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Geology

Petrochemistry and Geodynamic Settings of Plutons Formation of the Greater Caucasus Svaneti Segment

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The paper presents a petrochemical characteristics of plutons of different ages located in different zones and subzones of the Greater Caucasus Svaneti segment. In particular, petrochemical analysis of Svaneti segment of the Greater Caucasus showed that major magmatic phases of plutons are represented by different petrotype. Petrochemical studies show that Caledonian biotite orthogenesis and migmatites were formed in syn-collisional (syn-accretional) geodynamic settings. Late Variscan generation granodiorite-granite plutons were formed in syn-collisional (syn-accretional) geodynamic settings, though Middle Jurassic monzo-syenite plutons in the post-collisions (post-accretional). Despite such differences in petrotypes and geodynamic settings, all plutonic melts belong to calc-alkaline magmatic series. Based on these and available chronological data geodynamic settings and paleotectonic profiles of the Caucasus and adjacent areas for the Paleozoic and for the Middle Mesozoic, in particular, during Late Cambrian, Ordovician-Devonian, Early and Middle Carboniferous, from Late Triassic-up to Middle Jurassic time intervals are given. The formation of the plutons of the Main Range zone of the Greater Caucasus (island arc) took place in supra-subduction conditions of the active margin of the back-arc small oceanic basin of its southern slope, while the monzodiorites, monzosyenite andmonzinite plutons, located in the Paleozoic-Triassic Dizi series and Lower Jurassic black shales, were formed on the passive margin of this basin, in conditions of continental slope and foot, which have a thin sub-oceanic Earth's crust. *© 2024 Bull. Georg. Natl. Acad. Sci.*

Greater Caucasus, Svaneti segment, petrochemistry, geodynamic settings

The Greater Caucasus fold-and-thrust belt in geological past represented a rift-like trough, laid on the Precambrian basement, in its southern part since the Early Paleozoic, and in the central and northern parts – since the beginning of the Early Jurassic. It evolved throughout the Phanerozoic time and in the late Alpine period turned into a mountain range. The range extends in a NW-SE direction over 1 200 km from the Black Sea to the Caspian Sea. It represents the central segment of the Alpine-Himalayan collisional belt, between the still converging Gondwana derived Arabian plate and Scythan platform of the Eurasian plate [1-4].

In the Greater Caucasus two major formations are defined: pre-Jurassic crystalline basement and Meso-Cenozoic magmatic and sedimentary formations [5] (Fig.1). In the construction of the basement complex four regional tectonic zones

