Structure and Metamorphism of Rocks as a Criterion of Dissection and Correlation of Polymetamorphic Complexes (On Example of the Subpolar Urals)

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Abstract. According to the officially accepted stratigraphic schemes, pre-Upper Riphean stratigraphic units of the Subpolar Urals are divided (bottom-up) into the Nyartin metamorphic complex (PR_1), Manhobeyu (RF_1), Schekurya (RF_1), and Puiva (RF_2) suites. Studying the structure and metamorphism of the above-mentioned structural-material units, it was found that intensively and repeatedly deformed and metamorphosed formations of the Nyartin complex, Manhobeyu and Schekurya suites can be assigned to the same structural stage. Considering the available isotopic data on the early stages of metamorphic manifestations in rocks of the Nyartin complex, it can be stated that all of these stratigraphic units are attributed to the Lower Proterozoic, with a high degree of probability. The Upper Proterozoic section in the Subpolar Urals begins with sediments of the Middle Riphean Puiva suite. In contrast to the southern regions of the Urals, there are no Lower Riphean formations there.

1. Introduction

In polymetamorphic complexes, organic residues are usually absent, primary stratigraphic sequences are transformed, the mineral composition and structural-textural peculiarities are changed due to the repeated metamorphic alterations and deformations of rocks, and making dissection and correlation of these formations is very difficult, or almost impossible by traditional paleontological and lithological methods. Isotopic-geochronological data are not universal, since the distortion of isotopic ages can be "rejuvenated" in polymetamorphism. In this case, the additional, and sometimes determinative, information on the sequence of stratigraphic units' occurrence and their correlation can be obtained by structural observations, as well as in the mineralogical and petrographic study of the metamorphic features of rocks, [1].

2. Results and Discussions

2.1. Substantiation of rock ages

The most complete section of Precambrian and Lower Paleozoic formations in the Timan–Northern Ural region is exhibited in the Subpolar Urals. Polymetamorphic formations make up the pre-Upper Riphean part of the section (Figure 1).

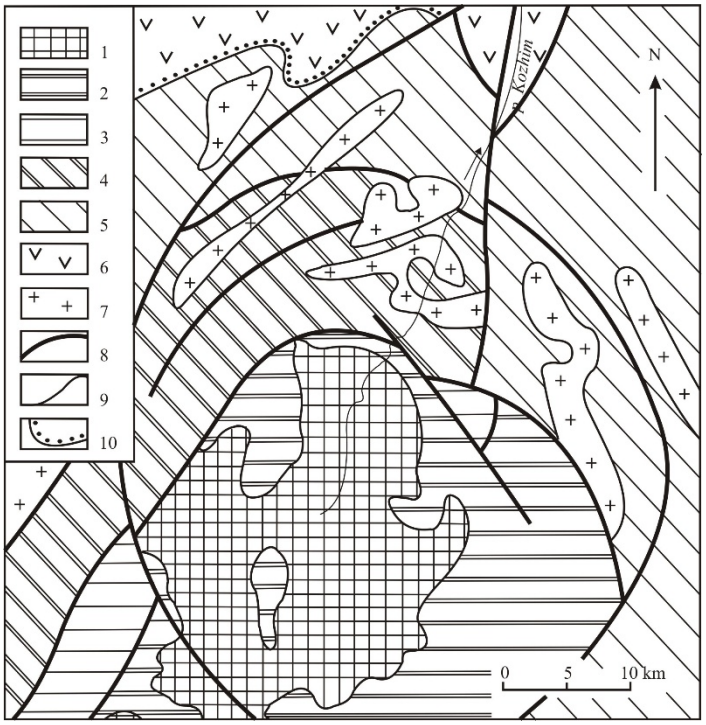

Figure 1. Scheme of the geological structure of the northern part of the Subpolar Urals:
1 - Nyartin metamorphic complex (PR_1), 2 - Manhobeyu suite, 3 - Schekurya suite; 4 - Puiva suite; 5 - Upper Riphean deposits, undissected; 6 - Paleozoic deposits, undissected; 7 - granites; 8 - faults; 9 - boundaries of stratigraphic and intrusive units; 10 - boundaries of stratigraphic unconformities.

