ISSN 1028-334X, Doklady Earth Sciences, 2006, Vol. 409, No. 5, pp. 774–778. © Pleiades Publishing, Inc., 2006.
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GEOCHEMISTRY

Isotope Age of Subvolcanic Granitoid Rocks of the Early Proterozoic Panarechka Volcanotectonic Structure, Kola Peninsula

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Received February 27, 2006

DOI: 10.1134/S1028334X06050229

The Panarechka volcanotectonic calderalike structure (PVTS) was found in the Early Proterozoic Pechenga–Varzuga Rift Belt (fault-lineament) of the Kola region [1]. This is an oval body (21 × 8 km in size) that extends in a NW direction and is discordant with host rocks of the Il'mozero Formation and Tominga Group of the Imandra–Varzuga structural zone (Fig. 1). The volcanic structure is filled with arkosic and graywacke

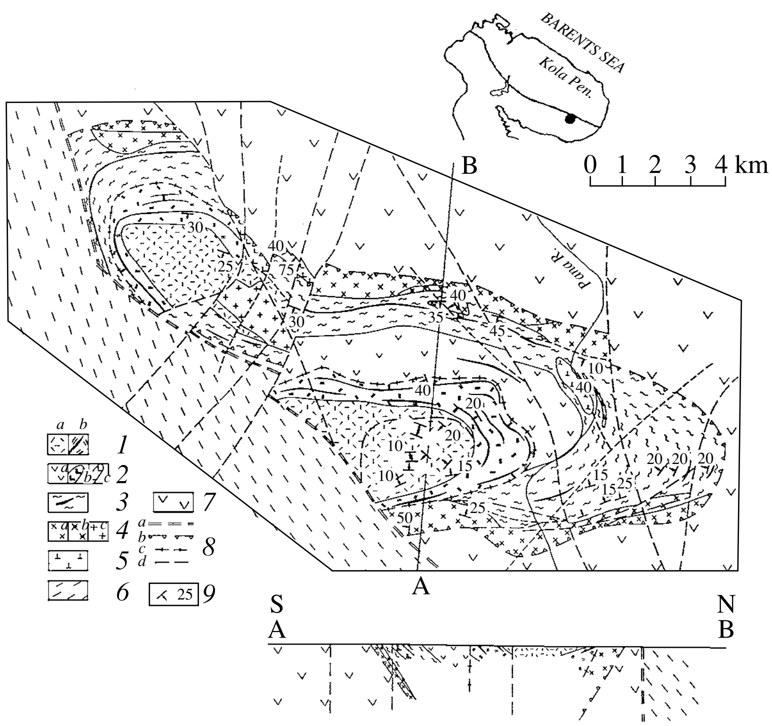

Fig. 1. Schematic geological map of the Panarechka volcanotectonic structure (PVTS). Schematic map of the Kola Peninsula (inset) shows confinement of the PVTS (black circle) to the Pechenga–Varzuga Belt. (*1–5*) Volcanosedimentary rocks of the PVTS: (*1*) Volcanic rocks of the Saminga Formation: (*a*) rhyolitic paleoignimbrites of the Upper Saminga Subformation; (*b*) rhyodacite and rhyolite lavas of the Lower Saminga Subformation with quartz–carbonaceous metasomatites; (*2*) volcanoplutonic gabbro–basalt association: (*a*) basaltic lavas of the Upper Panarechka Subformation; (*b*) gabbrodolerite and microgabbro intrusions; (*c*) picritic intrusions; (*3*) sedimentary rocks of the Lower Panarechka Subformation with quartz–carbonaceous metasomatites; (*4*) (*a*) trachydacites and (*b*) trachyandesites from ring-fault zone, (*c*) plagiomicrocline granites; (*5*) epizonal Panarechka peridotite massif; (*6*) Tominga Group; (*7*) Il'mozero Formation; (*8*) faults: (*a*) Tominga thrust; (*b*) ring-fault of the PVTS; (*c*) ring-faults bounding the Western and Eastern calderas; (*d*) linear faults; (*9*) dip and strike.

