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GEOLOGY

FIRST DATA ON THE AGE OF ZIRCON GRAINS FROM THE UPPER MESOZOIC LESKOVO UNIT OF THE UNDO-DAYA DEPRESSION OF EASTERN TRANSBAIKALIA

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Abstract. The results of the determination of the age of zircon grains from tuffites of the Leskovo Unit of the Unda-Daya Basin, Eastern Transbaikalia, are presented for the first time. The age of the youngest population of zircon grains is 145.8±3.8 Ma, approximately corresponding to the Jurassic–Cretaceous boundary and indicating the Early Cretaceous age of most of the Leskovo Unit. Given that the similar taxonomic composition of ostracods from the middle part of the Leskovo Unit and the Valanginian–Lower Hauterivian Dabeigou Formation of northeastern China, our U–Pb age from the lower part of the Leskovo Unit allows confident correlations of these lithostratons.

Keywords : *Lower Cretaceous, Transbaikalia, U–Pb age of zircon grains, Jehol Biota*

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Continental Upper Mesozoic deposits are widely distributed throughout Transbaikalia. They are confined to numerous depressions and are characterized by diverse facies composition and genesis. Despite a long history of study, the age of many strata remains a subject of discussion.

The new wave of interest in the continental Mesozoic of Transbaikalia is associated with the discovery of uniquely preserved vertebrate remains, including pterosaurs, feathered dinosaurs, birds, and mammals, in the deposits of the Jehol Group in northeastern China (Jehol biota) [1]. The core of this biota consists of an assemblage of organisms including the conchostracans *Eosestheria*, insects *Ephemeropsis* and bony fishes *Lycoptera*, widely distributed in the Lower Cretaceous deposits beyond northeastern China, including Transbaikalia [2-4]. Three evolutionary phases have been established in the development of the Jehol biota, successively replacing each other [5, 6]. To date, the age of strata containing the remains of organisms belonging to all three evolutionary phases of the Jehol biota has been established with high precision, thanks to numerous isotopic dating, which allows the continental Lower Cretaceous sections of northeastern China to be used as references for clarifying the age and correlation of the continental Lower Cretaceous of eastern Asia.

The area of localities with assemblages of organism remains characterizing the early phase of the Jehol biota evolution is the most limited compared to the middle and late phases, and covers a narrow region extending northward from the northern part of China's Hebei Province to Eastern Transbaikalia. Questions concerning the origin, paleogeographic distribution, and migration routes of organisms belonging to this evolutionary phase remain the least studied.

In Transbaikalia, several localities with fauna identified with the early phase of the Jehol biota evolution are known. Conchostracans *Keratestheria* are known from the Utan locality in the Olov Depression, *Nestoria* from the Ust-Kara Formation in the Ust-Kara Depression, where they occur together with conchostracans *Defretinia* [7, 8]. In southeastern Transbaikalia, between the Upper Jurassic Undino-Daya series and the overlying

