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GEOLOGY

First Results of U–Pb Dating of Detrital Zircons from the Ordovician Clastic Sequences of the Sol-Iletsk Block, East European Platform

N. B. Kuznetsov[a,b,c,d], V. M. Gorozhanin[e], E. A. Belousova[d], Corresponding Member of the RAS K. E. Degtyarev[a], E. N. Gorozhanina[e], T. V. Romanyuk[b,c,d]*, and N. A. Kanygina[a]

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Abstract—The first LA–ICP–MS U–Pb isotopic ages of detrital zircons from the Ordovician sandstones of the Sol–Iletsk Block (well 2–Ordovician), located at junction of the East European Platform with the Pre-Caspian Basin and the Pre-Uralian foredeep, are presented. Two detrital zircons with well-defined ages of 561 ± 4 and 570 ± 5 Ma were found in sample K15–501. They confirm the Ordovician age of the sandstones, which earlier had been defined on the basis of seismic–stratigraphic and lithological correlations. The age distribution of the detrital zircons indicates the significant role of Late Precambrian rocks as provenance sources. However, those rocks still remain unknown in the Early Precambrian basement of the Volga–Ural part of the EEP.

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The Sol–Iletsk Block is at the extreme southeastern edge of the East European Platform (EEP), bordering to the Pre-Caspian Basin and the Pre-Uralian foredeep (Fig. 1). The Ordovician rocks in the area occur at a considerable depth (2.5–3 km) under Upper Devonian and younger sediments and have been drilled with numerous wells. The Ordovician section has a threefold structure and thickness of more than 2000 m. Its upper part is composed of mudstones, siltstones, and sandstones; the middle part is dominated by sandstone, sometimes interbedded with siltstones and mudstones; the bottom part is comprised of quartzite-like sandstones [1, 2, 3, 8, 9]. The Ordovician age of those clastic rocks is confirmed by findings of fossils: Middle–Late Ordovician acritarchs (wells 28–Krasnokholmsk and 16–Krasnoyarsk), Middle Ordovician trilobites (well 1–Krasnoyarsk), and conodonts and chitinozoas of Early–Middle Ordovician (well 102–West Orenburg) and Ordovician brachiopods (well 17–Ordovician) [2, 3, 9, 13]. In wells 1– and 2–Ordovician, no fossils in the Ordovician rocks have been found. Their age is defined on the basis of seismic stratigraphic and lithological correlations [3, 8]. The Ordovician strata are underlain by Riphean and Lower Vendian clastic rocks (well 619–Salmysh; 301–, 307–, 311–Olshansk; 1–Ordovician), and the latter, in turn, rest upon the Early Precambrian metamorphic rocks (well 77–Zemlyansk) [1, 2, 8].

The Ordovician period was the time when paleoocean basins began to open: their relics now occur in the Southern Urals [3, 10, 12]. It is assumed that, in the conjugated parts of the EEP and in the western part of the Southern Urals, accumulation of Ordovician strata took place in grabens that inherited the position of Riphean aulacogens and that were emplaced at the opening of the Paleo–Urals ocean [2, 3]. Massive quartzitic sandstones in the lower part of the Ordovician section in the Sol–Iletsk Block are likely to occur at the base of the syn–rift transgressive complex. The Ordovician paleogeographic environment of sediment accumulation, in general, can be characterized as a shallow–marine (littoral) zone of a clastic shelf with variable hydrodynamics and a trend to deepen eastwards and southeastwards (herein and below are in present day coordinates).

To determine the source of provenance of the Ordovician clastic rock in the Sol–Iletsk Block, we

[a] *Geological Institute, Russian Academy of Sciences, Pyzhevsky per. 7, Moscow, 109017 Russia*
[b] *Schmidt Institute of Physics of the Earth, Russian Academy of Sciences, ul. B. Gruzinskaya 10, Moscow, 123810 Russia*
[c] *Gubkin Russian University of Oil and Gas, Moscow, Russia*
[d] *Australian Research Councul Centre of Excellence for Core to Crust Fluid Systems, GEMOC Centre, Macquarie University, Sydney, Australia*
[e] *Institute of Geology, Ufa Science Center, Russian Academy of Sciences, ul. Karla Marksa 16/2, Ufa, 450077 Russia*
* *e-mail: romanyuk@mail.ru*

