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GEOLOGY

Campanian Stage of Granite Formation in the South of the Sredinnyi Range in Kamchatka: New U–Pb SHRIMP Data

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Abstract—This article gives an account of the results of the U–Pb–SHRIMP study of zircons derived from gneissoid and equigranular granitoids of the Malka Uplift of the Sredynnyi Range in Kamchatka. It was established that intrusion and crystallization of granitoids occurred in the time interval from 76.2 ± 1.5 to 83.1 ± 2.0 Ma. The texture of zircon crystals suggests their magmatic origin. The obtained data reliably confirm that granite formation and emplacement of the recently formed continental crust in Kamchatka took place in the Late Cretaceous (Campanian).

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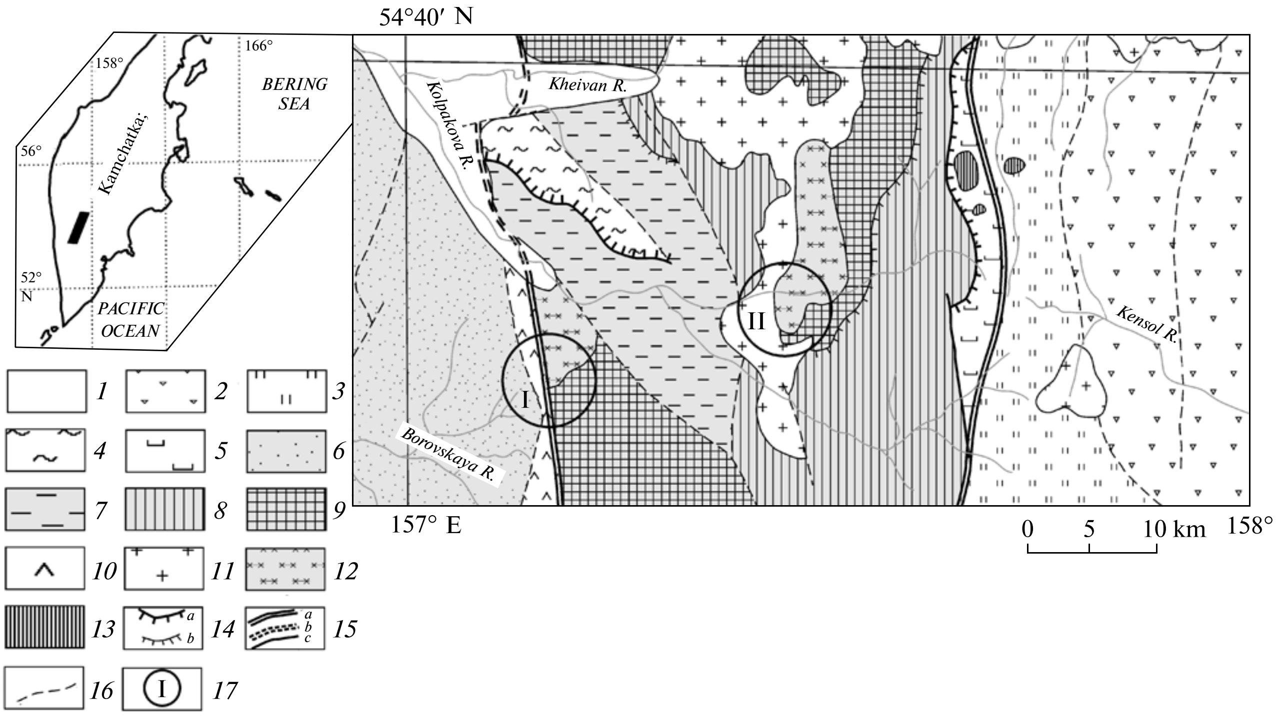