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sandstones and basaltic lavas of the Panarechka Formation ~1000 km thick. The separate Western and Eastern calderas distinguished in the southern part of the PVTS are made up of dacite–rhyolite lavas and rhyolite paleoignimbrites of the Saminga Formation up to 500 m thick. Rocks at the PVTS periphery show concentric distribution and dip inward at 25°–45°. Rocks in the central part have a gentler (subhorizontal in some places) dip. The PVTS is bounded by a steep ring-fault, along which are numerous lenslike and crescent-like subvolcanic trachyandesite and trachydacite intrusions. Rhyolites of the Western Caldera are cut by a stock of epizonal plagiomicrocline granites 2.5 × 1.5 km in size. Elevated contents of Au (0.1–1 g/t), Ag (up to 20 g/t), as well as Sn, Bi, Sb, Pb, Zn, W, and As, are found in quartz–carbonaceous metasomatites. The metasomatites are restricted to small synvolcanic faults that crosscut rhyolites and rhyodacites of the Lower Saminga Subformation and sediments of the Panarechka Formation (Fig. 1).

Several reliable reference dates were obtained on volcanic rocks of initial riftogenic stages of the Pechenga–Varzuga Belt. In particular, the volcanic rocks of the Seidorechka Formation (Imandra–Varzuga structure) have a U–Pb zircon age of 2448 ± 8 Ma [2]. Ferropicrites of the Matert Formation (Pechenga structure) have the Re–Os whole-rock age of 1970 ± 45 Ma [3]. Tuff from the Matert Formation yields a Pb–Pb age of 1970 ± 5 Ma [5]. The Pechenga gabbro–wehrlite intrusions, comagmatic to basalts of the Matert formation, define a similar U–Pb baddeleyite age of 1982 ± 8 Ma [5]. However, magmatic rocks of the orogenic stage at the top of the Karelian (Kalevian) Complex of the Pechenga and Imandra–Varzuga structures have an approximate Rb–Sr whole-rock age of 1865–1855 Ma (Pechenga structure) and 1765 Ma (Imandra–Varzuga structure) [6].

To determine the absolute age of the Kalevian magmatic rocks from the PVTS, a subvolcanic moderately acid intrusion from the ring-fault zone and granites of the Western Caldera were dated by the U–Pb zircon method. The subvolcanic trachydacites and trachyrhyolites are spatially associated within a single structural–facies zone of the ring-fault but are separated in time. The younger vitrophyric trachyandesite porphyries actively influence the well-crystallized epizonal trachydacite bodies, resulting in the formation of hornfelsization and partial remelting zones. The trachydacites compose three lenticular intrusive bodies 100–400 m wide and 2–6 km long (Fig. 1) along the northern and southeastern contacts of the PVTS. The rocks have a hypidiomorphic or cryptocrystalline texture with irregular patches of devitrified glass. The average mineral composition of the trachydacite is as follows (vol %): plagioclase, 45; microcline, 7; quartz, 30; devitrified glass, 13; biotite, 3; and muscovite, 2. Accessory minerals are represented by zircon (often ovoid), apatite, allanite, and sulfides. The trachyandesite porphyries form lenticular intrusive bodies 40–200 m thick and 0.5–4 km long in the vicinity of the ring-fault. They have a porphyritic texture with a cryptocrystalline or blastovitrophyric groundmass. Albite forms glomeroporphyric aggregates, occasionally with myrmekitic quartz ingrowths. The epizonal plagiomicrocline granite makes up a large (2.5 × 1.5 km) angular massif with a 100-m-wide contact zone of fine-grained rocks. The granite has a hypidiomorphic (prismatic-crystalline in the fine-grained varieties) texture. The average mineral composition is as follows (vol %): plagioclase, 40; microcline, 10; quartz, 35; biotite, 3; and muscovite, 12. Tourmaline, magnetite, hematite, zircon, and apatite are the accessory minerals.

Table 1. Average chemical composition of rocks from the PVTS (major components are given in wt %; other components, in ppm)

Component	1	2	3	4
	$n = 11$	$n = 14$	$n = 5$	$n = 28$
SiO_2	63.88	57.36	72.41	71.30
TiO_2	0.66	0.93	0.37	0.27
Al_2O_3	16.07	16.08	13.26	12.96
Fe_2O_3	2.64	3.33	0.97	1.62
FeO	1.95	2.67	1.95	2.63
MnO	0.08	0.09	0.04	0.06
MgO	1.67	2.94	1.12	1.65
CaO	2.41	4.19	0.88	1.53
Na_2O	3.85	4.96	4.64	2.59
K_2O	4.20	2.46	1.77	2.49
H_2O^-	0.17	0.22	0.17	0.20
H_2O^+	1.77	3.33	1.81	2.32
P_2O_5	0.18	0.18	0.20	0.12
S_{tot}	0.05	0.13	0.14	0.04
CO_2	0.42	1.33	0.27	0.22
Total	100.00	100.00	100.00	100.00
Cu	40	70	20	15
Ni	30	60	40	10
Co	15	30	20	15
Cr	40	70	40	30
V	80	120	180	40
Rb	200	130	50	70
Ba	450	400	800	240
Sr	190	100	80	80

