sredni and Rybachi Peninsulas. This correlation is not supported, however, by microphytolite studies. No Vendian forms are known in Sredni and Rybachi, whereas they are present in the sediments of the Tanafjorden, Vestertana and Løkvikfjellet Groups.

Late Proterozoic sedimentary rocks of the Varanger Peninsula point to conditions of sedimentation that are more closely related to a continental area than the supposedly contemporaneous sediments of Sredni and Rybachi. In contrast to the latter, they are almost completely lacking glauconite, have fewer varieties of stromatolites and oncolites, and contain no olistostromes such as those observed in the Volokov and Einov Groups. The sedimentation rate, in our view, seems to have been higher on the Varanger Peninsula than on the Kola coast of the Barents Sea.

Various conglomerates and diagenetic concretions are characteristic of Upper Proterozoic stratigraphic units from the Varanger Peninsula as well as of the corresponding rocks from the Kola Peninsula. We believe that conglomerates and concretions are very significant for stratigraphic correlations, although they have, so far, not been studied in detail.

With regard to the correlations and general stratigraphic scheme of the Upper Proterozoic sediments in the above territories, the stratigraphic significance of breaks within groups of sediments and contacts in separate formations, such as the Kongsfjord and Båsnæring, is not fully clear to us. The former is more similar to the sedimentary column of the Rybachi Peninsula, and the latter to the Kildin Series of Sredni. However, their stratigraphic relationship is opposite to that observed between the Kildin Series and the Rybachi sediments. The question arises as to why the erosion products of the Vadsø and Tanafjord Groups are comparatively uncommon in conglomerate pebbles and clastic grains of sandy rocks of the Vestertana Group? The same is also true for the contact between the Barents Sea Group and the Løkvikfjellet Group. The tectonic development of the region in the period between the Vendian and the Silurian is also unclear. What events have occurred in this region since the

Vendian and what happened to the Riphean-Vendian sediments in the interval between the Vendian and the Silurian?

**The Upper Proterozoic of Kildin Island,
Sredni and Rybachi Peninsula, and Malyi Ainov Island
A. Siedlecka & D. Roberts**

During the period of fieldwork we examined parts of formations of the Kildin Group, the contact between the Kildin Group and the Volokov Group, parts of the Einov and Bargout Groups and the Skarbeevskaya Formation.

Sredni Peninsula and Kildin Island

Kildin Group

Sections were examined in cliffs and in southern coastal exposures on Kildin Island, in Malaya Volokovaya Bay and Bolshaya Volokovaya Bay on the Sredni Peninsula, and on the Malyi Ainov Island. Together with our guides, Drs. Negrutsa, Lyubtsov and Predovsky, we focused our observations on the sedimentary facies development, mineralogy and tectonic deformation. This, we believe, can help us to understand the relationship between the sedimentary basin development and deformation in the Rybachi - Sredni - Kildin region and the Varanger Peninsula.

Only the lower part of the Kildin Group on Kildin Island was examined. This terrigenous-carbonate sequence has no facies equivalents on the Varanger Peninsula. The terrigenous sequence of the Kildin Group on the Sredni Peninsula may be interpreted on the whole as resulting from coastal, including deltaic, and shallow-marine sedimentation. In the examined parts of the sequence trends in facies change could be traced and a tentative interpretation of these changes is as follows:

- (1) The Middle Parajavri Formation — sandy, high-energy, wave and tide-influenced coast with an upwards increasing influx of immature fluvial material.
- (2) The Upper Parajavri Formation — prodelta and delta front progradation followed by coastal beach ridges (barrier islands?) in the Palvinskaya Formation.
- (3) The lower Parapelonskaya Formation — prodelta to delta-front prograding sequence.
- (4) Zemlepakhtinskaya Formation — tide-influenced sandy coastal and ? fluvial deposits.
- (5) Karhojarvi Formation — low-energy terrigenous carbonate sequence with (?) evaporitic nodules possibly representing a lagoonal and/or delta-plain environment.

The overall pattern of sedimentary facies development (with the exception of the Karhojarvi Formation) is reminiscent of that in the Vadsø Group, although the latter shows evidence of more fluvial sedimentation. Both groups are Late Riphean in age.