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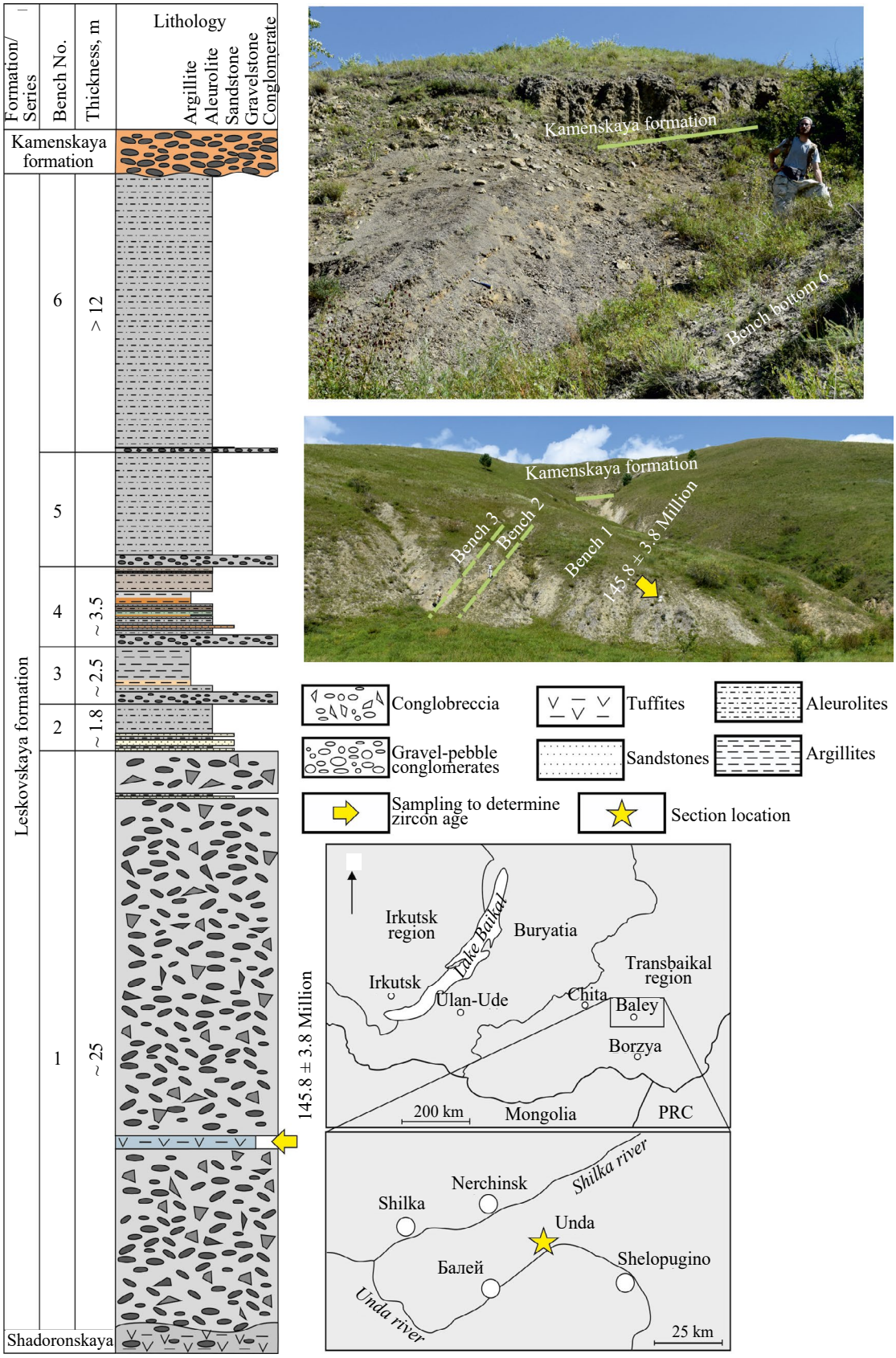

Fig. 1. Location, general view, and lithological column of the Leskovo sequence section near the village of Unda.

Lower Cretaceous Turga Formation, a so-called transitional Ust-Kara (Defretinian) horizon (characterized by conchostracans *Defretinia*) is recognized [8]. One of the few sections in which this horizon can be traced is the well-accessible and fauna-characterized section of the Leskovskaya strata near the village of Unda.

The "Unda" section is located on the right bank of the Unda River, 500 m upstream from the village of Unda, in a narrow steep ravine and on its western side on the southern slope of Mount Malaya Berezovaya [7, 9] (Fig. 1). Tectonically, the section is confined to the Leskovo graben, superimposed on the Unda-Daya depression. The Leskovo sequence, about 50 m thick, lies with angular unconformity on the volcanogenic-sedimentary rocks of the Middle-Upper Jurassic Shadoron series [9]. The basal member of the Leskovskaya sequence is represented by conglobreccias with rare thin interlayers of sandstones and siltstones, with a thickness of about 25 m. At 8 m from the base of the member, we discovered a tuffite layer about 0.5 m thick, from which a sample was taken to determine the absolute age of zircon grains. The middle and upper parts of the section (members 2–6) are composed predominantly of siltstones and mudstones. At the base of each member lie conglomerates or sandstones (Fig. 1). The Leskovo sequence is overlain with angular unconformity by conglomerates of the Lower Cretaceous Kamenskaya sequence.