Fig. 1. Scheme of the geological structure of the Kolpakova River district in the Sredinnyi Range of Kamchatka, made in accordance with [10, 11] amended by the authors. (*1*) Quaternary deposits; (*2*) volcanic and volcanic–sedimentary deposits of the Kirganik Formation (Maastrichtian–Paleocene); (3–5) Santonian–Campanian siliceous–volcanic deposits and their metamorphosed analogues: (*3*) Irunei Formation, (*4*) Khimka Formation, (*5*) Andrianovka Formation; (*6–8*) Upper Cretaceous–Paleocene terrigenous deposits and their metamorphic analogues: (*6*) Khozgon Formation, (*7*) Kheivann and Stol'nikov formations, (*8*) the Kamchatka Group (Shikhtina Formation); (*9*) Lower and Upper Cretaceous metamorphic rocks of the Kolpakova Formation; (*10*) Upper Jurassic–Lower Cretaceous (?) volcanic rocks of the Kvakhon Formation; (*11*) Eocene equigranular granitoids; (*12*) Upper Cretaceous gneissoid granites and granite–gneisses of the Krutigorova Complex; (*13*) Upper Cretaceous (Campanian–Maastrichtian) intrusions of the pyroxene–gabbro–syenite composition; (*14*) thrusts: (*a*) principal (between the autochthon and allochthon), (*b*) secondary; (*15*) near-vertical fractures: (*a, b*) principal ((*a*) mappable, (*b*) probable), (*c*) secondary; (*16*) probable fractures; (*17*) sampling sites (I, Poperechnaya R. head, Kolpakova R. right branch; II, Pravaya Kolpakova R. midstream).

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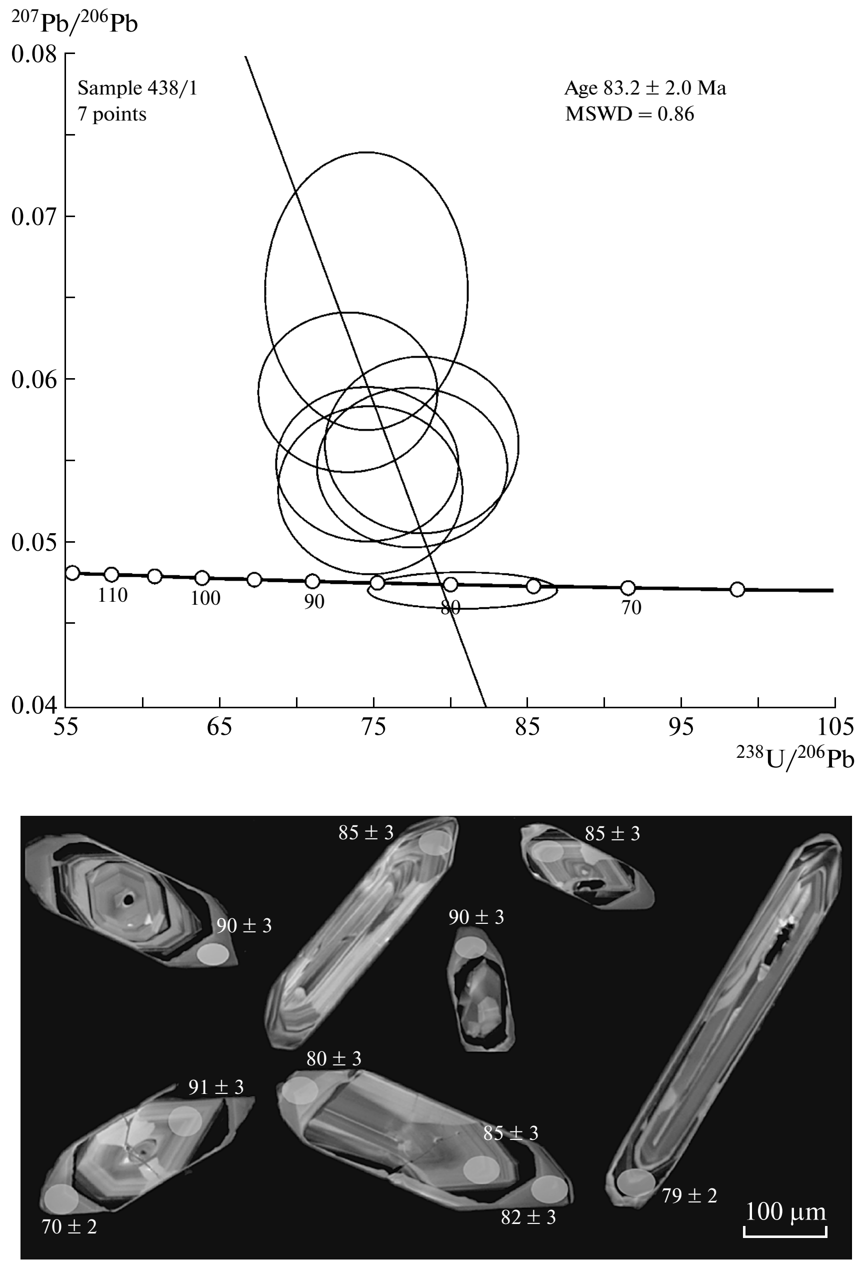