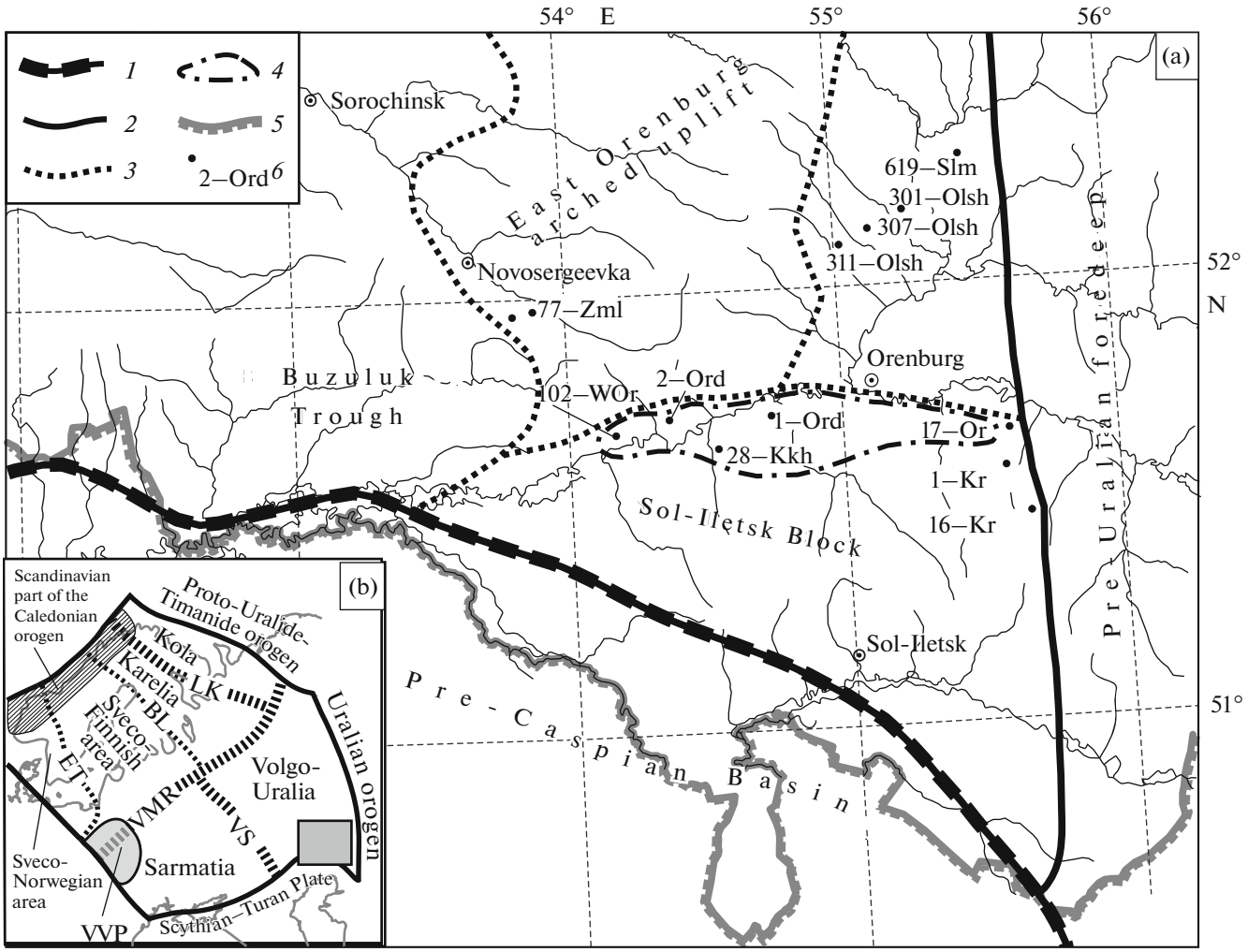

Fig. 1. Scheme of the southeastern part of the East European Platform and its junction with the neighboring structures (a). The inset (b) shows the segmentation of the basement of the East European Platform, its frame structures, and the position of sketch (a) *1–2*, Boundary of the East European Platform with the Pre-Caspian Basin (*1*) and the Pre-Uralian foredeep (*2*); *3*, the boundaries of tectonic units recognized within the southeastern part of the East European Platform; *4*, outlines of the Orenburg Block; *5*, the border of Russia and the Republic of Kazakhstan; *6*, position of the wells and their numbers (1–Ord, well 1–Ordovician; 2–Ord, well 2–Ordovician; 17–Op, well 17–Orenburg;. 102–WOr, well 102–West–Orenburg; 28–Kkh, well 28–Krasnokholmsk; 1–Kr, well 1–Krasnoyarsk; 16–Kr, well 16–Krasnoyarsk; 77–Zml, well 77–Zemlyansk; 301–Olsh, well 301–Olshansk; 307–Olsh, well 307–Olshansk; 311–Olsh, well 311–Olshansk; 619–Slm, well 619–Salmysh). (b) Dotted stripes and lines are orogens and sutures separating domains of the EEP basement; shaded area, the Scandinavian part of the Scandinavian Greenland Caledonian Orogen. Orogens: VS, Volga–Sarmatian; LK, Lapland–Kola; VMR, Volyn–Middle Russian; Suture Zones (tectonic sutures): BL, Bothnia–Ladoga; ET, Gothian–Älv; VVP, Volyn Volcanic Province.

