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GEOLOGY

First Results of U/Pb Dating of Detrital Zircons from Middle Riphean Sandstones of the Zigalga Formation, South Urals

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Abstract—The results of U/Pb dating of detrital zircons from sandstones of the Zigalga Formation, which is the base level of the Middle Yurmatu Group of the Bashkir uplift, southwestern Urals, are presented. The U/Pb ages of detrital zircons from sandstones of the Lower, Middle, and Upper Riphean are compared.

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In the Bashkir uplift (BU), which is located in the southwestern Urals, a thick (up to 12–15 km) complex of terrigenous, carbonate, rarely volcanic and volcanic–sedimentary rocks of a stratotypical Riphean sequence occurs between Early Precambrian rocks of the Taratash Complex [11] and the Asha Group of either Upper Vendian [6] or Upper Vendian–Middle Cambrian [3] age; it is subdivided into three series, from bottom to top: Burzyan, Yurmatu, and Karatau [5–7]. Presently, the degree of geological knowledge of the units mentioned is comparable to that characteristic of the other most well-known Upper Precambrian sedimentary sequences. In recent years, these data have been supplemented with analytical results of U/Pb isotope age studies of detrital zircons in order to obtain fundamentally new information about the provenance area and to test the paleotectonic reconstructions. The present work describes the results of U/Pb dating of detrital zircons from sandstones of the Zigalga Formation, which is the basic subdivision of the Yurmatu Group (Middle Riphean type) in the northeastern BU.

Sample K13-019 (~1.5 kg in weight) was collected on the upper edge of the southern side of the Irkuskan quarry (54°54′52.63″ N, 58°50′31.53″ E), from light-colored quartz sandstones. By using the technique from [4], we extracted ~300 zircon grains. We conducted 80 analyses for 79 grains (the technique is described in [13]). For one of the large grains (no. 136), where the core and rim are seen in the CLI image, two analyses were made (no. 136C and no. 136R) and identical results within the limits of error were obtained: 2481 ± 12 (D = 2.6%) and 2474 ± 20 (D = 3.7%) Ma. For 15 analyses, the discordance of U/Pb ages appeared to be >10% (Fig. 1); these data were not used further. The minimal U/Pb age was obtained for grain no. 113 (1697 ± 18 Ma; D = 7%), and the maximal one, for grain no. 24 (3137 ± 10 Ma; D = –2.5%).

Comparison of the U/Pb ages of zircons from sandstones of three levels of the Riphean standard sequence demonstrates a gradual decrease in the amount of Early Proterozoic grains over time (Fig. 2). In sandstones of the Lower Riphean, they dominate and their ages are mainly >2 Ga [2, 8]. In sandstones of the Middle Riphean, the fraction of early Proterozoic grains is comparable to that of Archean grains, and more than half of the Early Proterozoic grains are <2 Ga in age. In sandstones of the Upper Riphean, Archean zircons are predominant [9, 10].

The early stages of evolution of the Riphean sedimentary basin, relics of which are seen in the present-day structure of the BU (hereinafter, we will refer to this basin as the East Bashkir Basin, or briefly EBB),

