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GEOCHEMISTRY

First LA–ICP–MS Apatite Fission-Track Ages from the Basement of the Siberian Platform (Nepa–Botuoba Anteclise)

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Abstract—The first results of laser ablation inductively-coupled plasma mass-spectrometry apatite fission-track dating are presented from drill core of boreholes, which exposed the top of the Siberian Platform's crystalline basement in the Nepa–Botuoba Anteclise. Apatite fission-track ages, obtained for nine samples from a depth of ~2 km, form three groups with mean values of 200, 140, and 60 Ma. A thermal event with an age of ~200 Ma is widely abundant almost within the entire Siberian Platform and reflects the stage of its intense Early Jurassic uplifting. Resetting of the apatite fission-track system ~140 Ma corresponds to tectono-thermal events, which mark the final stage of collision of the Mongol–Okhotsk fold belt. The youngest apatite fission-track ages age of ~60 Ma, on the one hand, may reflect the beginning of the Baikal rifting and, on the other hand, may be a result of the high U content of apatite.

Keywords: fission-track dating, apatite, LA–ICP–MS, thermochronology, geochronology, Siberian Platform, thermal evolution, basement, tectonics

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INTRODUCTION

The rocks of the crystalline basement of ancient platforms are a source of unique data on tectonic and magmatic evolution. The methods of low temperature thermochronology are able to reveal the heating and cooling stages of rocks in the range of 40–300°C and possibly provide a highly detailed interpretation of the tectono-thermal evolution of the upper crust. The apatite fission-track (AFT) dating is one of the most popular method of the low-temperature thermochronology: it can estimate the time that passed from the moment of the last cooling of rocks below 120°C. This time can reflect both the secondary heating of the basement under the influence of magmatic processes and the rates of denudation due to vertical tectonic movements.

AFT ages for the rocks of the basement or igneous complexes of the Siberian Platform are few. The first data on boreholes, which reached the basement in the northeastern part of the platform [1], allowed the suggestion of relatively complex thermal evolution of the platform in the Mesozoic: the presence of AFT ages of ~200 Ma are explained by the formation of a large subcrustal intrusion (underplate) during eruption of the Permian–Triassic Siberian Traps Large Igneous Province (LIP). The AFT results for the Siberian Traps LIP intrusions [2, 3] supported the previous results and, as an alternative interpretation of the abundance of AFT ages of ~200 Ma, the authors suggested a regional event related to the tectonic uplift of the entire Siberian Platform in the Late Triassic and Early Jurassic. The elaboration of the model of tectono-thermal evolution of the Siberian Platform is thus a topical problem, the solution of which is necessary for the recognition and estimation of the duration and scale of tectonic and magmatic events in its geological evolution.

The study of the geological structure and tectono-thermal evolution of rocks of the crystalline basement of the Siberian Platform within the Nepa–Botuoba anteclise is important from the practical viewpoint, because these data govern the prospects of structures of the sedimentary cover in the hydrocarbon exploration. For the solution of this task, we collected a unique borehole material from the petroleum deposits, as well as the searching license areas within the Nepa–Botuoba anteclise.

