PETROGENETIC EVOLUTION LATE CENOZOIC VOLCANISM OF THE LESSER CAUCASUS

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Abstract

In the article analyze the nature of the substrate the Late collision volcanism of the Lesser Caucasus and the origin of volcanic associations. Revealed that a common feature for most of the Neogene-Quaternary volcanic rocks of the Lesser Caucasus is a relative enrichment in light REE and lithophile elements and weak depletion for heavy rare earth elements, as well as Nb, Ta, Hf. It is concluded that the rocks of the Neogene andesite-dacite-rhyolite and Upper Pliosen-Quaternary trachybasalt-trachyandesite associations melted from sources garnet (3-10% and 1-2,5%, respectively). The presence of adakites rocks of magmatic products in late collision after the cessation of subduction zones can be associated slab-melts. Upper Pliocene-Quaternary rhyolite-dacite magma rocks were granite-metamorphic layer of metamorphosed in the amphibolite and granulite facies rocks metamorphism. The rocks of andesite-dacite-rhyolite and trachybasalt-trachyandesite associations due to a single process of assimilation and fractional crystallization (AFC). The average rocks both associations may have formed during the fractionation of basalt in the absorption of a significant amount of the acid melt.

Interdiction

One of the pressing problems of conflict zones of the study is to elucidate the evolution of magmatism occurring within them. Display magmatic associations, their petrochemical charact-erristics reflect the specificity of their manifestations, as well as the development of magmatism from magmageneration to the evolution of magmatic melt in the earth's crust. Materials on the distribution of rare and rare earth elements in different rock types, as well as other of their geochemical and petrological characteristics allow using the well-known models to analyze some aspects of the processes of birth, evolution and crystallization of deep magmatic melts. In this sense, the study of the geochemical characteristics of mantle and crystal sources of magmatism that have come out in a conflict like the continent - the continent is quite topical. Therefore, the study late collision volcanism of the Lesser Caucasus is a theoretical and practical interest.

Research Methods

This article used data from the Neogene-Quaternary volcanism of the Azerbaijan part of Lesser Caucasus based on the authors.Chemical analysis of rocks was determined by the Institute of Geology of Azerbaijan Academy of Sciences flyurotsentnym X-ray method. Rare and rare-earth elements in Geological and Geochemical Bronitsk expeditions in Russia, the analytical laboratory (LTD) of Canada by Inductively Plasma Spectrometry (ICP).

Microprobe analysis of mineral composition written in IGEM Academy of Sciences of Russia and all in Sant Peterburg. Measuring the isotopic composition of He performed in

Geochemistry Institute of Academy of Sciences Russia, also used the data Sr and Nd [7-9], performed on the material of Armenia and Georgia.

Petrochemical features

Andesite-dacite-rhyolite association. For silica rock associations form a continuous series of andesites (SiO_2 > 60%) to rhyolites (Table 1), and the ratio (Na_2O + K_2O)-SiO_2 [10] are the rocks of normal alkalinity . (some breeds – mid alkaline) in the diagram K_2O-SiO_2 [11] most of the samples falls within the high K calc-alkaline series (Fig. 3), the diagram FeO */ MgO-SiO_2 composition points are located in the field calc-alkaline series .

The rocks of this association are characterized by different contents of major elements. In volcanic rocks with increasing SiO_2 content decreases TiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, P_2O_5, due to fractionation of titanomagnetite, clinopyroxene, plagioclase, and possibly apatite. Weak rates increased content of K_2O. Na_2O is distributed evenly, but also an increase in the number of its slower rate . The reason for this pattern may be a potassium feldspar in the more acidic varieties of rocks.

Rhyolitic association. Rocks associations, in contrast to the previous rock associations, are characterized by ultra-structure and high alkalinity. There is approximately equal ratio of Na_2O and K_2O and low contents of CaO, MgO, FeO (Table 1). In the normative composition of the rocks are calculated high content of salic components of quartz, feldspar and corundum.

