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Geochronology of Precambrian formations of the north of the Urals

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The paper summarizes results of work on the geochronological confirmation of the age of metamorphic structures occurring at the base of the Precambrian of the north of the Urals and the age of overlying Upper Precambrian basal sediments. It is shown that the occurrences of early stages of metamorphism of rocks of metamorphic (polymetamorphic) complexes date back to about 2.1 Ga. Their substrate is unambiguously related to the Lower Precambrian. We determined that Mesoproterozoic strata are absent Upper Precambrian sections of the north of the Urals, in contrast to more southern regions of the Urals. The basal strata in the Lyapin and Kharbey-Marunkeu anticlinoria, according to the data obtained, are dated to the Middle Neoproterozoic (cryogenian). The established fact of the absence of deposits of a huge age interval (Mesoproterozoic — at least 600 Ma) in the north of the Urals can be explained by a high standing of the territory of the northeast (in modern coordinates) of the Baltic craton, a fragment of which at that time was the Timan-Northern Ural lithospheric segment, and the location in the interiors of the Columbia (Nuna) supercontinent.

Keywords: North of the Urals, Lower and Upper Precambrian, basal deposits, geochronology.

Геохронология докембрийских образований севера Урала

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В статье обобщаются результаты работ по геохронологическому обоснованию возраста метаморфических образований, залегающих в основании североуральского докембрия, и возраста перекрывающих их базальных отложений верхнего докембрия. Показано, что проявления ранних этапов метаморфизма пород метаморфических (полиметаморфических) комплексов относятся к рубежу около 2.1 млрд лет назад, то есть их субстрат однозначно соответствует нижнему докембрию. Установлено, что в разрезе североуральского верхнего докембрия в отличие от более южных районов Урала отсутствуют отложения мезопротерозоя. Базальные толщи в Ляпинском и Харбейско-Марункеуском антиклинариях, по полученным данным, датируются средним неопротерозоем. Установленный факт отсутствия на севере Урала отложений огромного возрастного интервала (мезопротерозой — не менее 600 млн лет) может быть объяснен высоким стоянием территории северо-востока (в современных координатах) кратона Балтики, фрагментом которого в это время являлся Тимано-Североуральский литосферный сегмент, и нахождением ее во внутренней части суперконтинента Колумбия (Нуна).

Ключевые слова: север Урала, нижний и верхний докембрий, базальные отложения, геохронология.

Introduction

In the pre-Paleozoic section of the northern regions of the Urals, as in its southern part, the Lower and Upper Precambrian formations are distinguished. Most researchers refer the polymetamorphic complexes, exposed in the cores of the Lyapin (Subpolar Urals) and Kharbey-Marunkeu (Polar Urals) anticlinoria, to the Lower Precambrian (Paleoproterozoic). The limbs of the anticlinoria are composed of Meso (?) — and Neoproterozoic strata (Fig. 1).

The most complete Upper Precambrian section is known in the Subpolar Urals in the basin of the Kozhim river. It is stratotypical for the entire Northern Ural region.

In the approved stratigraphic schemes [43], it is compared with the Upper Precambrian section of the Bashkirian anticlinorium (South Urals). Here, as well as in the Southern Urals, Meso- and Neoproterozoic deposits are distinguished (Fig. 2). However, the degree of their study, in contrast to the southern regions of the Urals, is relatively low. Therefore, many questions concerning the identification of the Lower and Upper Precambrian strata, their geological relationships and age restrictions remain controversial.

Earlier, the authors of this paper, on the basis of structural, petrological and mineralogical data, showed that in the Subpolar Urals, straton, attributed to the Lower

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Fig. 1. Simplified geology of the Timan-Northern Ural region:

1 — Sedimentary cover of European platform; 2 — Sedimentary cover of the West-Siberian Basin; 3 — Paleozoic paleoceanic formations; 4 — Paleozoic paleocontinental formations; 5 — Meso-Neoproterozoic formations, mainly undergone greenschist metamorphism; 6 — Paleoproterozoic and presumably Paleoproterozoic polymetamorphic complexes. Rectangles indicate research areas: 1 — in the Subpolar Urals (see Figure 2), 2 — in the Polar Urals. Names of polymetamorphic complexes (figures in the scheme): 1 — Malyko, 2 — Marunkeu, 3 — Kharbey, 4 — Kharamatalou, 5 — Khord'yu, 6 — Nerkayu, 7 — Nyartin, 8 — Ufaley, 9 — Taratash, 10 — Aleksandrovsk, 11 — Mikulkin. The circles mark sample localities. The letter symbols in the circles correspond to the histograms letters in Fig. 4.

