Paleoproterozoic Rock Metamorphism of the Nyartin Complex, the Subpolar Urals

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Abstract. In the Urals, Archean and Paleoproterozoic formations are revealed as a part of some polymetamorphic complexes which crop out onto the day surface in relatively small tectonic blocks (up to the first thousand square kilometres in area). Belonging of rocks composing polymetamorphic complexes within the Western tectonic zone of the Urals, which located west of the Main Ural Fault, to the Archean-Paleoproterozoic section is most reliable. These complexes are interpreted as fragments of the heterogeneous crystalline basement of the Ural part of the East European craton. Nevertheless, belonging of only two South Ural complexes: the Taratash and Aleksandrov to the Archean-Paleoproterozoic section causes no special disputes due to the relatively weak geochronological study of the polymetamorphic formations. They are framed by the weakly metamorphosed Lower Riphean deposits; reliable geochronological data are obtained on them, which unambiguously indicate the early Precambrian age of rock metamorphism. The existing Early Precambrian dates (with the prevalence of Late Precambrian and Paleozoic ages) for other Ural polymetamorphic complexes are interpreted in different ways. Therefore, their attachment to the Lower Precambrian section is disputed by many researchers. Taking into account the already available data and the first results of mass U-Pb dating of metamorphogenic zircons from gneisses of the Nyartin polymetamorphic complex in the Subpolar Urals, the Paleoproterozoic age of the earliest stage of rock metamorphism is substantiated in the paper. This gives grounds for the conclusion that this geological object belongs, as well as the Taratash and Alexandrov complexes in the Southern Urals, to the Lower Precambrian formations involved into the Uralides’ structure.

1. Introduction

In the Urals, the manifestation of Early Precambrian metamorphic events is established in a number of polymetamorphic complexes. Polymetamorphic complexes, in which rocks with early Precambrian isotope-geochronological markers are present, mainly occur within the Western tectonic zone of the Urals, located west of the Main Ural Fault. They are compactly located in three "nodes" confined to the main transverse uplifts (in respect to the Urals): Sob – in the Polar Urals, Kozhim – on the border of the Polar and Subpolar Urals, and Ufa – in the Southern Urals (figure 1).
These complexes can be interpreted as exhumed fragments of the heterogeneous crystalline basement of the Ural margin of the East European craton. The validity of this assumption is confirmed, in particular, by geophysical data indicating the continuation of the structures of the platform basement beneath the Urals, at least up to the Main Ural Fault (figure 2).

Despite the early Precambrian rock ages of the most complexes shown in figure 1, belonging of only two South Ural complexes: the Taratash gneiss-granulite and Alexandrov gneiss-migmatite (figure 1) to the Archean-Paleoproterozoic section does not cause much controversy. They are framed by poorly metamorphosed Lower Riphean deposits, and reliable geochronological data are obtained on them, which unambiguously indicate the early Precambrian age of rock metamorphism [3, 4, 5, 6]. Available Early Precambrian dates (with the prevalence of Late Precambrian and Paleozoic ages) for other Ural polymetamorphic complexes are interpreted in different ways. Therefore, their attitude to the Lower Precambrian section is disputed by many researchers.

Figure 1. Scheme of localization of the Uralian polymetamorphic complexes

Symbols: 1–2 – Paleozoic formations (1 – paleoceanic, 2 – paleocontinental); 3 – East-European platform's sedimentary cover; 4 – 7 – polymetamorphic complexes (4 – gneiss – granulite, 5 – gneiss-migmatite, 6 – eclogite-gneiss and eclogite-schist, 7 – granulite-metasubbasite) 8 – Meso- and Neoproterozoic formation, that mainly underwent the green schist metamorphism, 9 – area of researches. Zone of cross-uplifts: I – Sob, II – Kozmin, III – Ufim. Names of polymetamorphic complexes (figures in the scheme): 1 – Marunkeu, 2 – Kharbey, 3 – Knyord’yu, 4 – Nerkayu, 5 – Nyartin, 6 – Tatarstan, 7 – Alexsandrov, 8 – Ufaley, 9 – Beloretsk, 10 – Maksyutov. URSEIS – lines of seismic profile, described in the text.
Figure 2. Profil URSEIS – 95 a) Combined (vibro-dynamit) seismic profile after the materials of “Spetzgeofizica” [1]; b) Geological interpretation overlain on the profile [2]. The position of the profile is shown on tie figure 1.

Symbols: 1 – faults and directions of movements, 2 – MOHO boundary from wide-angle seismic, 3 – top of the Archean-Paleoproterozoic basement, 4 – top of the Riphean, 5 – top of the crustal part of the ophiolites, 6 – bottom of the Lower Carboniferous, 7 – granites. MUF – Main Ural Fault.

Taking into account the already existing data and the first results of mass U-Pb dating of metamorphogenic zircons from gneisses of the Nyartin polymetamorphic complex in the Subpolar Urals, the Paleoproterozoic age of the earliest stage of rock metamorphism is substantiated in the paper. This gives grounds for the conclusion that this geological object belongs, as well as the Taratash and Alexandrov complexes in the Southern Urals, to the Lower Precambrian formations involved into the Uralides’ structure.

2. Results of researches and discussion

According to typification of Ural polymetamorphic complexes, the Nartin complex belongs to gneiss-migmatite complexes [7]. This composes the core of the Khobeiz block-anticline located in the northern part of the Lyapin anticlinorium. The complex can be traced in the northeast direction at a distance of 65 km. In the northeastern part of it, metamorphic strata crop out onto the day surface as a relatively isometric massif of 25-35 km in size (figure 3). As for many other Ural gneiss-migmatite complexes, the brachiformny folding type is characteristic of this complex. The rocks of the considered complex are schistose and altered into low-temperature diaphthorites near the contacts with the enclosing Riphean deposits.