Trachybasalt-trachyandesite association. For silica rock associations form a continuous series from basalts to andesites (Table 1) and belong to the mildly alkaline series .In the diagram K_2O-SiO_2 composition points fall in the region high -K calc-alkaline and shoshonite series .In rock associations in the range of "trachybasalt-basaltic trachyandesite" with increasing silica content of TiO_2, MgO, Fe_2O_3, CaO, P_2O_5 is reduced to a large extent, the contents of the same Al_2O_3, Na_2O decreases the slow pace . In the transition to trachyandesites content of these elements varies in a narrow range .The maximum content of MgO is observed in trachybasalts and alkaline olivine basalts and varies from 3,97 to 6,81% (Table 1), and the coefficient of Mg (M) from 56 to 71. In subsequent decrease differentiates the content of MgO and "M". In the normative part of some mildly alkali olivine basalts and trachybasalts calculated normative nepheline and olivine, in more acidic differentiates calculated hypersthene and quartz. Normative and mineral composition reflects the characteristic feature of the association: transition nepheline-normative, olivine containing mildly alkaline rocks to hypersthene-normative and sometimes quartz-bearing alkaline rocks.

Geochemical features

The concentrations of rare and rare earth elements in rocks of andesite-dacite-rhyolite association as a whole regularly changing. Thus, the concentration of lithophile elements increases from andesite to rhyolites (Rb from 44 to 128 ppm, Th 6 to 24 ppm) (Table 1). From the coherent elements in increasing the acidity of rocks in general, the content of V, Cr, Co, Ni decreases. These elements are the same Sr form of silica negative dependence. Positive, but more vague correlation with silica form the content of Y and highly charged elements (HFSE - Nb, Zr, Hf) (Fig. 7). The above features show the leading role of crystallization differentiation in the association of rocks. Comparison of impurity elements rocks andesite-dacite-rhyolite association and the primitive mantle [12] the reduced content of Nb and Ta and elevated levels of lung large ionic lithophile elements (Rb, Ba, Th, La, Ce, Sr) (LILE). Thus, in relation to the primitive mantle there is a maximum Rb, Ba, Th, La, Ce, Sr, and negative Ta-Nb anomalies. It is conceivable that this feature brings these rocks with supersubduction volcanic associations. As seen from Figure 8 the distribution of trace elements for andesite, quartz latite, dacite and rhyodacite are repeated in general terms, indicating that their genetic identity.

From the same type of rocks of andesite-dacite-rhyolite association rocks rhyolite associations differ depleted femic components, a lower content of iron group elements, highly charged elements and enrichment of ore elements in the earth crust, as well as lithophile elements (Pb, Th, U). The distribution of trace elements normalized to primitive mantle for the rhyolite, showed that, like the rock of the previous association, rhyolite is enriched in LILE and depleted in highly charged elements . However, the nature of the schedule rhyolite is different from the schedule rocks previous association and is close to the top of the crust [13], suggesting a different genesis of the rocks of this association. In the rocks trachybasalt-trachyandesite association occurs in about the same pattern as in the rocks of andesite-dacite-rhyolite association, but more clearly. Rocks of this association inherent to the high content of Rb, Ba, La, Sr (Fig. 8), as well as high values of La/Yb, La/Sm relations. Compared with the composition of primitive mantle [13] alkaline basalts are enriched in most LILE and some highly charged elements: Rb, Ba, Th, La, Ce, Sr, Zr . Geochemical data for this association show that the diversity of species association is due mainly to fractional crystallization. This is evidenced by: 1) with increasing SiO_2 content decreases compatible elements (Cr, Ni) and increasing concentrations of incompatible elements (Rb, Th, U) (Fig. 9) due to fractionation of olivine and clinopyroxene, and 2) revealed clear positive correlation connection LREE with phosphorus, calcium and fluoride, due to the concentration of light rare earth elements in apatite (the distribution coefficients of REE for apatite is 10-100). These data indicate that fractional crystallization is particularly important for trachybasalts and basaltic trachyandesites. In the process of differentiation of the content of trace elements naturally varies depending on the composition of the melt, its temperature, as well as the composition and crystal-chemical properties of rock-forming minerals. Content and types of spectra of these elements of the breed trachybasalt-trachyandesite associations of the Lesser Caucasus are close to the rocks of oceanic islands and the rift zones formed from the enriched mantle source. Similarity of plots the distribution of elements on the primitive mantle may indicate comagmatic members of the association.