Рис. 1. Упрощенная схема геологического строения Тимано-Североуральского региона:

1 — осадочный чехол Европейской платформы; 2 — осадочный чехол Западно-Сибирской плиты; 3 — палеозойские палеоокеанические формации; 4 — палеозойские палеоконтинентальные формации; 5 — мезо-неопроterozoические образования, преимущественно претерпевшие зеленосланцевый метаморфизм; 6 — палеопротерозойские и предположительно палеопротерозойские полиметаморфические комплексы; 6 — осадочный чехол Западно-Сибирской плиты. Прямоугольниками обозначены районы исследований: 1 — на Приполярном Урале (см. рис. 2), 2 — на Полярном Урале. Названия полиметаморфических комплексов (цифры на схеме): 1 — Маликовский, 2 — Марункеуский, 3 — Харбейский, 4 — Хараматалоуский, 5 — Хордьюсский, 6 — Неркаюсский, 7 — Няртинский, 8 — Уфалейский, 9 — Тараташский, 10 — Александровский, 11 — Микулкинский. Кружками отмечены места отбора образцов. Буквенные обозначения в кружках соответствуют буквенным обозначениям гистограмм на рис. 4.

Fig. 2. Simplified geology and sample location of the northern part of the Subpolar Urals:

1 — Paleoproterozoic Nyartin metamorphic complex; 2 — Lower Mesoproterozoic (?) Mankhobeyu suite; 3 — Lower Mesoproterozoic (?) Shchokurya suite; 4 — Middle-Upper Mesoproterozoic (?) Puyva suite; 5 — Neoproterozoic deposits, undissected; 6 — Paleozoic deposits, undissected; 7 — granites; 8 — faults; 9 — boundaries of stratigraphic and intrusive units; 10 — boundaries of stratigraphic unconformities; 11 — sampling site

Рис. 2. Упрощенная схема геологического строения северной части Приполярного Урала:

1 — палеопротерозойский няртинский метаморфический комплекс; 2 — нижнемезопротерозойская (?) маньхобеинская свита; 3 — нижнемезопротерозойская (?) шокуринская свита; 4 — средне-, верхнемезопротерозойская (?) пуйвинская свита; 5 — неопроterozoические отложения нерасчлененные; 6 — палеозойские отложения нерасчлененные; 7 — граниты; 8 — разломы; 9 — границы стратиграфических и интрузивных подразделений; 10 — границы стратиграфических несогласий; 11 — места отбора проб

Mesoproterozoic (calymmian): the Mankhobeyu and Shchokurya suites, in fact, are deeply altered (multiply diaphorized and complexly dislocated) polymetamorphic formations [25]. They are similar to those that form the supposedly Paleoproterozoic complexes of the core parts of the Lyapin and Kharbey-Marunkeu anticlinoria. In this regard, the question arose of obtaining correct geochronological data on the age of polymetamorphic formations in the north of the Urals and on the lower age boundary of the basal sediments of the Upper Precambrian, to which the Puyva suite belongs in the Subpolar Urals, and the Nyarovei series in the Polar Urals. The age of these stratigraphic units is currently conventionally accepted as Middle-Late Mesoproterozoic (ectasian—stenian) [38, 40, 41, 43 et al.]. To answer these questions, we performed U-Pb dating of detrital and metamorphic zircons. The research results, published recently in a number of Russian and foreign scientific journals [27—33, 35, 47 et al.] are summarized in this paper.