Fig. 2. Concordia diagram for U–Pb–SHRIMP data based on zircons from gneissoid granites (Sample 438/1) of the Malka Uplift in the Sredinnyi Range of Kamchatka and cathodoluminescence zircon images. In the figure, light circles show measurement points; numbers indicate age.

The continental crust in Kamchatka is newly formed, as the major part of its granite–metamorphic layer was formed in the Cretaceous–Paleogene. Granite formation and metamorphism processes are widespread in the Malka Uplift of the Sredinnyi Range in Kamchatka, which is an appropriate object for studying processes of continental crust formation in the Mesozoic–Cenozoic. Study of these processes at a basically new level became possible with the appearance of new precise methods in geochronology, such as U–Pb SHRIMP dating of zircon. Using these techniques we have recently revealed two stages in the granite formation and development of the newly formed continental crust in Kamchatka: Late Cretaceous (80–77 Ma) and Early Eocene (52 Ma) [1, 2]. The Early Eocene stage of granite formation and metamorphism coincides in time with the collision of the Achaivayam–Valagin ensimatic island arc with the Kamchatka margin of Eurasia [1, 3]. However, the Campanian state was distinguished on the basis of quite a limited amount of data and it was the subject of much controversy. The Late Cretaceous was believed

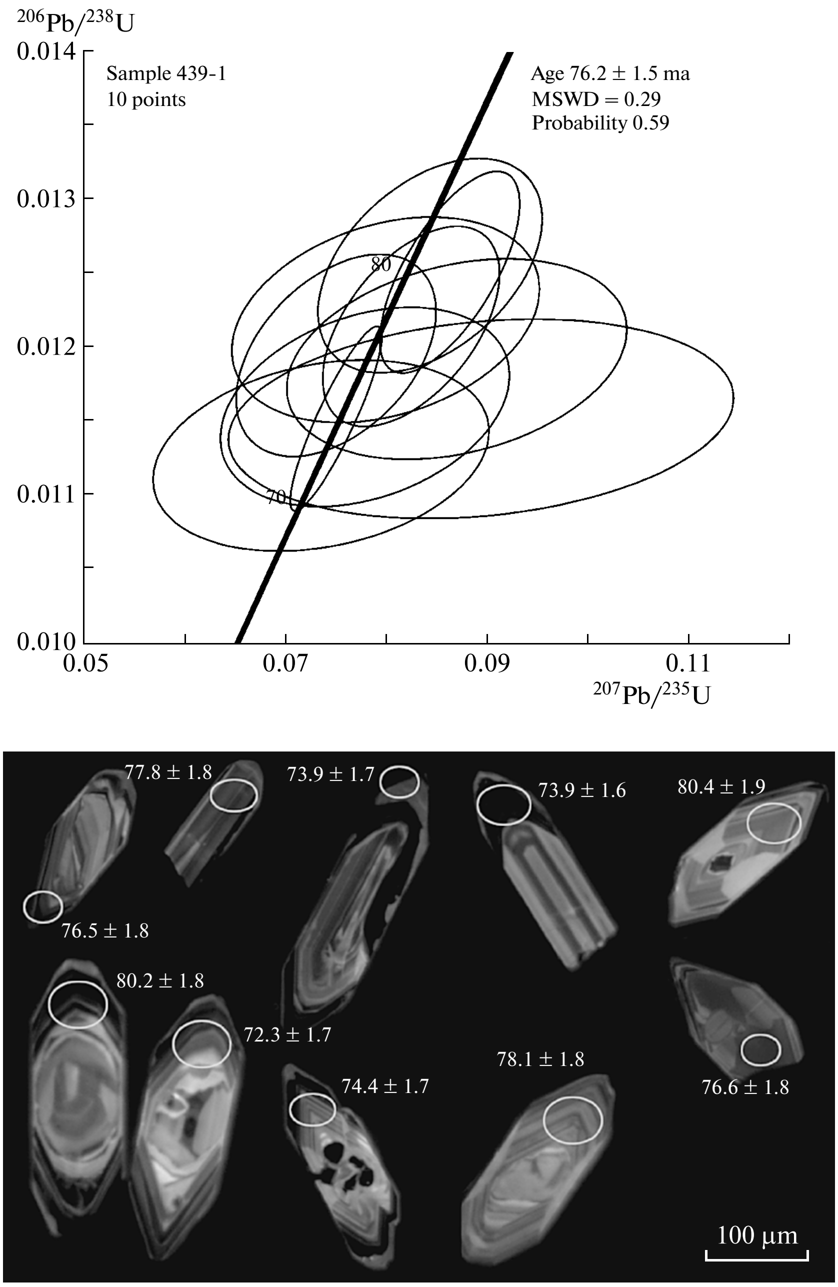

Fig. 3. Concordia diagram for the U–Pb–SHRIMP dating on zircons from gneissoid granites (Sample 439/1) of the Malka Uplift of the Sredinnyi Range in Kamchatka.

to be associated with the accretionary setting in the Kamchatka margin of Eurasia [2]. Detailed thematic research was conducted in 2004–2005 to substantiate the scope of the Campanian granite magmatism in the southern part of the Sredynnyi Range. The research has shown the significant role of the Campanian Stage of granite formation for continental crust development.

According to recent works, the Malka Uplift of the Sredinnyi Range is a fold–nappe structure [1, 4, 5]. The allochthon includes units of the Kolpakova Group, cut by the Krutogorova gneissoid granites and overlain by deposits of the Kamchatka group of the Kheivan and Khozgon formations. The allochthon is composed of rocks of the Andrianovka, Khimka, Irunei, and Kirganik formations. The neoautochthon of the Sredinnyi Range includes Lower Eocene deposits of the Barabsk Formation unconformably overlying metamorphic and Cretaceous deposits of the Irunei Formation [1].

The Malka Uplift in the Sredinnyi Range exhibits two types of granitoids: gneissoid and equigranular

Results of U–Pb–SHRIMP analysis of zircons from granitoids of the Malka Uplift of the Sredynnyi Range