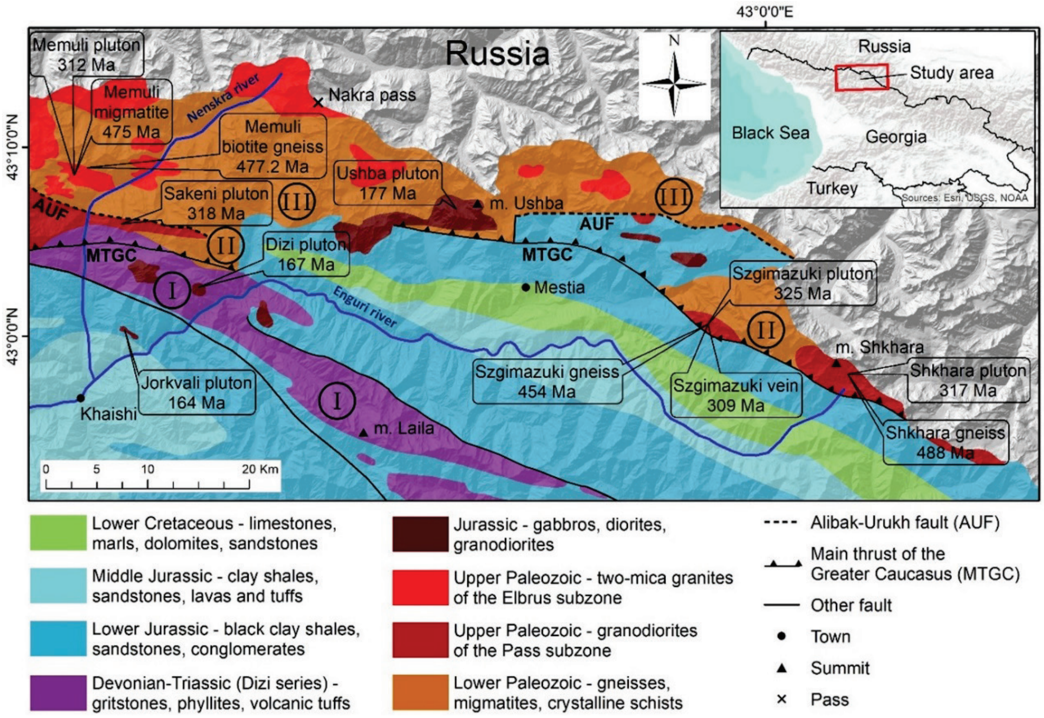

Fig. 1. Geological map and zircon U-Pb geochronological data of the plutons and their xenoliths of the Greater Caucasus Svaneti segment according to [9].

are recognized from S to N: Southern Slope, Main Range, Forerange and Bechasyn [6]. The Main Range zone is the best-exposed part of the basement complex and is divided into two subzones based on the difference in structure and composition.

The southern slope zone of the Greater Caucasus exposed in the Svaneti segment (Dizi series) is composed of terrigenous, intensely folded sedimentary rocks of ≈2 000 m thickness, metamorphosed to the chlorite-sericite subfacies of the greenschist facies [2,7,8]. The metasediments are cut by numerous plutons that are considered in this paper. The Dizi series was deposited during the Devonian to the end of the Triassic period [8]. The Mesozoic period of the Greater Caucasus starts with Jurassic oceanic transgression, when ≈3 000 m thick black shales and sandstones were deposited. The middle Jurassic deposits of the Greater Caucasus are cut by gabbros, diorites, syenites and quartz-diorites [4, 9].

Roman numerals in a circle-structural-tectonic zones of the crystalline basement: I – The Southern Slope, II – The Pass sub-zones of the Main Range zone, III – The Elbrus sub-zone of the Main Range zone. The map is modified according to Geological map of Georgia [10].

The Svaneti segment of the Greater Caucasus located in Georgia is its highest, most expose central part. Numerous plutonic bodies of different ages, scales and genesis make this segment the perfect site for the investigation of tectonics and plutonic magmatism [9]. These plutons are: Shkhara, Szgimazuki, Memuli, Sakeni, Ushba, Disi and Jorkvali. (Fig.1). The geological position, composition and U-Pb zircon chronology of the plutons under consideration were previously studied in detail [9]. It was shown that there are three major age groups, corresponding to different geodynamic settings in this region: Caledonian, Variscan and Middle Jurassic.

Petrochemistry

Petrochemical analysis of Svaneti segment of the Greater Caucasus showed that major magmatic phases of dated plutons are represented by different petrotypes (Table 1, Fig. 2). On TAS discrimination diagram (Fig. 2A) the Late Carboniferous plutons are placed in granite and granodiorite fields. They are Al-rich rocks with SiO_2 contents varying between ≈68-74 wt%, while total alkalis (Na_2O+K_2O) content does not exceed 7.5 wt%. In contrast with the Late Carboniferous plutons, the Middle Jurassic

Table 1. Major and some trace elements chemical analyses of the plutons and their xenoliths of the Greater Caucasus Svaneti segment