Note: (1) Trachydacite; (2) trachyandesite; (3) plagiomicrocline granite; (4) rhyolite of the Saminga Formation. Analyses were made in the Chemical Laboratory of the Geological Institute, Kola Scientific Center (Yu.N. Novikova, L.V. Malyshvea, T.V. Ivonina, and E.A. Apanasevich, analysts).

Table 1 demonstrates the average chemical compositions of subvolcanic rocks from the ring-fault zone,

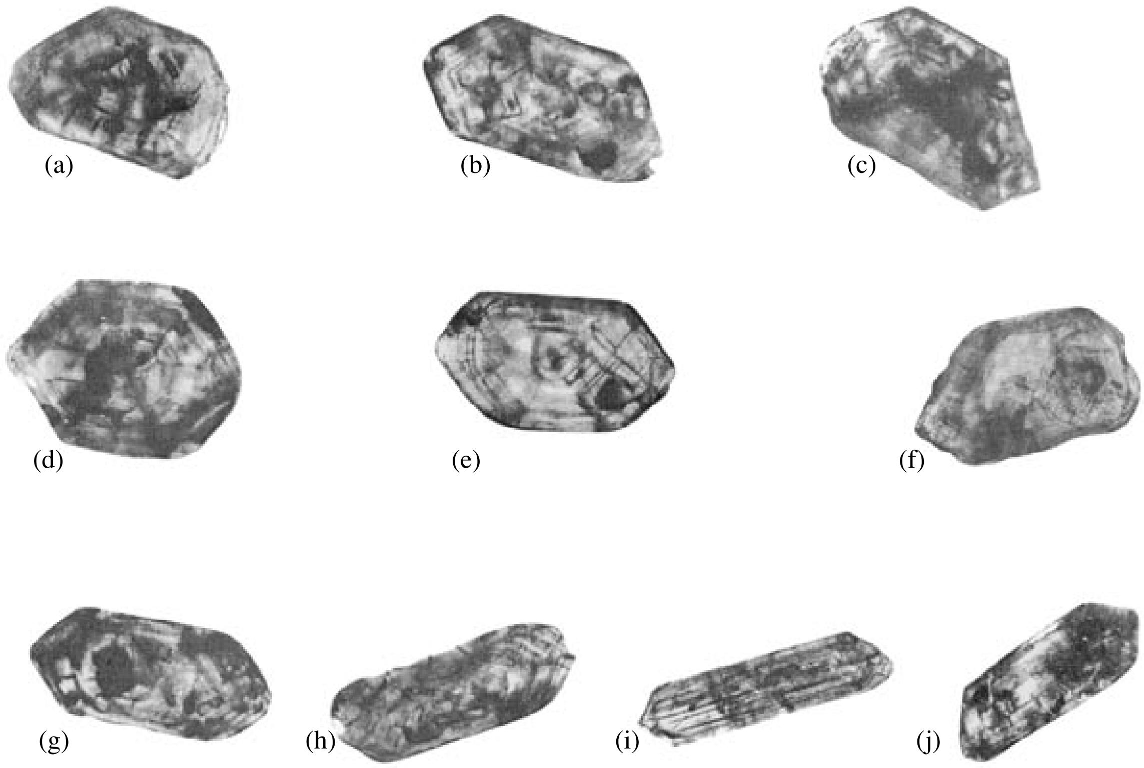

Fig. 2. Microimages of zircon made on an Axioplan-2 microscope. Samples from (a–e) subvolcanic trachydacite and (f–j) plagiomicrocline granite.

rhyolites from the Saminga Formation, and plagiomicrocline granites.

