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PRECAMBRIAN REGIONAL METAMORPHISM AND MAGMATISM OF GEORGIA AND GEODYNAMICS OF THE CAUCASUS

In the Caucasian segment of the Mediterranean collisional orogenic belt the Greater Caucasian, Black Sea-Central Transcaucasian, Baiburt-Sevanian and Iran-Afghanian terranes are identified, which in geological past represented island arcs or microcontinents. In terms of modern structure they are accretionary terranes of the first order separated by trustworthy or supposed ophiolite sutures of different age — relicts of small or large paleooceanic basins. Within the territory of Georgia sedimentary, volcanic and intrusive rocks of Precambrian age crop out: in the Dzirula and Khrami crystalline massifs (the Black Sea-Central Transcaucasian terrane), in the Main Range zone (the Greater Caucasian terrane) and in the Loki crystalline massif (Baiburt-Sevanian terrane). The age of rocks is established on the basis of geological data and by *LA-ICP-MS* U-Pb zircon dating. The Precambrian rocks underwent Grenville (100—800 Ma), Baikalian (660—550 Ma) and Late Baikalian (540—500 Ma) stages of prograde regional metamorphism in supra-subduction conditions by both sides of Proto-Paleotethys and along the northern margin of small oceanic basin of the Southern slope of the Greater Caucasus. Later, they experienced supra-subduction regional metamorphism mainly during the Early (~345—335 Ma) and Late Variscan (330—315 Ma) orogenies.

Keywords: Caucasus, Precambrian rocks, metamorphism, magmatism, geochronology, geodynamics.

Introduction. The revival of mobilistic ideas in the form of a plate tectonic theory led to the new interpretation of the Tethys Ocean. Paleomagnetic and paleokinematic, as well as traditional geological data (character of sedimentation and magmatism, geology and age of ophiolites, paleoclimatic and paleogeographic data) indicate that within the oceanic area of Tethys (future Mediterranean fold belt), which separates the Afro-Arabian and Eurasian continental plates, in geological past relatively small continental or subcontinental plates (terranes) were situated. They have various geodynamic nature and are characterized by specific lithologic-stratigraphic section and magmatic, metamorphic and structural features. During the Late Precambrian, Paleozoic and Early Mesozoic these terranes underwent horizontal displacement in different directions within the oceanic area of Proto-Paleo- and Mesotethys (Neotethys) and as a result of Variscan, Early Kimmerian, Bathonian and Austrian orogenies underwent mutual accretion and ultimately joined the Eurasian continent.

The Caucasian segment of the Mediterranean collisional orogenic belt represents complicated polycyclic geological structure involving mountain foldsistems of the Greater and Lesser Caucasus and adjacent foredeeps and intermountain troughs. There the Greater Caucasian, Black Sea-Central Transcaucasian, Baiburt-Sevanian and Iran-Afghanian terranes are identified, which in geological past represented island arcs or microcontinents. In terms of modern structure, they represent accretionary terranes of the first order separated by trustworthy or supposed ophiolite sutures of different age — relicts of small or large paleooceanic basins (Fig. 1) [2].

Terranes of the first order, in their turn, consist of great number of subterranes delimited as a rule by deep faults or regional thrusts. They were considered earlier as separate tectonic units (zones) of the Caucasus. Besides, in many places of the Caucasian region there are ophiolite terranes — relicts of the oceanic crust of small or large oceanic basins overthrust (obducted) from the above-mentioned ophiolite sutures. Precambrian rocks within Georgia crops out: 1) in the Dzirula and Khrami crystalline massifs (the Black Sea-Central Transcaucasian terrane); 2) in the Main Range zone (the Greater Caucasian terrane) and 3) in the Loki crystalline massif (Baiburt-Sevanian terrane) [5, 6, 8].

Geological structure and composition of the Dzirula massif. Precambrian rocks are widespread in the Dzirula massif. They are represented by: Neoproterozoic gneiss-migmatite complex, three generation metabasites and quartz-diorite orthogneisses [4, 7, 22] (Fig. 2).

The oldest — Grenville regional metamorphism causes the formation of plagiogneiss-plagiomigmatite complex and it is represented by biotite-cordierite-plagioclase-sillimanite-hercynite bearing crystalline schists, plagiogneisses, plagiomigmatites and clinopyroxene bearing plagioamphibolites and amphibolites. Among crystalline schists, plagiogneisses, plagiomigmatites saturated K_2O metapelites are dominating [7]. There occur critical mineral assemblage: $Crd_{53-59} + Pl^{35-45} + Bt_{52-60}(1) + Sil + Kfs \pm Spl \pm Qtz \pm C$. Bi(1) is characterized by $TiO_2 = 4.5$ wt. % and $X_{Fe} = 0.56—0.57$ [16]. The plagiogneisses correspond to *S*-type granites. According to geochemical parameters, they belong to the upper crust. According to Shengelia et al. [24] plagiogneisses of the Dzirula massif are represented by the rocks of subalkaline and normal alkaline group of calc-alkaline series and plagiomigmatites — only by normal alkaline varieties [9]. By Sm/Nd La_n/Yb_n parameters these rocks are attributed to upper-and common crustal formations. During the Grenville regional metamorphism subcontinental or primitive continental crust was formed in supra-subduction conditions by both sides of Proto-Paleotethys.

Metabasite component (amphibolites) of plagiogneiss complex is found as concordant, schistose and boudinated bodies. They are schistosed and boudinated all over the area concordantly to schistosity of the whole plagiogneiss-plagiomigmatitic complex. Primary magmatic structure due to its intensive polymetamorphism rarely occurs. Critical mineral assemblage of these rocks is: $Hbl + Cpx + Pl \pm Grt$. By petrochemical data metabasites belong to normal alkaline group of calc-alkaline and tholeiite series and are characterized

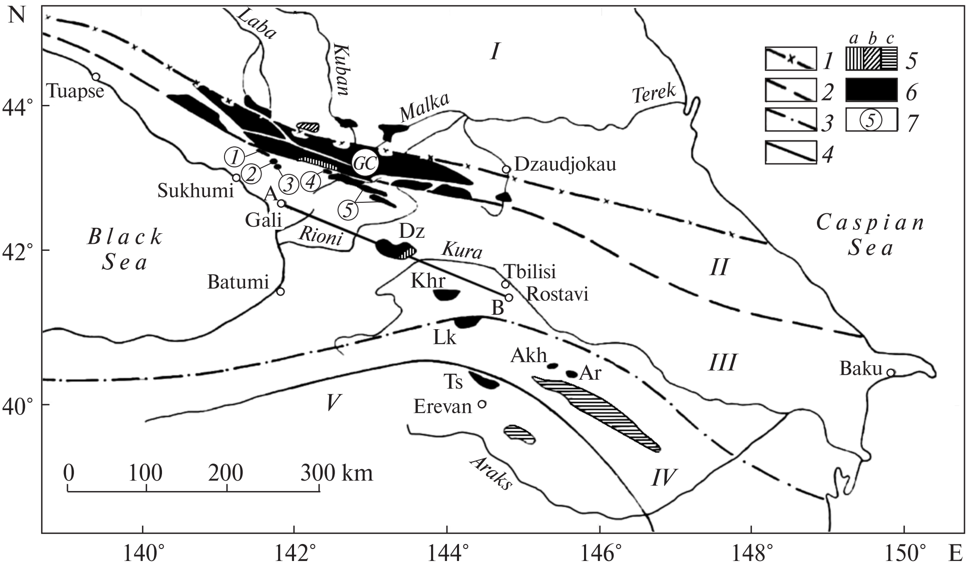

Fig. 1. Tectonic subdivision of the Caucasus on the basis of the terrane analysis [2], simplified. *I*. The Scythian platform; accretionary terranes of the first order: *II* — Greater Caucasian, *III* — Black Sea-Central Transcaucasian, *IV* — Baiburt-Sevanian, *V* — Iran-Afghanian; *1—4* — ophiolite sutures, marking the location of small and large oceanic basins of: *1* — Early?-Middle Paleozoic age, *2* — Late Precambrian-Paleozoic age, *3* — Late Precambrian-Early Mesozoic age, *4* — Mesozoic age; *5* — ophiolite terranes (obducted sheets) of: *5a* — Late Precambrian age, *5b* — Paleozoic age, *5c* — Mesozoic age; *6* — exposures of the pre-Alpine crystalline basement: *GC* — Greater Caucasian, Southern slope of the Greater Caucasus (letters in circles): *1* — Atsgara tectonic wedge, *2* — Shoudidi exposure, *3* — Gorabi exposure, *4* — Nenskra tectonic wedge, *5* — Dizi series), *Dz* — Dzirula, *Khr* — Khrami, *Lk* — Loki, *Akh* — Akhum, *Ar* — Asrikchai, *Ts* — Tsakhkunyats

