Provenance Area and U-Pb Age of Detrital Zircons from the Upper Proterozoic Deposits of the Polar Urals

Natalia Ulyasheva 1, Oksana Grakova 1, Aleksandr Pystin 1, Yulia Pystina 1

1 Ural Branch of RAS, Komi Science Centre, Institute of Geology, Syktyvkar, Russia

nsulasheva@geo.komisc.ru

Abstract. Conducted isotopic-geochemical study of the Upper Proterozoic rocks of the Nyarovey series was provided from the Polar Urals. U-Pb LA-SF-ICP-MS dating of detrital zircons from metasandstone the lower part of the series showed that the eroded substrate was dominated by Proterozoic rocks. Analysis of the obtained dating allowed us to conclude that the final stages of sedimentation Nyarovey series are limited to the age of 660 million years ago. According to the contents of indicator rare elements in the meta-sedimentary rocks of the Nyarovey series, it was established that in the provenance area the acid rocks, as well as the formation of the basic and average composition, prevailed. The obtained results indicate the inaccuracy of the selection of the Nyarovey series as the Middle Riphean stratum and suggest that in the Upper Precambrian section of the Northern Urals region the Middle Riphean deposits, if present, have an extremely limited distribution. The obtained results indicate that the Nyarovey series is distinguished as the Middle Riphean of the strontium. They give reason to believe that in the Upper Precambrian section of the Northern Urals of the region, the Middle Riphean of sediment, if present, has extremely limited distribution.

1. Introduction

In the Timan-Northern Urals region, unlike the southern regions of the Urals, there is no complete Riphean section in the Upper Proterozoic deposits. In recent years, it has been established that the Lower Riphean stratones isolated in stratigraphic schemes do not really belong to the Lower Riphean. They belong to the Lower Precambrian crystalline base [1]. The earlier Middle Riphean deposits refer to the Upper Riphean [2]. The problem of the age of the basal deposits of the Timan-Northern Urals region remains, since many supposedly Middle Riphean stratones do not have geochronological substantiation yet.

The article specifies the age of the Nyarovey series (Figure 1). Based on the first results of mass U-Pb dating of detrital zircons from the Upper Proterozoic rocks of the Kharbey anticlinorium of the Polar Urals. The Nyarovey series is composed of metamorphosed to the level of the greenschist facies by volcanic-sedimentary rocks. The series is conditionally referred to the Middle Riphean. [3]. An analysis of the age dating of zircons and geochemical features of meta-sedimentary rocks made it possible to establish the expected sources of demolition.
2. Methods

The contents of the indicator rare elements La, Sc, Th, Co, Hf, Ce, Cr and V were used for reconstruction of the demolition sources for meta-terrigenous rocks of the Nyarovey series. Their quantity in the rocks may indicate the features of the composition of the eroded substance [4]. The concentration of rare and dispersed elements in rocks was determined by acid decomposition of the initial samples and further analysis with the help of the sector mass spectrometer with ionization in inductively coupled plasma (FS HR ICP-MS) Element2 at the Institute of Geology and Geochemistry of AN Zavaritsky in Yekaterinburg. To determine the lower boundary of the formation of the Nyarovey series, and also to establish the age of eroded rocks of the substrate, isotope studies of terrigenous zircons from the meta-sandstone U-Pb LA-SF-ICP-MS were carried out by the method. This method is implemented on the basis of a single-collector magnetocenter mass spectrometer with inductively coupled plasma Element XR and an apparatus for laser ablation of UP-213 in the GIS SO RAN [5].

Age values of terrigenous zircons correspond to the age of the eroded material. The youngest dating of allotogenic zircon shows the maximum age of the beginning of accumulation of sedimentary material. Terrigenous zircons were selected from the rocks of the lower part of the series. The rock is represented by chlorite-muscovite-quartz schist. The primary composition of the schist corresponds to the ferruginous sandstone.
In meta-sandstone, zircon is represented by three morphological types of different shapes, colours and degrees of roundness. The first morphological type is well-rounded zircons 0.1-0.2 mm in size. They form an insignificant part of the total amount of zircon fraction in the rock (about 5-10%). These are transparent light pink, light yellow rounded grains with a characteristic rough surface. In some cases, scores and scratches are visible, indicating the mechanical nature of roundness. The internal structure is homogeneous, inclusions of isometric and elongated forms are noted.