Sample	12Ge12	12Ge14	12Ge15	12Ge17	12Ge18	12Ge30	12Ge32	12Ge28	12Ge05	12Ge25	12Ge27	12Ge33
Major elements (wt.%)												
SiO_2	68.27	71.43	70.97	76.97	73.47	71.37	72.05	64.8	66.80	63.65	57.82	71.23
Al_2O_3	15.40	14.98	16.42	14.34	15.24	16.10	15.12	15.13	15.20	16.37	16.86	15.18
Fe_2O_3	4.55	2.23	1.45	0.75	0.77	2.19	2.38	6.04	3.70	4.24	6.78	2.33
CaO	2.33	0.95	2.78	2.00	2.10	1.91	1.24	5.32	3.55	3.87	5.57	0.85
MgO	1.31	0.52	0.38	0.88	0.96	0.59	0.61	1.83	1.34	2.91	3.77	0.72
Na_2O	4.34	3.75	5.53	4.26	6.12	4.24	3.17	2.60	3.62	4.22	4.88	3.55
K_2O	2.27	4.76	1.25	0.12	0.68	2.52	4.25	2.50	4.18	3.05	2.85	4.56
MnO	0.05	0.05	0.09	0.04	0.07	0.04	0.04	0.25	0.10	0.21	0.17	0.25
TiO_2	0.63	0.29	0.09	0.08	0.15	0.33	0.49	0.39	0.55	0.46	0.56	0.53
P_2O_5	0.39	0.31	0.37	0.15	0.13	0.17	0.22	0.47	0.13	0.28	0.27	0.49
Some trace elements (ppm)												
Co	31	45	33.4	24.4	18.7	21	5.3	35.9	8.3	6.3	5.7	18
Hf	3.3	3.76	2.90	0.91	1.7	3.23	1.03	2.3	1.12	0.95	0.78	3.89
Nb	3.2	17.5	22.56	15.93	8.86	7.2	12.6	4.8	11.9	17.8	15.3	11.2
Rb	385	317	105.5	485.4	434	288	543	456	83.6	90.6	65.8	249
Sr	581	397	173	212.7	198,6	649	457	567	358	573	345	136
Ta	3.4	2.16	2.13	1.84	2.75	2.57	3.2	2.8	2.21	1.96	1.83	2.26
Th	8.7	17.7	29.7	12.24	17.8	8.2	15.3	8.7	10.7	51.5	37.5	29.8
U	4.5	2.2	2.77	0.75	1.99	3.5	7.8	6.5	2.4	9.23	7.57	17.4

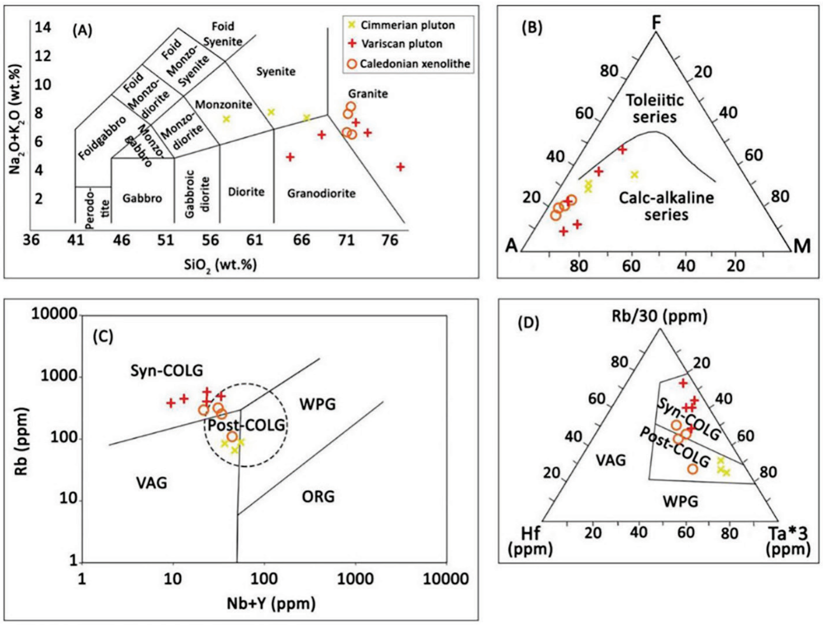

Fig. 2. Petrochemical diagrams for the plutonic rocks and their xenoliths of Greater Caucasus Svaneti Segment. (A) – TAS discrimination diagram [11]; (B) – AFM discrimination diagram [12]. (A=Na_2O+K_2O wt.%; F=FeO total wt.%; M=MgO wt.%), (C) – Rb-(Nb+Y) geodynamic discrimination diagram [13]; (D) – Hf-Rb/30-TaX30 geodynamic discrimination diagram [14]. Abbreviations: syn-COLG=syn-collision granite; post-COLG = post-collision granite; VAG = volcanic arc granite; WPG = within-plate granite; ORG = ocean ridge granite.