Lower Precambrian in the structure of the paleozooids in the north of the Urals

The section of reliably substantiated by geological and geochronological data of the Lower Precambrian Urals (Taratash and Aleksandrovsk complexes of the Southern Urals) is represented exclusively by polymetamorphic formations. Therefore, the concept of the Early Precambrian age of the most part of the polymetamorphic complexes in the north of the Urals (Fig. 1) seems to be the most substantiated today [44]. The Marukeu and Kharbey metamorphic complexes of the Polar Urals, the Nyartin and Nerkeyu of the Subpolar Urals belong to the Lower Precambrian (namely, to the Paleoproterozoic part of the section) on the unified stratigraphic schemes of the Urals [43] and published state geological maps [38, 40–42 at al.]. The Paleoproterozoic age of the rocks of the Marunkeu complex is substantiated by the dating by the Rb-Sr and Sm-Nd isochronous systems for the rocks (eclogites) as a whole and for metamorphogenic minerals [2]. In addition, for all of the above polymetamorphic complexes of the north of the Urals, including the Marunkeu complex, there are single U-Pb datings of metamorphogenic zircons with Paleoproterozoic ages [2, 30, 44 et al.]. Even older (Neoproterozoic) age values were obtained by U-Pb dating of zircons from metabasites of the Malyk complex of the Polar Urals [9]. The age of 2736 ± 42 Ma was determined for 18 local zones along the upper intersection of discordia with concordia. Within analytical errors, it coincides with the Nd simulation dating of 2694 Ma based on the bulk composition of the sample. These data, according to the cited authors, confirm the reality of a geological event at the «rock» level.

And yet, despite the available geochronological data, they are still scarce and not always unambiguous; therefore, the question of the age of the rocks of polymetamorphic complexes in the north of the Urals remains controversial. Moreover, the results of dating of single zircon grains by thermal ion emission of lead and U-Pb (SIMS, SHRIMP) obtained in the last two decades lead some researchers to the conclusion about the post-Paleoproterozoic age of the protoliths of a number of polymetamorphic complexes: Neoproterozoic — Marunkeu [12] and Kharbey [14], Early Mesoproterozoic (calymmian) — Nyartin [39] complexes.

To correctly estimate the upper age boundary of the protoliths of the lower part of the Precambrian section of the Subpolar Urals, we attempted mass U-Pb dating of metamorphogenic zircons from the crystalline schists of the Nyartin complex. The studies were carried out by the U-Pb LA-SF-ICP-MS method implemented on the basis of the Element XR single-collector magnetic-sector mass spectrometer with inductively coupled plasma and UP-213 laser ablation device at the Geological Institute SB RAS [13].

In the Nyartin complex, a sample of fine-grained gray garnet-biotite gneiss was taken without signs of migmatization and other secondary processes (sample K-7, Fig. 2). The monofraction was dominated by metamorphogenic zircons of the so-called «granulite» type [15], which are rounded polyhedrons. Taking into account that the most ancient age values were received for such zircons, both in the rocks of the Nyartin complex and in other polymetamorphic complexes of the Urals [34], zircons of this morphotype that were carefully manually selected under a binocular. A total of 110 grains of such zircons were isolated. Their size varies from 80 to 300 microns. Grains are transparent, pale pink. Optical zoning is absent or poorly expressed. When analyzed by a mass spectrometer, the purest,

non-eroded and non-fractured grains were selected. A total of 44 crystals were analyzed.

The age calculated from the upper intersection of discordia with concordia (2127 ± 31 Ma) confirms previously obtained dating by the thermoionic lead emission method (2125 ± 25 Ma), [34]) and gives reason to interpret it with a high degree of confidence as the time of the early stage of metamorphism of rocks of the Nyartin complex (Fig. 3) Note that we determined a close age of similar zircons in the Aleksandrovsk gneiss-migmatite complex of the South Urals (2081 ± 14 Ma, SHRIMP-II, [26]).

Fig. 3. Concordia diagram for «granulite» type zircons from garnet-biotite gneiss (sample K-7, U-Pb isotope LA-SF-ISP-MS method)

Рис. 3. Диаграмма с конкордией для цирконов «гранулитового» типа из гранат-биотитового гнейса (проба К-7, U-Pb-изотопный LA-SF-ICP-MS метод)

Thus, for the first time, based on the results of mass U-Pb dating of metamorphogenic zircons from the gneisses of the Nyartin polymetamorphic complex of the Subpolar Urals, taking into account the data already available, the Early Proterozoic age of rock metamorphism was established. It allows confirming that the considered complex, as well as the Taratash and Aleksandrovsk complexes of the South Urals, belongs to the Lower Precambrian formations involved in the structure of the Uralids.