The second morphological type is represented by slightly rounded crystals of the dipyramidal-prismatic habitus, caused by the development of the faces of the prisms \{100\}, \{110\} and the dipyramid \{311\}, \{331\}. The coefficient of elongation is 2.5-3.5. The grain size is 0.05-0.2 mm. The mineral is transparent, has a light pink colour. The internal structure is characterized by zonality. The zones are more or less symmetrical. Inclusions of isometric forms are noted. The content of this variety of zircon is 45% -50% of the total amount of mineral in the rock.

The third morphological type is formed by slightly rounded zircons with a clearly expressed crystallographic shape due to the development of \{311\}, \{111\}, \{110\}, \{100\} faces. They have a light pink colour. The grain size is 0.01-0.1mm. The internal structure of zircons is uniform. Their content is 40% -45% of the total amount of mineral in the rock.

100 terrigenous zircon grains represented by all three morphological types were analysed, approximately in the same proportions in which they are present in the rock.

3. Results and discussions

An analysis of the ratios of La/Sc, Th/Co, La/Th, and Hf elements in the metamorphosed sedimentary formations of the Nyarovey series showed (Figure 2) that the main source for them was rocks of the acidic composition of the mature continental crust. At the same time, the high values of the ratios of the elements Cr/Zr (1.3-2.09) and Cr/V (0.44-0.6) indicate the presence of mafics and medium rocks in the eroded material.

100 grains of clastic zircon were analysed. 21 analyses with high discordance (D≥10%) were excluded from consideration. The remaining number of analyses (79 datings) is sufficient to establish the age of the rocks that formed the erosion area when accumulating sediments of the Nyarovey series. The distribution of the ages of zircons carried out as a result of U–Pb dating is shown in figure 3. The
maximum Late Archaean age was obtained from zircon of the third morphotype – 2859 million years. The minimum Early Vendian age for grains of the second morphotype is 595.2 Ma. The main sample of dating includes 77 analyzes (or 97.5%). It covers an interval of 2028.1 – 660.1 million years and forms three age groups with maxima at the levels of 1,700.1225, and 675 million years. In the first two age groups, there are single definitions that are obtained for well-rounded zircons of the first morphotype. Consequently, it can be concluded that the products of erosion of remote Lower Proterozoic, Lower-, Middle- and Upper Riphean breed associations were involved in the formation of the deposits of the Nyarovey Series. However, the predominant number of age values in these groups belongs to the very slightly rounded zircons of the second and third morphotypes. The low degree of roundness of zircons indicates a close location of sources of demolition.

![Histogram and the curve of the relative density of the distribution of the ages of detrital zircons from the metasandstone of the Nyarovey series.](image)

**Figure 3.** Histogram and the curve of the relative density of the distribution of the ages of detrital zircons from the metasandstone of the Nyarovey series.

Similar zircons are typical for rocks of gneiss-migmatitic and other polymetamorphic complexes of the Urals, including the Polar Ural ones. They are represented by similar age populations (but not ovate, newly formed) [6]. The obtained data on the age of zircons allow us to conclude that the dominant role in the formation of deposits of the Nyarovey series belonged to the products of erosion of massifs of metamorphosed rocks of the East European craton. Their fragments are probably the polymetamorphic complexes of the Urals.