plutons are represented by monzo-diorites, monzinites and syenites (Fig. 2A). SiO_2 content in these plutons varies between ≈58-67 wt%, while total alkali content exceeds 7.5 wt%. It should be noted that the SiO_2 content in these plutons decreases from the Ushba pluton (≈67%) to the Jorkvali pluton (≈58%) (from the north to the south). As for the Ordovician biotite gneisses and migmatites, on TAS discrimination diagram they are placed within granite field (Fig. 2A).

On AFM discrimination diagram Svaneti segment plutons and their xenoliths are placed almost entirely within the calc-alkaline series field; only one point of Sakeni pluton is placed within the tholeitic series field (Fig. 2B).

Below, we used Rb-(Nb+Y) geodynamic discrimination diagrams for syn-collisional and post-collisional geodynamic settings, since accretional processes are similar to collisional ones.

On Rb-(Nb+Y) geodynamic discrimination diagram Late Carboniferous plutons are placed within the syn-collisional (syn-accretional granite field, while the Middle Jurassic Middle Jurassic plutons are fully within the post-collisional (post-accretional) granite field. As for Ordovician biotite xenoliths of gneisses, they are mostly placed within an island-arc granite field and only one point is placed within a syn-collisional (syn-accretional) granite field (Fig. 2C).

Geodynamic Settings of Plutonic Magmatism Formation

The reconstruction of past geodynamic settings seeks to establish the nature and location of paleo-oceanic basins, along with their active and passive margins. Previously, it was shown [14, 15, 2] that a location of Proto-Paleotethis Ocean in the Caucasus and adjacent areas was to the south of the Black Sea-Central Transcausian terrane (microcontinent) (Fig. 3). The existence of Paleozoic and older oceanic basins is suggested also in the regional geology of the Greater Caucasus. It is confirmed by the existence of Paleozoic ophiolites in the Fore Range zone of the Greater Caucasus indicative of the existence of the Archyz small oceanic basin and also a small oceanic basin of the southern slope of the Greater Caucasus [2], as indicated by the intrusive complex of Beshta-Kamenistaia in its Pass subzone, which is composed of tonalitic gneisses that genetically resemble granites of the tholeitic series of the ophiolite complex [16]. It was overthrust from south to north, on the Greater Caucasus Island arc during the Early Variscan (Bretonian) orogeny [17] (Fig. 3 III).

The rest part of the oceanic crust of the back-arc small oceanic basin of the southern slope of the Greater Caucasus, as previously suggested [2] to be completely absorbed in the subduction zone along the southern edge of the Greater Caucasus Island arc.

Taking into account the paleomagnetic data and age of supra-subduction regional meteamor-phism in the Greater Caucasus [4], it can be assumed that the back-arc basin of the southern slope of the Greater Caucasus was formed in the Late Precambrian and represented a relatively small spreading oceanic basin [2].

In the Main Range zone of the Greater Caucasus (island arc), on the active margin of back-arce oceanic basin of the southern slope of the Greater Caucasus in Ordovician Early Caledonian biotite orthogneisses, gneisses and migmatites of Shkara pluton and Late Caledonian Szgumazuki plagio gneisses were formed. (Fig. 3 I). Caledonian intrusive activity is developed in the Black Sea Central Transcaucasian microcontinent as well (Fig. 3 II).

In the Late Carboniferous the second phase of large-scale supra-subduction plutonic magmatism occurred. During these processes, both the Pass and the Elbrus subzones of the Greater Caucasus, as well as the Black Sea Central Transcaucasian microcontinent were migmatised and formed gneissic infrastructures, which were cut by large plutonic bodies of granitoids. Later, plutonic bodies were cut by leucocratic vein systems. These processes are related to the Late Variscan subduction and orogeny, when typical continental crust was formed [17] (Fig. 3 III).