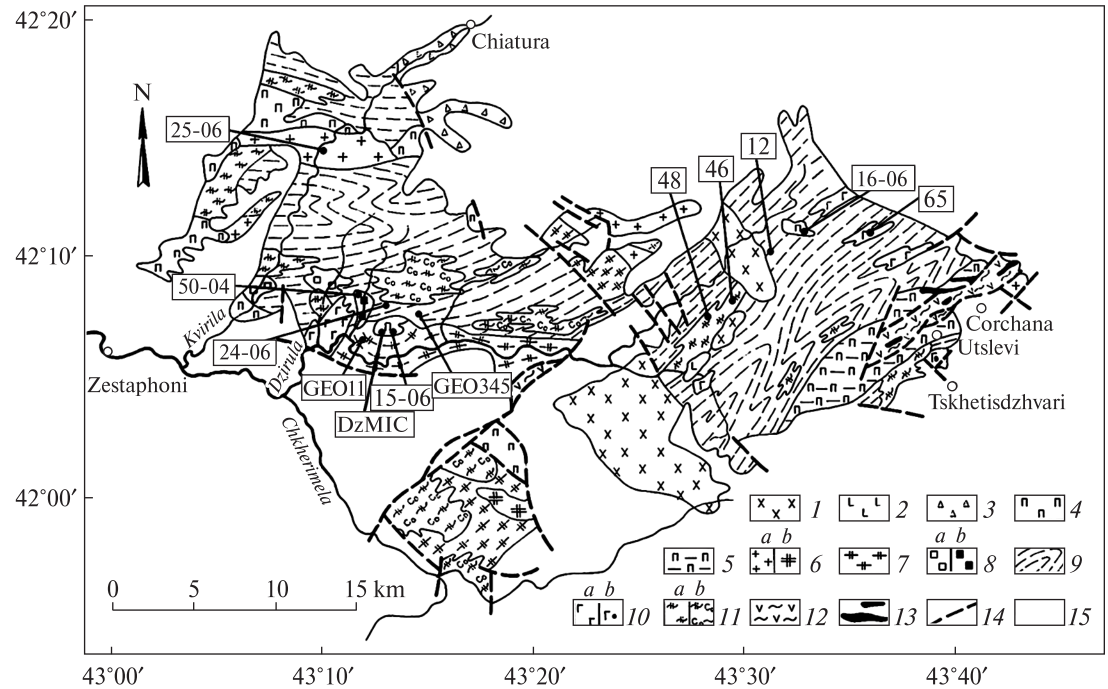

Fig. 2. Schematic geological map of the Dzirula crystalline massif: *1* — granitoids (Middle Jurassic); *2* — feldspar gabbros (Early-Middle Jurassic?); *3* — rhyolite volcanits (Late Paleozoic); *4—7* — Late Variscan: *4* — microcline bearing granites, *5* — foliated granites and mylonites, *6a* — porphyritic microcline bearing granites, *6b* — porphyry granites, *7* — microcline bearing granite-gneisses and migmatites; *8a* — massive tonalites and granodiorites (Late Baikalian), *8b* — massive gabbro-gabbro-diorites (Cambrian?); *9* — quartz-diorite orthogneisses (Late Precambrian); *10* — metabasites (gabbro-gabbro-amphibolites) of: Precambrian (?) (*a*), Cambrian age (*b*); *11* — Precambrian gneiss-migmatite complex: *a* — crystalline schists, amphibolites, amphibole-biotite bearing schists, plagiogneisses, and plagiomigmatites, *b* — cordierite bearing plagiogneisses and plagiomigmatites; *12* — metavolcanic-phyllite complex (of Cambrian — Early-Middle Paleozoic age); *13* — serpentinite protrusion (part of the Precambrian — Paleozoic metaophiolite terrane); *14* — faults; *15* — Mesozoic-Cenozoic sedimentary cover. In rectangles — sample numbers

by considerable prevalence of Na_2O over K_2O and low K_2O content. According to geochemical parameters, they belong to intraplate basalts and intraplate transitional to *MORB*. According to Tsutsunava et al. [31] the metabasites are of highaluminiferous and of medium-magnesian order. Two petrochemical groups — REE enriched and aluminiferous and depleted in REE and medium-aluminiferous are distinguished. The considered metabasites correspond to *N*- and *T-MORB* formations. In comparison with *MORB* MnO and K_2O content is rather increased in them. As the metabasites occupy 25 % of the plagiogneissic complex, we consider that intraplate basaltoid volcanism has a definite role in the formation of the subcontinental crust of the Black Sea-Central Transcaucasian terrane.

For main rock-building minerals microprobe analysis was performed (Table 1). On the basis of obtained data different geothermobarometers [12, 21, 23, 34] were used to establish the conditions for *PT* of the regional metamorphism. Thus, *PT* conditions of Grenville regional metamorphism corresponds to subgranulitic facies (T = 700—720 °C, P = 2.6—2.7 kb).

Plagiogneissic complex of the Dzirula massif is cut by Neoproterozoic dyke- and stock-like bodies of gabbroids transformed later into metagabbroids. In metagabbroids mineral assemblage of Precambrian magmatic stage is Cpx + Hbl + Pl. Metagabbroids belong to the normal alkaline group of calc-alkaline series and are characterized by high content of K_2O (1.35—2.09). Two petrogeochemical groups — normal and highly enriched by REE — are distinguished. In these rocks in comparison with *MORB* the content of Al_2O_3, CaO and rare elements is increased, TiO_2 and MgO is decreased but of Ta, Lu, Yb, Tm, Fr, Dy, Tb, Gd, Eu and Hf is equal. According to rare elements content metabasites correspond to ensialic island-arc basalts of the Sea of Japan [24].

The complex is intruded as well by large (several hundred km^2) body of Baikalian (Cadomian) quartz-diorites, which as a result of Late Baikalian

Table 1. **Microprobe analysis of minerals from Precambrian metamorphic complexes of the Dzirula and Khrami crystalline massifs**

Number of sample	Mineral	SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O
					The Dzirula crystalline massif					
55	Crd	48.80	—	31.62	10.22	0.21	7.78	—	—	—
	Bt	37.30	2.93	19.63	22.30	—	8.30	—	—	8.71
	Pl	53.03	0.01	31.70	0.10	—	—	15.20	2.80	—
	Spl	—	0.19	68.84	49.66	0.48	5.75	—	—	—
57	Crd	48.61	—	32.69	6.70	0.55	8.92	0.10	—	—
	Pl	56.48	—	26.20	0.02	0.01	—	8.72	6.90	0.12
	Ort	64.01	—	20.50	0.07	—	0.10	0.01	1.53	15.59
58	Crd	48.30	—	33.01	9.81	—	7.29	—	—	—
	Pl	55.49	—	29.22	0.10	0.01	—	13.05	3.29	0.11
	Ort	63.18	—	21.00	0.08	0.02	0.11	0.02	1.55	13.69
	Bt	35.42	3.69	20.32	20.78	0.16	8.55	—	0.16	8.21
60	Crd	48.05	—	34.02	8.90	—	8.59	—	—	—
	Pl	57.05	0.01	28.99	0.03	—	—	10.05	3.29	0.09
	Ort	64.13	—	20.17	0.08	—	0.09	0.02	1.60	14.02
10	Crd	46.03	0.02	33.35	10.18	0.45	7.17	—	—	—
		47.03	—	32.02	1062	0.24	7.30	—	—	—
		48.30	—	32.21	9.76	0.17	7.87	—	—	—
	Bt	37.02	3.65	18.89	22.99	0.06	7.94	0.02	0.25	9.39
	Ort	65.60	—	20.25	—	0.01	0.01	0.02	0.48	11.01
	Pl	64.56	0.01	24.20	—	0.02	0.02	6.99	3.97	0.12
	Spl	—	0.21	68.52	30.63	0.50	2.90	—	—	—
9	Crd	48.30	0.02	33.81	9.99	0.30	7.43	—	—	—
		48.47	—	31.50	9.26	0.28	7.91	0.01	—	—
		48.11	—	31.15	9.58	0.12	7.97	—	—	—
	Bt	36.83	3.04	16.94	22.95	—	7.54	—	0.11	
	Ort	64.95	—	21.25	0.01	—	0.01	0.03	2.50	11.10
	Pl	58.55	0.01	26.99	0.03	—	0.01	10.82	4.60	0.60
	Spl	—	0.22	66.62	30.06	0.48	2.92	—	—	—
16	Crd	48.87	—	31.25	10.38	0.36	7.78	—	—	—
		48.97	—	31.73	10.38	0.13	7.62	—	—	—
		48.90	0.01	31.40	10.32	0.20	7.80	—	—	—
	Bt	35.56	3.42	18.03	18.20	0.35	9.80	0.47	1.03	8.42
	Pl	63.97	—	23.78	—	—	—	10.90	5.78	0.10
15	Crd	48.47	—	—	—	31.32	10.12	0.23	8.79	—
		48.03	—	—	32.67	9.49	0.20	8.35	—	—
		48.54	—	32.08	9.52	0.23	8.23	—	—	—
	Bt	36.51	3.05	17.38	19.03	0.32	9.72	0.72	0.49	8.51
	Pl	58.58	0.01	28.98	0.04	—	0.01	9.69	4.30	0.10
	Ort	64.65	—	21.04	—	—	—	0.04	0.92	15.17
17	Hbl	46.21	0.45	12.31	20.03	0.37	10.80	11.25	1.72	0.43
	Pl	49.98	—	31.70	0.10	—	—	15.29	2.79	2.01
	Cum	56.20	0.01	2.31	11.28	—	2.12	1.82	0.02	0.01
	Cpx	51.12	0.21	2.60	11.02	0.41	10.19	22.50	0.63	0.01
	Bt	36.56	3.02	17.41	18.56	—	10.98	0.01	0.28	8.66
61	Hbl	45.78	0.42	12.35	20.93	0.14	11.88	10.47	1.31	0.47
	Pl	52.07	—	30.76	0.06	—	—	14.21	3.26	—
	Cpx	51.23	0.26	0.62	9.21	0.46	10.26	23.02	0.66	0.01
56	Pl	50.01	—	31.57	0.07	—	—	15.29	2.80	—
	Hbl	42.26	0.56	12.35	22.56	0.12	6.19	11.30	1.26	0.20
	Bt	35.30	3.21	20.02	17.91	—	7.48	0.06	0.33	8.40

