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GEOCHEMISTRY

Basic Magmatism in the Geological History of the Elbrus Neovolcanic Area, Greater Caucasus: Evidence from K–Ar and Sr–Nd Isotope Data

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The age and genesis of basic rocks in the magmatic evolutionary series are of principal significance for regions with predominant acid, mainly crustal volcanism. The appearance of basic volcanic rocks in the rhyolite–dacite volcanic sequences is usually a sensitive indicator of a change in the conditions of magma generation, the involvement of different mantle and/or crustal reservoirs, or a change in the geotectonic and geodynamic settings of the volcanic activity. This is evident from the abundance of Neogene–Quaternary acid and moderately acid volcanism in the Elbrus neovolcanic area, Greater Caucasus.

The Neogene–Quaternary magmatic centers of the Greater Caucasus are localized within three (Kazbek, Central Georgian, and Elbrus) neovolcanic areas. The Elbrus area located in the central part of the northern slope of the Greater Caucasus is bounded by the upper reaches of the Kuban River in the west, the Kuma River in the north, the Cherek River in the east, and the Main Caucasus Range in the south (Fig. 1).

Evolution of the young magmatism in the Greater Caucasus is divided into three stages [1] with age boundaries determined by isotope–geochronological investigations [2–8].

The first (Late Miocene) stage (9.5–8.3 Ma) is represented by subalkaline acid intrusive rocks of the Caucasian Mineral'nye Vody area of the Elbrus volcanic area [2, 3].

Products of the second (Pliocene) stage are found in the central sector (Chegem and Tyrnyauz regions). In the Chegem region, the products are represented by acid and moderately acid volcanic rocks of the Upper Chegem caldera and Lower Chegem highland (2.9–2.7 Ma) [2, 5, 6], andesites of the postcaldera Kumtyube and Kyuigenkaya volcanoes (2.8 Ma) [6], granodiorites of the Dzhungusu Massif (2.84 Ma) [2, 6], and rhyolite tuffs of river terraces of the Lower Chegem highland (1.9 ± 0.2 Ma). Magmatism of the Tyrnyauz area is represented by the El'dzhurta granite massif (2.5–2.1 Ma) [2, 4–6], necks and dikes of rhyolites and vitrophyres (1.95–1.90 Ma) [8], and Kyrtyk granite porphyry massif (2.00 ± 0.15 Ma) [2].

The third stage of the Late Cenozoic magmatism in the Elbrus area is marked by volcanic activity in the Kuban–Baksan interfluve. Rhyolite–dacite ignimbrites and tuffs preserved as small remnants north of the Elbrus Volcano and trachyandesite lavas in the Khudes River mouth were erupted in this area approximately 900–700 ka ago [2, 7]. Eruption of mainly dacite lavas of the Elbrus Volcano began less than 250 ka ago and continued up to the Holocene [7, 9]. Trachyandesites of the Tash-Tebe Volcano in the upper reaches of the Khudes River and dacites in the upper reaches of the Syltransu River formed at the same time [9].

These data indicate that the young magmatism of the Elbrus area is mainly represented by acid or moderately acid rocks. However, the central part of the zone includes two small fields of basic rocks of controversial age (Fig. 1). Therefore, the evolution of young magmatism and petrogenesis of its products in the study region are uncertain. One field is located 25 km southwest of the town of Nal'chik in the Chegem–Cherek-Khulam interfluve. The field includes remnants of volcanic edifices (massive and porous basaltic andesites) at the summits of the Surkh and Krandukh mountains. Fragments of lava flows from these volcanoes are observed in the northern area in the foothills of the Shaukhna and older Tarakla mountains [1]. According to [1], ignimbrites and tuffs of the Lower Chegem highland rest on the older basaltic andesites. The ^{39}Ar–^{40}Ar whole-rock data on basaltic andesite from the foothills of Mt. Tarakla are reported in [6]. The Ar spectrum defines a nearly linear pattern. However, the scatter of age values for individual steps ranges from 3.1 to 3.8 Ma (average