Isotopic composition

For the Neogene - Quaternary rocks of the Lesser Caucasus, we have obtained for the 7 samples of volcanic rocks and their nodules isotopic compositions of He (Table 2). The highest ratio of $^{3}He/^{4}He$ ($^{3}He/^{4}He = 0,93 \times 10^{-5}$) is characteristic for alkali olivine basalts, which brings them to the mantle derivatives. Approximately the same value is obtained for amphibole megacrysts from trachyandesite approaching the isotope ratios of primary helium mantle reservoirs ($1\text{-}5 \times 10^{-5}$) [14] and to the gases carbon sources, the most active areas associated with manifestations of modern volcanism of the Lesser Caucasus ($^{3}He/^{4}He = 10^{-5}$) [15]. A fractional difference between the rocks of trachybasalt-trachyandesite association, their nodules, as well as andesite of andesite-dacite-rhyolite association have lower values of helium isotopes (Table 2). These data indicate that differentiate the first association, incorporation and andesite second association crystallized in the earth crust.

Table 2. Isotopic composition He in Late Cenozoic rocks of the Lesser Caucasus

No samples	Rocks and minerals	$^3He/^4He \cdot 10^{-6}$	$^4He \cdot 10^{-6}$
132	Alkaline olivine basalte	9,29 (±1,46)	0,604 (±0,006)
21	Trachybasalte	1,76 (±0,27)	2,70 (±0,03)
13	Trachyandesite	1,05 (±0,18)	1,54 (±0,02)
15	Andesite	0,924 (±0,162)	2,36 (±0,02)
Nodules			
25-в	Pyroxsenites	3,33 (±0,49)	3,43 (±0,03)
13-м	Megacryste amphybole	9,39 (±1,42)	2,90 (±0,03)

Unfortunately, isotopic data Sr, Nd of the Azerbaijan part of Lesser Caucasus absent. There is anecdotal evidence about the Armenian and Georgian part of the Lesser Caucasus. I.V. Chernyshev, and his co-workers [8, 9] determined the absolute age of alkali basalts Javakheti Plateau, we propose a new version of the geochronological scale of the Neogene-Quaternary magmatism of the Caucasus. Dan precise absolute age of rhyolite volcanism for different volcanic highlands of the Lesser Caucasus [7]. Data above authors argue that the dominant role in the petrogenesis of lavas played by processes of fractional crystallization and contamination of the parent melts geochemically distinct from them, crustal matter [9]. A sour rhyolite volcanism developed in the context of tectonic and thermal activity of mantle lesions and relationship with the processes of local anatexis in the lower crust zones of metamorphism [7]. Our petrology and geochemistry data confirm these findings.

Discussion of results

This section discusses the nature of the mantle substrate region under study, as well as the origin of each of volcanic associations.

Mantle sources

These isotopic composition of Sr and Nd for late Cenozoic volcanic rocks of the Lesser Caucasus show that the primary melts to produce a mantle sources. Acid rock has mostly crustal origin. There have been offset mantle and crustal magmas. In general, this assumption is acceptable for the Azerbaijan part of the region. A common feature for most of the Neogene-Quaternary volcanic rocks of the Lesser Caucasus is a relative enrichment in light REE and large lithophile elements (Rb, Ba), and weak depletion for heavy rare earth elements, as well as Nb, Ta, Hf. These geochemical data confirm the presence of restite of garnet in the magmatic source for the andesite-dacite-rhyolite and trachybasalt-trachyandesite associations. In addition, we believe in the petrogenesis of Late collision basaltoids important role played mantle substance metasomatically processed by previous subduction processes, as evidenced by the relatively high oxidized rocks associations. $(Ce/Yb)_{MN}$ - Yb_{MN} shows the calculated line of equilibrium partial melting of garnet peridotite with different content of garnet. Calculated trends melting portions of garnet peridotite, containing 2,5, and 4% garnet, borrowed from [16]. As seen from Fig.10, composition points of rocks of andesite-dacite-rhyolite associations are in the range of values with a relatively high degree of melting (3-10%) mantle source containing 4% garnet. Lineups alkali basaltoids trachybasalt-trachyandesite association on this chart are in the range of values with a low degree of melting (1-2,5%) garnet peridotite and, apparently, mantle source was more metasomatized (17, 18). It can be assumed that a lower degree of melting of the mantle of the substrate led to the association of basaltic melt at high alkalinity and a significant enrichment of the melt K, P, F, Ba, LREE due priority to the melting of phlogopite, apatite, amphibole, which are the main carriers of these elements. Fig.10. Normalized to primitive mantle [12] the ratio of Ce / Yb-Yb in the Late Cenozoic basalts and andesites of the Lesser Caucasus. Calculated trends melting portions of garnet peridotite, containing 2,5, and 4% garnet [16]. The numbers along the curves - the percentage of melting. Legend: 1 - andesites, andesite-dacite-rhyolite association, 2 - alkaline basalts trachybasalt-trachyandesite association.