The end of the Table 1

Number of sample	Mineral	SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O
The Khrami crystalline massif										
10-*kh*	Crd	48.52	0.07	33.45	8.87	0.15	6.02	0.51	0.35	0.68
	Pinite	46.08	0.07	32.61	8.25	0.14	6.79	0.38	0.43	0.81
	Bt	36.25	2.68	18.43	19.13	0.10	10.68	0	0.04	9.38
	Pl	56.14	0	27.25	0.09	0	0	10.54	5.87	0.12
	Ort	63.88	0	17.96	0.25	0.01	0	0.03	1.60	16.08
21-*kh*	Crd	47.65	0.09	33.54	9.78	0.28	7.04	0.12	0.03	0.19
	Pinite	46.15	0.05	32.38	8.47	0.16	6.05	0.40	0.22	0.78
	Bt	37.13	3.12	18.70	21.43	0.05	9.97	0.03	0.12	9.41
	Pl	56.47	0.02	27.53	0.10	0	0	10.41	6.00	0.10
	Ort	64.66	0	21.00	0.08	0	0	0.02	0.88	16.16
98-12	Crd	47.65	0.05	32.06	9.54	0.38	6.98	—	0.12	—
	Bt	36.82	3.48	18.12	22.64	0.06	9.59	0.20	0.11	9.22
	Pl	58.73	0.02	27.14	0.08	—	0.02	10.16	5.98	0.13
	Ort	63.98	—	18.37	0.21	—	—	0.02	1.56	15.11
01-12	Crd	48.30	0.09	33.28	8.98	0.41	7.03	0.23	0.18	—
	Bt	37.05	3.60	17.96	21.96	0.04	10.02	0.10	0.21	9.34
	Pl	57.09	0.01	27.45	0.10	—	—	10.35	5.79	0.11
	Ort	64.57	—	19.47	0.27	0.01	0.02	0.02	1.62	14.97
9-kh	Hbl	44.52	0.76	10.00	18.14	0.50	9.53	11.30	1.30	0.51
	Pl	56.00	0	27.50	0.08	0.01	0	11.54	4.87	0.13
	Bt	35.54	2.92	17.00	22.9	0.20	8.62	0.10	0.39	7.90
10-1	Hbl	45.90	0.50	10.91	13.66	0.14	10.24	11.32	1.54	0.40
	Pl	55.80	0.01	28.02	0	0	0.02	11.41	5.90	0.10
	Bt	35.70	2.48	14.24	21.88	trace	9.60	0.45	0.41	8.20
66-12	Cum	54.61	0.44	2.16	24.77	0.39	14.30	1.53	0.43	0.07
	Bt	36.62	3.17	17.68	21.46	0.07	9.70	0.07	0.16	9.27
	Pl	55.92	—	27.36	—	—	0.01	11.62	5.88	0.09

Note. The Dzirula crystalline massif: crystalline schists — No 55 (Crd + Bt + Pl + Spl + Sil), No 57 (Crd + Pl + Ort + + Sil + Qtz), No 58 (Crd + Pl + Ort + Bt + Sil + Qtz) and No 60 (Crd + Pl + Ort + Sil + Qtz); plagiogneisses — No 10 (Crd + Bt + Pl + Ort + Sil + Spl) and No 9 (Crd + Bt + Kfs + Pl + Ort + Sil + Spl); plagiomigmatites — No 16 (Crd + + Bt + Sil + Pl + Spl) and No 15 (Crd + Bt + Ort + Pl + Spl); amphibolites — No 17 (Hbl + Pl + Cum + Cpx + Bt), No 61 (Hbl + Pl + Cpx) and No 56 (Hbl + Pl + Bt); the Khrami crystalline massif: plagiogneisses — No 10-*kh* (Crd + + Bt + Ort + Pl + Spl), No 21-*kh*, No 98-12 and No 101-12 (Crd + Bt + Pl + Ort); quartz-dioritic orthogneisses — No 66-12 (Bt+ Pl + Cum + Ort), No 9-*kh* and No 10-1 (Hbl + Pl + Bt). Microprobe analysis is accomplished in the Laboratory of the Local Methods of the Department of Petrography of Lomonosov Moscow State University, using a scanning microscope *Scan*-4*DV* (operator E. Guseva).

regional metamorphism turned into orhtogneisses. Gabbroids and quartz-diorite orthogneisses contain the xenoliths of already metamorphosed and strongly deformed plagiomigmatites, plagiogneisses and crystal schists, formed apparently at the Grenville stage of regional metamorphism (Fig. 3). Quartz-diorites have active intrusive contacts with gabbroids. The main mineral paragenesis of magmatic stage of quartz-diorite orthogneisses is — Hbl + Bt + Pl^{25-38} + Qtz. These rocks are characterized by predominant content of Na_2O. They belong to rocks of normal alkalinity of calc-alkaline series and correspond to *I*, partially *S* type granites that, along with the other geologic-petrological signs, indicate the existence of admixture of continental material [7, 24]. According to Rb/Sr — SiO_2 and Eu/Eu* — Sr/Nd ratio quartz-diorites belong to common and upper crust formations [18]. They were formed in an ensimatic immature island-arc during subduction in intra-oceanic conditions and without significant participation of continental material. They belong to mantle-island-arc group corresponding to *M* type granites by Pitcher [20]. These rocks composed to a considerable degree the subcontinental crust of the Dzirula massif.

Later all the above mentioned rocks underwent Late Baikalian high temperature diaphtoresis of amphibolitic facies (T = 500—650 °C, P = 2.7 kb) and Late Variscan retrograde metamorphism of green schists facies (T = 410—510 °C, P = 1.3—1.6 kb).

In south-eastern part of the Dzirula massif among the Late Variscan granites so called Chorchana-Utslevi allochthone metamorphic complex is preserved. Rocks of typical ophiolite complex — serpentinites and metabasites are associated with the Chorchana-Utslevi metamorphic complex and are overthrust together with one [3]. Serpentinites correspond to oceanic restitic clynopyroxene-bearing spinelic harzburgites. Metabasites correspond to *N-MORB* and *T-MORB* [32, 33]. They belong to sub-alkaline rocks of tholleiitic and calc-alkaline series. In process of granite formation both — mantle material and component of ancient continental crust were involved. Sm-Nd age of these rocks is T = 810 ± 100 Ma, $\varepsilon\text{Nd}_{init}$ = 7.37 ± ± 0.55 [32]. These metabasites apparently corresponds to transitional parts of second and third oceanic layers: upper — non-cumulative part of gabbro constituent of the third layer and lowermost part of sheeted complex of the second layer.

The Khrami massif. In the Khrami massif of the Black Sea-Central Transcaucasian terrane Proterozoic formation is represented by plagiogneisse-plagiomigmatite complex (Fig. 4). For main rock-building minerals microprobe analysis was performed (Table 1). *PT* conditions of Grenville regional metamorphism — 700—720 °C, 2.6—2.7 kb are established [7, 28, 29]. It corresponds to subgranulitic facies of one. The complex is represented by biotite-cordierite plagiogneisses (Crd + Bt + + Pl^{20-30} + Ort + Qtz) and biotite-hornblende bearing quartz-diorite gneisses and migmatites (Hbl + Pl + Bt ± Cum ± Qtz). Among these rocks undersaturated K_2O metapelites are dominating [30]. Plagiogneisses are represented by the rocks of subalkaline and normal alkaline group of calc-alkaline series but plagiomigmatites — only by normal alkaline varieties. In Precambrian complex veined bodies of metagabbro of Paleozoic age are observed. These rocks experienced Late Variscan retrograde metamorphism (T = 410—510 °C, P = 1.3—1.6 kb) and are cut by microcline bearing granites of the same age. As a result of these processes, metapelites oversaturated with K_2O dominate in the composition of the rocks [30].

Fig. 3. Xenolith of migmatized and postcrystallization folded biotite bearing crystalline schists in Precambrian (Baikalian) quartz-diorite orthogneiss

The Main Range zone. In contemporary structure the Greater Caucasian terrane corresponds to the Main Range zone of one. The Main Range zone is divided into the Pass and Elbrus subzones (Fig. 5).