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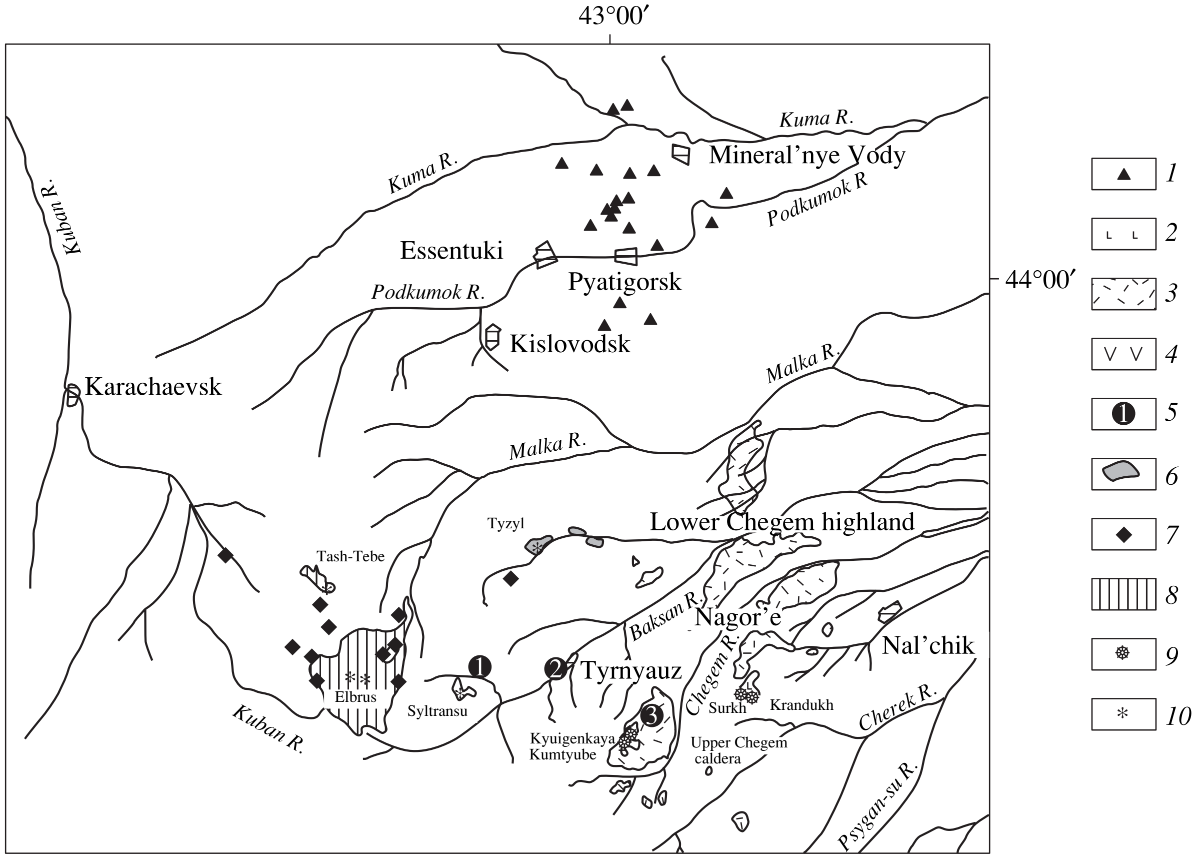

Fig. 1. Scheme of the Neogene–Quaternary magmatism within the Elbrus area. (*1*) Miocene, intrusive subalkaline granitoid massifs of the Caucasian Mineral'nye Vody; (*2–5*) Pliocene: (*2*) basaltic andesite lavas of the Surkh and Krandukh volcanoes, (*3*) rhyolite and dacite ignimbrites, tuffs, and lavas of the Chegem area, (*4*) andesite lavas of the Kyuigenkaya and Kumtyube volcanoes, (5) granite and granodiorite massifs: (1) Kyrtyk, (2) El'dzhurta, (3) Dzhungusu; (*6–10*) Anthropogene: (*6*) basaltic andesite lavas of the Tyzyl River, (*7*) Eopleistocene rhyolite and dacite pyroclastic rocks and trachyandesite lavas, (*8*) Late Pleistocene–Holocene dacite lavas of the Elbrus volcanic center, (*9*) Pliocene volcanoes, (*10*) Quaternary volcanoes.

weighed age 3.58 ± 0.38 Ma). Therefore, the authors of [6] consider that these data should be refined on the basis of monomineral fractions.