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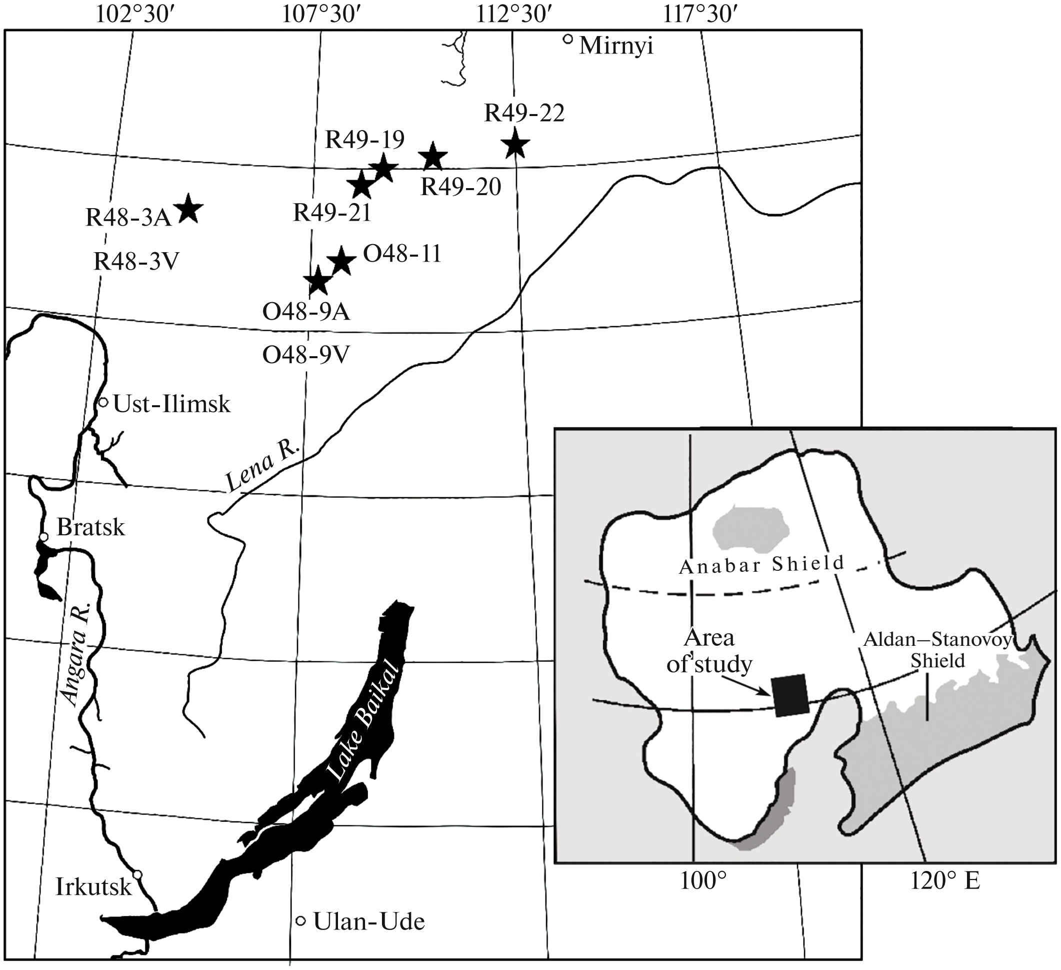

Fig. 1. Region of study of sampling areas for AFT dating from boreholes within the Nepa–Botuoba anteclise (shown with sample numbers).

OBJECTS OF STUDY

An apatite monofraction for AFT dating was extracted from the drill core of rocks of the crystalline basement of the Siberian Platform, which was sampled at a depth of 1800–2600 m in searching-exploration boreholes. These boreholes were drilled for hydrocarbons and characterize the northern, western, and eastern parts of the Nepa–Botuoba anteclise (Fig. 1). The boreholes are distributed along a latitudinal profile more than 500 km long.

METHODS AND RESULTS

Fission tracks, track lengths, and diameters were measured using an Olympus BX53M microscope in the Shared Research Facilities Center of the Schmidt Institute of Physics of the Earth, Russian Academy of Sciences (IPE RAS, Moscow, Russia). The F and Cl contents of apatite, which are responsible for the kinetic parameters of track annealing [5], were estimated at the same place on a Tescan MIRA LMS scanning electron microscope equipped with an energy-dispersive detector. The U content was measured in the Analytical Center "Geospectr" of Dobretsov Geological Institute, Siberian Branch, Russian Academy of Sciences (GIN SB RAS, Ulan-Ude, Russia), on a high-resolution Element XR ICP-MS mass-spectrometer equipped with an UP-213 NewWave laser ablation system following [6].

The AFT ages are shown in Table 1 and Fig. 2. According to the current method, the AFT ages are reliable if tracks of spontaneous fission of ^{238}U calculated no less than in 20 grains; i.e., all our determinations, except for the age of sample P48-3A, are reliable.

DISCUSSION

The AFT ages form three clusters (Fig. 2): (i) the Late Triassic–Early Jurassic (230.8–179.3 Ma), (ii) the end of Late Jurassic–Early Cretaceous (149.9–121.4 Ma), and (iii) Paleocene (62.3–59.4 Ma).