To determine the possible lower age limit of the deposits of the Nyarovey series, the most important are the youngest dating of zircons. The youngest age value is 595.2 million years, hence the accumulation of sedimentary deposits of the Nyarovey series did not occur earlier than in the Vendian. However, the Vendian age is obtained only one grain of mineral. It contradicts the available geological data (the occurrence of deposits of the Miniseyshor series is lower than the limestones of the Nemuregan series with microphytolites of the IV complex of Riphean). This dating should probably be excluded from consideration. More realistic is the restriction of the lower age interval of the Nyarovey series, 660 million years ago, the end of the Late Riphean. This age corresponds to the dating of five grains of zircons (660.1, 661.9, 666.5, 668.7 and 669.1 million years). This, in our opinion, cannot be accidental or erroneous. At the same time, the upper age line of the series should not go beyond the borders of
Riphean and Vendian. Since in the overlying rocks there are Riphean microphytolites. Consequently, the deposits of the Nyarovey series formed in a narrow age interval at the end of the Late Riphean.

4. Conclusions
The main conclusions U-Pb dating of detrital zircons and geochemical investigation of metasedimentary rocks of the Nyarovey series of the Polar Urals are performed. They made it possible to establish that in the feeding province for the terrigenous formations the predominantly acidic, basic and middle breeds were mainly Proterozoic. It is likely that it could be closely located polymetamorphic complexes.

The obtained U-Pb dating also indicates an inaccuracy in the selection of the Nyarovey series as a Middle Riphean stratum. Most likely, the entire section of the series refers to the upper Riphean. The final stages of the accumulation are limited to 660 million years.

The results of the conducted studies do not entirely remove the question of the lower age boundary of the North Ural Upper Precambrian. They give grounds to believe that in the Upper-Cambrian section of the region the Middle Riphean deposits, if, but have extremely limited distribution.

Acknowledgment(s)
The study was financially supported by RFBR in the framework of a research project № 16-35-00146 mol a, as well as with the support of the Programme of Fundamental Research RAS № 15-18-5-17.

References
[1] Pystin A. M., Pystina Yu. I. Basal deposits of the Upper Precambrian in the Timan-Northern Urals region // Lithosphere, 2014. No. 3. P. 41-50.
[2] Andreychev V. L., Soboleva A. A., Gerels J. U-Pb age and sources of demolition of detrital zircons from Upper Precambrian deposits of Northern Timan // Stratigraphy. Geological Correlation, 2014, vol. 22, № 2. P. 32–45. DOI: 10.7868/S0869592X14020021.
[3] Ulyasheva N. S., Grakova O. V. Primary composition of the Nyarovey series (Polar Urals) // Bulletin of the Institute of Geology of the Komi Scientific Center of the Ural Branch of the Russian Academy of Sciences, 2016. № 2. P. 24-35.
[4] Cullers R. L. // Chem. Geol. 2002. V. 191. P. 305–327.
[5] Khubanov V. B., Buyantuyev M. D., Tsygankov A. A. U-Pb isotope dating of zircons from PZ3-MZ magmatic complexes of Transbaikalia using the method of magnetic-sector mass spectrometry with laser sampling: determination procedure and comparison with SHRIMP Data // Geology and geophysics, 2016, Vol. 57, No. 1. C. 241-258. http://dx.doi.org/10.1016/j.rgg.2016.01.013
[6] Pystina Yu. I., Pystin A. M. The Zircon Chronicle of the Urals Precambrian. Ekaterinburg: he Ural Branch of the Russian Academy of Sciences combination of SAR image texture and Landsat TM data: An assessment of predictions between regions,” ISPRS J. Photogramm. Remote Sens., vol. 70, pp. 66–77, 2012.
[7] Z. A. Latif, I. Zamri, and H. Omar, “Determination of tree species using Worldview-2 data,” 2012 IEEE 8th Int. Colloq. Signal Process. Its Appl., pp. 383–387, 2012.
[8] M. E. J. Cutler, D. S. Boyd, G. M. Foody, and a. Vetrivel, “Estimating tropical forest biomass with a combination of SAR image texture and Landsat TM data: An assessment of predictions between regions,” ISPRS J. Photogramm. Remote Sens., vol. 70, pp. 66–77, 2012.