The second field of basic volcanism in the Elbrus area is located in the Tyzyl River valley. A remnant of lava flow of massive, weakly porphyric basaltic andesites and trachybasaltic andesites is situated at the mouth of its left tributary (Kinzhal River) [1, 10]. Small lava remnants are also found downstream the Tyzyl River on the upper terraces of both banks of the river. The supposed age of these lavas varies from Middle Pleistocene [11] to Pliocene [1].

The present work reports isotope–geochronological data on the basic rock samples K-62A (black lava) and K-62B (red lava) from the Krandukh Volcano (collection of D.A. Ivanov) and samples 50-8 (upper horizon) and 50-3 (lower horizon) from a volcanic remnant near the mouth of the Kinzhal River in the Tyzyl River valley (collection of V.M. Gazeev).

The typical phenocryst assemblage of the basaltic andesites of the Krandukh Volcano comprises plagioclase (normally, bytownite), pyroxene, olivine, and occasional quartz xenocrysts (or diacrysts). Analyzed lavas belong to calc-alkaline series. They contain 55.9–56.6 wt % SiO_2, 4.9–5.3 wt % $K_2O + Na_2O$ (1.3–1.6 wt % K_2O). The studied rocks from the Tyzyl River correspond to trachybasaltic andesites. The predominant phenocryst, olivine, is commonly associated with augite. Quartz xenocrysts (diacrysts) often occur in plagioclase–clinopyroxene rim. The rocks are ascribed to K–Na subalkaline series. They contain 54.8–56.5 wt % SiO_2 and 6.4–6.2 wt % $K_2O + Na_2O$ (2.5–1.4 wt % K_2O).

Isotope–geochronological and geochemical investigations were conducted at the Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry. K–Ar dating was performed following our technique developed for study of the youngest rocks [7]. The content of radiogenic Ar was analyzed on a high-precision MI-1201 IG mass spectrometer. To avoid an age disturbance owing to excess ^{40}Ar retained in phenocrysts, the K–Ar measurements were performed on groundmass [7]. The Sr and Nd isotope analyses were also performed on a groundmass using a Micromass Sector 54 mass spectrometer.

Results of the geochronological and isotope–geochemical study of basic lavas from the Elbrus neovolcanic area

Sample no.	K, % ± σ	$^{40}Ar_{rad}$, ng/g ± σ	$^{40}Ar_{air}$, % in sample	K–Ar age, Ma ± 2σ	Rb, g/t	Sr, g/t	$^{87}Rb/^{86}Sr$ ± 2σ	$^{87}Sr/^{86}Sr$ ± 2σ	$^{143}Nd/^{144}Nd$ ± 2σ	ε_{Nd}
Basaltic andesites of Mt. Krandukh										
K-62A	1.25 ± 0.02	0.332 ± 0.004	73.2	3.85 ± 0.15	52	480	0.3126 ± 9	0.704601 ± 16	0.512749 ± 10	+2.2
K-62B	1.18 ± 0.03	0.298 ± 0.004	80.4	3.65 ± 0.15	45	480	0.2710 ± 7	0.704644 ± 16	0.512732 ± 9	+1.8
Basaltic andesites of the Tyzyl River valley										
50-8	2.05 ± 0.03	0.126 ± 0.004	90.3	0.89 ± 0.06	72	970	0.2163 ± 6	0.705031 ± 14	0.512669 ± 7	+0.6
50-3	2.15 ± 0.03	0.133 ± 0.001	77.9	0.90 ± 0.04	75	760	0.2859 ± 7	0.705066 ± 17	0.512660 ± 9	+0.4

Note: Analyzed material is groundmass.