Garnet and garnet-bearing micaceous gneisses and crystalline schists, as well as the products of their granitization – migmatites, predominate in the section of the Nyartin complex among rocks which were not affected by low-temperature retrograde metamorphism. Amphibolites, amphibole-bearing crystalline schists, quartzite, and marbles are present in a subordinate amount.
Figure 3. Scheme of the geological structure of the northern part of the Subpolar Urals

Symbols: 1 – Nyartin metamorphic complex (PR1), 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, 11 – place of selection of sample K-7

These rocks were first conditionally attributed to the pre-Riphean formations by M. V. Fishman and B. A. Goldin [8]. The first isotope date confirming the assumption of the pre-Riphean age of rocks of the Nyartin complex (1680 Ma) is given in the article of V. N. Puchkov and L. A. Carsten [9]. It was obtained by the thermo-isochronous method on zircon from garnet-biotite-muscovite-feldspar schists. Several thermo-isochronous Pb-Pb dates (2210 ± 25, 2125 ± 25, 700 ± 20, and 665 ± 25 Ma) were received on zircon sampled from garnet-mica gneisses by us [10]. The first age refers to detrital zircons, the second to isometric weakly zonal or non-zonal (spherical) zircons with an abundance of faces which are characteristic of ultrahigh-temperature metamorphites. In the Urals, they are distinguished as zircons of the "granulite" type [11], they are also known as zircons of the "soccer ball" type in world literature [12]. The third and fourth ages are obtained on distinctly zoned transparent prismatic zircons. Such zircons are typical of the amphibolite facies rocks, especially of their migmatized species. Their formation is associated with the presence of a liquid silicate phase and, therefore, in fact, they are magmatic zircons. In literature they are known as zircons of the "migmatite" type [11]. The presence of zircon of the "granulite" type in rocks of the Nyartin complex allowed us to assume that they are medium-high-temperature diaphthorites after granulites [13]. Later U-Pb dating of metamorphogenic zircons conducted with the ion microprobe SHRIMP-II (VSEGEI, Russia) has led to ambiguous results [14]. Three age intervals were recorded for zircons of the "granulite" type: 1746-1722, 960-942, and 752-662 Ma. It is unlikely that these figures reflect the real age boundaries of several successive stages of the granulite facies metamorphism. Apparently, these are "rejuvenated" dates associated with the manifestation of lower-temperature processes (metamorphism of the amphibolite and epidote-amphibolite facies). Larger age dispersion for zircons of the "migmatite" type was obtained: 1748-498 Ma, with prevailing dates in the intervals of 1748-1574, 1284-1204, and 782-634 Ma.
Recently, we attempted to mass U-Pb dating of metamorphogenic zircons from crystalline schists of the Nyartin complex. U-Pb zircon dating was carried out by laser ablation and sector-field mass spectrometry with inductively coupled plasma (LA-SF-ICP-MS) is an accessible local method with easy sample preparation. This method was applied using a Thermo Scientific Element XR single-collector SF ICP mass spectrometer and a UP-213 (New Wave Research) laser ablation system at the Geological Institute SB RAN, Ulan-Ude [15]. Fine-grained gray garnet-biotite gneiss with no marks of migmatization and other secondary processes was sampled in the Nyartin complex. Zircons of the "granulite" type prevail in the monofraction. Taking into account that the oldest ages were obtained on such zircons, both from rocks of the Nyartin complex and other polymetamorphic complexes of the Urals [11, 13], the zircons of this morphotype were carefully selected manually under the binocular. In total, 110 grains of such zircon were distinguished. Their size varies from 80 to 300 microns. Grains are transparent, pale pink in color; optical zoning is absent or weakly expressed (figure 4).

Figure 4. Pictures of zircon of the “granulite” type from garnet-biotite gneiss (sample K-7) in the backscattered electron image (composition) (1-3) and in a cathode luminescence (4–6)

The cleanest, not eroded and non-fractured grains without inclusions and dark areas were selected for the analysis with a mass spectrometer. The age calculated at the upper intersection of discord with concordia (2127 ± 31 Ma) confirms the previous date obtained by the method of Pb thermionic emission (2125-25Ma) and gives grounds, with a great degree of confidence, to interpret the figure as the time of the earliest metamorphic stage of rocks of the Nyartin complex (figure 5).

Note that the analogous age of similar zircons was established by us in the Aleksandrov gneiss-migmatite complex of the Southern Urals (2081 ± 14 Ma, SHRIMP-II, [6]). A significant error for the lower intersection of discord with concordia (555 ± 120 Ma) results from the fact that figurative age points are localized mainly near the upper intersection. Nevertheless, this age (about 600 Ma) corresponds to real endogenous events. This is the time of the formation of metamorphic zoning under conditions of the amphibolite, epidote-amphibolite, and green schist facies, which determines the modern appearance of the Nyartin metamorphic complex and its Riphean framing, as well as the altitudinous manifestations of granitites magmatism [14].
3. Conclusions
Thus, the Paleoproterozoic age of the earliest stage of rock metamorphism is established on the results of firstly conducted mass U-Pb dating on metamorphogenic zircons from the gneisses of the Nyartin polymetamorphic complex in the Subpolar Urals, taking into account the already available data. This gives grounds for asserting that the complex under consideration, as well as the Taratash and Aleksandrov complexes in the Southern Urals, belongs to the Lower Precambrian formations involved into the Uralids structure.

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