At present, the association of these volcanic rocks are often associated with the association of subduction “windows” (slab-window) and see the result of decompression melting of asthenospheric diapir. These volcanics differ from typical subduction magma and have geochemical characteristics of OIB sources. They are described for the active continental margin of North America, Philippines, Kamchatka, East Sikhote-Alin .For collision volcanics this idea is developed [24-28]. Such rocks are called adakites. They are characterized by high ratio LREE / HREE and are formed by melting of garnet containing material (eclogite) oceanic plate. Note that we also do not deny the delamination subduction lithospheric slab in the association of Late Cenozoic volcanic rocks of the Lesser Caucasus . This is evidenced Seismic and some of petrology and geochemistry data. Part of Late Cenozoic andesite and dacite of the Lesser Caucasus can be considered derivatives adakites melts. They $(La/Yb)_n$ varies from 17,5 to 26,4, the concentration of Y from 6 to 13 ppm, Yb from 1,2 to 1,8 ppm. Figure Sr/Y-Y majority of species fall into the field adakites [19] . Thus, it is found that the rocks of the Neogene andesite-dacite-rhyolite and Upper Pliocene-Quaternary trachybasalt-trachyandesite association smelt garnet sources at a depth of not less than 60-80 km [5, 30]. Not be excluded on the association of andesite melting subduction oceanic crust [9]. As Upper Piocene-Quaternary acidic volcanic rocks, as shown by the full range of studies and published isotopic data for the region, the source of rhyolite-dacite magmas could serve as a rock granite-metamorphic layer, metamorphosed to amphibolite and granulite facies metamorphism. The high concentrations of K, Li, Rb, Cs, U, Th, Rb and low Sr, Ba, Zr, Ti and light lanthanides, the presence of a deep negative Eu - anomalies may indicate relatively low levels of fusion substrate, in which a significant portion of plagioclase and accessories remained in the restite. The eastern part of the Lesser Caucasus (Vardenis and Syunik uplands) ^{87}Sr / ^{86}Sr are 0,70444-0,70811 [7].

Fractional crystallization

Petrochemical data show that the association of andesite-dacite-rhyolite and trachybasalt-trachyandesite association of fractional crystallization occurred. Thus, in the rocks of andesite-dacite-rhyolite association with increasing silica content decreases femic rock-forming oxides, increasing the content of incompatible elements due to fractionation of dark-colored minerals and feldspars. However, fuzzy trends show the influence of processes of assimilation and crustal contamination on the association of these rocks. Thus, an attempt to get out of andesitic dacites and from dacitic rhyolites by fractionation of clinopyroxene, amphibole, biotite, magnetite and feldspar failed. Therefore, as will be shown below, apparently, the association of these rocks is dominated by a single process of AFC, i.e. assimilation and fractional crystallization. We believe that fractional crystallization played a leading role in the association of rocks trachybasalt-trachyandesite association. This is evidenced by the behavior of a number of rock-forming trace elements. For example, a change in slope of trends MgO-SiO_2, TiO_2-SiO_2, Ni-SiO_2 in the field trachyandesite explained by fractionation of olivine, clinopyroxene, magnetite (Fig. 9).

Past balance calculations on a computer showed that the evolution of the melt occurred as a result of changes in the composition and quantity of rock-forming minerals. The results of balance calculation of fractional crystallization of alkaline olivine basalt-trachybasalts showed that the latter is obtained by fractionation of 19,8% Cpx, 57,6% Pl (An_{65}), 15,0% Ol (Fo $_{84}$) and 7,6% Mt. The absolute and calculated values for major and trace elements in the whole match ($\Delta R^2 = 0.507$). The degree of fractionation at the same time is about 61%.

D – Bulk partition coefficient (are taken from [5, 31])

Fractionation of the above minerals, and amphibole leads to further differentiates associations and the result is a continuous differential series - trachybasalt-basaltic trachyandesite-trachyandesite. Possible further differentiation of the melt to the trachytes, trahyriodasites that is, for example, in a large polygenic volcano Ishyhly. Although, FC simulation of least squares using the basic rock-forming oxides and some trace elements gives good results, the majority of trace elements do not conform to this model. Thus, the content of LREE and HREE for different types of rocks vary in narrow limits. At Harker diagrams micronutrients - SiO_2, where not all elements give a clear linear dependence. This suggests their association by other mechanisms, too.