Age of the Upper Precambrian basal deposits in the north of the Urals

The problem of the age of the basal deposits of the Upper Precambrian in the north of the Urals and Timan-Northern Ural region as a whole, and, consequently, the time of the formation of the Timan passive margin remains open. Recently U-Pb data on detrital zircons have been actively used to solve it. They were obtained for terrigenous deposits in the lower parts of the visible Precambrian section of the Northern [3–5], Middle [8, 46] and Southern [18] Timan, Northern Urals [20], as well as the western part of the Polar Urals [37]. The minimum age of zircons, which determines the possible lower age limit for the formation of these deposits, is close to 1.0 Ga, i. e. the Meso- and Neoproterozoic boundary. A younger age (670 Ma) was de-

terminated for zircons from the deposits of the Bedamel series of the Polar Urals [37].

Thus, in the last decade, a fairly large bulk of isotope-geochronological information was accumulated on the terrigenous Upper Precambrian deposits of the Timan-Northern Ural region and especially the Timan part. These data indicate that the sediments at the base of the visible section of the Upper Precambrian in this area belong to the Neoproterozoic and, possibly, partly to top Upper Mesoproterozoic. However, these data do not yet answer the question of the age of the basal deposits of the Upper Precambrian of the Timan-Northern Ural region and the time of the formation of the Timan passive margin, since the basal status of the dated to the present post-Paleoproterozoic strata of Timan and the northern regions of the Urals is not clear because of the lack of the underlying Lower Precambrian structures.

Lower Precambrian complexes, overlapping by younger Proterozoic strata, are known in the Ural part of the Timan-Northern Ural region, namely, within the Lyapin (Subpolar Urals) and Kharbey-Marunkeu (Polar Urals) anticlinoria. Within the Timan-Kanin ridge, the Lower Precambrian is determined on the Kanin Peninsula (Paleoproterozoic Mikulkin metamorphic complex [23]). Therefore, these areas are interesting to isolate the basal levels of the Upper Precambrian section and to determine their age.

The first priority for this kind of research is the Subpolar Urals, where the Early Precambrian (Paleoproterozoic) age of the rocks of the Nyartin complex, which lies at the base of the Subpolar Ural Precambrian, is most reliably substantiated. As noted above, the metamorphic formations previously identified at the base of the Upper Precambrian section of the Subpolar Urals (the Mankhobeyu and Shchokurya suites) are low-thermal diaphorites based on highly metamorphosed rocks, including formations similar to those of the Lower Precambrian complexes, i. e. they belong to the structures of the pre-Mesoproterozoic structural stage. The pre-Mesoproterozoic age of the rocks of these suites has recently been confirmed by isotope-geochronological data [27, 28]. Thus, the Puyva suite should be considered as the basal stratum of the Subpolar Ural Upper Precambrian (Fig. 2).

The degree of confirmation of the age of the rocks of the Puyva suite should be considered low at present. It is taken on the basis of the occurrence of the suite deposits under the faunistically characterized Neoproterozoic strata, as well as the presence of Late Mesoproterozoic microfossils in the rocks. Mass dating of detrital zircons from the rocks of the Puyva suite has not yet been carried out. The suite is composed of gray and greenish-gray mica-albite-quartz schists with interlayers of amphibole and calcareous schists and quartzites. Rhyolite and dacitic metaporphyries and their tuffs are found in subordinate quantities. The base of the Puyva suite fragmentarily includes the Oshiz formation composed of mica-feldspar quartzites and quartzite-sandstones with lenses of gravelites and conglomerates. The thickness of the Oshiz formation reaches 350 m, and the section of the Puyva suite as a whole — 1600 m [34]. To clarify the age boundaries of the formation of the Puyva suite, as well as to establish the age of the eroded rocks of the substrate, we studied detrital zircons by the U-Pb LA-SF-ICP-MS method.