The Pass subzone consists of the Laba (Paleozoic) and Buulgen metamorphic complexes. The Buulgen complex is divided into three units. At the base of the amphibolites facies Gvandra unit is presented, which is tectonically overline by the Klich unit. Within the subzone Precambrian rocks are spread in these units. It should be mentioned that according to M.L. Somin [26] the age of the rocks of these two units corresponds to Low-Middle Paleozoic time, but the age of metamorphism is Variscan. The Gvandra and the Klich units share a common two-stage metamorphic history: Baikalian regional metamorphism of amphibolite facies (T = 430—540 °C, P = 3.3—3.5 kb) and Variscan (T = 530—630 °C, P = 2—3 kb) [7, 19]. The Klich unit is characterized by the presence of ophiolite assemblages including *N-MORB* type basalts. The age of both units is Neoproterozoic. The upper part of the Buulgen complex is represented by metapelites of the Early Paleozoic age.

The Elbrus subzone is divided into two parts: infrastructure and suprastructure i.e. autochthone and allochthone. In this subzone Precambrian rocks are observed in sialic autochthone — gneiss-migmatite complex, where polimetamorphism is established. Sequence of regional metamorphic events is following: Grenville or older prograde stage corresponding to subgranulitic and high-temperature amphibolite facies (T = 700—750 °C, P = 2.9—3.7 kb), apparently Baikalian prograde,

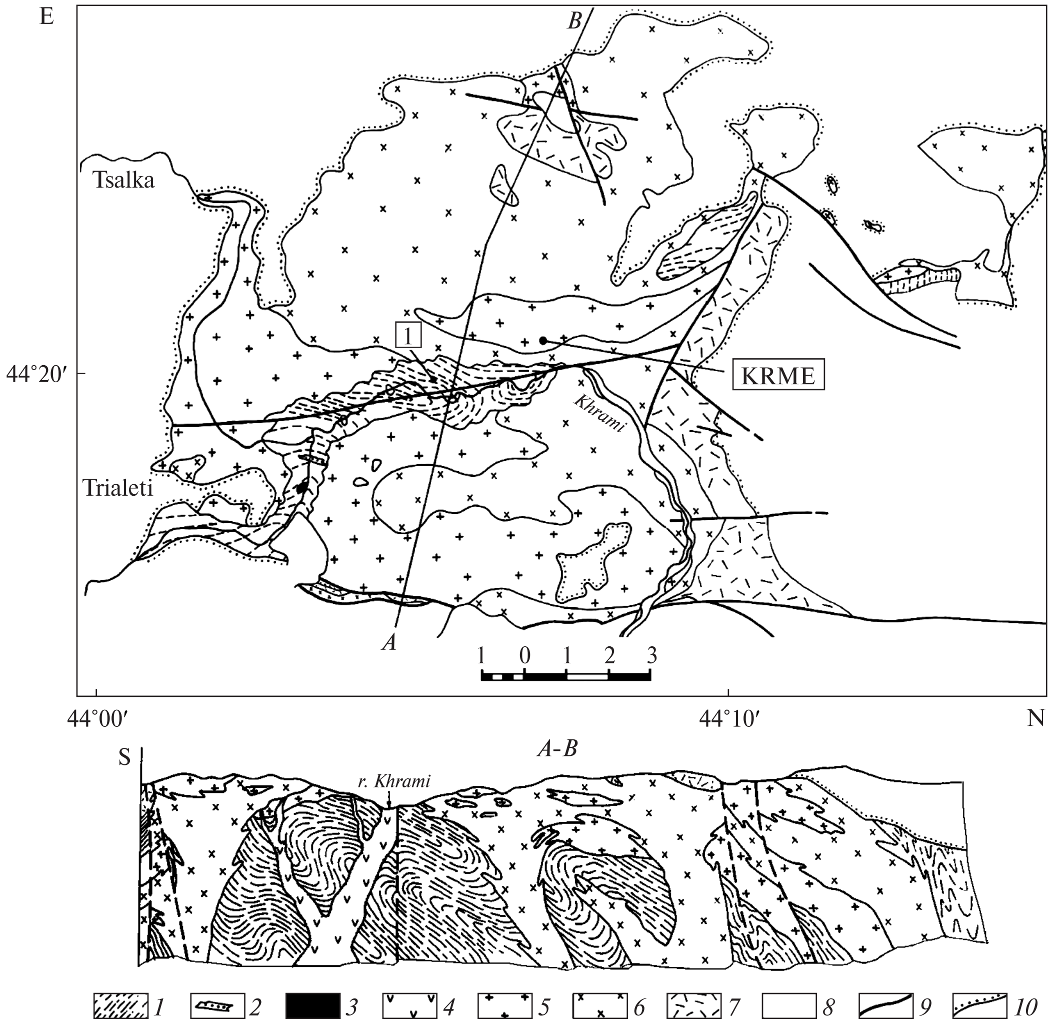

Fig. 4. Geological map of the Khrami crystalline massif after O. Khutsishvili [14], with authors changes: *1—7* — Basement: *1* — Precambrian gneiss-migmatite complex, *2* — packet of Lower-Middle Paleozoic (?) metasandstones in gneiss-migmatite complex, *3* — protrusion of mantle serpentinites (enlarged), *4* — Paleozoic gabbroids, *5* — Late Variscan microcline bearing granites, *6* — Upper Paleozoic quartzporphyric-graniteporphyric complex, *7* — Upper Paleozoic volcanogenic-sedimentary complex; *8* — Mesozoic-Cenozoic sedimentary cover; *9* — faults; *10* — transgressive overlapping. In rectangle — sample numbers

Late Caledonian and Early Variscan diapthoresis of amphibolite facies (T = 500—620 °C, P = = 2.8—3 kb) and Late Variscan retrograde stage of green schist facies ($T < 430$ °C, $P < 1.4$ kb) [7, 19]. All stages of regional metamorphism in the autochthone correspond to low pressure and high temperature belts.

The Loki massif. In the Loki crystalline massif of the Baiburt-Sevanian terrene Precambrian rocks are represented by metabasic tectonic sheet [5, 7] (Fig. 6). It contains basalts with *N-MORB*, possibly *P*- and *T-MORB* chemistry and hypabissal leucocratic granites of sodium type (fragment of Precambrian-Paleozoic? ophiolite complex). Precambrian regional metamorphism of the metabasites corresponds to the lowest stage of green schist facies. The tectonic sheet represents a fragment of ophiolitic association. It includes apparently transitional parts of second and third layers of oceanic crust. In particular, upper non-cumulate part of gabbro component of third layer and the lower most part of sheeted dikes of the second layer. Protoliths of metabasites of Loki massif ophiolitic complex belong to tholeiitic series of basalts. Initial magma of mafites has features of *E-MORB* (possibly *P*- or *T-MORB*) composition and by petrochemical parameters they partly approach to intraplate basalts.

Dikes of hypabissal leucocratic silicic and intermediate magmatic rocks, connected with meta-

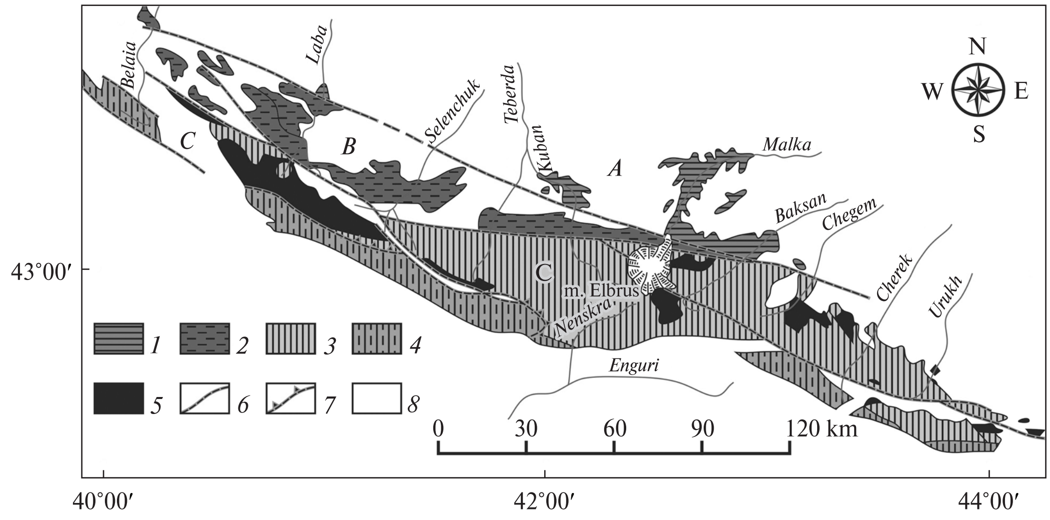

Fig. 5. Scheme of subdivision of the Greater Caucasus pre-Alpine basement [7]: *A—C* — structural-formational zones: *A* — Bechasin, *B* — Fore Range, *C* — Main Range; *1—4* — main exposures of pre-Alpine crystalline complexes: *1* — in the Bechasin zone, *2* — in the Fore Range zone, *3* — in the Elbrus sub-zone of the Main Range zone, *4* — in the Pass sub-zone of the Main Range zone; *5* — fragments of the Macera nappe; *6* — faults; *7* — overthrust of infrastructure of the Elbrus subzone; *8* — Upper Paleozoic and Mesozoic nonmetamorphosed sedimentary cover

