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GEOLOGY

First Results of Zircon LA-ICP-MS U–Pb Dating of the Rocks from the Granulite Complex of Khanka Massif in the Primorye Region

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This work is dedicated to the first results of zircon LA–ICP–MS U–Pb dating of the rocks from the granulite complex of the Khanka Massif in the Primorye region. Similar to the Khingan–Bureya (Russia) and Jiamusi (China) terranes, the Khanka Massif (terrane) represents one of the principal structural elements in the Near-Pacific segment of the Central Asian fold belt. The age and origin of metamorphic rocks from these massifs are of importance for understanding the structural evolution of the latter. According to [1], granulite complexes of crystalline massifs in the Russian Far East are attributed to the Archean, although available isotopic dates are inconsistent with this standpoint. In this connection, isotopic geochronological studies of granulite rocks from the Khanka Massif are of particular significance.

The granulite complex of the Khanka Massif is developed in its northern part, where it is defined as the Iman Group [2] (Fig. 1). The basal part of the Iman Group is composed of diopside–calcite marbles with rare intercalations of biotite schists and calcareous–silicate rocks (Ruzhino Formation). They are overlain by biotite and high-alumina schists and gneisses with rare thin beds of different quartzites (garnet, magnetite, graphite), eulisites, marbles, calcareous–silicate rocks, and two-pyroxene–amphibole schists (Matveevo Formation). The rocks of the Iman Group experienced high-grade metamorphism of the granulite facies and are to a significant extant granitized and migmatized [2]. The Iman Group of the Khanka Massif in the Primorye region is traditionally correlated by its lithological–petrographic composition and granulite metamorphism with the Mashan Group of the Jiamusi Massif, the neighboring structure of China [3 and others]. Our isotopic studies concern the rocks from the Matveevo Formation of the Iman Group. Samples were taken from two-pyroxene–amphibole schists occurring in the form of a conformable bed approximately 1 m thick among granitized rocks of the Matveevo Formation (sample H-1) in a quarry 3 km southwest of the Nevskoe Settlement. The sample is characterized by the following mineral composition (wt %): plagioclase 38; hypersthene 20; clinopyroxene 12; amphibole 25; biotite 5. Accessory minerals are represented by apatite, zircon, and magnetite. The chemical composition of the two-pyroxene–amphibole schist is as follows (wt %): SiO_2 47.16; TiO_2 1.0; Al_2O_3 17.12; Fe_2O_3 1.93; FeO 8.10; MnO 0.12; MgO 8.57; CaO 13.42; Na_2O 1.30; K_2O 0.40; P_2O_5 0.05 (sum 99.17). By its petrochemical composition, the two-pyroxene–amphibole schist corresponds to tholeiitic basalt.

Isotopic measurements were performed in the Laboratory of Analytical Chemistry (Far East Geological Institute, Far East Division, Russian Academy of Sciences) on the ICP mass spectrometer Agilent 7500a combined with a system of laser ablation of samples UP-213. Accessory zircon was extracted from samples using the standard technique. Zircon grains were picked by hand under a binocular microscope. The selected grains were fixed together with the TEMORA zircon standard [5] by the resin EPO-KWICK. Backscattered electron (BSE) microscopy images of zircon grains were obtained on the JXA-8100 electron microprobe for detailed study of their internal structure and selection of particular points for isotopic measurements. The diameter of the ablation crater was approximately 40 μm. The analyzed material from the sample cell was transported by a helium–argon mixture. The technical details of the method are described in [6–8]. The obtained data were processed using the programs Glitter v. 4.4.2 (Access Macquarie Ltd). The U–Pb ratio was normalized for the corresponding value of isotopic ratios of the standard zircon TEMORA, the age of which is accepted to be 416.75 Ma [5]. The accuracy of individual analyses (ratios and ages) is 1σ and that of the calculated concordant ages and intersects with concordia is 2σ. Dia-

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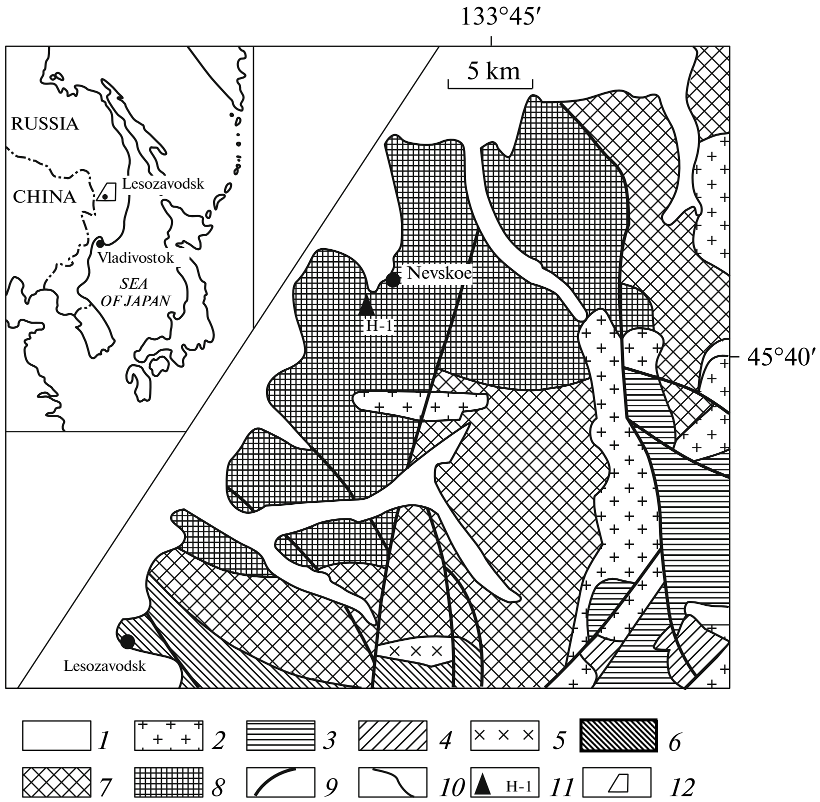