Point number	$^{206}Pb_{normal}$, %	U, g/t	Th, g/t	Th/U	Not corrected		^{204}Pb corrected
					$^{238}U/^{206}Pb$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{238}U$-age
438-1.1.1	2.27	267	55	0.21	73.42 ± 2.3	0.0594 ± 0.0020	85.0 ± 3.0
-1.2.1	1.93	220	33	0.15	70.02 ± 2.3	0.0556 ± 0.0019	90.0 ± 3.0
-1.3.1	0.86	213	39	0.19	74.68 ± 2.4	0.0550 ± 0.0019	85.0 ± 3.0
-1.4.1	0.05	244	36	0.15	74.78 ± 2.5	0.0534 ± 0.0021	85.0 ± 3.0
-1.5.1	1.38	768	62	0.08	90.77 ± 2.9	0.0597 ± 0.0014	70.0 ± 2.0
-1.5.2	1.62	177	36	0.21	69.47 ± 2.3	0.0562 ± 0.0025	91.0 ± 3.0
-1.6.1	1.37	127	22	0.18	74.63 ± 2.7	0.0656 ± 0.0035	85.0 ± 3.0
-1.6.2	0.38	346	25	0.08	77.59 ± 2.5	0.0548 ± 0.0020	82.0 ± 3.0
-1.6.3	2.04	279	28	0.1	78.21 ± 2.6	0.0562 ± 0.0022	80.0 ± 3.0
-1.7.1	0.06	4542	406	0.09	80.86 ± 2.5	0.0473 ± 0.0005	79.0 ± 2.0
439-1_1.1	0.4	434	157	0.37	83.3 ± 1.9	0.0487 ± 0.0012	76.6 ± 1.8
-1_2.1	2.67	827	27	0.03	84.4 ± 1.9	0.0779 ± 0.0025	73.9 ± 1.7
-1_3.1	1.92	775	181	0.24	82.2 ± 1.9	0.0684 ± 0.0011	76.5 ± 1.8
-1_4.1	0.33	2053	275	0.14	79.7 ± 1.8	0.05267 ± 0.0006	80.2 ± 1.8
-1_5.1	0.79	446	115	0.27	88.0 ± 2.0	0.0536 ± 0.0012	72.3 ± 1.7
-1_6.1	0.38	256	73	0.29	79.3 ± 1.8	0.0517 ± 0.0016	80.4 ± 1.9
-1_7.1	0.02	2568	178	0.07	86.7 ± 1.9	0.04739 ± 0.0005	73.9 ± 1.6
-1_8.1	0.88	440	63	0.15	85.4 ± 2.0	0.0557 ± 0.0013	74.4 ± 1.7
-1_9.1	0.2	542	246	0.47	82.2 ± 1.9	0.0508 ± 0.0011	77.8 ± 1.8
-1_10.1	0.58	409	111	0.28	81.5 ± 1.9	0.0522 ± 0.0013	78.1 ± 1.8
427_1.1.1	0.52	964	39	0.04	79.2 ± 2.1	0.0526 ± 0.0017	80.4 ± 2.1
_1.2.1	0.3	2485	314	0.13	118.6 ± 3.1	0.0514 ± 0.0011	54.0 ± 2.1
_1.2.2	0.09	708	136	0.2	109.6 ± 3.0	0.0534 ± 0.0039	58.5 ± 2.1
_1.3.1	0.38	307	133	0.45	76.5 ± 2.1	0.0633 ± 0.0070	83.3 ± 2.1
_1.4.1	0.23	1603	110	0.07	93.7 ± 2.4	0.0488 ± 0.0012	68.2 ± 2.1
_1.5.1	2.56	334	52	0.16	76.9 ± 2.2	0.0743 ± 0.0074	81.1 ± 2.1
_1.6.1	2.64	525	143	0.28	80.2 ± 2.2	0.0673 ± 0.0022	78.0 ± 2.1
_1.7.1	0.74	382	133	0.36	75.9 ± 2.1	0.0585 ± 0.0051	83.7 ± 2.1
_1.8.1	2.5	333	73	0.23	79.0 ± 2.2	0.0566 ± 0.0024	79.1 ± 2.1
_1.9.1	2.35	267	171	0.66	76.4 ± 2.2	0.0557 ± 0.0025	81.9 ± 2.1

granitoids [1, 2], with markedly varying structural positions. Gnessoid granites are believed to cut solely deposits of the Kolpakova Formation, and they were formed in the Campanian, whereas equigranular granites are Early Eocene in age and cut both autochthon sequences and lower parts of the allochthon. Thus, an attempt was made to use the structural features of granitoids for classifying them by age: gneissoid are Campanian and equigranular are Early Eocene. The geochronological data available at that time confirmed it [1, 2]. However, recent evidence suggested that there are exceptions.

Geochronological research was performed on zircons both from gneissoid (438/1 and 439/1) and from equigranular (427/1) granitoids. Samples 438/1 and 439/1 were picked up on the right bank of the Poperechnaya River (54°27,405' N, 157°09.850' E, 945 m and 54°26.194' N, 157°09.650' E, 993 m, respectively) (Fig. 1). The first sample is represented by biotite gneissoid granites; the second, by slightly gneissoid double-micaceous granites with garnet. Sample 427/1 was picked up in the Pravaya Kolpakova River district (54°32.472' N, 157°24.272' E, 1303 m) from medium-grained double-micaceous granites, which cut shales and gneisses of the autochthon and contain their xenoliths.