VIEWS ON THE AGE OF THE LESKOVO SEQUENCE

The Leskovo sequence is most completely represented in the "Unda" section. There are different perspectives on its age. G.G. Martinson [10] attributed the Leskovo sequence to the Unda-Baley Formation, which he considered younger than the Turga Formation. A.N. Oleynikov [7] attributed the Leskovo sequence to the Baley Formation, which, according to his stratigraphic scheme of Transbaikalia, is also younger than the Turga Formation and corresponds to the upper part of the Lower Cretaceous. In the regional stratigraphic scheme of the Cretaceous deposits of Transbaikalia, the Leskovo sequence is considered as part of the Dain Formation, which belongs to the upper part of the Turga Horizon [11]. On modern geological maps, this sequence is attributed to the Turga Formation, the age of which is accepted as Berriasian-Barremian [12].

The most complete list of paleontological remains found in the "Unda" section is provided by S.M. Sinitsa [9]. From the basal horizon (corresponding to packages 1–4 in Fig. 1), the ostracods *Daurina* and " *Torinina"*, gastropods *Radix* and conchostracans *Defretinia* are indicated. In the overlying siltstones, insect remains are numerous, and among the stratigraphically important fossils are taxa characteristic of the Turga Formation: conchostracans *Eosestheria* (= *Bairdestheria*) *middendorfii* (Jones, 1862), fish *Lycoptera middendorfii* Müller, 1847, insects *Ephemeropsis trisetalis* Eichwald, 1864, plants *Pseudolarix*. It is concluded that the upper part of the section corresponds to the Turga Formation, while the lower part of the section, based on the presence of conchostracans *Defretinia*, belongs to the Ust-Kara transitional horizon [8, 9]. The authors of this article, during the investigation of the "Unda" section, did not find conchostracans *Eosestheria* , insects *Ephemeropsis* , and fish *Lycoptera* , which are characteristic of the Turga Formation fossil assemblages.

Data on ostracods from the Lower Cretaceous of northeastern China show that the species *Ocrocypris obesa* (Pang et al., 1984) from the Dabeigou Formation is very similar to the Transbaikalian species *Ocrocypris* (= *Torinina*) *tersa* (Sinitsa, 1992) [13]. In the fossil assemblage from the Dabeigou Formation, which characterizes the early phase of the Jehol biota evolution [6], ostracods of the genus *Daurina* are characteristic, also described from the Leskovo sequence [8]. In the "Unda" section, according to S.M. Sinitsa [8, 9], conchostracans *Defretinia* were found, which occur together with conchostracans *Nestoria* in the section of the Ust-Kara Formation in the Ust-Kara depression [8].

It can be concluded that at least the middle part of the Leskovo sequence, which lies on basal conglomeratic breccia and is characterized by ostracods *Daurina* and *Ocrocypris*, can be correlated with the Dabeigou Formation in northeastern China, the age of which is dated within the Valanginian-early Hauterivian range [13]. Evidence supporting this correlation is the results of the first study of the absolute age of zircon grains from tuffites confined to the lower part of this sequence, which are discussed in this paper.

METHODOLOGY FOR DETERMINING THE ABSOLUTE AGE OF ZIRCON GRAINS FROM TUFFITES OF THE LESKOVO SEQUENCE

For U-Pb dating of zircon grains, a laser ablation system based on an excimer laser (wavelength 193 nm) Analyte Excite ("Teledyne