Fig. 1. The schematic geological structure of the northern Khanka Massif (after [4] modified). (*1*) Cenozoic sediments; (*2*) Paleozoic–Mesozoic gabbro–granite complexes; (*3*) Upper Paleozoic rocks; (*4*) Cambrian Orlov Group; (*5*) Early Paleozoic granitoids of the Ussuri Complex; (*6*–*8*) Proterozoic rocks of the Lesozavodsk (*6*), Ussuri (*7*), and Iman (*8*) groups; (*9*) faults; (*10*) geological boundaries; (*11*) sampling site for the isotopic analysis and its number; (*12*) the study area is shown in the inset.

grams with concordia were constructed using the program Isoplot/Ex v. 3.00 [9].

Two types of zircon grains differing in color and morphological and structural features are distinguishable in the monofraction from sample H-1.

(1) Zircons of the first type (I) are represented by light pink transparent elongated–prismatic bipyramidal crystals 250 to 500 μm long (K_{elong} = 2.5–3.0). The BSE images demonstrate their distinct two-phase structure: unzoned core and zoned rim (Fig. 2a). Some grains are crossed with fissures orthogonal to the long axis (Fig. 2) or chaotic. Some zircons contain abundant solid-phase inclusions (Fig. 2b). Crystals are bordered by facets {100}, {110}, and {111}. The morphological features of grain cores imply a magmatic origin of such grains [10]. The point U–Pb isotopic analysis was performed for the central and marginal parts of grains (table). Cores of zircon grains yielded a weighted average concordant age of 757.4 ± 4.4 Ma (Fig. 3, table). In our opinion, this age estimate corresponds to crystallization of the magmatic protolith of two-pyroxene–amphibole schists, which likely represented a basite sill in the initial sedimentary–terrigenous Matveevo Formation.

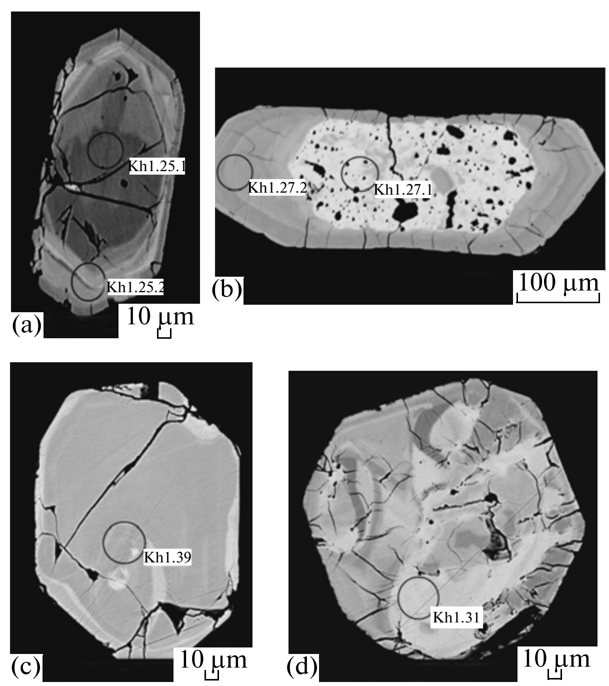

Fig. 2. BSE images of the analyzed: zircons of types I (a, b) and II (c, d) from sample H-1. Numbers of the analyzed points correspond to those in the table.

