Structural and Compositional Characteristics of the Rocks of the Nyarovey Series (Polar Urals)

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Abstract. Nyarovey series is a poorly studied subject of the Central Ural region of Polar Urals. The aim of this work is to establish the structural changes, primary structure and geodynamic conditions of formation of protolith rocks of the Nyarovey series. As a result of petrographic and petrochemical study of rocks as part of the Nyarovey series highlighted several groups of metamorphic rocks, separated by primary and chemical composition. Among them are the ortho-rocks and para-rocks. Ortho-rocks present metabasalts and metatuffs. Para-rocks are metapealites, metagraywacke, arkose and quartz sandstones. It was found that the rocks have undergone three stages of deformation, the most typical folds associated with the formation of Uralides (Hercynian orogeny). Overall, it can be assumed the formation of volcanogenic-sedimentary material in Nyarovey time in oceanic-margin or margin-sea environment.

1. Introduction

Nyarovey series is represented by formations of Upper Precambrian of the Central Zone of the Polar Urals in the northern east part of Europe (Figure 1), metamorphosed in conditions of green-schist and epidote-amphibolite facies. It stretches in the form of bands of the northern and northern-east directions and frames of deeply Early Proterozoic complexes [1, 2]. In the Nyarovey series, it stands out from the bottom up Verhneharbey (quartzite’s, mica-albite-quartz, mica-quartz graphitiferous schist) (RF2 vh) and Miniseyshor (filitolivnye, epidote-chlorite-amphibole, albite-chlorite schists carbon) (RF2 mn) series. It contains of the precious metals and uranium mineralization, as well as manifestations of pyrite and pyrite-polymetallic type. Carbonaceous shales are characterized by elevated concentrations of silver, zinc, lead, vanadium, phosphorus, and other platinum group metals. Age series applied provisionally as the Middle Riphean [3].

Many questions of geology of Nyarovey series still remain unresolved: the establishment of features of structural and material transformations of rocks, their primary structure, geodynamic conditions of formation source rock and others. The aim of this work is to establish the structural changes, primary structure and geodynamic conditions of formation of protolith rocks of the Nyarovey series, which is very important for understanding the geological history of promising mineral formation Riphean age of the Polar Urals.
2. Methods
To establish the structural and material characteristics of the rocks of the Nyarovey series expeditions were conducted, measured dip and strike of rock and folds, retrieve sampled for the study of the mineral and chemical composition. Mineral composition and microstructural characteristics of rocks were determined using a polarized microscope. Due to the fact that the regional metamorphism almost completely erases primary lithological features, the main focus in the reconstruction of the primary composition of metamorphic rocks has been made to study their chemical composition using discriminant function of Velikoslavinsky et al. [4], various identity diagrams and geochemical modules of Yudovich and Ketris [5], as the chemical classification may partly or completely replace the lithological. At the same time, it was proceeded from the assumption that the regional metamorphism proceeded as isochemical.

The chemical compositions of the rocks were obtained by the method of wet lab, X-ray fluorescence and atomic-emission spectral analysis in CCU Geonauka IG Komi SCUB RAS (Syktyvkar, Russia).

3. Results and Discussions
3.1. Structural features of rocks of the Nyarovey series
It was found that for species of Nyarovey series is characterized by linear structures, which conformable to surround the Early Proterozoic complexes. At the same time, they are characterized by lateral changes in the meridional direction. Field studies showed that Riphean rocks have undergone structural and compositional transformations. These changes are associated with the occurrence of the
Urals (Hercynian folding) and thrust. The folds and planar structures associated with thrust formed in the third stage of deformation. Earlier structural elements in monotone section occur as relics. Sections are composed of different of rocks. In sections with veins and dykes of granites mapped asymmetric folds. They have a steep drop of the axial surfaces and steeply plunging apex. They precede the folds of moderate to severe degree of appressed with hollow plunging apexes. The predominant orientation of earlier structural elements has a north-west direction.

3.2. Petrographic and petrochemical characteristics of rocks of Nyarovey series
Petrographic studies have allowed to allocate mineral composition among breeds of Nyarovey series of two varieties: quartz-epidote-chlorite-actinolite rocks and mica-quartz schist.

The quartz-epidote-chlorite-actinolite rocks are schistose, sometimes slightly foliaceous and massive texture granoblastic rarely porphyry structure. They are characterized by calcite contents (0-10%), quartz (1-10%), muscovite (1-3%), albite (3-30%), chlorite (5-25%), epidote (5-40%) and amphibole (mainly actinolite) (15-35%). The depth thickness varies from 1 to 17 m. According to the content of alumina and according to the discriminant function by Velikoslavinsky et al. [4], they were divided into two groups. Middle aluminiferous (Al2O3 - 12.63-15.68%) slates have an affinity mainly orthorocks (I group), and high aluminiferous (Al2O3 - 16.06-17.66%) breeds fall into the area of uncertainty (II group). The first of group of rocks has a silica content of 39.06-51.67%. These rocks are basalts. Based on the chemical composition of tholeiitic meta-basalts are sodium and potassium-sodium low- and middle aluminiferous rocks. In the ternary diagram by Pearce and Cann [6], Zr-Ti-Y and Zr-Ti-Sr point metamorphosed ortho compounds are located in the low-K tholeiitic island arcs (Fig. 2). Content in metabasites is comprised by rare elements - Ba (14-472 ppm), Cr (54-285 ppm), Ni (42-134 ppm), Sr (121-210 ppm), La (0.8-7 ppm), Ce (8-25 ppm), Nd (10-19 ppm), Zr (24-64 ppm) and Nb (1.6-2 ppm), which indicate that they are similar both with oceanic basalts and low-K tholeiitic island formations arcs.