Results of the isotope–geochronological study of basaltic andesites from the Elbrus area are given in table. K–Ar datings of the Krandukh Volcano lavas are within a range of 3.85–3.65 Ma, which corresponds to the end of the early Pliocene. They refine the aforesaid ^{39}Ar–^{40}Ar data and are highly consistent with stratigraphic data, which indicate that basaltic andesites are older than ignimbrites and tuffs of the Lower Chegem highland (2.9–2.8 Ma) [1, 5, 6]. Thus, the appearance of the Surkh and Krandukh basaltic andesite volcanoes marks the beginning of Pliocene magmatism in the Elbrus area. They are significantly separated in time (by almost 1 Ma) from the later rhyolite–dacite volcanism in the Chegem area. The scale of initial impulse of basic (basaltic andesite) magmatism was relatively small (local manifestation and insignificant volume of erupted material). The magmatic activity correlates in time with the onset of the Pliocene basaltic magmatism that was most widespread in southern Georgia (Dzhavakheti highland). According to our K–Ar data, the age of the lowermost lava flows in this area is approximately 3.75–3.65 Ma.

The obtained data show that trachybasaltic andesites of the Tyzyl River valley are significantly younger than basic volcanic rocks of the Surkh and Krandukh volcanoes. Their age (900 ka) corresponds to the end of the Eopleistocene, with datings on the upper and lower horizons of lava flow coinciding within the measurement error. Thus, as in the case with basaltic andesite volcanism in the Chegem area, trachybasaltic andesites of the Tyzyl River valley mark a relatively weak impulse of Quaternary basic volcanism, which began the Anthropogene stage of Late Cenozoic magmatism in the Elbrus area. This impulse is correlated with the beginning of Quaternary volcanic activity in the Aragats zone of the Lesser Caucasus, where the first phase of the activity (~900 ka ago) also produced basic lavas [12].

Basic rocks of the Krandukh Volcano and the Tyzyl River valley differ in Sr and Nd isotope signatures (table). Subalkaline volcanic rocks of the Tyzyl flow have a more radiogenic Sr isotopic composition ($^{87}Sr/^{86}Sr$ = 0.70503–0.70507) as compared to the Krandukh calc-alkaline basaltic andesites ($^{87}Sr/^{86}Sr$ = 0.70460–0.70464). The relationship of radiogenic Nd isotopic compositions is reversed (εNd from +0.4 to +0.6 in the Tyzyl area and from +1.8 to +2.2 in the Krandukh area). Petrographic (olivine–quartz assemblage) and isotope–geochemical (position of data points of lavas relative to mantle correlation array on the $^{87}Sr/^{86}Sr$–εNd diagram) data indicate that the basic rocks were presumably derived from magmas related to the contamination of mantle melts by acid crustal material and/or the mixing of mafic mantle melts with minor crustal melts. The hybrid (mantle–crustal) origin of young volcanic rocks was previously proposed in [10, 13, 14]. As compared to other young magmatic rocks of the Elbrus area, the studied basic rocks have a less radiogenic Sr isotopic composition and more radiogenic Nd isotopic composition ($^{87}Sr/^{86}Sr$ = 0.7069 for the El'dzhurta granite; 0.7069 for dikes of rhyolites and vitrophyres of Tyrnyauz; 0.7083–0.7085 for laccoliths of Mineral'nye Vody; 0.7064–0.7077 for Eopleistocene ignimbrites and tuffs of the Elbrus region; and 0.7053–0.7064 (εNd from –0.9 to –3.5) for lavas of the Elbrus Volcano [4, 5, 8, 10]). At the same time, isotope characteristics of acid and moderately acid rocks of the Elbrus area do not reach crustal values, indicating the participation of basaltic mantle magmas in their genesis [10, 13].