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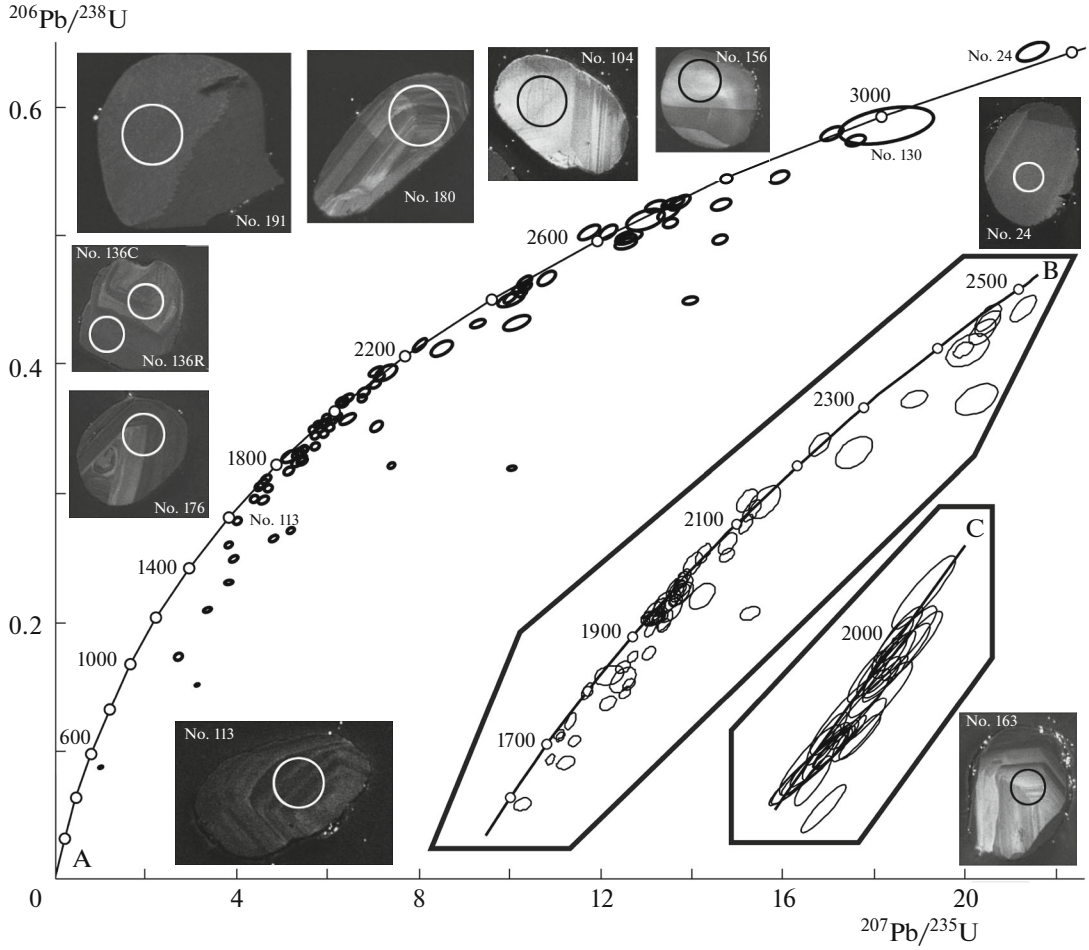

Fig. 1. Results of studying the U–Th–Pb isotope system in detrital zircons from sample K13-019: (A) concordia and ellipses showing 95% confidence interval of measurements for all analyses; (B) and (C) are enlarged fragments of concordia. In insets are the CLI images of some studied zircons from sample K13-019 (136C and 136R are analyses for the core and rim of grain no. 136, respectively). The diameter of the crater is 40 μm.

correspond to the final stages of evolution of the supercontinent Columbia. The part of Columbia corresponding to the Baltica continent incorporated the Kola, Karelia, Sarmatia, and Volgo-Uralia blocks (protocratons) of Archean age, as well as the Svecofennian block formed at the beginning of the Early Proterozoic (Fig. 3). Protocratons were sutured by Early Paleoproterozoic orogens, including the Volgo-Sarmatian orogen (VSO), which formed resulting from the collision between Volgo-Uralia and Sarmatia. The uncertainty in the data on which the positions of protocratons in the structure of Columbia are based (correlation of Early Proterozoic fold belts and paleomagnetic studies) leaves great freedom in the interpretation of their configurations; e.g., some reconstructions attribute the Varanger–Timan–Uralian margin of Columbia to be a passive margin [15], whereas the others place it bordering with Siberia [14]. In Fig. 3, the possible crustal block bordering with Volgo-Uralia as part of Columbia is indicated as Peri-Volgo-Uralia.

