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GEOLOGY

EVIDENCE OF THE EARLY PRECAMBRIAN AGE OF METAMORPHIC ROCKS OF THE UFALEY BLOCK (MIDDLE URALS): RESULTS OF U-Th-Pb (LA-ICP-MS) DATING OF DETRITAL ZIRCON FROM QUATERNARY DEPOSITS

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Abstract. U-Th-Pb (LA-ICP-MS) geochronological studies of detrital zircon from the Quaternary deposits of the western part of the Ufaley block in the Middle Urals, in a tectonic fragment composed of amphibolite-gneiss complex and associated bodies the Precambrian clinopyroxenites, were performed. The main statistical age maximum corresponds to the range of 2100-2000 Ma. Several small peaks correspond to the range of 3200-2500 Ma. So there is the real reason to believe that rocks of the Early Precambrian age are present within the Ufaley block. They were not previously identified here.

Keywords : *detrital zircon, U–Th–Pb isotope studies, quaternary deposits, age of the substrate*

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The modern appearance of the Uralian Orogen was formed as a result of time-varying geodynamic regimes, from the destruction of an ancient platform, through the development of an oceanic basin, to subduction and subsequent collisional and post-collisional events. As a result of these processes, an accretion zone consisting of blocks of different ages and origin was formed in the area of the junction of the Uralian Orogen with the East European Platform (EEP) [1]. In particular, there are blocks in the structure of which rocks of Early Precambrian age are involved. In the Southern Urals, these are the Taratashsky and Alexandrovsky blocks (the rock types composing these blocks are often described in the literature as complexes of the same name), which are considered fragments of the EEP integrated into the structure of the Uralian Orogen ([2, 3, 4], etc.). These blocks are composed mainly of granulites, gneisses, and amphibolites, which contain zircon with a U–Th–Pb age of 2800-2500 Ma, and the model Nd age of the rocks reaches 3.5 billion years [4, 5]. Structural metamorphic transformations of the rocks of these blocks occurred in the intervals of 2460–1800, 1350–1200 Ma and further up to 300 Ma [3-5].

In the post-collisional structure of the Paleo-Uralian Hercynian orogen, the Ufaley block (UB) is located at the same latitude as the Taratashsky and Alexandrovsky blocks, but somewhat to the east, which is the southern part of the anticlinorium of the same name. The UB is bounded on the north by the Kukazar fault, which separates it from the northern part of the Ufaleysky anticlinorium, on the east by the Main Uralian Fault zone (MUF), and on the west by the Ufa fault.

The eastern part of the UB, adjacent to the MUF, is composed of schists, amphibolites, quartzites, and eclogite-like rocks of the Kurtinskaya Formation, while the western and central parts consist of amphibolites and gneisses of the Yegustinskaya and Slyudyanogorskaya Formations (Fig. 1). The age of metamorphism of the latter two formations is estimated to be in the range of 550–480 Ma [6–8], although on the geological map they are assigned to the Proterozoic, and the Kurtinskaya Formation to the Middle Riphean [9]. Reliable geochronological data confirming the Precambrian age of the UB rocks and a consensus on their nature do not yet exist [1, 6–8].

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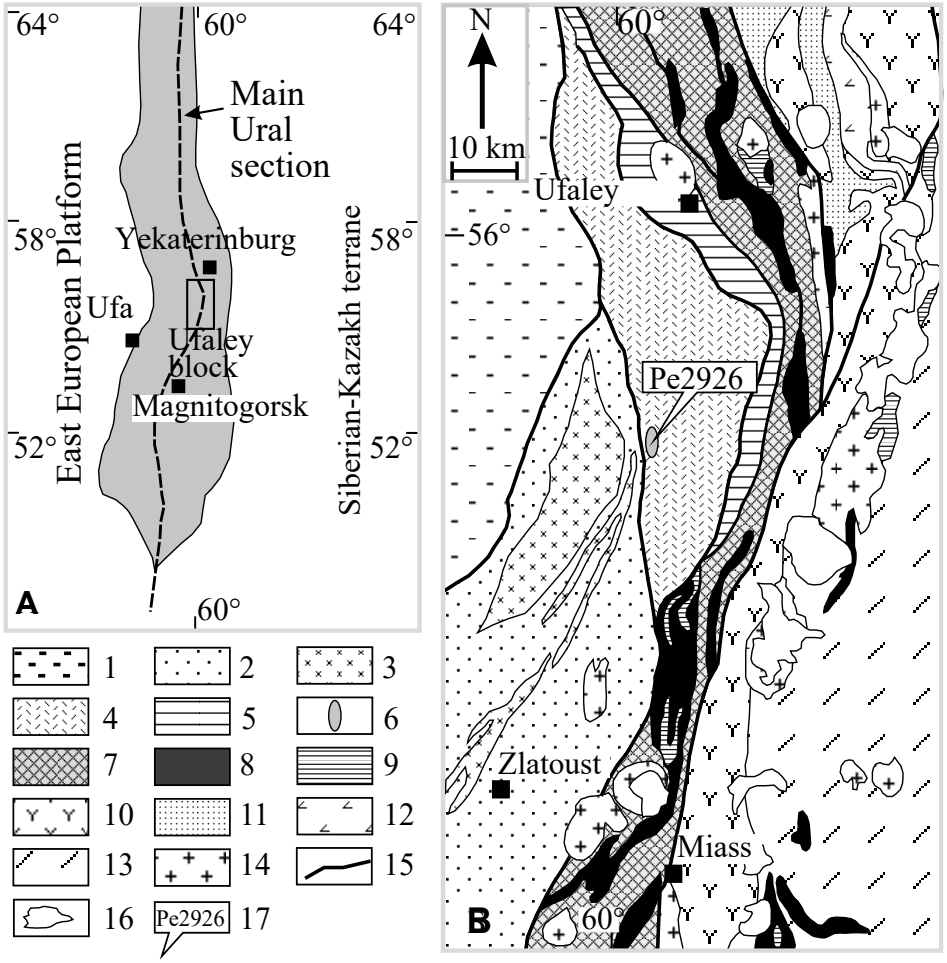