A sample of crystallized subvolcanic trachydacite (52 kg) was taken to date volcanic rocks of the PVTS. After crushing the sample and separating zircon grains, four varieties were hand-picked (Figs. 2a–2e; Fig. 3a, points 1–4). Zircon I is observed as brown relatively large (100×75 to 125×75 μm, K_{el} ~1.6) grains or frag-

Table 2. Isotope U–Pb zircon data on the Panarechka structure

Sample no.	Weight, mg	Content, ppm		Pb isotopic composition*			Isotope ratios and age, Ma**			*Rho*
		Pb	U	$^{206}Pb/^{204}Pb$	$^{206}Pb/^{207}Pb$	$^{206}Pb/^{208}Pb$	$^{207}Pb/^{235}U$	$^{206}Pb/^{238}U$	$^{207}Pb/^{206}Pb$	
Subvolcanic trachydacite										
1	0.35	19.0	52.7	905	7.6002	3.65710	4.70292	0.292220	1907	0.72
2	0.50	40.9	136.9	1926	8.0991	4.02880	4.03278	0.251087	1903	0.76
3***	0.40	244.2	205.4	31	1.8353	0.75539	3.07372	0.191843	1899	0.89
4***	0.20	42.4	53.8	30	1.7729	0.73176	1.87578	0.116496	1908	0.51
Plagiomicrocline granite										
1	0.75	95.7	264.2	4856	8.2233	12.042	5.70891	0.348385	1939	0.99
2	0.75	36.8	106.9	2842	8.0658	10.980	5.38067	0.327194	1945	0.86
3	0.45	126.7	419.6	7608	8.2776	12.240	4.78163	0.291313	1942	0.89
4	0.60	77.3	257.7	10765	8.3197	12.096	4.74876	0.289539	1940	0.85
5	0.50	72.3	242.2	3180	8.1355	11.042	4.65499	0.284419	1937	0.87

Note: (*) All ratios are corrected for procedure blanks (0.08 ng for Pb and 0.04 ng for U) and mass discrimination ($0.12 \pm 0.04\%$).
(**) Correction for common lead was made with model [7].
(***) Correction for isotopic composition of light plagioclase: $^{206}Pb/^{204}Pb = 19.51 \pm 0.02$; $^{207}Pb/^{204}Pb = 15.22 \pm 0.03$; $^{208}Pb/^{204}Pb = 34.82 \pm 0.02$.

ments. The grains are characterized by a prismatic or equant shape and a hyacinth or zircon habit (Figs. 2a, 2b). The crystals have weakly corroded surfaces. Zircon II appears as small (75 × 75 μm) brown crystals (Fig. 2c). Zircon III is found with light brown medium-sized (125 × 100 μm, K_{el} ~1.3) short-prismatic or equant grains of the zircon or hyacinth habit (Fig. 2d). Zircon IV makes up light brown grains (Fig. 2e) with an average size of 100 × 75 μm.

Table 2 and Fig. 3 present all analytical data and a U–Pb isochron for zircons from the trachydacites. The four-point discordia define an upper intercept age of 1907 ± 18 Ma (MSWD = 0.07). A lower zero intercept suggests recent lead loss. The U–Pb zircon system is almost undisturbed.

A sample of well-crystallized medium-grained plagiomicrocline granite (35 kg) was taken for the U–Pb dating. After crushing and separation, five zircon varieties were hand-picked (Fig. 2f–2j, Fig. 3b, points 1–5). Zircon I is represented by light brown short-prismatic or equant grains (Fig. 2f) (100 × 75 μm, K_{el} ~1.3). Zircon II is observed as light to dark brown large short-prismatic zircon and its fragments (Fig. 2g). The morphology of zircons is dominated by the {100} prism and {111} bipyramid, with less developed {221}, {331}, and {311}. The average size is 150 × 100 μm (K_{el} ~1.5). Zircon III is represented by large (200 × 75 μm, K_{el} ~2.5) brown prismatic crystals (Fig. 2h). Zircons IV and V are long-prismatic (275 × 50 μm, K_{el} ~5.5) light brown to brown crystals (Figs. 2i, 2j). The predominant faces are the {100} prism and the {111} bipyramid, with less developed {221}, {331}, and {311}. The results of U–Pb dating of zircons from medium-grained plagiomicrocline granites are shown in Table 2 and Fig. 3b.

The five-point discordia yields an upper intercept age of 1940 ± 5 Ma (MSWD = 3). The near-zero lower intercept indicates the recent Pb loss.