Volokov Group

We have seen only the lowermost part of the Volokov Group, developed as a phosphorite-bearing conglomerate. There is no similar rock-type on Varanger Peninsula. It is, however, possible that the break in deposition between the Volokov and Kildin Groups corresponds to that in the uppermost part of the Vadsø Group.

Rybachy Peninsula

Einov and Bargout Groups

The formations of both groups consist primarily of turbidites. Associated with the turbidites are debris flow and slump deposits, and channel-sandstone beds. The sequence starts with an olistostrome and seems to reflect a gradual transition from slope deposits through inner-fan and mid-fan to outer-fan accumulations and ?prodelta facies. In general, this development is reminiscent of that in the Kongsfjord Formation (the Kongsfjord Submarine Fan) and lowermost Båsnæringen Formation on the Varanger Peninsula. However, the most proximal facies types are unknown in the Kongsfjord Formation although they may be present in the subsurface. The Rybachy sequence seems to have accumulated at a continental margin which was much more tectonically active than that along which the lower Barents Sea Group sediments were deposited. The Kongsfjord Formation is of Late Riphean age. A Late Riphean - Vendian age has been suggested for the Einov and Bargout Groups.

Skarbeeviskaya Formation

The part of the formation which was briefly visited seems to be representative of deposition on a submarine fan, similar to the sequence of the Einov and Bargout Groups.

Tectonic deformation and metamorphism

Tectonic structures and associated metamorphic features observed in the rocks of the Rybachy-Sredni-Kildin region show clear differences between (1) the Kildin-Sredni zone and (2) the Rybachy zone. In the area of the Rybachy Peninsula, the prominent mesoscopic and larger fold structures show fairly consistent NW-SE trends and carry a penetrative axial plane cleavage which generally dips at moderate to high angles to the northeast. The regionally developed folds are thus overturned towards the southwest. The cleavage is of a slaty cleavage character and the metamorphic grade appears to have been in sub-greenschist facies, probably from mid to upper anchizone or possibly lowest epizone. Work on samples taken for illite crystallinity studies will hopefully reveal the precise grade of metamorphism.

On Kildin Island and Sredni, tectonic fold structures are virtually absent, except for large-scale very gentle folds on Sredni, and the pelitic rocks are devoid of penetrative cleavage. The metamorphic grade is probably that of diagenesis, at most in low anchizone on northern Sredni.

Comparing the structure of the Rybachi-Sredni-Kildin region with that of the Varanger Peninsula, it seems clear that the fold structure and cleavage development on Rybachi relates most readily to the eastern part of the Barents Sea Region. There, folds are also locally overturned towards the west or southwest. Further west the same folds steepen through the vertical and then show a consistent SE vergence in the central and western parts of the same region. The state of 'metamorphism', i.e. diagenesis grade, on Sredni and Kildin on the other hand is comparable to that in the Tanafjord-Varangerfjord Region of the southern part of the Varanger Peninsula.

Good direct field evidence for the southeastern continuation of the Trollfjord-Komagelv Fault Zone from Varanger on to Rybachi-Sredni is lacking, simply because we have not yet visited all the critical localities; but the clear differences in fold structure and metamorphism between Rybachi and Sredni do argue for the presence of some form of structural-metamorphic break. There is also a dramatic change in sedimentary facies development over a very short distance in the Bolshøy Ozierko area. Detailed mapping and structural work will be required to solve this problem.

The important question of the age of tectonic deformation and metamorphism in the Rybachi and Barents Sea Regions is not yet resolved. On Varanger, we consider the folding and metamorphic features to relate to the 'Scandian' orogenic event, of Late Silurian / Early Devonian age, although some traces of a 'Finnmarkian' (Early Ordovician) metamorphism cannot be entirely ruled out. Strongly cleaved metadolerite dykes occurring north of the Trollfjord-Komagelv Fault have yielded K-Ar whole-rock ages of around 640 Ma. On NW Rybachi, a dolerite dyke which, according to V. Negrutsa, cuts across the prominent cleavage and main fold structures at a high angle has been K-Ar-dated to 620 Ma, suggesting that the main folding and metamorphism there is pre-620. Quite clearly, more isotopic dating work is urgently needed to help resolve this important problem. An appropriate method in this case might be that of $^{40}\text{Ar} / ^{39}\text{Ar}$ to try to date the penetrative cleavages.