Fig. 1. Geotectonic position (A) and simplified geological structure scheme (B) of the Ufaley Block [1, 2]. 1 – Paleozoic sedimentary cover complexes of the East European Platform; 2 – Proterozoic sedimentary complexes, 3 – Taratash and Alexandrovsky blocks (AR-PR), 4–5 – Ufaley Block: 4 – amphibolites and gneisses of the Egustinskaya and Slyudyanogorskaya Formations, undivided; 5 – eclogite-schist Kurtinskaya Formation; 6 – pyroxenites of Shigir Hills; 7–9 – zone of the Main Uralian Fault with fragments of Magnitogorsk and Tagil island arc complexes (7), serpentinized ophiolites (8) and gabbroids (9); 10–12 – complexes of the Sysert-Ilmenogorsk anticlinorium: 10 – metamorphic and alkaline rocks, 11 – metasedimentary rocks, 12 – metavolcanic rocks; 13 – Middle-Upper Paleozoic sedimentary-volcanogenic rocks with ultrabasic bodies (also sign (8)); 14 – diorites and granodiorites; 15 – tectonic faults; 16 – lakes; 17 – number and position of detrital zircon sample.

In the western part of UB, along the right bank of the Ufa River, in a fragment bounded on all sides by faults, among gneisses and amphibolites of the Yegustinskaya Formation, there is a submeridional body (4 x 0.5 km) of orthopyroxene-plagioclase-olivine clinopyroxenites, expressed in the relief as the northern and southern Shigir Hills (SH), separated by a sublatitudinal valley of a temporary watercourse. The geological relationships of pyroxenites with surrounding rocks have not been established. Pyroxenites have petrogeochemical similarities with the same-named rocks from dunite-clinopyroxenite-gabbro complexes of the Ural-Alaskan type. It is assumed that the original melt for them had ankaramite characteristics: a high CaO/Al2O3>1 ratio, indicating a wehrlitic composition of the mantle source [10]. According to data from A.A. Krasnobaev et al., the U–Pb age of the oldest zircons from the SH pyroxenites corresponds to 1651±47 and 1444±46 Ma [11], based on which the Paleoproterozoic age of the rocks was accepted, as recorded on the geological map [9]. However, these works do not discuss the probability that ancient zircons could have been captured during the intrusion of the SH pyroxenites. It is significant that in rocks of similar composition