The chemical decomposition of the zircon was conducted following the technique [8]. The U and Pb contents were measured in a single-filament mode by the silicagel technique [9]. The coordinates of data points and isochron parameters were calculated using programs [10, 11]. Errors are given at the 2σ level. Decay constants used in calculations were taken from [12]. The U–Pb isotope study was performed on a seven-channel Finnigan MAT-262 (RPQ) mass spectrometer in static mode. The reproducibility error along axes was taken to be 0.5% [13].

The morphology of accessory zircons from the subvolcanic trachydacites and plagiomicrocline granites, as well as distinct thin zoning in immersion, indicates their magmatic origin. Hence, the obtained U–Pb ages of 1907 ± 18 and 1940 ± 5 Ma can be considered the formation age of the volcanic rocks of the Panarechka volcanotectonic structure.

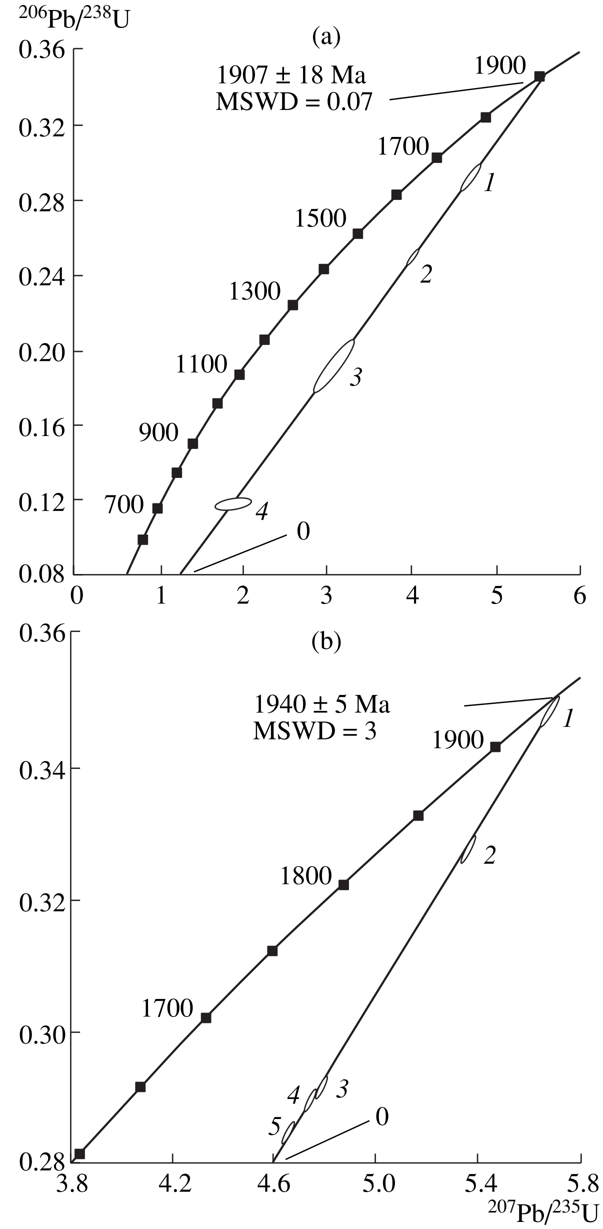

Fig. 3. U–Pb diagram with concordia for zircons from (a) subvolcanic trachydacite and (b) plagiomicrocline granite.

The obtained age data on felsic magmatic rocks from the PVTS testify to long-term evolution of this structure. The early magmatic phases are represented by basaltic rocks of the Panarechka Formation and rhyodacites and rhyolites of the Saminga Formation. The late phase produced plagiomicrocline granite of epizonal massifs emplaced in the rocks of the Saminga Formation in the core of the Western Caldera, as well as series of subvolcanic moderately acid intrusive bodies restricted to the ring-fault. The age of the studied rocks correlates with the crystallization age of plagiogranites of the Shuonijarvi Massif and quartz diorites of the Kaskeljavr Massif (1939 ± 7 [14] and 1940 ± 17 Ma, respectively [15]) in the southern framing of the Pechenga structure. In addition, new ages obtained for the Kalevian magmatism make it possible to date the Panarechka noble and sulfide mineralization in thick synvolcanic zones of quartz–carbonaceous metasomatites.

ACKNOWLEDGMENTS

This work was supported by the Russian Foundation for Basic Research (project nos. 04-05-65154 and 04-05-64179), the Foundation of the President of the Russian Federation for the Support of Leading Scientific Schools (project no. 2305.2003.05).

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