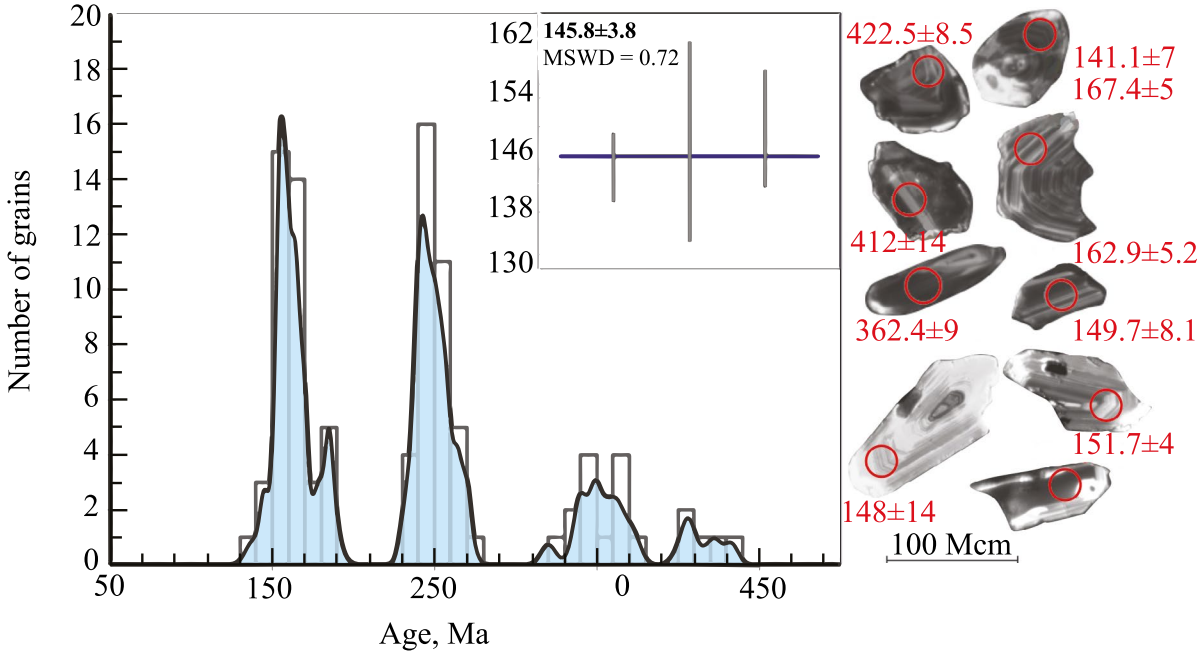

Fig. 2. Results of U-Pb dating of zircon grains from tuffites in the lower part of the Leskovo sequence section near the village of Unda.

Cetac Technologies") connected to a quadrupole mass spectrometer with inductively coupled plasma ionization "ThermoScientific" iCAP Q at the Geothermochronology Center of Kazan Federal University (KFU) was used. The diameter of the laser beam was 35 μm, the pulse repetition frequency was 5 Hz, and the laser energy density was 3.0 J/cm^2. Reference samples of zircon grains were used for analysis: 91500 as a control sample (1065 Ma) and Plešovice as an external standard (337 Ma). At the beginning, middle, and end of the measurement session, standard synthetic glass NIST SRM 612 was additionally measured to account for the mass spectrometer sensitivity. Processing of mass spectrometric data, accounting for corrections, selection of the optimal signal segment, calculation of isotopic ratios and corresponding ages were carried out using Iolite 3.65 software integrated into Igor Pro 7. Calculation of weighted average age values based on isotopic ratios, plotting concordia diagrams were performed in Microsoft Excel with the integrated Isoplot 4.15 package. For discordance calculation, the formulas D = 100*(Age(^{207}Pb/^{235}U)/Age(^{206}Pb/^{238}U)–1) were used. Measurements where discordance < –5% or >5% were excluded from the sample.

RESEARCH RESULTS

In the Unda-1 sample, 131 zircon grains were analyzed, of which 96 zircon grain ages fell within the discordance interval from –5% to 5%. The sample is dominated by zircon grains with oscillatory zoning, less frequently with banded zoning (Fig. 2). Some grains show secondary, younger crystal growth zones and recrystallization. The Th/U ratio in all analyzed zircon grains is greater than 0.1, which is characteristic of zircon grains from igneous rocks.