analyzed detrital zircons from the sandstone from the 2–Ordovician well. The sample K15–501 was collected from the core at a depth of 3439.7 m from a layer of sandstone, occurring at the base of the upper part of the Ordovician section. The sandstone is represented by a light-colored non-layered poorly sorted medium- to fine-grained rock with poorly rounded fragments, mainly of quartz, with less frequent quartzite debris and individual small flakes of white mica. Accessory minerals are zircon and opaque minerals.

The zircon grains, separated from the K15–501 sample, are characterized by variable colors, sizes up to 150 μm, and a prominent roundness. Zircon analysis was carried out at the GEMOC Centre (Macquarie University, Sydney, Australia). A description of the equipment employed, techniques, and decay constants used for acquiring and treatment of primary analytical data was published earlier [15].

U/Pb zircon isotope system was analyzed in 120 grains (Fig. 2). For 32 of them the obtained U–Pb data are highly discordant ($|D| > 10\%$): they are not considered in the further discussion. One grain (number 33) gave concordant but unexpectedly old result of 4662 ± 39 Ma ($D = -0.41\%$). This result requires further examination and confirmation, which was not an aim of our research objectives. Therefore, this result

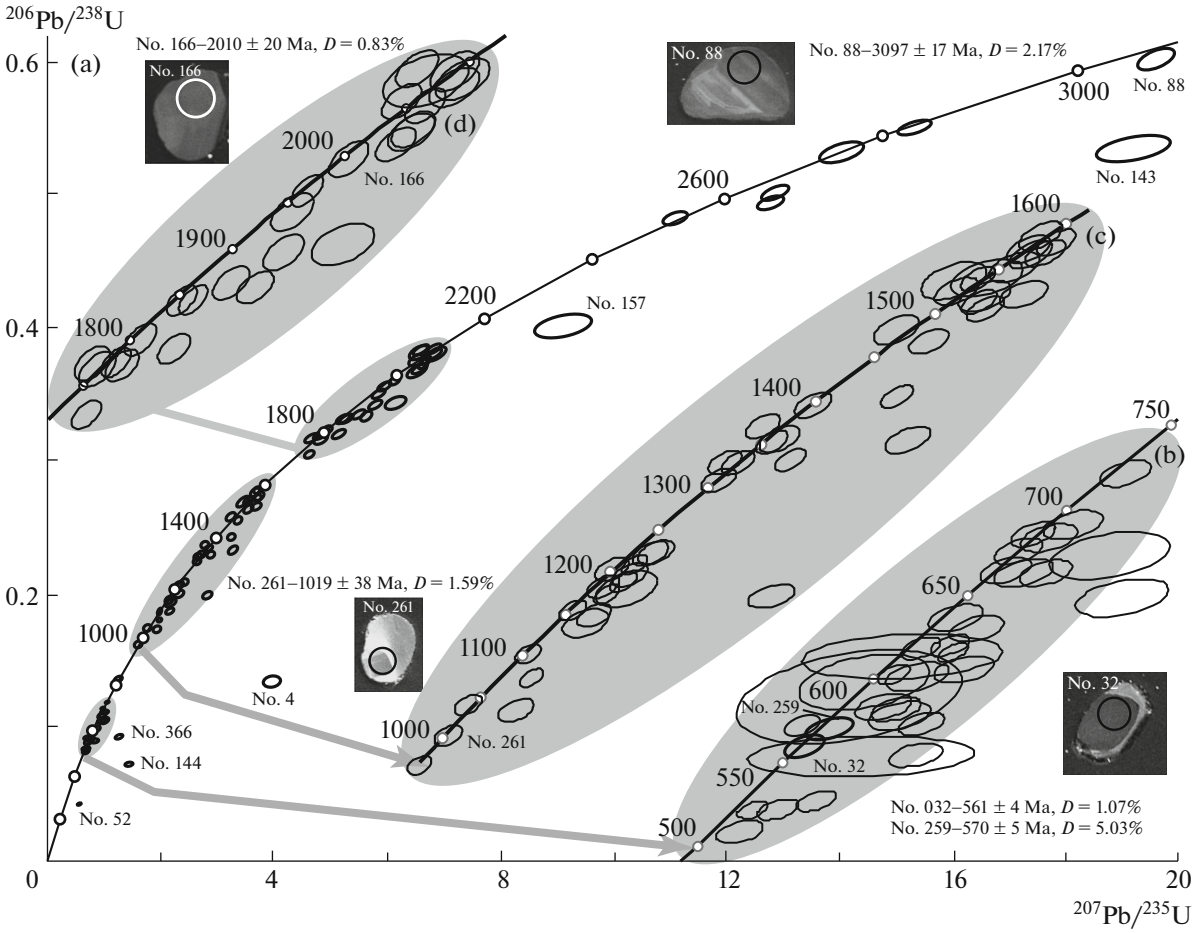

Fig. 2. The Arens–Wetherill diagram with concordia for detrital zircons from the Ordovician sandstone (K15–501 sample) well 2–Ordovician (depth 3439.7 m), drilled within the Sol–Iletsk Block (a) and detailed parts of the different segments of the concordia (b, c, d). Selected representative cathodoluminescent images of the studied zircons are demonstrated in the margins.