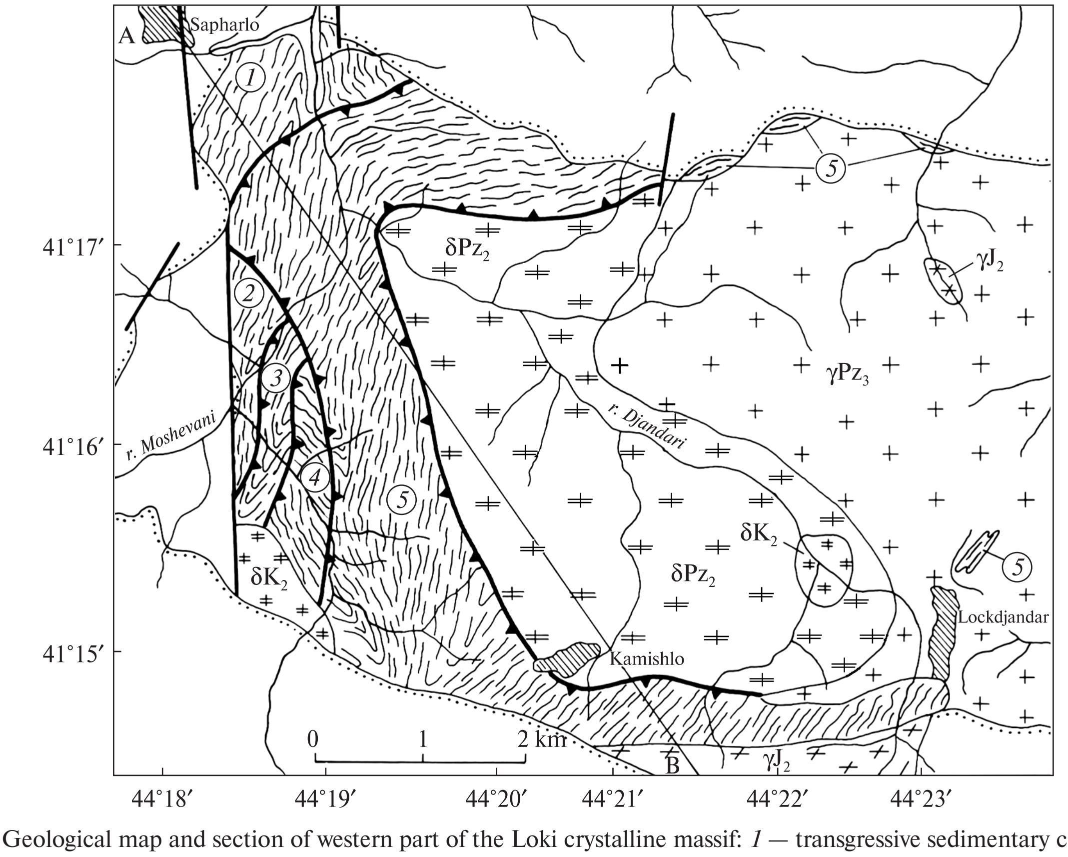

Fig. 6. Geological map and section of western part of the Loki crystalline massif: *1* — transgressive sedimentary cover (Jurassic-Quaternary). *Geological formations of the Loki massif*: *2—4* — granitoid intrusions: *2* — Upper Cretaceous diorite-granodiorite-porphyrites, *3* — Middle Jurassic (Bathonian) granitoids, *4* — Upper Paleozoic (Late Variscan) granites; *5* — Upper Devonian (Early Variscan) diorite-granodiorite series; *6* — Middle (?) Paleozoic metamorphites (the signs are oriented along the schistosity and banding); *7* — faults; *8* — sole of overthrust sheets. *Figures in circles*: Early Variscan (Saurian) allochthone sheets: *1* — Sapharlo (Paleozoic chloritoid bearing schists), *2* — Moshevani (andalusite bearing schists and graphitic quartzites), *3* — Lower Gorastskali (Precambrian (?) — Paleozoic metabasites), *4* — upper Gorastskali (tectonic melange of andaluzite bearing schists, quartzites and metabasites), *5* — Lock-Djandari (sericite-chlorite bearing schists)

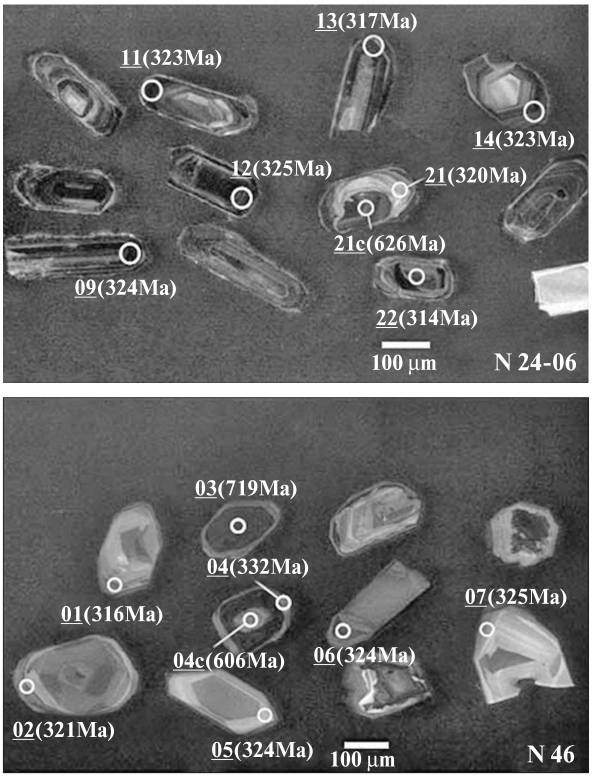

Fig. 7. Cathodoluminescence images and points of *LA-ICP-MS* U-Pb dating of zircons

ophiolitic sheet, form independent complex. After mineralogical-petrographical classification of granites they, most likely, correspond to *RTG* and partly to *ATG* types. These rocks, according to different petrochemical and geochemical parameters, have hybrid character. Apparently their formation took place in spreading condition, which was bound up with, probably, mantle plums of Iceland type.

LA-ICP-MS U-Pb zircon dating of rocks. For age determination of rocks *LA-ICP-MS* U-Pb zircon dating was used. Analyses were performed at the laboratories of the Department of Geosciences of National Taiwan University, Institute of Earth Sciences of Academia Sinica. The Dzirula material includes plagoigneisses, quartz-diorite orthogneisses, metagabbros and Variscan granitoids. The Khrami samples are represented by plagiogneisses and Late Variscan granitoids, but the Greater Caucasian material includes plagiogneisses and Variscan granitoids.

Zircons were separated from ~3 kg samples using conventional heavy-liquid and magnetic separation techniques. Cathodoluminescence (*CL*) images were taken for examining the internal structures of individual zircon grains and selecting suitable positions for U-Pb and Lu-Hf isotopic determinations. Zircon mounts were ultrasonicated within ~3 % HNO_3 solution and then were wiped with methanol to eliminate possible contamination on the zircon surfaces before analyses.

Zircon U-Pb isotopic analyses were performed by *LA-ICP-MS* using an *Agilent* 7500*s ICP-MS* and a *New Wave UP*213 laser ablation system. A spot size of 30 or 40 μm with laser repetition rate of 4 Hz was used and the laser energy density was ~15 J/sm^2. Calibration was performed using the zircon standard *GL*-1 with a ^{207}Pb/^{206}Pb age of 608.5 ± 0.4 Ma [13]. Two other well-known zircon standards 91500 and Mud Tank, together with a newly available zircon standard Pleśovice (337.1 ± ± 0.4 Ma [25]) were used for data quality control. Measured U-Th-Pb isotope ratios were calculated using the *GLITTER* 4.0 (*GEMOC*) software and the relative standard deviations of reference values for *GJ*-1 were set at 2 %. The common lead was directly corrected using the common lead correction function proposed by T. Anderson [1] and the weighted mean U-Pb ages and Concordia plots were carried out using Isoplot v. 3.0 [17].

In situ Lu-Hf isotopic measurements were subsequently performed by the *LA-MC-ICP-MS* method using a *Thermo Finnigan Neptune ® Multicollector-ICP-MS* and a *Geolas PLUS* 193 nm laser ablation system. The Lu-Hf isotopes were measured on the dated spots of individual zircons to minimize zoning effect and the laser ablation size is ~50—65 μm, slightly larger than that of preexisting pits, sizing 30—40 μm, made by the U-Pb dating. Lu-Hf isotopic compositions were corrected by using the zircon 91500 and the ^{176}Hf/^{177}Hf value of 0.282305 is recommended as the standard value.