Analytical methods. U–Pb dating of zircons was performed by D.I. Matukov and S.L. Presnyakov on the SHRIMP II ion microprobe at the Isotopic Research

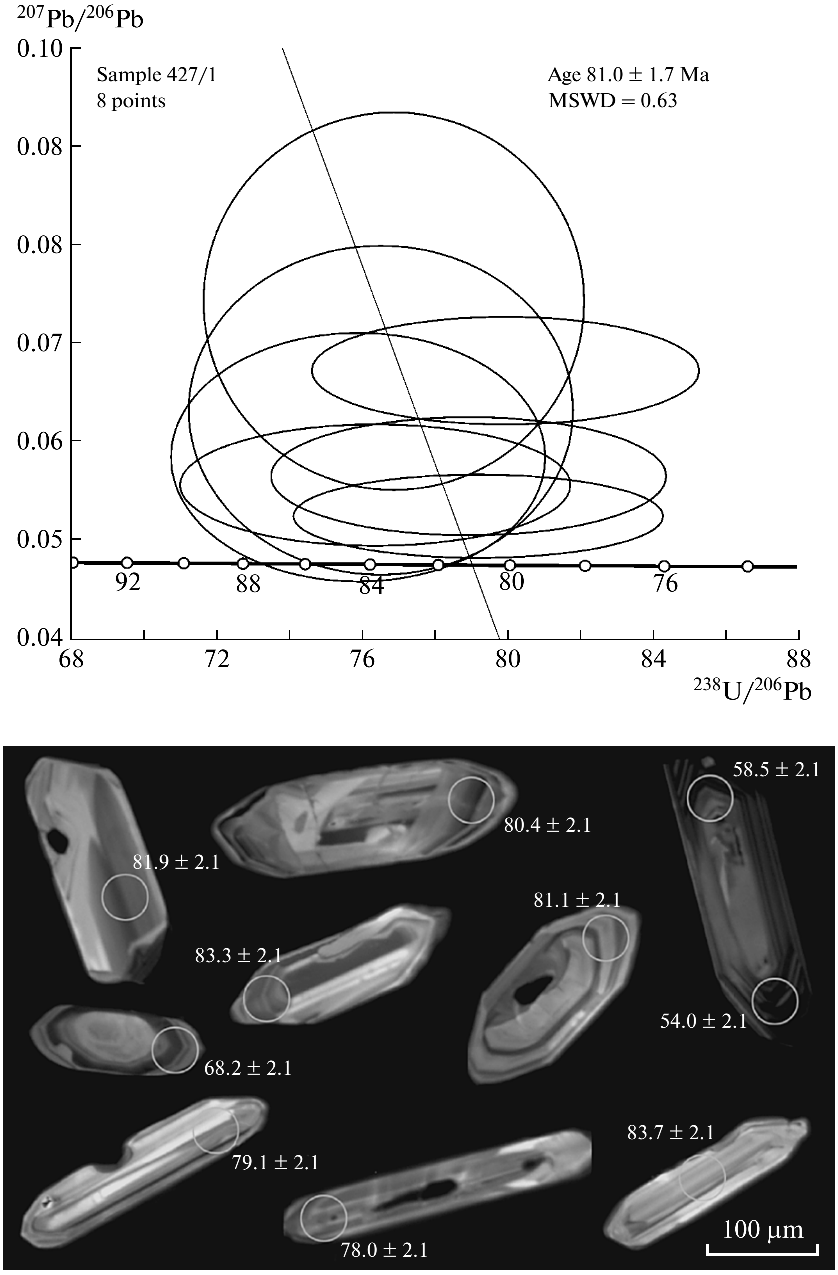

Fig. 4. Concordia diagram for U–Pb–SHRIMP dating on zircons from medium-grained double-micaceous granites (Sample 427/1) of the Malka Uplift in the Sredinnyi Range of Kamchatka.