In the modern stratigraphic schemes, they are divided (bottom-up) into the Nyartin metamorphic complex (PR_1), Manhobeyu (RF_1), Schekurya (RF_1), and Puiva (RF_2) suites. The boundaries between the stratigraphic units are of unreliable biostratigraphic justification. There are no traces of organic residues in rocks of the Nyartin complex and the Manhobeyu suite. Biostratigraphic data on rock ages of the Schekurya suite cause serious doubts. Only the Middle Proterozoic age of the Puiva suite can be considered as more or less established. This is substantiated by findings of stromatolithes and a microfossil complex of the Middle Riphean age [1]. The lowest age boundary of Precambrian formations in the Subpolar Urals has isotope-geochronological confirmation. The following ages were obtained on metamorphic zircons from rocks of the Nyartin complex, (Ma): 2125 ± 25, 1950 ± 35, 1820 ± 30 (TIMS [2, 3]), 1748 ± 12, 1748 ± 14 (SHRIMP-II [4]), 1680 (TIMS [5]).

The Early Riphean age of the Manhobeyu and Schekurya suites is determined by their occurrence beneath the Puiva suite. Thus, the isotope-geochronological and paleontological data provide a basis for attributing lower parts of the Upper pre-Riphean section in the Subpolar Urals (Nyartin complex) to the Lower Proterozoic, and upper (Puiva suite) ones to the Middle Riphean. The question of rock ages of the Manhobeyu and Schekurya suites remains unresolved.

2.2. Geological structure of the area

Polymetamorphic formations of the Nyartin complex occur in the bottom of the Precambrian section of the Subpolar Urals. Garnet and garnet-bearing micaceous gneisses and crystalline schists, as well as products of their granitization (migmatites) are most widespread in the section of this complex.

Amphibolites, amphibole-bearing crystalline schists, quartzites and marbles are of the subordinate amount. Rocks of the Nyartin complex are schistic and converted into low-temperature metamorphic schists (blastomylonites) near the contacts with the enclosing sediments. The total thickness of the

Nyartin complex exceeds 1200 m. The Manhobeyu suite is represented by muscovite-albite-quartz and muscovite-quartz crystalline schists interbedded with micaceous-feldspathic quartzites and epidote-albite-chlorite-actinolite schists. The thickness of the suite is 800-900 m. Relicts of high-temperature metamorphites (garnet amphibolites and garnet-micaceous crystalline schists), similar to those which are present in the section of the Nyartin complex, were revealed among low-temperature metamorphic rocks in a number of sections of the Manhobeyu suite during the investigation.

Besides the revision of some outcrops, where coarse fragmental rocks (conglomerates, gritstones, arkose sandstones) have been described earlier, it is shown that these formations are obviously of cataclastic and diaphtoritic nature, formed from crystalline schists and other strongly metamorphosed rocks. The Schekurya suite. Micaceous marbles and calcareous micaceous crystalline schists predominate within the suite. Common to lower strata, micaceous and amphibole-bearing schists and feldspathic quartzites have a subordinate value. As in rocks of the Manhobeyu suite, the relicts of garnet amphibolite and garnet-micaceous gneisses are also revealed there. Relationships of rocks of the Schekurya suites with the Nyartin complex and the Manhobeyu suite are tectonic.

The Puiva suite lies, with the washout, on sediments of the Schekurya suite and in some places – on rocks of the Nyartin complex. The suite is composed of gray and greenish-gray micaceous-albite-quartz schists interbedded with amphibole and limy schists and quartzites. Rhyolite and dacite metaporphyries and their tuffs are of the subordinate amount. The stratum of micaceous-feldspathic quartzites with lenses of conglomerates occurs at the base of the Puiva suite. The thickness of the Puiva suite is 1400-1600 m.

2.3. Structural peculiarities of rocks

The rock folds of the Nyartin complex are formed by the planes of metamorphic banding, foliation and veins of granitic composition (in migmatized rocks). Compressed and isoclinal folds with steeply dipping flexures are the earliest. They, in turn, are wrinkled into folds, open and of the average degree of compression, with steeply falling axial surfaces and gently dipping flexures (Figure 2).