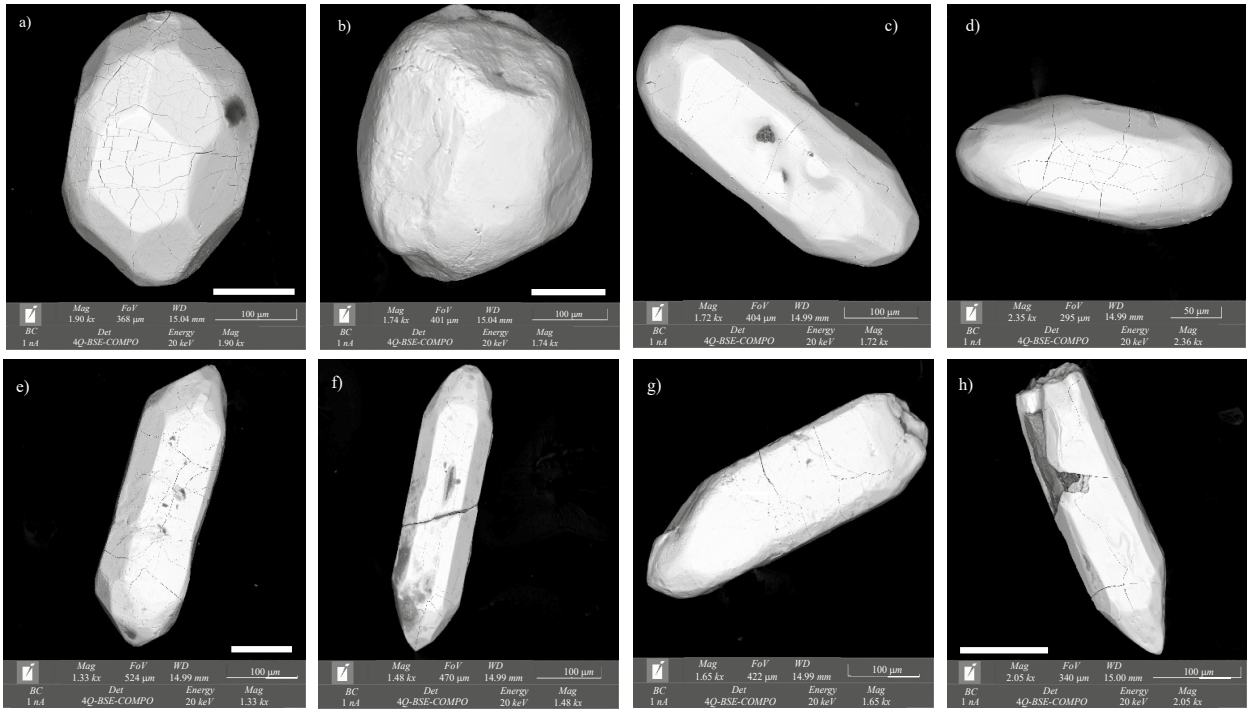

Fig. 2. Morphology of detrital zircon grains from Quaternary gravel-clay deposits surrounding the pyroxenites of Shigir Hills. Scanning electron microscope Mira Tescan, backscattered electron mode.

in the Alexandrovsky block [12], an older U–Pb zircon age of 2022±15 Ma was determined, and an Archean age of the protolith is assumed [5, 13]. Even if we assume the xenogenic nature of zircon in the SH pyroxenites, we can suggest the presence of Early Precambrian metamorphic rocks in their frame, which had not been previously established.

To verify this assumption, a U–Th–Pb (LA-ICP-MS) age determination of detrital zircon was performed from Quaternary clay-gravel deposits of the dry bed of a temporary watercourse in a sublatitudinal valley about 1 km long, separating the pyroxenites of the Northern and Southern Shigir Hills. The drainage area of the watercourse captures both the ultramafic rocks themselves and the directly enclosing gneisses and amphibolites of the Yegustinskaya Formation. The introduction of material from distant sources is not excluded but unlikely.

Research was conducted at the "Geoanalytik" Shared Research Facility, IMG UB RAS, Yekaterinburg. The morphology and internal structure of zircon were studied using a TESCAN MIRA scanning electron microscope in backscattered electron and cathodoluminescence modes. U–Th–Pb isotope studies were performed on a NexION 300S quadrupole ICP-MS with a NWR 213 laser ablation attachment (LA-ICP-MS). The crater diameter was 25 μm, pulse repetition rate 10 Hz, energy density 10–11 J/cm². Calibration was performed using the standard zircon GJ-1 [14]. Standard zircon crystals 91500 and Plešovice were used to control the quality of analytical data. During the studies, weighted average age estimates were obtained for the ratio $^{206}Pb/^{238}U$– $^{207}Pb/^{235}U$: for standard 91500, 1065±5.8 Ma (1σ, *n*=8, MSWD=0.00079, probability=0.98), for standard Plešovice, 337.9±1.6 Ma (1σ, *n*=9, MSWD=0.078, probability=0.38). The age values obtained for zircon standards are consistent with the recommended data [15]. U–Th–Pb isotope ratios were calculated using GLITTER 4.0 GEMOC software [16]. Corrections for common lead were made using the ComPb program [17]. Calculation of concordant ages (Concordia Ages) was performed using IsoplotR software. When constructing histograms, relative probability distribution curves of ages, and calculating peak ages (Peak Ages) [18], only concordant age estimates (D</5/) were taken into account (Analysts V. S. Chervyakovsky, M. V. Chervyakovskaya). The results of isotopic studies are presented in the supplementary materials to the article (Suppl. Table 1).

Detrital zircon is represented predominantly by large (600–200 μm) slightly rounded grains and unrounded crystals, with short- and long-prismatic habits (K_{el} = 0.5–2 and 3–5, respectively) (Fig. 2).