The study of zircons showed morphological and optical inhomogeneity of zircon populations. In some crystals there occur relic cores of an earlier zircon, including the detrital zircons, covered with the later envelope. Heterogeneity of the zircon crystals is conditioned by the presence of several generations of zonal crystals with different characteristics. Consequently, in the studied crystals of zircon endogenic events of different age are encoded.

In Precambrian metamorphic and magmatite rocks of the Dzirula massif three age groups and three genetic types of zircons are established [10]. The age groups of zircons are: *Zrn*1 — detrital (>1450 Ma); *Zrn*2, forming at the Grenville stage of metamorphism (~1000—800 Ma), *Zrn*3, corres-

Table 2. **U-Pb and Lu-Hf isotopic data of zircons from the Precambrian rocks of the Dzirula and Khrami crystalline massifs**

Spot	Th/U	$^{207}Pb/^{206}Pb$	± 1σ	$^{206}Pb/^{238}U$	± 1σ	$^{207}Pb/^{235}U$	± 1σ	Error corr.	$^{206}Pb/^{238}U$ age (Ma ± 1σ)		$^{176}Hf/^{177}Hf$	±1σ	$^{176}Lu/^{177}Hf$	±1σ	εHf(*T*)	±1σ	T_{DM}	T_{DM}^{C}
*Detrital Zrn*1																		
*N*46-09	1.190	0.12064	0.00112	0.35411	0.00706	5.88949	0.12425	0.945	1954.0	34.0	0.281148	12	0.000126	0	−13.8	0.4	2863	3434
25-06-13	0.526	0.18097	0.00157	0.44920	0.00843	11.20684	0.22130	0.950	2392.0	37.0	0.281022	9	0.000972	3	−3.8	0.3	3098	3359
25-06-25	0.543	0.09360	0.00080	0.25054	0.00457	3.23310	0.06338	0.930	1441.0	24.0	0.281836	7	0.000677	1	−0.5	0.2	1972	2260
25-06-26	0.621	0.10704	0.00094	0.27731	0.00513	4.09222	0.08215	0.922	1578.0	26.0	0.281527	11	0.000418	2	−5.6	0.4	2376	2767
25-06-34	1.299	0.11284	0.00098	0.33040	0.00629	5.13988	0.10196	0.960	1840.0	30.0	0.281478	10	0.001199	4	−6.1	0.4	2492	2874
*Zrn*2, *Grenville stage of polymetamorphism*																		
24-06-27	1.099	0.07256	0.00064	0.16782	0.00309	1.67873	0.03419	0.904	1000.0	17.0	0.281502	10	0.000804	2	−23.3	0.3	2435	3304
12-04*c*	0.752	0.07349	0.00068	0.17036	0.00335	1.72594	0.0363	0.934	1014.0	18.0	0.281911	10	0.000599	2	−8.2	0.4	1865	2380
16-06-02*c*	0.847	0.07150	0.00072	0.14613	0.00277	1.44030	0.03274	0.834	879.0	16.0	0.282449	10	0.000409	4	7.8	0.4	1117	1266
16-06-38*c*	0.565	0.06914	0.00083	0.13909	0.00276	1.32595	0.03483	0.755	840.0	16.0	0.282077	12	0.000777	6	−6.5	0.4	1645	2134
25-06-29	1.333	0.06573	0.00061	0.13279	0.00254	1.20330	0.02581	0.892	804.0	14.0	0.282232	12	0.000953	4	−1.8	0.4	1436	1816
25-06-32*c*	0.699	0.06711	0.00078	0.13495	0.00265	1.24874	0.03187	0.769	816.0	15.0	0.282463	9	0.001254	13	6.4	0.3	1123	1304
KRME-2*c*	0.286	0.07150	0.00059	0.15540	0.00282	1.53166	0.02848	0.976	931.0	16.0	0.282328	8	0.001272	4	4.1	0.3	1313	1538
1-1*c*	0.567	0.07150	0.00066	0.15077	0.00282	1.48598	0.03061	0.905	905.0	16.0	0.202389	9	0.000841	4	5.9	0.3	1215	1402
*Zrn*3, *corresponding to the crystallization age of quartz-diorite orthogneisses*																		
46-04*c*	0.297	0.06047	0.00055	0.09861	0.00192	0.82200	0.01709	0.937	606.0	11.0	0.282675	9	0.001046	3	9.5	0.3	819	946
46-11	0.254	0.06095	0.00066	0.09392	0.00189	0.78922	0.01928	0.824	579.0	11.0	0.282475	11	0.000281	1	2.1	0.4	1078	1392
46-17 *c*	0.671	0.05901	0.00053	0.09058	0.00178	0.73697	0.01481	0.978	559.0	11.0	0.282082	10	0.000301	2	−12.2	0.3	1618	2283
24-06-21*c*	0.379	0.06143	0.00054	0.10191	0.00186	0.86298	0.01749	0.901	626.0	11.0	0.282363	9	0.000688	2	−0.9	0.3	1245	1624
24-06-24	0.775	0.06127	0.00058	0.09775	0.00181	0.82575	0.01789	0.855	601.0	11.0	0.282031	10	0.000733	10	−13.3	0.3	1707	2381
16-06-03*c*	0.167	0.06268	0.00059	0.10222	0.00192	0.88327	0.01911	0.868	627.0	11.0	0.282579	11	0.001946	14	6.0	0.4	977	1172
16-06-27	0.617	0.06012	0.00051	0.10009	0.00187	0.82960	0.01590	0.975	615.0	11.0	0.282358	12	0.001125	8	−1.5	0.4	1267	1653
16-06-31	0.370	0.06476	0.00056	0.10029	0.00186	0.89532	0.01788	0.929	616.0	11.0	0.282437	12	0.001646	10	1.1	0.4	1172	1489
25-06-18	0.262	0.06274	0.00053	0.09488	0.00175	0.82064	0.01594	0.950	584.0	10.0	0.281972	7	0.001076	5	−15.8	0.3	1803	2528
25-06-24	0.402	0.05895	0.00166	0.09660	0.00193	0.78512	0.03509	0.447	594.0	11.0	0.282578	8	0.000559	5	6.0	0.3	943	1159
25-06-33	0.415	0.05924	0.00071	0.09643	0.00188	0.78754	0.02046	0.750	593.0	11.0	0.282497	12	0.001321	2	2.8	0.4	1077	1360
25-06-35	1.887	0.06129	0.00056	0.10403	0.00198	0.87907	0.01831	0.914	638.0	12.0	0.282250	13	0.000671	4	−4.7	0.5	1401	1869

ponding to the crystallization age of quartz-diorite orthogneisses (650—550 Ma). To the genetic types of zircons belong: detrital (*ZrnD*), metamorphic (*ZrnMt*) and magmatic (*ZrnM*) zircons.

Zircons from two samples (No 46 and 48, Fig. 7; Table 2) of paraplagiogneisses, which are intensely injected with later granite material, are analyzed U-Pb local dating. Zircons from the sample No 46 are sharply heterogeneous. The age of detrital zircon by ^{206}Pb/^{238}U is 1954 ± 34 Ma. Simultaneously Th/U = 1.19, $\varepsilon_{\mathrm{Hf}}(T)$ = 13.8 and Hf crustal model age ($T_{DM}{}^{C}$) = 3434 Ma. In the same sample Baikalian ages 579 ± 11 and 559 ± ± 11 Ma are determined (Th/U = 0.254 and 0.671, $\varepsilon_{\mathrm{Hf}}(T)$ = 2.6 and –12.2 and $T_{DM}{}^{C}$ = 1392 and 2283 Ma), which presumably correspond to the age of quartz-diorite crystallization. For the zircon of sample No 48 only in one case the Baikalian age of quartz-dioritic crystallization is apparently defined — 673 ± 12.6 Ma (*Zrn*3) (Th/U = = 0.33, $\varepsilon_{\mathrm{Hf}}(T)$ = –4.5 and $T_{DM}{}^{C}$ = 1866 Ma).

Sample No 24-06 is an intensely feldspathized quartz-diorite orthogneiss (Fig. 7; Table 2). Zircon crystal has short prismatic shape. Edges of prism facets are flat and slightly deformed. The ribs of the bipyramid facets are almost smoothed and rounded. In the prismatic face plane, zonality is observed. In the core (*Zrn*3) of the crystal *3* presumably the age of orthogneiss crystallization (626 ± 11 and 601 ± 11 Ma) is determined (Th/U = = 0.339 and 0.775, $\varepsilon_{\mathrm{Hf}}(T)$ = –0.9 and –13.3, $T_{DM}{}^{C}$ = 1624 and 2381 Ma) but in its periphery the age of Late Variscan feldspathization is obtained (320 ± 6 Ma).

In the granitized quartz-dioritic orthogneiss (sample No 12) in one case the age of detrital zircon was received. In particular by ^{206}Pb/^{238}U — 1014 ± ± 18 Ma (*Zrn*1) (Th/U = 0.752, $\varepsilon_{\mathrm{Hf}}(T)$ = –8.2 and $T_{DM}{}^{C}$ = 2380 Ma) (Table 2).