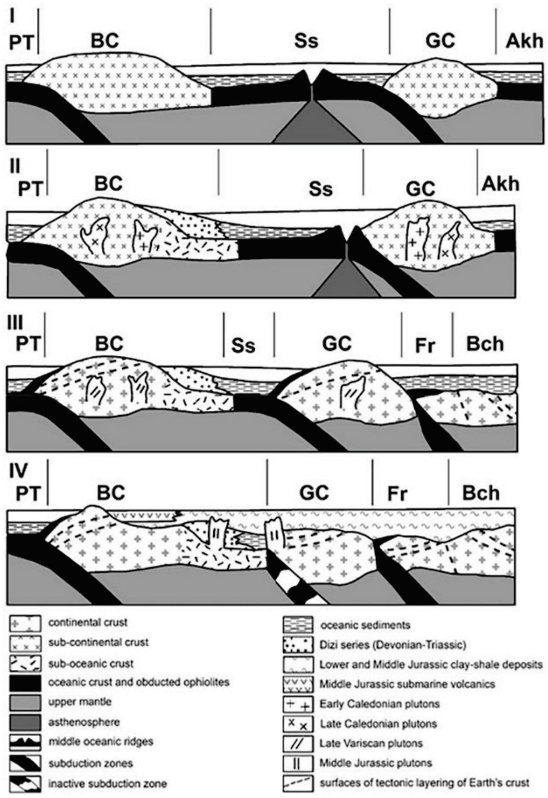

Fig. 3. Paleotectonic profiles of the Caucasus and adjacent areas for the Paleozoic and for the Middle Mesozoic. Time intervals: I – Late Cambrian, II – Ordovician-Devonian, III – Early and Middle Carboniferous, IV – from Late Triassic up to Middle Jurassic. The vertical scale is exaggerated about 10 times. Paleooceanic basins: PT – Proto-Paleotethis; Ss – of the southern slope of the Greater Caucasus; Akh – Arkhys. Continental plates (terranes): BC – Black Sea-Central Transcaucasian microcontinent; GC – Greater Caucasus island arc. Contemporary tectonic zones: Fr – Forerange, Bch – Bechasin.

Then at the end of the Late Triassic, during Early Cimmerian (Indosinian) orogeny, there is a closure of the oceanic basin of the southern slope of the Greater Caucasus, as well as the Arkhiz one (Fig. 3 IV).

Plutons located in the Paleozoic-Triassic Dizi series and in the Early Jurassic black shales, (Dizi and Jorkvali plutons) (Fig. 3 IV) were formed in different geodynamic settings and were connected with stretching of the Earth's crust. It should be noted that the Early and Middle Jurassic is the time of the most significant stretching and subsidence of the Earth's crust in the entire Caucasus. At this time, the subduction zone along the northern edge of the oceanic basin of the Southern Slope of the Greater Caucasus was inactive (Fig. 3 IV). Therefore, clay-sandy deposits are deposited here. However, further south, within the Transcaucasian microcontinent, they are replaced by andesitic submarine island-arc volcanic rocks (the so-called Bajocian porphyrite series), which were formed in supra-subduction conditions (Fig. 3 IV).

It was previously argued [2] that the deposits of the Dizi series were formed under the conditions of the continental slope and the foot of the southern passive margin of the small oceanic basin of the southern slope of the Greater Caucasus. This position is confirmed by our data on the nature of the plutons located within the Dizi series. In particular, as noted above according to the isotopic investigation, in the Middle Jurassic plutons there is clearly an increase of the mantle component from north to south, from Ushba pluton, which is located along the main thrust of the Greater Caucasus to plutons located in Dizi series. Therefore, it is natural to assume that the sediments of the Dizi series, developed on the continental slope and the foot of the southern passive margin of the small oceanic basin of the southern slope of the Greater Caucasus, are underlain by thinned sub-oceanic crust (Fig. 3 II, Fig. 3 III, Fig. 3 IV).