The study of Neogene–Quaternary basic lavas of the Elbrus area has shown that rocks of the Surkh and Krandukh volcanoes and Tyzyl flow formed, respectively, during the Pliocene and Anthropogene stages of the magmatic evolution of the region. However, their magmatic activity followed a similar scenario (Fig. 2). In both cases, eruptions of basic lavas predated the larger scale acid volcanism. After a certain interval of time, volcanism of the second phase acquired an explosive character. During the third phase, volcanic activity produced lavas, in particular, intermediate lavas of the Kumtyube and Kyuigenkaya volcanoes at the Pliocene stage and Elbrus lavas at the Anthropogene stage. Rocks of the last (fourth) intrusive phase are known only for the Pliocene stage. Thus, basic volcanism occurred at two stages in the evolution of the Elbrus area, being in both cases a precursor of the subsequent large-scale acid magmatism. Obtained data indicate that magmatic activity at each stage was presumably

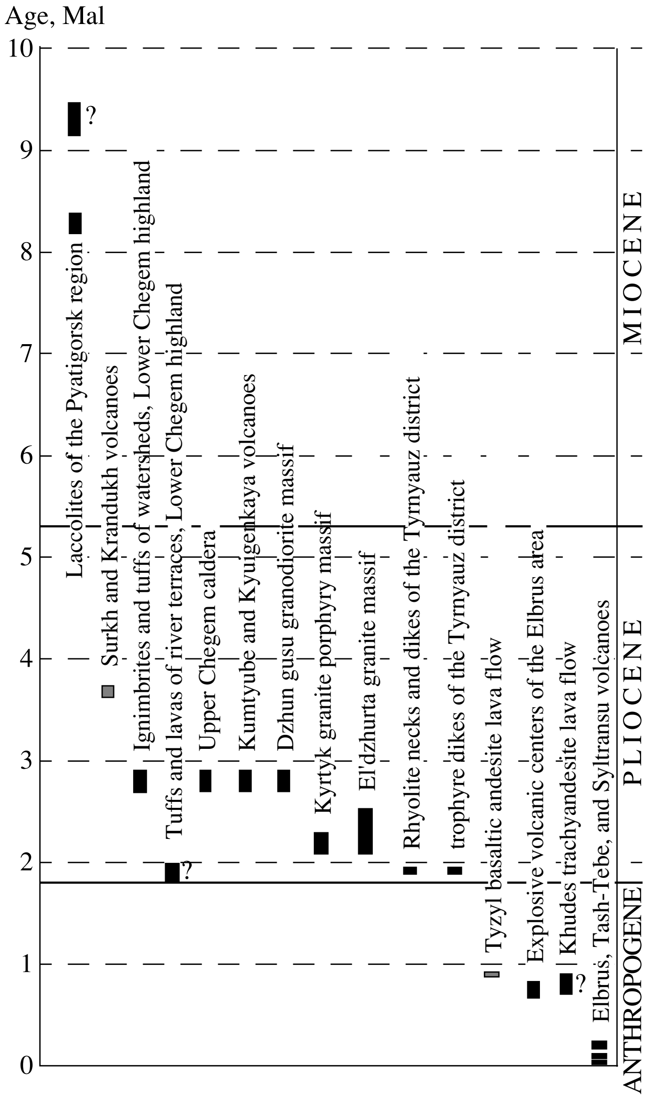

Fig. 2. Geochronological scale of Neogene–Quaternary magmatism in the Elbrus area. Based on data presented in this work and [3–9].

caused by the activation of deep-seated mantle source. This led to the eruption of primary mantle magmas slightly contaminated by crustal material. Subsequent intense interaction of mantle melts and their contaminated basic derivatives with sialic crust triggered the acid to moderately acid explosive magmatism of later magmatic stages at the Greater Caucasus. The scales of Pliocene magmatism exceed those of Anthropogene magmatism. However, the interval between the first (basic magmatism) and second (explosive magmatism) phases in the Pliocene was several times longer.

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