For constructing the relative probability histogram, the ratio ^{206}Pb/^{238}U was used. Within the studied sample, four populations of zircon grains are distinguished, with a characteristic feature being an increase in the proportion of zircon grains from older to younger ones. The oldest population of zircon grains is represented by five grains with Silurian-Early Devonian age (433–403 Ma) (here and below according to [14]). The next population of 12 grains has an age range of 373–339 Ma, suggesting the involvement of Late Devonian-Early Carboniferous source areas. The Middle Permian-Middle Triassic population contains 37 grains with an age range of 271–237 Ma. The largest and youngest population of 41 grains has an age range of 187–144 Ma (Early-Late Jurassic up to the boundary with the Cretaceous). The age of the

youngest population, determined by the weighted average age of the three youngest zircon grains, has a value of 145.8±3.8 Ma (MSWD = 0.72), which approximately corresponds to the Jurassic-Cretaceous boundary.

DISCUSSION OF RESULTS

Potential sources of detrital zircon grains for the oldest cluster of Early Paleozoic age may be rocks of the Olyokma granodiorite-granite complex, which are exposed in the Unda and Urulga river basins in close proximity to the location of the "Unda" section. The age of the Olyokma complex granitoids was determined by the Rb-Sr method as 438±39 Ma [12], which, within the margin of error, corresponds to the age of the oldest population of zircon grains in the dated sample. It should also be considered that zircon grains of this age may be present in the rocks of the Aginsk-Borshchovochny dynamometamorphic complex of the Middle Paleozoic, for which the older rocks of the Olyokma complex likely served as a protolith.

The probable source material for the Late Devonian-Early Carboniferous cluster of zircon grains could be rocks of the Alenui granodiorite-rhyolite complex, which formed volcanic cover structures in the eastern part (Gazimur block) of the Argun terrane. The age of the Alenui complex rocks is accepted as Early-Middle Carboniferous [12].

The source of detritus for the large cluster of Permian-Triassic zircon grains is most likely the rocks of the Unda granodiorite-granite complex, which is widely distributed within the study area. The age of the Unda complex granitoids, according to Rb-Sr isochron dating, is 275-250 Ma [15], and according to U-Pb dating – 254-249 Ma [16]. The geodynamic nature of the Unda complex rocks is currently under discussion.

The youngest cluster of zircon grains in the studied tuffite has a Mesozoic age. Within the Argun terrane, granitoid complexes of Jurassic-Cretaceous age are widely developed: Borshchovochny, Shakhtaminsky, Amudzhikano-Sretensky (163–142 Ma) [17, 18], associated with the intraplate stage of the region's development. Also, most likely, a significant portion of the Mesozoic zircon grains in the dated sample are the indigenous zircon grains of the volcanic rocks of the Leskovo strata. The obtained age of the youngest population in the sample (145.8±3.8 Ma) implies that the formation of the dated volcanogenic-sedimentary rocks occurred no earlier than the Tithonian age of the Late Jurassic.

The new data obtained on the age of zircon grains from tuffites in the lower part of the Leskovo strata section allow us to conclude that most of the section is of Early Cretaceous age, although a Late Jurassic age for the basal conglomeratic breccias cannot be excluded. The presence of ostracods *Daurina* and *Ocrocypris*, typical taxa of the Luangpingella–Ocrocypris–Eoparacypris ostracod zone identified in the Dabeigou Formation in northeastern China, suggests a Valanginian-Early Hauterivian age for the middle part of the Leskovo strata and allows correlation with the Dabeigou Formation. The presence of ostracods *Daurina* and *Ocrocypris*, conchostracans *Nesthoria* and *Keratestheria* in the sections of strata united in the Ust-Kara horizon is evidence that the range of organisms belonging to the early phase of the Jehol biota evolution extended northward as far as Eastern Transbaikalia. This allows us to consider the territory of Eastern Transbaikalia together with northeastern China as the center of origin of the Jehol biota, from where its subsequent dispersal occurred.

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