Center of the Karpinskii All-Russia Research Institute of Geology.

Hand-selected zircon grains were mounted into epoxy together with standard zircon grains TEMORA and 91 500 and then were polished to expose their interior. To select dating sites (points) on the grain surface, optical (in transmitted and reflected light) and cathodoluminescence images were used, which reflected the internal structure and zonality of zircons.

The measurements of the U–Pb ratios were carried out on SHRIMP-II by the methods described in [6]. The intensity of the initial cluster of molecular negatively charged ions of oxygen was 2 nA, the diameter of the spot (crater) was 15 mkm. The obtained data were processed by the SQUID program [7]. The U–Pb ratio was normalized to the 0.0668 value that was assigned to the TEMORA standard zircon, which corresponds to the age of that zircon, which is 416.75 Ma [8]. The errors of analyses (in ratios and age) are given at a level of 1σ, the errors in the dated concordant ages and crossings with concordia are given at a level of 2σ. The concordia diagrams were drawn on the basis of ISOPLOT/EX programs [9].

U–Pb–SHRIMP data. Zircons from gneissoid granitoids (samples 438/1, 439/1) are represented by euhedral short and elongated prismatic crystals, from 80 to 400 mkm. Cathodoluminescence images of zircon crystals exhibit zonation, which is parallel to crystallographic faces, and the absence of xenogenic nuclei (Figs. 2, 3), which suggests the magmatic origin of the zircon population. The weighted mean of the age in Sample 438/1 for 7 points is 83.1 ± 2.0 Ma (Fig. 2, table) and in Sample 439/1 for 10 points is 76.2 ± 1.5 Ma (Fig. 3, table).

Zircons from medium-grained double-micaceous granites (Sample 427/1) are represented by euhedral short and elongated prismatic crystals, from 100 to 250 mkm in size. As in the case of gnessoid granites, cathodoluminescence images of zircon crystals display magmatic zonation and an absence of xenogenic nuclei (Fig. 4). The weighted mean of the age of 8 points is 81.0 ± 1.8 Ma, and the standard deviation is 0.86 (Fig. 4, table). Moreover, a single crystal yielded two age values, 54.0 ± 1.4 and 58.5 ± 1.6 Ma. Most likely, the appearance of this grain in the sample was caused by contamination during extracting zircons from the rock.

The obtained U–Pb datings of zircons indicate that intrusion and crystallization of granitoids occurred in the time interval from 76.2 ± 1.5 to 83.1 ± 2.0 Ma, which corresponds to the Late Cretaceous (Campanian) stage of granite formation. Since the gneissoid and equigranular granites are of the same age within the accuracy of the technique, the use of the textural criterion for attributing granitoids to the corresponding age in the given district is not universal.

The analysis of this data and comparison with earlier received dates on zircons derived from granitoids of other districts of the Malka Uplift (the Sredinnyi Range) and spreading the U–Pb–SHRIMP evidence over the area have shown that the northern parts of the Uplift are dominated by Early Eocene granites (52 ± 2 Ma), and the southern, by Late Cretaceous granites (76–82 Ma).

CONCLUSION

(1) The U–Pb–SHRIMP dating of zircons recovered from granitoids of the Malka Uplift of the Sredinnyi Range in Kamchatka enabled us to conclude that the time of their intrusion and crystallization lay in the time interval from 76.2 ± 1.5 to 83.1 ± 2.0 Ma. In this way, the Late Cretaceous (Campanian) stage of granite formation and the emplacement of a newly formed continental crust in Kamchatka were reliably substantiated.

(2) The analysis of the age of granitoids involving the area shows that the northern parts of the Malka Uplift are dominated by granites aged 52 ± 2 Ma, which mark the collision of the Achaivayam–Valagin ensimatic island arc with the Kamchatka margin of Eurasia in the Early Eocene, while in southern regions, Late Cretaceous granites (76–82 Ma) prevail, the intrusion of which occurred in the accretion setting at the Kamchatka margin of Eurasia.

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