Crust contamination

We have previously shown that the role of crustal contamination in the genesis of Late Cenozoic volcanic rocks of the Lesser Caucasus is negligible [5]. In other works [32, 33] speculation about a significant transassociation of the primary magmas of crustal processes. We obtained the last petrogeochemical data suggest involvement in petrogenesis Late Cenozoic volcanic enriched mantle source (lithospheric mantle) and a significant contribution to processes of crustal contamination. The calculations show AFC - a model of crustal material required for the appropriate changes to the source mantle composition of rocks trachybasalt-trachyandesite association can be achieved during the fractionation of basalts (degree of fractionation of $F = 0,5$-$0,6$) with the absorption of a large number of acid melt (the ratio of assimilation rock and cumulates $r = 0,3$-$0,5$) . A similar pattern is observed for rocks of andesite-dacite-rhyolite association, but this shift is achieved with a high degree of fractionation ($F = 0,7$-$0,9$) and with a large number of acidic substances ($r = 0,6$). Obviously, with such volumes of assimilation acidic substances are not stored petrochemical characteristics of the primary rocks (andesites and basalts). Therefore Harkers figures are not observed clear trends. Below are the results of AFC - modeling for rocks trachybasalt-trachyandesite association. As seen from Table. 4, the intermingling rhyolite and basic rocks (alkaline olivine basalts and trachybasalt) may be formed basaltic trachyandesite and trachyandesite. Summarizing the above data, the association of Late Cenozoic volcanic series of the Lesser Caucasus can be represented as follows.

Within the Lesser Caucasus in the late Cenozoic volcanism expressed high-K calc-alkaline, mildly alkaline and partly alkaline associations. In Neogene time (Upper Miocene-Lower Pliocene), with decompression occurs anatexis metasomatized mantle and lower strata of basalt layer at a sufficiently large depth, which determines the enrichment of these melts with alkali, alkaline earth and light rare earth elements. This process resulted in association of basaltic melts, enriched in alkalis. Perhaps such a melt was formed at low degrees of partial melting (3-10%) of garnet peridotite or eclogite. We can assume that it corresponds subduction oceanic crust. In the future, as a result of growing tension mantle melts penetrated the upper layers of the earth crust, where it mixes basic and acid magma, with the association of hybrid andesite, andesite-dacite lavas. Progressive cooling of the deep source magma origin may be the cause of education dike fields in the region studied and possibly fractured outpouring mildly alkaline volcanism observed in the other parts of the Lesser Caucasus. Due to additional heating and the flow of volatiles formed fairly large volcanoes of calc-alkaline composition of Neogene age. Then Upper Pliocene-Quaternary formed bimodal volcanism. Thus, the temporal spatial conjugation of crustal and mantle magmatism led to the introduction of mantle melts, under conditions of tension in the lower crust, which resulted in its melting and the association of acidic volcanic rocks rich in radiogenic Sr and Nd (rhyolite association). Simultaneously, in this situation, a change of scenery compression and tensile contributed to the development rifts depressions, arching and exercise slow differentiated and undifferentiated volcanic (trachybasalte- basaltic trachyandesite-trachyandesite and basanite-tefrite series). Thus, the evolution of the melt in the earth crust dominated by a single process of AFC (assimilation and fractional crystallization). As the fractionation rare elements, intermediate rocks can be formed by mixing trachybasaltic and rhyolite melts.

Conclusions

1. In Late Cenozoic stage of development of the Lesser Caucasus formed high-K calc - alkaline, mildly alkaline and alkaline part series.

2. The common feature for most of the Neogene-Quaternary volcanic rocks of the Lesser Caucasus is a relative enrichment in light REE and large cation lithophile elements and weak depleted for heavy rare earth elements, as well as Nb, Ta, Hf.

3. The Neogene andesite-dacite-rhyolite and Upper Pliocene-Quaternary trachybasalt-trachyandesit associations melted from sources garnet (3-10% and 1-2,5%, respectively). Not excluded in the association of andesites subduction melting of oceanic crust. Presence adakite rocks of magmatic products in late collision after the cessation of subduction zones may be associated slab-melts. Source Upper Pliocene-Quaternary rhyolite-dacite magma rocks were granite-metamorphic layer, metamorphosed in the amphibolite and granulite facies metamorphism.

4. The andesite-dacite-rhyolite and trachybasalt-trachyandesite associations due to a single process of assimilation and fractional crystallization (AFC). Medium rocks both associations could be formed during the fractionation of basalt in the absorption of a significant amount of the acid melt.

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