has also been omitted. The remaining 87 dates have been used to construct a histogram and Probability Density Curve (Fig. 3). To calculate zircon ages younger than 1 Ga (16 grains), the $^{206}Pb/^{238}U$ ratio was used, while for ages older than 1 Ga, the $^{206}Pb/^{207}Pb$ ratio (61 grains) was taken. The minimum age is 561 ± 4 Ma (no. 32, $D = 1.07\%$), the maximum one is 3092 ± 17 Ma (no. 88, $D = 2.17\%$). The following age peaks, which include more than two results, are identified in the Probability Density Curve: 573, 603, 685, 1263, 1584, and 2087 Ma. In the K15–501 sandstone, two detrital zircons yielded (nos. 32 and 259) very reliable ages of 561 and 570 Ma, which limit the maximum age of the studied rock and exclude the possibility that this sandstone was part of the Upper Riphean–Lower Vendian (Neoproterozoic) strata, recovered in the well 1–Ordovician under the Ordovician section [8].

It is assumed that the sources of detrit in the Ordovician sedimentary basin at the Uralian EEP edge were uplifts of the Early Precambrian basement of the Volga–Urals part of the EEP: the Tatar, Zhiguli–Pugachev, and other swells [8]. However, our dating of detrital zircons from the Ordovician sandstone showed that along with the Early Precambrian zircons, whose age corresponds to the ages in the EEP basement, also present are numerous zircons younger than 1.65 Ga, which are not typical for basement rocks of the central, southern, southeastern, and eastern parts of the EEP. Indeed, the basement of these parts of the EEP comprises several domains: Archean protocratons of the Volga–Uralian, Sarmatia, Kola, and Karelia with ages 2.5–3.5 Ga, sutured by Late Proterozoic orogens (Volga–Sarmatian, Lapland–Kola, Volyn–Middle Russian) with ages 1.65–2.2 Ga. [14] Note that in the Western Urals, as well as in some Riphean aulacogenes in the southeastern part of the EEP (the Gusikha complex in the Pachelma aulacogen, etc.) rocks with ages younger than 1.65 Ga are known. They could be a source of single zircons with Late Precambrian ages in the K15–501 sample, but cannot explain the entire spectrum of Late Precambrian ages.

Previous studies have demonstrated that at two stratigraphic levels of the Riphean in the Bashkir uplift