The content of silica in the second group of rocks ranges from 40.41 to 47.32%. These rocks compared with metabasalts have a higher content of alumina, titanium oxide, and in some cases potassium oxide. According to identification diagrams are defined as metatuff. The content of rare elements in them and metabasalts identical, indicating that they are close to the genesis.

Quartz mica schists may be divided by the number of dark-coloured minerals into melanocratic (50% or more), mesocratic (30-50%) and leucocratic (30%) species.
Melanocratic rocks are represented by epidote-muscovite-quartz, albite-muscovite-chlorite-quartz, quartz-muscovite, carboniferous muscovite-quartz, biotite-chlorite-muscovite-quartz schists with banded texture, porphyroblastic and lepidogranoblastic structure and the following variations in the rock-forming minerals: epidote (0-20%), albite (1-10%), muscovite (5-40%), chloride (0-30%), actinolite (0-20%), quartz (20-60%), and biotite (0-10%) and garnet (0-2%). The depth of these shales is from 0.5 m to 6 m. According to the formula of Velikoslavinsky et al. (2013) they have an affinity with the sedimentary formations of the points falls into the area of uncertainty.

Among the rocks were allocated Group III and Group IV with different content of silica and alumina. The third group includes species with silica content of 48.54 to 60.59% and alumina from 16.3 to 22.45%. According to the identification diagrams, shale is defined as pelites. According to the work of Yudovich [5] petile have chlorite-montmorillonite-hydromicaceous composition. Compared with metabasalts, metatuffs viewed formation and have somewhat elevated content of La, Ce, Zr and Cr and reduced Ni. This probably indicates that source rock could be the breed of both mafic and average compounds.

The fourth group species is characterized by silica content of 58.73-65.18%, and alumina content of 14.99-19.62%. According to the classification diagrams, these rocks also similar to clay formations. On the chemical composition the rocks are chloride-montmorillonite-hydromicaceous pelites. Content of light rare earth elements (La, Nd, Ce), and Zr markedly higher than metabasalts and the amount Cr and Ni – lower. These rocks differ only in the composition of the genesis rock.

For the mesocratic rocks include calcite, muscovite-garnet-epidote-chlorite-quartz and muscovite-albite-quartz schist. The depth layers of 1-9 m. The rock-forming minerals are calcite (0-3%), pomegranate (0-2%), epidote (0-20%), muscovite (10-30%), chloride (0-15%), albite (0-10%), silica (50-70%), and biotite (0-5%). By discriminant function Velikoslavinsky et al. [4] mesocratic formations are similar with both pararocks and fall within the orthorocks and uncertainties. Metasedimentary formation was classified as the V group and rocks similar to the igneous rocks with low contents of titanium oxide and high - alkali assigned to the VI group.

In the V group content of silica varies from species of 66.88 to 73.6 %, alumina - from 11.4 to 15.32%. According identification diagrams these rocks are similar to greywacke sandstones and siltstones.

Leucocratic formation presented muscovite quartzites, often carbon, muscovite-clinozoisite-chlorite-quartz, chloride-muscovite-quartzschists with quartz content (70% or more), muscovite (0-20%), chloride (0-15%), epidote (0-10%) with a capacity of 2-7. These rocks are dense shale with a lilaceous texture. For these breeds, silica content was divided into groups VI and VII.

The content of silica in the rocks of the sixth group ranges from 71.79 to 86.64%, from 4.46 to 7.98% of alumina. According identification diagrams these rocks are similar to quartz sandstones and arkose silicites. Carbonaceous shale species most likely formed by siliceous rocks, and the others for arkose sandstones. According to the content of trace elements, these rocks are close to metapelites.

Silica content of the seventh group of rocks was 93.78%. According identification diagrams these rocks are similar to quartz sandstones.

4. Conclusions

The study of the structural features and material composition of rocks of Nyarovey series revealed that the studied education has undergone three stages of deformation. For them, the most typical folds associated with the formation of Uralides (Hercynian orogeny), the earlier deformation occur as relics. They have a north-west (Timan) stretch, which is an additional sign of their belonging to douralid. In mineral composition schist are divided into aktinolitferous and mica-quartz varieties. The chemical composition of shale Nyaroveyserieswas divided into seven groups that differ in the primary structure. Among them are the ortho and para-rocks. Ortho represented metabasalts, metatuffes and metarioles. Para-rocks were metapelites and graywacke metamorphosed sandstones and siltstones, sandstones and quartz arkose. Overall, given the interbedding of metapsammites and metapelites, as well as the
presence of cross-sectional metabasalts with ocean and island-labels, the formation of volcanogenic-sedimentary material in Nyarovey time in oceanic-margin or margin-sea environment.

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