It is obvious that only Columbian protocratons could be primary sources of Archean zircons in sandstones from basal level of all three Riphean groups of the EBB. The U/Pb isotope ages themselves do not allow us to find exactly which craton provided the clastic material. Nevertheless, data on Hf isotopes from detrital zircons of Lower and Upper Riphean sandstones mark very ancient (>3.5 Ga) crustal model ages of source rocks for these zircons; hence, we can consider with quite high confidence that the sandstones contain destruction products of basement rocks of the Volgo-Uralian part of the East European Craton (EEC) [8, 9].

The virtual coincidence of the most ancient age peaks for Lower and Middle Riphean sandstones (2476 and 2477, 2760 and 2736, 2942 and 2936 Ma, respectively) gives us grounds to suppose that Archean zircons in sandstones of the Zigalga Formation are most likely rewashing products from Lower Riphean

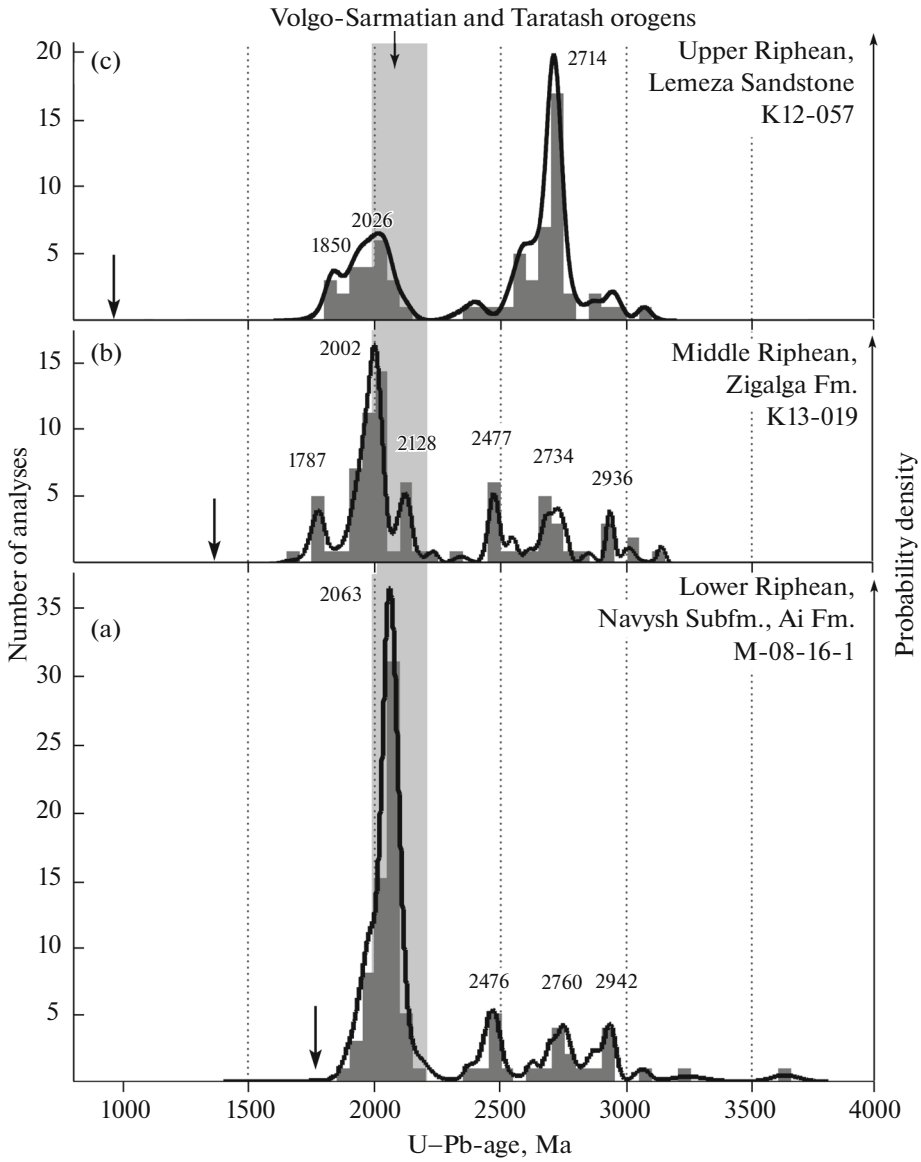

Fig. 2. Aggregated results of dating studies of detrital zircons from basal levels of (a) the Lower [2], (b) Middle (present work), and (c) Upper [10] Riphean of the BU. Arrows indicate the approximate sedimentation ages of the sandstones studied.

deposits of the BU, rather than products of direct washing of Archean complexes of Columbia.