Table 1. Results of LA–ICP–MS apatite fission-track dating

	Sample no.	Depth of core sampling, m	Rock	Number of grains	Track density ($\times 10^6$ tracks cm^{-2}) (Number of tracks)	U content (ppm)	$\zeta_{ICP} \pm 2\sigma$	Age (Ma) ($\pm 2\sigma$) (Pooled age)
1	R48-3A	2560.3	Granite	15	3.93 (942)	32.70	0.60 ± 0.04	**179.3 ± 34.8**
2	R48-3V	2560.3	Granite	57	2.03 (1855)	18.00		**195.2 ± 19.6**
3	R49-19	2044.9	Granite	101	1.52 (2453)	14.30		**203.4 ± 15.7**
4	R49-20	2058.2	Granodiorite	39	1.03 (642)	29.80		**59.4 ± 6.4**
5	R49-21	1933.9	Gneiss	76	1.11 (1348)	33.20		**62.3 ± 5.9**
6	R49-22	1935.0	Granite	100	2.60 (4161)	19.87		**230.8 ± 18.7**
7	O48-9A	2000.4	Gneiss	58	0.92 (868)	10.91		**146.4 ± 16.8**
8	O48-9V	2000.4	Gneiss	95	0.99 (1493)	15.20		**121.4 ± 19.2**
9	O48-11	1820.4	Mylonitized granite	67	0.60 (652)	7.51		**145.2 ± 27.6**

ζ_{ICP}, zeta-factor calculated as a result of zeta-session according to the protocol [6].

According to the chemical composition, apatite from all samples is Cl-free fluorapatite. In spite of the significant confidence intervals of some, first of all, the oldest AFT ages, the age groups can be ascribed to the following tectonic events on the Siberian Platform and its adjacent areas. The Late Jurassic–Early Jurassic AFT ages coincide with the first AFT ages for the Siberian Platform [1–3]. According to our interpretation, these ages mark the regional stage of uplifting and erosion on the entire Siberian Platform, which was synchronous with deformations on the Taimyr and Mongol–Okhotsk fold belt [3].

The Late Jurassic–Early Cretaceous AFT ages could reflect the cooling of the basement rocks of the southern part of the Siberian Platform at the stage of tectonic event, which was synchronous with the collapse of the Mongol–Okhotsk Orogen, and a vast extension, which spanned Central and Eastern Asia [7], as well as the stage of intraplate volcanism in Transbaikalia [8].

The interpretation of the Paleocene AFT ages is most debatable. These ages are coeval with those for rocks of Primorie [9] and Barguzin [10] ranges and, probably, could register the cooling of the basement rocks after the initial stage of the Baikal rifting [11]. On the other hand, the presence of the Triassic–Jurassic (e.g., sample R-49-19) and Paleocene (samples R49-20 and R49-21) AFT ages in adjacent boreholes can be considered either the result of the blocky structure of the basement or can be related to the high U content of samples with younger ages (Fig. 2). The solution of this question requires additional thermochronological studies in the southern part of the Siberian Platform.

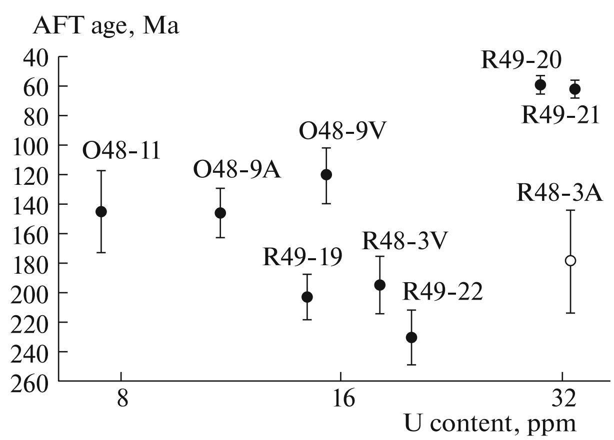

Fig. 2. Correlation between apatite fission track age and U content. The errors are given at a level of 2σ. Black circles mean reliable estimations of track age; the white circle (sample R48-3A) means unreliable age determination.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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