U–Pb isotopic data on zircons from two-pyroxene–amphibole schist (sample H-1) of the granulite complex of the Khanka Massif

Number of the analyzed point	Isotopic ratios			Age, Ma	
	$^{207}Pb/^{235}U$, ±%	$^{206}Pb/^{238}U$, ±%	$^{207}Pb/^{206}Pb$, ±%	$^{207}Pb/^{235}U$	$^{206}Pb/^{238}U$
Zircons of type I					
H1-14	1.05917 ± 6.36	0.12586 ± 2.11	0.06821 ± 6.58	733.4 ± 33.2	764.2 ± 15.2
H1-16	1.0991 ± 6.20	0.12274 ± 2.00	0.07258 ± 6.41	752.9 ± 32.9	746.3 ± 14.1
H1-17	1.08086 ± 6.37	0.12225 ± 2.12	0.07166 ± 6.60	744.1 ± 33.6	743.5 ± 14.9
H1-19	1.061 ± 6.16	0.12727 ± 1.99	0.06757 ± 6.38	734.3 ± 32.3	772.3 ± 14.5
H1-20.1	1.06152 ± 6.21	0.12471 ± 2.01	0.06899 ± 6.42	734.6 ± 32.4	757.6 ± 14.4
H1-20.2	1.05709 ± 6.16	0.12629 ± 1.98	0.06784 ± 6.37	732.4 ± 32.1	766.6 ± 14.3
H1-23.1	1.05834 ± 3.49	0.12348 ± 1.92	0.06943 ± 3.66	733 ± 18.2	750.6 ± 13.6
H1-25.1	1.08298 ± 3.17	0.1286 ± 1.78	0.06821 ± 3.28	745.1 ± 16.7	779.9 ± 13.1
H1-27.1	1.10286 ± 6.32	0.12395 ± 2.09	0.07212 ± 6.54	754.7 ± 33.7	753.3 ± 14.8
H1-35	1.07331 ± 4.96	0.12719 ± 2.37	0.06836 ± 5.24	740.4 ± 26.1	771.8 ± 17.3
H1-25.2(r)	0.66639 ± 3.01	0.08273 ± 1.72	0.06525 ± 3.10	518.5 ± 12.2	512.4 ± 8.4
H1-27.2(r)	0.65647 ± 3.45	0.08254 ± 1.85	0.06442 ± 3.59	512.4 ± 13.9	511.3 ± 9.1
H1-38(r)	0.6269 ± 6.20	0.0803 ± 2.43	0.0632 ± 6.61	494 ± 4.91	498 ± 2.34
Zircons of type II					
H1-26.1	0.66757 ± 3.05	0.08479 ± 1.72	0.06377 ± 3.14	519.2 ± 12.4	524.7 ± 8.7
H1-32	0.6645 ± 3.83	0.08233 ± 1.94	0.06538 ± 3.99	517.4 ± 15.5	510 ± 9.5
H1-33	0.67567 ± 3.90	0.08375 ± 1.96	0.06535 ± 4.06	524.2 ± 16.0	518.5 ± 9.8
H1-34	0.65436 ± 4.30	0.08384 ± 2.09	0.06322 ± 4.51	511.2 ± 17.3	519 ± 10.4
H1-36	0.6340 ± 4.12	0.0803 ± 1.36	0.0573 ± 3.96	499 ± 3.25	498 ± 1.31
H1-37	0.6286 ± 4.12	0.0799 ± 1.31	0.0571 ± 3.86	495 ± 3.18	496 ± 1.26
H1-39	0.6415 ± 4.43	0.0810 ± 1.48	0.0574 ± 4.32	503 ± 3.49	502 ± 1.42

Note: Errors are at the level of 1σ; (r) margin of the zircon grain (type I).

(2) Zircons of the second type (II) prevail in the monofraction (approximately 70%). They are represented by dolioform rounded transparent colorless crystals 100–200 μm in size (K_{elong} = 1.0–1.5) with numerous facets and diamond luster. Grains are moderately fissured; some of them are characterized by a spotty structure (Fig. 2). The morphological features of grains imply their metamorphic origin [10]. The

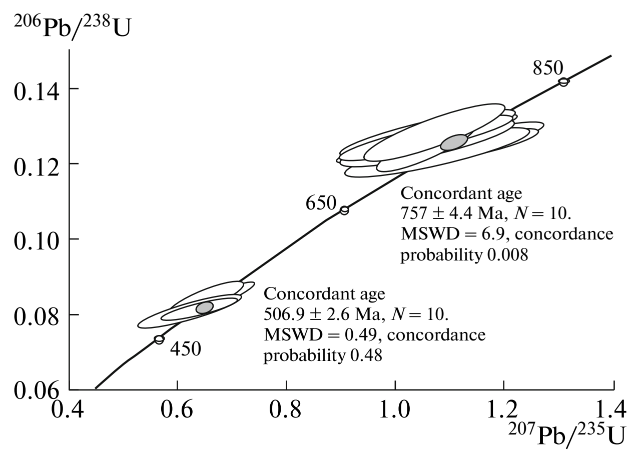

Fig. 3. Diagram with concordia for zircons of types I and II from sample H-1.

BSE images demonstrate the practically single-phase structure (Figs. 2c, 2d). Zircons of the first type (I) and marginal zones of zircons of the second type (II) yielded a concordant age of 506.9 ± 2.6 Ma (Fig. 3, table). The obtained results indicate that the examined rocks of the Upper Proterozoic Iman Group experienced granulite metamorphism in the Late Cambrian. These results are confirmed by previous isotopic–geochronologic SHRIMP studies of granulite rocks from the Mashan Group of the neighboring Jamusi Massif in China [11, 12].

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