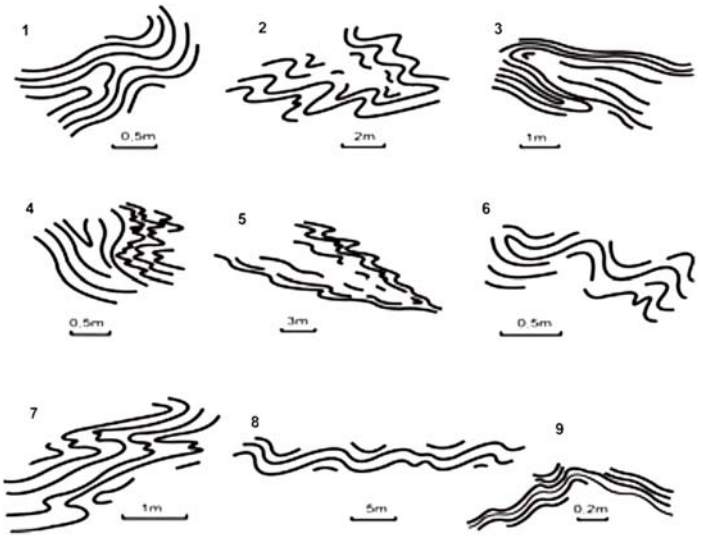

Figure 2. Morphology of folds in rocks of the Nyartin complex (1–3), Manhobeyu (4, 5), Schekurya (6, 7), and Puiva (8, 9) suites

In the Manhobeyu suite, both early and later folds are morphologically similar to the rock folds of the Nyartin complex (Figure 2). Strongly compressed and isoclinal folds are rare in the section of the Schekurya suite. This is due to the fact that early structures were largely destroyed by relatively later

schist-forming process. According to the observed fragments of folds in marbles, rocks of the Schekurya suite are deformed as much as rocks of the Nyartin complex and the Manhobeyu suite (Figure 2). Fragments of relatively same schistic sections are mainly exhibited in outcrops of the Puiva suite. They are monotonously occurring strata due to the axial plane cleavage intensively manifesting itself in many areas of development of the Puiva suites. Fragments of primary structures are relatively well recorded only in the sections where interlayers of white metaporphyries occur among the gray and greenish-gray schists. In these sections, the rocks are deformed into open and moderate compressed folds with the gently dipping flexures (Figure 2). The results of structural studies provide a basis for the assumption that the intensively and multiply deformed rocks of the Nyartin complex, Manhobeyu and Schekurya suites may belong to the same structural level. Rocks of the Puiva suite are deformed considerably weaker and, of course, belong to a higher structural level.

2.4. Rock metamorphism

Mineral parageneses which define the modern look of the Nyartin complex correspond to the conditions of moderate pressures of the amphibolite facies. Similar parageneses (in relicts) are observed in rocks of the Manhobeyu and Schekurya suites. The modern look of the Manhobeyu and Schekurya suites (with respect to low-temperature metamorphites) is caused by the manifestations of low-temperature retrogressive metamorphism.

Metamorphogenetic zircon is absent in the overlying sediments of the Puiva suite. Rounded (terrigenous) zircons with the traces of transportation are typical there. The observed mineral parageneses in rocks of this suite correspond to the greenschist facies conditions.

The chemical composition of garnet was studied for a comparative analysis of metamorphic conditions of Middle Riphean and older deposits in the Subpolar Urals. It was determined by a scanning electron microscope JSM-6400 with an energy dispersive spectrometer LINK (ISIS-300) and a wave spectrometer Microspec at the Institute of Geology, Komi SC, UB of RAS (analyst V. N. Filippov). Chemical peculiarities of garnet are clearly visible on the paired diagrams shown in Figure 3. In all the diagrams, figurative points of garnets from the Puiva suite, on the one hand, and from the Nyartin complex and Manhobeyu suite - on the other hand, are disjoined in spatial areas. The fields of the garnet compositions from the Nyartin complex and Manhobeyu suite overlap each other. At the same time, garnet cores from the Manhobeyu suite best correlate with "nyartin" garnets in composition. The rims of "manhobeyu" garnets are sharply depleted in manganese, in comparison with their central parts. According to this indicator, they are similar to the rims of "puiva" garnet (Figure 3). The diagram analysis leads to the following conclusions:

- The early stages of garnet crystallization in the Nyartin complex and Manhobeyu suite are characterized by analogical P-T parameters.
- Garnet formation in the Puiva suite is associated with another (apparently later) metamorphic stage (the discrepancy of their compositions with garnets from other stratigraphic units, particularly in the ratio of calcium and spessartine components).
- Garnets from the Puiva suite, in comparison with garnets from the Nyartin complex and Manhobeyu suite were formed under relatively low-temperature conditions (low content of the pyrope minal). The process took place under increasing pressure (large scattering of the spessartine minal in the center of grains and the low value of this component in their rims).
- The rim growth of "manhobeyu" garnets is associated with metamorphism, which, apparently, was also responsible for crystallization of "puiva" garnets (similar concentrations of the spessartine minal in the rims of "puiva" and "manhobeyu" garnets).
- The data above on rock metamorphism confirm the assumption that the Nyartin complex together with the Manhobeyu and Schekurya suites are formations of the same structural level. Deposits of the Puiva suite belong to another structural level, occupying a higher position in the section.

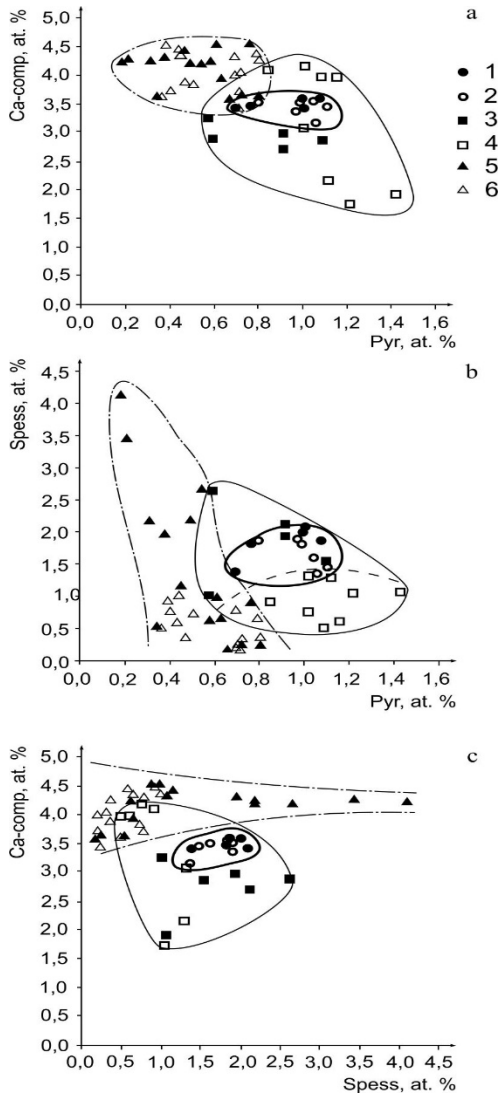

Figure 3. Charts of the garnet compositions from rocks of the Nyartin complex, Manhobeyu and Puiva suites

The garnet from rocks of the: 1–2 – Nyartin complex, 3–4 – Manhobeyu and 5–6 – Puiva suites.

Lines, limiting the fields of garnet compositions: continuous bold – garnets from the Nyartin complex, continuous thin – garnets from the Manhobeyu suite, dashed – garnet rims from the Manhobeyu suite, dashed-dotted – garnets from the Puiva suite.

1, 3, 5 – compositions the grain cores, 2, 4, 6 – compositions of the grain rims

3. Conclusions

The research results presented in this paper demonstrate the ability of using structural and metamorphic criteria for the division and correlation of polymetamorphic formations. It is shown that intensively and repeatedly deformed and metamorphosed rocks of the Nyartin complex, Manhobeyu and Schekurya suites may be assigned to the same structural level. Taking into account the available isotopic dates on early metamorphic manifestations in rocks of the Nyartin complex, it is likely that all of these stratigraphic units are related to the Lower Proterozoic.

The Upper Proterozoic section in the Subpolar Urals begins with the Middle Riphean deposits of the Puiva suite. In contrast to the southern regions of the Urals, there are no Lower Riphean formations there.

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