Samples of Late Variscan granites have also been analyzed, where internal zonality is observed in the center. The ages of the crystal core (sample No 16-06, Table 2) 879 ± 16 and 840 ± 16 Ma (*Zrn*2) (Th/U = 0.847 and 0.565, $\varepsilon_{\mathrm{Hf}}(T)$ = –7.8 and –6.5, $T_{DM}{}^{C}$ = 1266 and 2134 Ma accordingly) presumably corresponds to the Grenville stage of the endogenic process and the age of the peripheral part reflects the age of crystallization of Late Variscan granites.

Zircons from sample No 25-06 are extremely heterogeneous (Table 2). These are hyacinth type bipyramidal-prismatic crystals. Their internal zonal structure is faintly visible. The core of crystal *5* (*Zrn*2) is dated as 816 ± 15 Ma (Th/U = 0.699, $\varepsilon_{\mathrm{Hf}}(T)$ = 6.4 and $T_{DM}{}^{C}$ = 1304 Ma) and most likely corresponds to the Grenville stage of endogenic process. In the peripheral rim (320 ± 5 Ma) the Late Variscan age is established. 28 zircon crystals of the same sample are also analyzed. In 18 of them the Late Variscan age was determined but in 4 crystals — the pre-Grenville age of detrital zircons was obtained. In particular, by ^{206}Pb/^{238}U was determined: 2392 ± 37, 1840 ± 30, 1578 ± 26 and 1441 ± 24 Ma (*Zrn*1). In two cases the figures corresponding to the Grenville stage of regional metamorphism are obtained — 816 ± 15 and 804 ± 10 Ma (*Zrn*2) (Th/U = 0.699 and 1.333, $\varepsilon_{\mathrm{Hf}}(T)$ = 6.4 and –1.8, $T_{DM}{}^{C}$ = 1304 and 1816 Ma respectively). The results of 6 local determinations (*Zrn*3) fall within 584—638 Ma (691 ± 12, 638 ± ± 12, 594 ± 11, 593 ± 11 and 584 ± 10 Ma) (Th/U vary from 1.887 to 0.262, $\varepsilon_{\mathrm{Hf}}(T)$ — from 28 to –15.8 and $T_{DM}{}^{C}$ — from 2528 to 1360 Ma) and they mainly correspond to the Baikalian stage.

The result of U-Pb local dating of heterogeneous zircon crystals from paraplagiogneisses of the Neoproterozoic gneiss-migmatite complex of the Khrami massif (sample No 1) in the crystal core shows the age 905 ± 16 Ma (*Zrn*2) (Th/U — 0.567, $\varepsilon_{\mathrm{Hf}}(T)$ — 5.9 and $T_{DM}{}^{C}$ — 1402) (Table 2), but in the peripheral rim — Late Variscan ages. The first corresponds to the Grenville age of prograde regional metamorphism, but the others — to the Late Variscan age of granite crystallization.

In one case, in the core of one of the crystals from the Late Variscan granitoids of the Khrami crystalline massif (sample No *KRME*, Table 2) the hereditary age 931 ± 16 Ma (*Zrn*2) is determined (Th/U = 0.286, $\varepsilon_{\mathrm{Hf}}(T)$ = 4.1, $T_{DM}{}^{C}$ = 1538 Ma). It presumably corresponds to the Grenville stage of regional metamorphism of the Neoproterozoic gneiss-migmatite complex of the massif.

The results of *LA-ICP-MS* U-Pb zircon dating of Precambrian endogenic events of the Pass and Elbrus subzones of the Main Range zone of the Caucasus are shown in the table (Table 2).

In Late Variscan granites of the Pass subzone inherited age of zircons is encoded in the core of the zircon crystals. Among them zircons of three generations are established: 1 — Middle Proterozoic detrital zircons with the age 2160 ± 32 and 1814 ± 28 Ma; 2 — zircons of the Grenville endogenic event corresponding to 828 ± 14 Ma (Th/U = 0.463, $\varepsilon_{\mathrm{Hf}}(T)$ = –1.2 and $T_{DM}{}^{C}$ — 1792 Ma) and 1009 ± 17 Ma (Th/U = 1.01, $\varepsilon_{\mathrm{Hf}}(T)$ = –4.3 and $T_{DM}{}^{C}$ = 2135 Ma); 3 — zircons from the

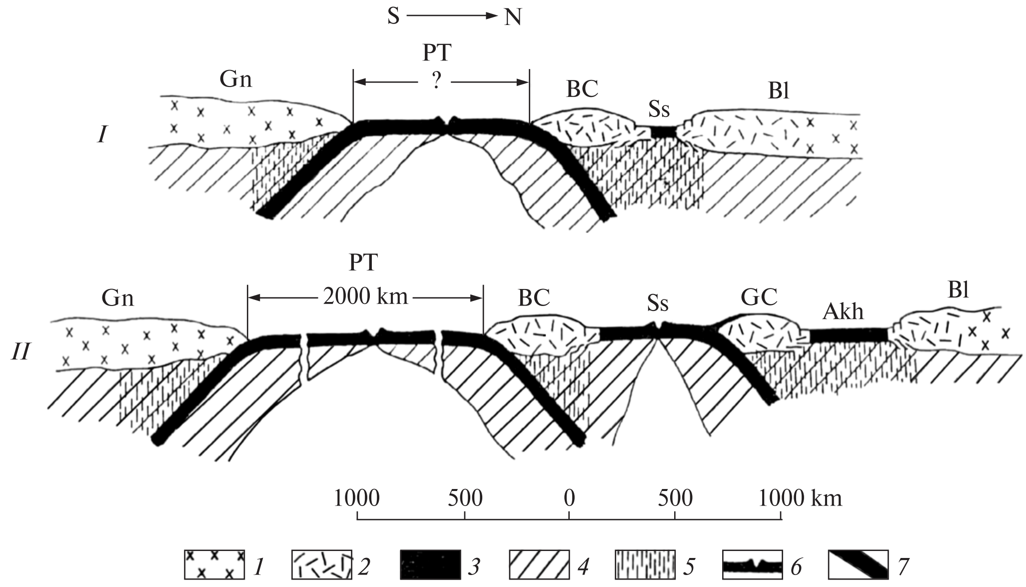

Fig. 8. Schematic palinspastic profiles of the Caucasian segment of the Mediterranean orogenic belt for: *I* — Late Precambrian (Neoproterozoic) and *II* — Late Cambrian times (vertical scale is exaggerated approximately for the five times): *1* — continental crust, *2* — subcontinental crust, *3* — oceanic crust and obducted ophiolites, *4* — upper mantle, *5* — streams of heat, fluids and magmatic melts in mantle, *6* — Mid oceanic ridge, *7* — subduction zones. *Paleooceanic basins*: *PT* — Proto-Paleotethys, *Ss* — of the Southern slope of the Greater Caucasus, *Akh* — Arkhis. *Continental plates*: *Gn* — Gondvana, *Bl* — Baltica. *Terranes*: *BC* — Black Sea-Central Transcaucasian microcontinent, *GC* — Greater Caucasian island arc

Baikalian endogenic event with the following age figures — 603, 609, 642, 648, 651, 657 and 658 ± ± 11 Ma (Th/U = 0.362—1.613, $\varepsilon_{Hf}(T) = -1.6 \div -18.2$ and T_{DM}^{C} = 1689—2696 Ma). M.L. Somin [26] by *SHRIMP* method in magmatites and metamorphites of Buulgen metamorphic complex the age of detrital zircons — 2390—670 Ma is established.

In the Late Varisscan granites of the Elbrus subzone in the cores of three zircon crystals inherited Baikalian age of endogenic mineralization is established (Table 2): 629 ± 11, 630 ± 11 and 690 ± ± 12 Ma (Th/U = 1.1206—0.758, $\varepsilon_{Hf}(T)$ = –2.1—3.8 and T_{DM}^{C} = 1325—1743 Ma). In infrastructure of the zone M.L. Somin [26] by *SHRIMP* method detrital zircons age dated — 1780—560 Ma, but V.I. Gerasimov et al. [11] by isotopic dating U-Th-Pb system of detrital zircons from metamorphites — 2850—540 Ma are obtained.

Geodynamic evolution of the Caucasus during Precambrian and Early Paleozoic time. Aforecited data about geological structure, character of sedimentation and magmatism, geology and the age of ophiolites, side by side with paleomagmatic data and global plate tectonic reconstructions, allow to consider main features of the geodynamic evolution of the territory of Georgia and adjacent areas. The evolution is closely related to the development of a very vast surrounding area; therefore, it is considered against the background of entire central segment of the Mediterranean orogenic belt.

Magmatism and metamorphism of different type, being a reflection of thermobaric field variation in external shells of the Earth, represent direct consequence of geodynamic settings in various structural unites of the Earth's crust and lithosphere. A model revealing tectonic settings of realization of magmatism and metamorphism and their connection with other endogenic processes participating in formation of the Earth's crust can be constructed namely on geodynamic basis.

The most important issue for reconstruction of geodynamic settings is to establish a nature and location of Paleooceanic basins. The existence of oceanic realm in the area of the Mediterranian belt in Neoproterozoic is shown by a number of various global reconstructions.