The zircon sample was taken from gray medium-

grained chlorite-muscovite-albite-quartz schists (sample 21, Fig. 2). The metamorphism of the rocks in this part of the suite did not exceed P-T conditions of the greenschist facies. In the given sample, zircons are mainly represented by well-rounded grains of a spherical and elliptical shape, colored in smoky and brownish-cream tones. The grain size is 100–250 μm . A total of 111 randomly selected zircon grains were analyzed. 17 analyzes with high discordance ($D \geq 10\%$) were excluded from consideration. The age distribution of 94 dating after sorting is shown in Fig. 4-a. Zircon with the maximum dating is of the Paleoproterozoic age — 1959 ± 52 Ma, with the minimum — Neoproterozoic — 867 ± 71 Ma. The main sampling of ages, including 93 analyzes (or 99 %), covers the interval 867–1579 Ma and has a polymodal distribution. The datings are grouped into two age populations: 1179–867 Ma (67% of analyzes) and 1579–1274 (30 % of analyzes), separated by a deep minimum in the interval 1274–1179 Ma. Globally, the first age interval can be associated with the activity of mantle plumes during the collapse of the Columbia (Nuna) supercontinent [6]. In the Timan-Northern Ural region, shows of basic magmatism in Northern Timan correspond to this time [1]. The earlier age interval (1579–1274 Ma) may reflect the Mesoproterozoic stages of the Late Precambrian continental rifting, which is associated with the Navysh and Mashak volcanism, which is well manifested in the Southern Ural margin of the Baltic.

The determined minimum values of the dating of detrital zircons (867 ± 71 , 889 ± 55 , 892 ± 86 , 907 ± 54 , 909 ± 46 , 910 ± 77 Ma) indicate that the formation of the Puyva suite deposits was completed no earlier than 900 Ma. The insignificant thickness and fragmentary development of the underlying rocks of the Oshiz formation of the Puyva suite with a significant proportion of zircons with Neoproterozoic dating in the sample (22 determinations or 23 %) allow asserting that the lower age boundary of the Upper Precambrian basal deposits (Puyva suite) does not go beyond the Neoproterozoic in the Subpolar Urals. The good roundness of the zircons allows making assumption that the products of distant source areas prevail in the deposits of the Puyva suite.

In the Polar Urals, the Nyarovey series can be confidently related to the Upper Precambrian basal deposits, which lies directly on the highly metamorphosed formations of the Kharbey-Marunkeu anticlinorium (Kharbey and Marunkeu metamorphic complexes). The stratigraphic gap is clearly marked by polymictic conglomerates at the base of series of the basal horizon [40]. The series conditionally relates to top of Mesoproterozoic (stenian). The age of the rocks is based on their position under the marbleized limestones of the Nemuryugan suite with microphytolites of the Neoproterozoic Uksk complex (cryogenian). The series (from bottom to top) is subdivided into the terrigenous-carbonate Verkhnekharbey suite with a thickness of 400–500 m and the terrigenous-volcanogenic Miniseyshor suite with a thickness of 1400–1500 m [40].

The sample for the separation of zircons was taken from the chlorite-muscovite-albite-quartz schists of the base of the Miniseyshor suite from the outcrop on the Nyarshor stream, left tributary of the Nemuryegan River (sample 4–28). The zircons have various degrees of roundness, but very low rounded varieties of this mineral predominate. Isotopic studies of detrital zircons, as well as for zircons of the Puyva suite, were carried out by the U-Pb LA-

SF-ICP-MS method. 100 grains were analyzed from the monomineral zircon fraction at random. 21 analyzes with high discordance ($D \geq 10\%$) were excluded from our consideration. The zircon with the maximum dating showed Mesoarchean age — 2859 Ma, and with minimum dating — Late Neoproterozoic (Ediacarian) — 595.2 Ma. The main dataset, including 77 analyzes (or 97.5%), covers the interval 2028.1–660.1 Ma and has a polymodal distribution with maxima at 1700, 1225, and 700 Ma (Fig. 4, b). The age of zircons, determining the possible lower age limit for the formation of deposits of the Miniseyskor suite, corresponds to 660 Ma, i. e. the second half of the Neoproterozoic (Cryogenian) [47]. The younger age (595.2 Ma) was obtained for only one grain of the mineral, and it contradicts

the available geological data (the occurrence of deposits of the Miniseyskor suite below limestones of the Nemuryugan suite with microphytolites of the Neoproterozoic Uksk complex); this dating should probably be excluded from consideration. The relatively small thickness of the underlying sediments of the Verkhnekharbey suite (400–500 m) suggests that the lower age interval of the accumulation of rocks throughout the section of the Nyarovey series was limited to the Neoproterozoic. The low degree of roundness of the most of the zircons indicates close location of source areas. Such source areas could be metamorphic complexes and associated igneous formations, fragments of which are exposed in the modern erosional section in the Kharbey, Marunkeu and Malyk blocks in the Polar Urals.