The main primary source of Paleoproterozoic zircons in the Riphean strata of the BU were seemingly orogens of the same age. At present, there are many available dates for crystalline rocks from Paleoproterozoic orogens within the limits of the Siberian, Laurentian, and Baltic parts of Columbia (Fig. 3): the most characteristic dates among them are <2.0 Ga and only in the case of the VSO, which is the oldest among them and nearest to the BU, were ages of 2.1–2.0 Ga obtained. In the northeastern BU, the Taratash complex also contains intensively metamorphozed (up to granitization) Archean rocks hosting Early Proterozoic post-tectonic granitoids [6]. We consider all these rocks relics of the Taratash orogen (TO) of Paleoproterozoic age, which had not been distinguished earlier and has characteristic magmatism and metamorphism ages of 2.1–1.8 Ga (see overview in [11]). Since zircons with U/Pb ages >2 Ga dominate in Lower Riphean sandstones of the EBB, we can quite reliably think that the VSO and TO were their sources.

By approximately 1.7–1.75 Ga B.P., foundation of aulacogens had begun in the EEC; they inherited Early Proterozoic orogens [12], which were considerably eroded by that time. In particular, the Middle Russian aulacogen (MRA) formed along the Volyn–Central Russian orogen; the Pachelma aulacogen (PA), along the VSO; and the Kama-Belaya aulacogen (KBA), along the TO. The KBA began its devel-