The modern plate tectonic reconstructions are made at the global scale, as well as for Variscan-Alpine orogeny. For global plate tectonic reconstructions integrated data on dynamic plate boundaries, ocean spreading rates, restored synthetic oceanic isochrones and major tectonic and magmatic events are used [27]. According to these reconstructions at the beginning of Ordovician (~490 Ma age) the Prototethys was located between the Baltica and Gondwana land.

Geological information and paleomagnetic data referring separate regions are not completely applied in these global reconstructions. Indicative facts of that in the Caucasian region are the following: disregarding the existence of some exposures of Late Precambrian — Paleozoic ophiolites and paleomagnetic data indicated seemingly inherited development of the Paleotethys from Prototethys and preserving of relict oceanic basin up to Middle Jurassic. Therefore making the palinspastic sections of the Caucasus from above mentioned global paleoreconstructions we have used the following data: approximate size of oceans on separate stages of their development, location of big continental masses in the space. Principal attention was paid on specific geological (nature of magmatism, peculiarities of lithologic-stratigraphical section, geology and age of ophiolites) and also available paleomagnetic data for the Caucasian region.

The birth of the Prototethys in Neoproterizoic time is also confirmed by the existence of ophiolites of Late Precambrian age not only in its southern periphery (the Anti-Atlas, the Arabian-Nubian shield, the Loki, Murguz and Tsakhkunyats massifs), but also in northern periphery (the Alps, Bohemian and Dzirula massifs). Thus, proceeding from the presence of Precambrian ophiolites and Grenville and Baikalian supra-subduction regional metamorphism and granitoid formation within the Dzirula, Loki and Khkrami massifs, we can assume quite confidently the existence of Prototethys ocean in the Caucasian segment of the Mediterranean belt (Fig. 8).

At the pre-Grenville time (1200 Ma and more) between the Baltica and Gondvana ancient continents, on the Proterozoic oceanic crust of Prototethys accumulation mainly of terrigenous sediments (mainly graywackes and psammites) and in a few amounts of basic volcanites took place. The land, supplying the Neoproterozoic basin by clastic material, was composed of subcontinental crust with predominant content of unsaturated by K_2O rocks. Total thickness of Neoproterozoic sedimentary cover was not less than 10 km.

The existence of Paleozoic or older oceanic basins is supposed also in the area of the contemporary Greater Caucasus (Fig. 8). It is confirmed by Paleozoic ophiolites in the Fore Range zone and the Klich ophiolite sheet in the Pass subzone of the Greater Caucasus Main Range zone.

Data on magnetic anomalies indicating spreading of ophiolite belt of the Northern Caucasus show, that side by side with oceanic basin located to the south from the contemporary Main Range zone in Early and Middle Paleozoic between the contemporary Fore Range and Main Range zones another, so-called Arkhiz oceanic basin was located representing the "motherland" of ophiolite nappes of the Fore Range zone (Fig. 8). With the consideration of zircon age of the Buulgen complex amphibolites (600 ± 20 Ma), the existence of *N-MORB* type rocks in composition of Klich ophiolites, as well as paleomagnetic data, it can be assumed, that Southern Slope oceanic basin of the Greater Caucasus was laid in Late Precambrian as relatively small spreading basin (Fig. 8).

Later (apparently in Early-Middle Paleozoic) the Arkhiz basin began to develop. According to nature of volcanic complex of ophiolite association of the Fore Range zone this basin was of the marginal sea type.

The rocks of the Caucasian segment of the Mediterranean orogenic belt underwent prograde regional metamorphism in supra-subduction conditions by both sides of Proto-Paleotethys and along the northern margin of small oceanic basin of the Southern slope of the Greater Caucasus (Fig. 8). Later they experienced supra-subduction regional metamorphism, mainly during the Early- and Late Variscan orogenies.

Conclusions. Precambrian magmatites and metamorphites within Georgia crops out in the Dzirula, Khrami and Loki crystalline massifs and in the Pass and Elbrus subzones of the Main Range zone of the Greater Caucasus.

In the Dzirula massif by geological and isotope-geochronological data the following ages of different rocks and events are confidently dated: Proterozoic age (>1200 Ma) of initial rocks of the gneiss-migmatite complex; their Grenville regional metamorphism (1000—800 Ma, $T = 700—720$ °C, $P = 2.6—2.7$ kb); Neoproterozoic age of metagabroids (800—640 Ma) and Baikalian age of the quartz-diorite orthogneisses (640—560 Ma). Precambrian rocks of typical ophiolite complex are associated with the allochthone metamorphic complex of the Dzirula massif.

Within the Khrami massif Proterozoic (>1000 Ma) volcanic-sedimentary rocks as a result of Grenville regional metamorphism (~940—900 Ma,

T = 700—720 °C, P = 2.6—2.7 kb) are metamorphosed into the plagiogneiss-plagiomigmatite complex.

In the Loki crystalline massif Precambrian rocks are represented by tectonic sheet of ophiolite complex and by "oceanic granites".

Scanty isotope-geochronological data of Precambrian rocks of the Main Range zone of the Caucasus, along with geological data, show that in the Pass subzone endogenic events of Grenville (1000—800 Ma) and Baikalian (660—600 Ma) age took place, but in the Elbrus subzone — only Baikalian (690—630 Ma) endogenic process is established.

The Precambrian rocks underwent prograde regional metamorphism in supra-subduction conditions by both sides of Proto-Paleotethys and along the northern margin of small oceanic basin of the Southern slope of the Greater Caucasus. Later they experienced supra-subduction regional metamorphism, mainly during the Early- and Late Variscan orogenies.

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ДОКЕМБРІЙСЬКИЙ РЕГІОНАЛЬНИЙ МЕТАМОРФІЗМ І МАГМАТИЗМ ГРУЗІЇ ТА ГЕОДИНАМІКА КАВКАЗУ

У межах Кавказького сегмента Середземноморського колізійного орогенного поясу виділено Великокавказький, Чорноморсько-Центральнозакавказький, Бейбурт-Севанський та Іран-Афганський террейни, які в геологічному минулому були острівними дугами або мікроконтинентами. З точки зору сучасної структури, це акреційні террейни першого порядку, розділені достовірними або передбачуваними офіолітовими швами різного віку — релікти великих і малих океанічних басейнів. Докембрійські осадові, вулканогенні та інтрузивні породи в межах території Грузії відслонюються у Дзирульському та Храмському кристалічних масивах (Чорноморсько-Центральнозакавказький террейн), у зоні Головного хребта (Великокавказький террейн) і в Локському кристалічному масиві (Бейбурт-Севанський террейн). Вік порід встановлений за геологічними даними і за допомогою *LA-ICP-MS* (U-Pb датування по цирконах). Докембрійські породи зазнали впливу регіонального метаморфізму Гренвільського (1000—800 Ма), Байкальського (650—550 Ма) і Пізньобайкальського (540—500 Ма) етапів в супрасубдукційних умовах по обидві сторони від Прото-Палеотетісу і вздовж північного краю малого океанічного басейну Південного схилу Великого Кавказу. Пізніше вони підлягали змінам в умовах супрасубдукційного регіонального метаморфізму протягом ранньо- (~345—335 Ма) і пізньогерцинського (330—335 Ма) тектогенезу.

Ключові слова: Кавказ, докембрійські породи, метаморфізм, геохронологія, геодинаміка.

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ДОКЕМБРИЙСКИЙ РЕГИОНАЛЬНЫЙ МЕТАМОРФИЗМ И МАГМАТИЗМ ГРУЗИИ И ГЕОДИНАМИКА КАВКАЗА

В пределах Кавказского сегмента Средиземноморского коллизионного орогенного пояса выделены Большекавказский, Черноморско-Центральнозакавказский, Бейбурт-Севанский и Иран-Афганский террейны, которые в геологическом прошлом представляли собой островные дуги или микроконтиненты. С точки зрения современной структуры, это аккреционные террейны первого порядка, разделенные достоверными или предполагаемыми офиолитовыми швами разного возраста — реликты больших и малых океанических бассейнов. Докембрийские осадочные, вулканогенные и интрузивные породы в пределах территории Грузии обнажаются в Дзирульском и Храмском кристаллических массивах (Черноморско-Центральнозакавказский террейн), в зоне Главного хребта (Большекавказский террейн) и в Локском кристаллическом массиве (Бейбурт-Севанский террейн). Возраст пород установлен на основании геологических данных и с помощью *LA-ICP-MS* (U-Pb датирование по цирконам). Докембрийские породы подверглись влиянию регионального метаморфизма Гренвильского (1000—800 Ма), Байкальского (650—550 Ма) и Позднебайкальского (540—500 Ма) этапов в супрасубдукционных условиях по обе стороны от Прото-Палеотетиса и вдоль северного края малого океанического бассейна Южного склона Большого Кавказа. Позже они испытали изменения в условиях супрасубдукционного регионального метаморфизма в течение ранне- (~345—335 Ма) и позднегерцинского (330—335 Ма) тектогенеза.

Ключевые слова: Кавказ, докембрийские породы, метаморфизм, геохронология, геодинамика.