Fig. 4. Histograms and probability density curves of the distribution of $^{207}\text{Pb}/^{206}\text{Pb}$ detrital zircon ages from terrigenous Meso-Neoproterozoic deposits of Timan and the Urals:

a, b — author's data; c — after Andreichev et al. [5]; d — after Udoratina et al. [46]; e — after Kuznetsov et al. [18]; f — after Romanyuk et al. [36]

Рис. 4. Гистограммы и кривые плотности вероятности U-Pb $^{207}\text{Pb}/^{206}\text{Pb}$ -возрастов детритовых цирконов из терригенных мезо-неопротерозойских отложений Тимана и Урала:

a, b — авторские данные; c — по Андреичеву и др. [5]; d — по Удуратиной и др. [46]; e — по Кузнецову и др. [18]; f — по Романюк и др. [36]

At the same time, the presence of well-rounded grains of this mineral indicates that the formation of deposits of the Miniseyshor suite could also be influenced by the products of erosion of distant rock associations.

Comparison of the received data with the results of zircon dating from the Upper Precambrian terrigenous deposits of Timan and the Southern Urals

Noteworthy is the certain similarity of the graphs of the age distribution of detrital zircons from the rocks of the Puyva and Miniseyshor suites in the northern part of the Urals and terrigenous deposits of the Middle and Northern Timan (Fig. 4, a, b, c, d). All these formations are characterized by an insignificant fraction or absence of zircons with Archean age and the predominance of zircons with modal values of isotopic ages in the intervals of 2.0–1.4 and 1.2–1.0 Ga.

Zircons of the Middle Paleoproterozoic (orosisian) age level could be eroded during the destruction of orogens that connected separate parts of the Volga-Uralia in the interval 2.1–1.8 Ga, such as the hypothetical Taratash orogen [19] and, possibly, an orogen in the northern part of the Volga-Uralia (in modern coordinates), the relics of which may be Paleoproterozoic metamorphic and granitoid complexes of the Kozhim and Sob transverse uplifts of the Subpolar and Polar Urals, respectively, as well as the Volga-Sarmatia orogen, which arose during the collision of the Volga-Uralia and Sarmatia. Endogenous formations of the Volyn-Central-Russian orogeny, resulted from the collision of the Volga-Sarmatia and Fennoscandia, could be sources of demolition of zircons of the Late Paleoproterozoic (statherian) age level. According to modern concepts, this event occurred in the interval 1.8–1.75 Ga as a result of the final assembly of the Columbia (Nuna) supercontinent [7]. During the formation of the basal deposits of the Polar Urals (Miniseyshor suite), the nearby metamorphic and magmatic complexes were the main sources of terrigenous material. This is evidenced, as noted above, by the predominance of weakly rounded zircon grains in the sample and their morphological features. The absence of zircons with Paleoproterozoic age in the Puyva suite from the Subpolar Urals, with the exception of one age value (1959 ± 52 Ma), with a high degree of roundness of the grains of this mineral, may be associated with the great remoteness of the main source areas and a high degree of erosion of local sources.

The Mesoproterozoic interval of zircon dating can be associated with the activity of mantle plumes during the collapse of the Columbia (Nuna) supercontinent [6]. On the eastern margin of the Volga-Ural part of the Baltic, occurrences of Mesoproterozoic plume magmatism, associated with active rifting, are distinguished in the Bashkir anticlinorium in the Southern Urals in the form of Navysh alkaline-basaltic volcanics [22]. Based on the results of local U-Pb dating of zircons, the age of these rocks is estimated at 1752 ± 11 Ma [16, 17]. Within the Timan-Northern Ural region we did not determine endogenous events of the «Navysh» time. These include only the activation of metamorphic processes in the Subpolar Urals, where zircons with an age of 1722–1660 Ma are dated in the Nyartın complex [24].

At the boundary of the Early and Middle Mesoproterozoic, the Mashak stage of rifting occurred on a large

scale. The U-Pb isotope age of zircons from rhyolites of the Mashak suite is 1385–1380 Ma [21]. Within the Timan-Northern Ural region, only a few isotopic ages of igneous and metamorphic rocks correspond to the Mashak stage. Thus, the Rb-Sr age of diorites in the basement of the Izhma zone of the Pechora plate (borehole 21-Pal'yu) is 1369 ± 56 Ma [45]. Single comparable U-Pb (SHRIMP-II) ages of metamorphogenic zircons were obtained from the rocks of the Nyartın metamorphic complex of the Subpolar Urals — 1370 ± 10 Ma [24] and the Mikulkin metamorphic complex at the Kanin Peninsula — 1372 ± 17 Ma [23].