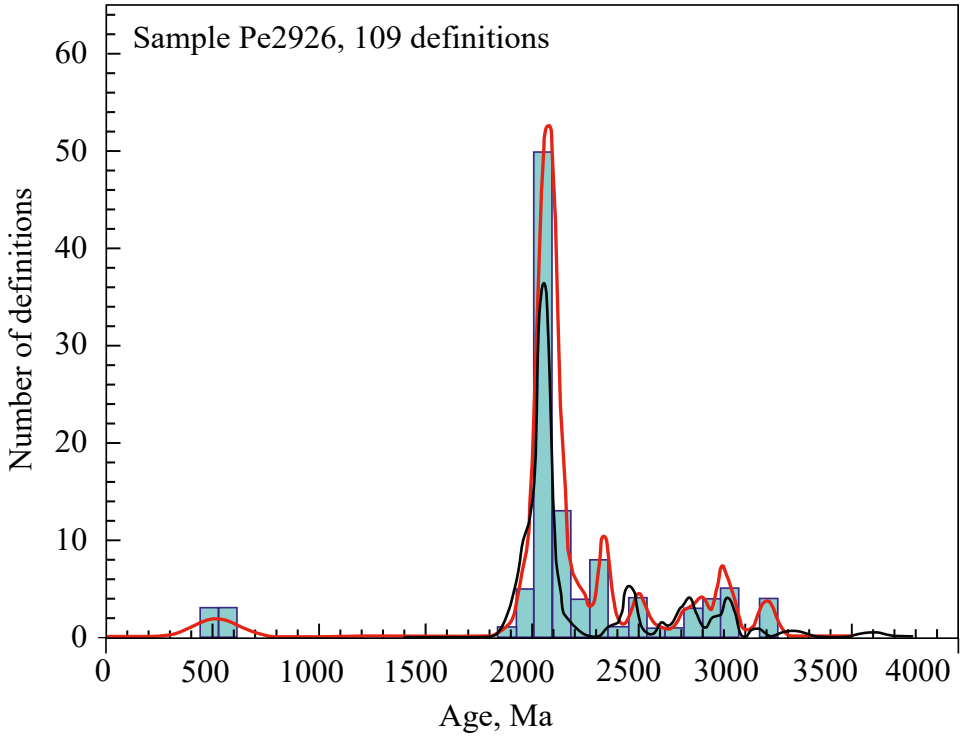

Fig. 3. Histogram of distribution and relative probability curve (red line) of detrital zircon ages from Quaternary deposits of the Ufaley block (n =109). Black line is the relative probability curve of detrital zircon age distribution from sandstones of the Ai Formation of the Riphean [19].

Reddish-brown and dark tea-colored grains strongly predominate; pink and pale yellow individuals are also found. Prism faces {100}, {110} and dipyramid {111} are developed. The internal structure of most grains is characterized by cores surrounded by zonal shells. Inclusions of quartz, potassium feldspar, apatite, phlogopite, monazite, and rutile are found in the zircon.

176 zircon grains were used for isotope-geochronological studies, from which 253 age estimates were obtained from cores and shells. 109 of them are concordant (D</5/), and 22 are sub-concordant (5%<D<10%). The relative probability curve of age distribution shows a main peak at 2100–2000 Ma, which includes about 30% of all determinations, and several weakly expressed peaks in the range of 3200–2500 Ma (Fig. 3). Individual zircon grains have ages of 570–485 million years, corresponding to the time of metamorphism in the UB, synchronous with the Timanian orogeny in the Urals [1, 7]. It should be noted that among the studied zircon grains, there are no samples with ages of 1650–1400 Ma, previously established in pyroxenites of SH [11]. This may be due to low zircon content in ultramafic rocks and the flotation size (less than 50–60 μm) of its grains, which prevents accumulation in sedimentary rocks.

Thus, in the Quaternary deposits from the tectonic fragment in the western part of the UB, where clinopyroxenites of Precambrian age occur among the amphibolite-gneiss strata, detrital zircon with an age of 2100–2000 Ma predominates. This interval corresponds to the time of granulite metamorphism and migmatization in the Taratash and Alexandrovsky blocks, the rocks of which served as a source of detrital zircon for sandstones at the base of the Ai Formation of the Riphean [4, 5, 19]. In our case, the transport distance was insignificant, and the source of clastic material is predominantly the rocks of the UB directly surrounding the clinopyroxenites of the Shigir Hills. The obtained results suggest that the structure of the UB contains metamorphic rocks of Early Precambrian age, which had not been previously established. The presence of Proterozoic clinopyroxenites here enhances the similarity in geological structure and evolution of the Ufaley block with the Taratash and Alexandrovsky fragments of the East European Platform, exposed in the structures of the folded Urals.

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