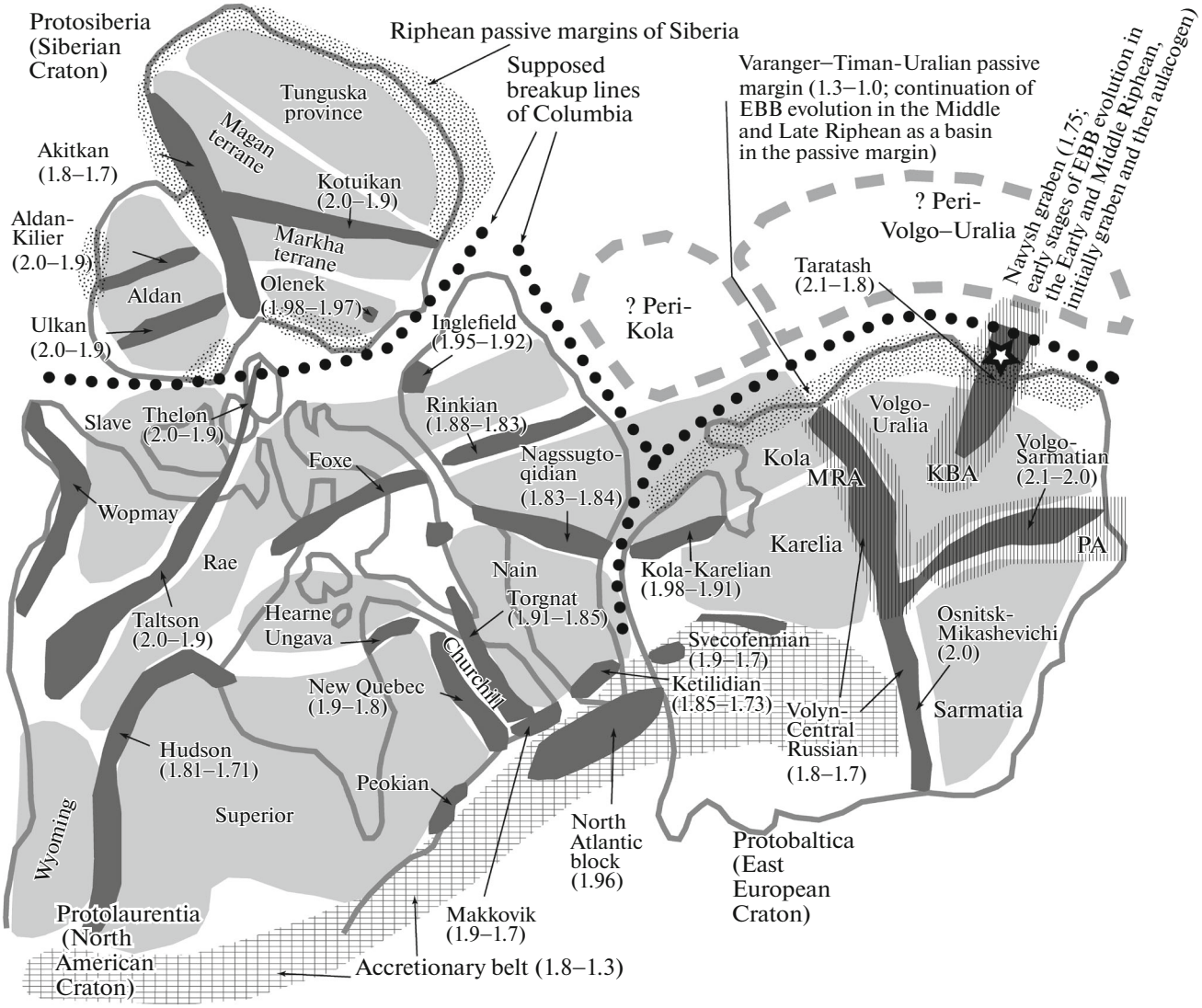

Fig. 3. Fragment of arrangement of Archean blocks/protocratons (light gray) linked by Paleoproterozoic orogens (dark gray) within the structure of Columbia (Nuna) supercontinent (boundary of the Paleoproterozoic and Mesoproterozoic), including Protobaltica, Protolaurentia, and Protosiberia, after [15]. Numerals mean ages in Ga. The approximate position of the BU is shown by a star. Aulacogens: PA, Pachelma; KBA, Kama-Belaya; and MRA, Middle Russian.

opment as the Navysh graben [1], and the basal strata of its filling accumulated sandstones of the Ai Formation. Throughout the entire Riphean, the MRA and PA acted as elongated sedimentation traps for detrital material from Sarmatian and other parts of the EEC located far from the EBB. This is verified by the fact that even singular zircons with ages corresponding to those of crystalline complexes from parts of the EEC located far from the BU, e.g., plutons of Sarmatia (Korosten', New Ukrainian, and others [12]) and rapakivi granites of the Svecofennian domain, are absent in Riphean strata of the BU.

The breakup of Columbia led to separation of Protobaltica from its structure and to foundation of the Varanger–Timan–Uralian passive margin. By the beginning of the Middle Riphean, crystalline complexes in the part of the TO that later became the basement of the KBA and that after the breakup of Columbia entered the structure of the eastern Volgo-Uralian domain of Protobaltica appeared to be covered by a complex of terrigenous and carbonate deposits of ~5 km thick [5]. In this respect, the presence of early Proterozoic detrital material in sandstones of the Zigalga Formation could have been caused by the following fact: part of the eroded material from the VSO and TO (probably a considerable part) initially accumulated in submontane troughs, coupled with these orogens, and only later was it recycled in the EBB. This mechanism was likely valid in part for psammites of the Ai Formation.

In the beginning of the Late Riphean, Protobaltica became a part of Rodinia [12]. By this time, the provenance areas from which erosion in the Early and Middle Riphean provided the filling of the EBB had changed significantly: relics of the VSO and TO ceased to be the primary sources of detrital material (large sedimentary basins/aulacogens had existed for a long time in their places), while Archean crystalline complexes were removed to erosion areas, e.g., in Upper Riphean sandstones of the BU, zircons with ages of ~2.7 Ga dominate, and the isotope-geochemical peculiarities of these zircons coincide with those of quartz diorites from the Bakaly block of Volgo-Uralia [9].

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