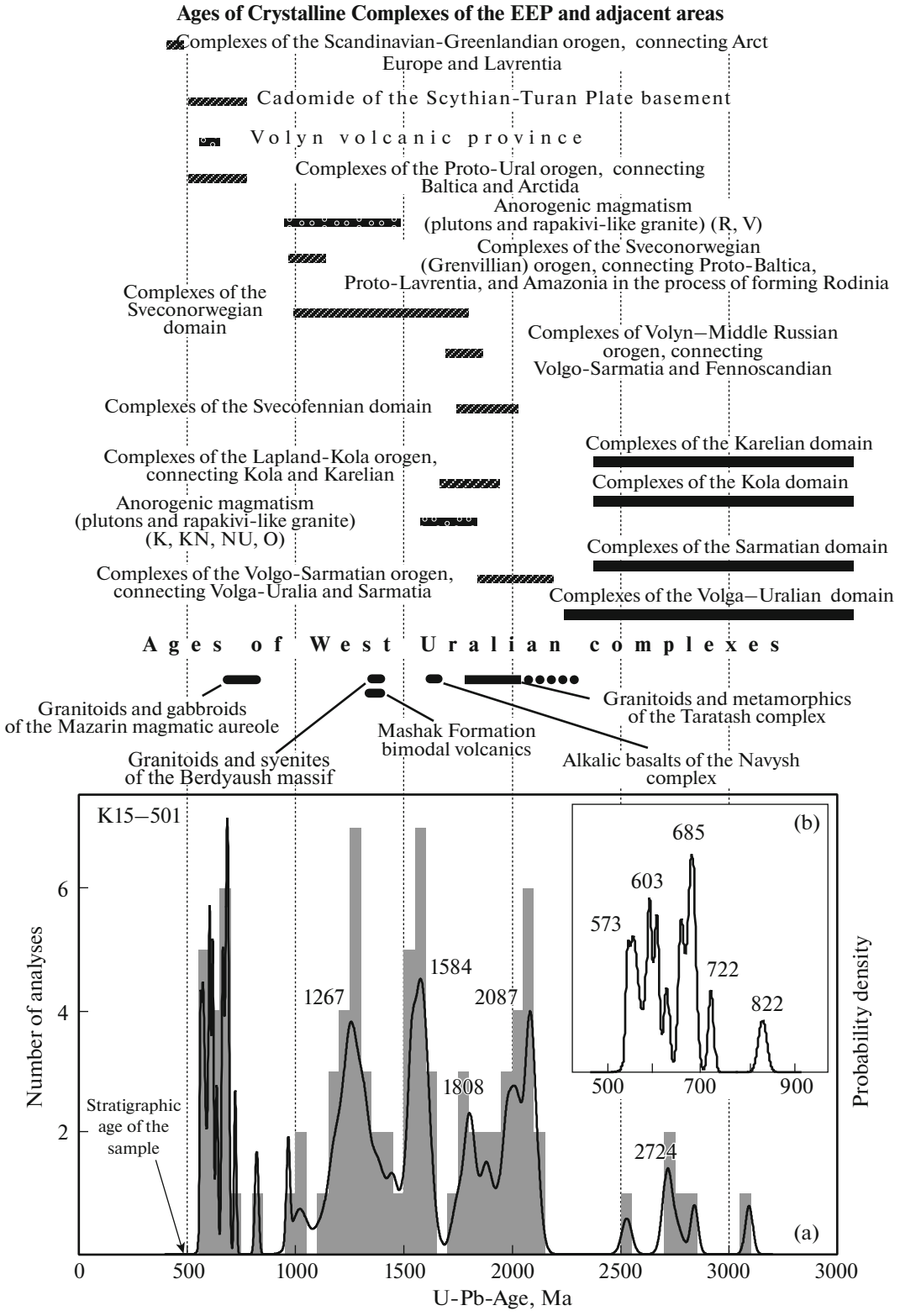

Fig. 3. Histogram and Probability Density Curve of detrital zircon ages from the K15–501 sample (a) and a detailed plot for the Neoproterozoic interval (b). Above is the diagram displaying the age ranges of complexes comprising the basement of the East European Platform and surrounding potential provenance source areas (after [5, 11] with additions). Anorogenic plutons: V, Vyborg; K, Korosten; KN, Korsun–Novomirgorod; NU, Novoukrainsk; O, Oktyabrskii; R, Riga.

in the Western Urals detrital zircons with ages only older than 1.65 Ga have been revealed [5, 11]: this assumes that only source rocks of Early Precambrian ages were available and is consistent with the idea that the Riphean detrital material in the Western Urals basin was supplied from the Volga–Uralian part of the EEP. But at higher stratigraphic levels, namely, the Vendian [7] and Ordovician [6], alike in the studied sandstone K15–501, numerous zircons with Meso- and Neoproterozoic ages, atypical for the Volga–Uralian part of the EEP basement, have been detected. Potential sources of these Meso– and Neoproterozoic zircons could be rocks of the Sveconorwegian domain, the Proto-Uralian–Timanidides Orogen, the Cadomian basement of the Scythian–Turan plate (most likely), or rocks of an unknown crustal block, located during the Vendian (Late Neoproterozoic time) eastwards of the Ural edge of the EEP.

Thus, the dating of detrital zircons from the Sol–Iletsk Block sandstone (sample K15–501, well 2–Ordovician) is in agreement with the Ordovician age of the sampled sandstones, which was assumed previously on the basis of seismic-stratigraphic, and lithological correlations. The obtained distribution of detrital zircon ages suggests that among the detrital sources a significant role was played by Late Precambrian rocks unknown in the Early Precambrian basement of the Volga–Uralian part of the EEP.

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