Zircons with isotopic ages of 1.2–0.9 Ma can be associated with the rock complexes of the Svekonorwegian orogenic belt. The modal values in this interval are well pronounced on all plots of zircon ages from the deposits of the Subpolar and Polar Urals, Northern and Middle Timan (Fig. 4, a, b, c, d). This age level of endogenous activation was clearly manifested in the rocks of many Ural metamorphic complexes [34], from which terrigenous material could also partially come during the formation of Neoproterozoic sediments in the northern part of the Urals.

In the geochronological aspect, perhaps the only significant feature of the Subpolar and Polar Ural Upper Precambrian, which distinguishes it from the Upper Precambrian deposits of the Northern and Middle Timan, is that detrital zircons with Neoproterozoic isotopic age play a significant role here: 23 % in the Puyva suite and 19 % in the Miniseyshor suite. This may indicate a later time of the formation of basal sediments of the Upper Precambrian in the Subpolar and Polar Urals in comparison to the Northern and Middle Timan or, most likely, a higher degree of erosion of the sources of demolition of the Timan terrigenous complexes.

The distribution of the ages of detrital zircons from the Neoproterozoic terrigenous deposits of the Southern Timan (Dzhezhim suite) differs from the observed distribution pattern of zircon dates from the rocks of the strata considered above (Fig. 4, e). During the formation of the Dzhezhim suite, the main role was played by the products of erosion of the Archean and Paleoproterozoic complexes. A certain similarity is found when comparing the ages of detrital zircons from sandstones of the Dzhezhim suites and deposits of the same age of the Lemezín sub-suite of the Zilmerdak suite of the Bashkir anticlinorium in the Southern Urals (Fig. 4, e, f). As applied to the Southern Ural Neoproterozoic deposits, it is assumed that the Volga-Sarmatia and Taratash orogens were the main source of the Early Proterozoic zircons [19]. This is probably also true for the deposits of the Dzhezhim suite. The higher role of the Archean population of zircons in the Southern Ural sections of the Neoproterozoic in comparison to the Southern Timan ones is most likely associated with the proximity to the first of the Archean complexes of the basement of the Volga-Ural part of the Baltic. The presence of Mesoproterozoic detrital zircons in the Dzhezhim suite (considering absence of such zircons in the Lemezín sub-suite) indicates that during the accumulation of the Neoproterozoic deposits of South Timan, the terrigenous material also came from other source areas, possibly the same ones that participated in the formation of the Neoproterozoic strata of the Middle and Northern Timan, Subpolar and Polar Urals.

Conclusion

The established minimum age of detrital zircons from terrigenous basal deposits of the Upper Precambrian of the Subpolar and Polar Urals: about 900 and 660 Ma, respectively, along with the available data on the age limits of the Upper Precambrian of different regions of the Timan-Northern Ural region, suggest absence of Mesoproterozoic deposits. It is most likely that the Timan-North Ural Upper Precambrian begins with the Lower Neoproterozoic (tonian) deposits. Similarity of the graphs of the age distribution of detrital zircons from the rocks of the Puyva and Miniseysk suites in the northern part of the Urals and terrigenous deposits of the Middle and Northern Timan indicates that they were formed by the same sources, which, most likely, were Baltic pre-Neoproterozoic structural-material complexes. The absence of Mesoproterozoic deposits here can be explained by a high standing of the territory of the north-eastern Baltic in the Mesoproterozoic time and its location in the inner part of the Columbia (Nuna) fragment, which escaped destruction until the Baltic entered Rodinia. This explanation supports the hypothesis of the existence of a transproterozoic supercontinent (a fragment of Columbia) that transformed into Rodinia [10, 11]. Thus, the establishment and development of the Timanids in the north-eastern margin of the Baltic is associated with the evolution of Rodinia.

New data on the age limits of the Upper Precambrian of the north of the Urals can be used for paleogeodynamic reconstructions and to clarify processes of assembly-disintegration of supercontinents in the Proterozoic period (2500–540 Ma) of the Earth evolution.

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