CONCLUSIONS AND PROPOSALS

The fieldwork carried out in 1990 enabled us to reach a better understanding of the stratigraphy, sedimentation and deformation of the Upper Proterozoic rocks of the Varanger Peninsula and the Rybachi - Sredni - Kildin region. However, the data obtained so far are insufficient for correlation and joint interpretation of the development of the sedimentary basins and their subsequent deformation and metamorphism. Obviously, more fieldwork is needed both on the Russian and the Norwegian side of the national border. We therefore propose the following specific work in 1991:

1. On the Norwegian side:

- 1.1. Examination of the contact zone between the Tanafjord-Varangerfjord Region and the Barents Sea Region.
 - 1.2. Examination of the contact between the Barents Sea Group and the Løkvikfjellet Group (in outer Båtsfjord).
 - 1.3. Study of the transition between the Kongsfjord Formation and the Båsnæringen Formation (Finnvik section).
 - 1.4. Closer examination of the Vadsø Group.
 - 1.5. Study and sampling of concretions in several formations in both regions of Varanger Peninsula.
2. On the Russian side:
- 2.2. Examination of the contact zone between the Kildin Group of the Sredni Peninsula and the lowermost Einov Group of the Rybachi Peninsula (mouth of the Eina river and Cape Motka).
 - 2.3. Examination of the Volokov Group.
 - 2.4. Sampling of dolerite dykes for age determination and geochemistry (Cape Kijski to Cape Kekurski) and work on the structural deformation of the Skarbeevskaaya Formation.
 - 2.5. Additional observations on the sequences of the Einov and the Bargout Groups (slopes of the Mountain Mai).

During fieldwork carried out in 1990 it emerged that there are some considerable differences in the nature of the research work and type of geological data existing on the Russian and the Norwegian side. Systematic mapping, map production, and sedimentological and structural studies have been carried out mainly on the Norwegian side. On the Russian side, on the other hand, work on the geochemistry and mineralogy of the sediments has resulted, in places, in the discovery of phosphorites, Ti-Zr paleoplacers and sulphide mineralisation, while on the Norwegian side very little work has been done on these topics. We feel that geochemical studies should be extended on to the Norwegian side and that a sedimentary geochemist should join the Russian team also on the Norwegian side. In 1990 Dr. Predovsky joined the group only on the Russian side.

A realisation of the above plan for 1991 would require participation of 3 Russian and 3 Norwegian geologists over a period of 24 days, 12 days on each side of the national border. The scope of the continuing joint studies of the Riphean and Vendian rocks in the adjacent territories of Norway and Russia is envisaged as follows: -

1. A refining and modification of the local stratigraphic schemes and establishing a unified lithostratigraphy for the northern East European Platform. In this connection, the area of investigations should be extended in 1992 to include the Upper Precambrian rocks of the Terski coast of the Kola Peninsula, the Zimni coast of the White Sea

and Kanin Peninsula in Russia, western Finnmark and the Sparagmite Region in southern Norway.


2. Modelling of the sedimentary basins in the northern coastal areas by (a) analysing changes of depositional environments and climatic conditions in time and space; (b) studying the contacts of the main lithostratigraphic units, and the extent of breaks in sedimentation and periods of erosion; (c) defining the provenance areas by studying conglomerates, their origin and pebble composition, as well as the mineralogy of sandstones; and (d) continuing the studies on stromatolites, microphytolites and trace fossils.
3. Investigating the typical parageneses of the Upper Proterozoic sedimentary rocks of East Finnmark using their geochemical characteristics.
4. Establishing the relative ages of the structural deformation episodes, associated metamorphic fabrics and dykes, and attempting to date both the metamorphism and the dolerite dykes by radiometric methods; also to carry out a more detailed study of the illite crystallinity of the pelitic rocks.

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