Conclusion

Petrochemical analysis of the Greater Caucasus Svaneti segment has shown that major magmatic phases of plutons are represented by different petrotype. Petrochemical study reveals that Caledonian biotite orthogenesis and migmatites were formed in syn-collisional (syn-accretional) geodynamic settings. Late Variscan generation granodiorite-granite plutons were formed in syncollisional (syn-accretional) geodynamic settings, though Middle Jurassic monzo-syenite plutons-in the post-collisi (post-accretional) ones. Despite such differences in petrotypes and geodynamic settings, all plutonic melts belong to calc-alkaline magmatic series. On the basis of these and available geochronological data, geodynamic settings and paleotectonic profiles of the Caucasus and adjacent areas for the Paleozoic and the Middle Mesozoic, in particular, during the Late Cambrian, Ordovician-Devonian, Early and Middle Carboniferous, from Late Triassic-up to Middle Jurassic time intervals are given.

The formation of the plutons of the main range zone of the Greater Caucasus took place in conditions of the active margin of the small oceanic basin of its southern slope while the Middle Jurassic plutons were formed in conditions of crustal stretching and rifting. In the Middle Jurassic plutons there is clearly an increase of the mantle component from north to south, from Ushba pluton, which is located along the main thrust of the Greater Caucasus to plutons located in the Dizi series. Therefore, it is natural to assume that the sediments of the Dizi series, developed on the continental slope and the foot of the southern passive margin of the small oceanic basin of the southern slope of the Greater Caucasus, are underlain by thinned sub-oceanic crust.

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გეოლოგია

კავკასიონის სვანეთის სეგმენტის პლუტონების პეტროქიმია და წარმოშობის გეოდინამიკური პირობები

ე. გამყრელიძე[*], გ. ბოიჩენკო[**], ს. გოგოლაძე[**], რ. გაბრიელაშვილი[*]

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კავკასიონის ნაოჭა-შეცოცებითი სარტყელი გეოლოგიურ წარსულში წარმოადგენდა რიფტის მსგავს როფს, რომელიც ჩაისახა კავკასიონის კამბრიულის წინა ფუნდამენტის სამხრეთ ნაწილში ადრე პალეოზოურში,ხოლო ცენტრალურ და ჩრდილო ნაწილებში ადრე იურულის დასაწყისში. ის ვითარდებოდა მთელი ფანეროზოურის განმავლობაში და გვიან ალპურ დროს გადაიქცა მთათა ნაოჭა სისტემად. ნაშრომში განხილულია ახალი მონაცემები კავკასიონის სვანეთის სეგმენტის სხვადასხვა ასაკისა და შედგენილობის პლუტონების პეტროქიმია და წარმოშობის გეოდინამიკური პირობები. პლუტონების პეტროქიმიური კვლევის მიხედვით, კალედონური ორთოგნეისები ჩამოყალიბდა გარდამავალ, სინ-აკრეციულ გეოდინამიკურ პირობებში. გვიანვარისკული პლუტონები ასევე წარმოიქმნა სინ-აკრეციულ გეოდინამიკურ პირობებში, ხოლო შუაიურული პლუტონები – პოსტ-აკრეციულში. მიუხედავად პეტრო-

ტიპებისა და გეოდინამიკური პირობების ასეთი განსხვავებისა, ყველა პლუტონური მდნარი მიეკუთვნება კირ-ტუტე მაგმურ სერიას. კავკასიონის მთავარი ქედის (კუნძულთა რკალი) პლუტონების ფორმირება მიმდინარეობდა სუპრა-სუბდუქციურ პირობებში კავკასიონის სამხრეთი ფერდობის მცირე ოკეანური აუზის აქტიურ კიდეზე, ხოლო მონცოსიენიტური პლუტონები, რომლებიც შეიჭრა პალეოზოურ-ტრიასული დიზის სერიასა და ქვედაიურულ შავ ფიქლებში, ჩამოყალიბდა ამ აუზის პასიურ კიდეზე, კონტინენტური ფერდობისა და ძირის პირობებში, რომელსაც თხელი სუბოკეანური ქერქი გააჩნდა.

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