PLIOCENE-QUATERNARY SAMTSKHE-JAVAKHETI VOLCANIC HIGHLAND, LESSER CAUCASUS – AS A RESULT OF MANTLE PLUME ACTIVITY

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Introduction

In the SW part of the Lesser Caucasus, at the Pliocene-Quaternary, the Samtskhe-Javakheti subaerial volcanic highland (elevation 1500-2500 m) was formed, which is located discordantly on mid-Eocene sediments. In Georgian territory, the highland occupies more than 4500 km^2, however, its larger part is located to the south in Turkey and Armenia.

The study of the Samtskhe-Javakheti volcanic highland has lasted for some decades. Among the researchers, N. Skhirtladze (1958) has made a valuable contribution. In the formation of the highland, three large episodes of magmatic activity should be noted: (1) Early Pliocene – when dacite-andesitic volcanic tuffs of 700-1100 m thickness and flows (i.e. Goderdzi suite) were formed; (2) Late Pliocene-Early Pleistocene – when dolerite flows of 100-250 m thickness were formed; and (3) Mid-crust Pleistocene-Holocene volcanic activity, when the Abul-Samsari linear volcanic ridge was formed to the south of the dolerite flows.

Based on field, petrologic, petrochemical, and isotopic studies, we consider that all three stages of the Samtskhe-Javakheti volcanic highland formation were connected with the activity of mantle plume flows (Morgan, 1972) and not with melting processes of the residual subduction of oceanic crust in the mantle as is considered at present (Neill et al., 2013). Our consideration is confirmed by the results of a new experimental modeling (CNRS/IRD/Blaise Pascal University): the melting of the subducted oceanic crust into the mantle. According to the experiment, an oceanic crust submerged into the mantle at the beginning is melting, although in the Mg-rich environment a perovskite ($MgSiO_3$) mineral envelope is permanently formed at a melting point that is significantly higher than that of the mantle. It melts fully already at the border of the lower mantle and outer core, in the area of layer D, where the temperature increases to 1000° C.

Field, petrological, and geochemical investigations

A large part of the highland is built up by the Goderzi suite, which is represented by volcanic lava-breccias, pyroclastic rocks, andesite-basalt lava flow and ash fall, as well as huge deposits of andesite-dacitic composition. Formation of the series was conditioned by several cycles of volcanic eruptions in the range of 5.2 to 2.6 Ma (zircon U-Pb dating), with a mantle source in the magma chamber (Chang et al., 2013). The question about the magmatic center of the Goderzi suite is still debated, but it is clear that it was a huge formation. Based on physical volcanology, the analogy of such a structure is considered super/mega volcanoes. The evidence of such structure includes the following: a large volume of volcanic material

(>1500 km^2); great thickness (700-1100 m in average); large size of the volcanic breccias (diameter >1 m); substantial scale of lava flows (length 35 km, thickness 30-80 m); and great thickness of volcanic ash horizons, 300 cm in some places (Fig. 1).

According to the descriptions above, a volcano yielding the Goderdzi suite was not an ordinary formation but a mega volcano (Okrostsvaridze et al., 2016). In addition, taking into consideration all petro- and geochemical parameters, these rocks do not belong to the island arc formations.

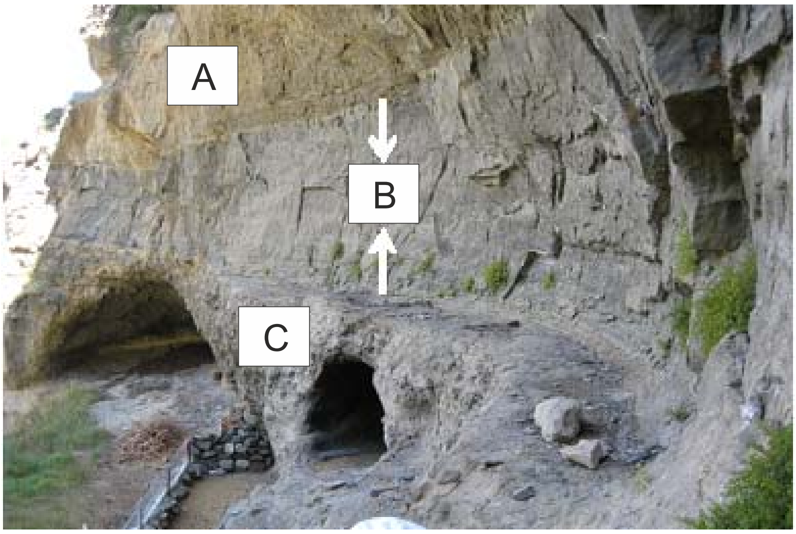

Figure 1. Exposure of a thick layer of volcanic ash at the northern benches of Vani kettles. A-medium-grained tuffs, B – grey volcanic ash, C – coarse-grained volcanic tuffs.

Basaltic flows of the Javakheti volcanic plateau of 100-250 m thickness were formed as a result of the second magmatic activity of this volcanic highland, Late Pliocene-Early Pleistocene (2.4-1.6 Ma; Chang et al., 2013). The strata are dark grey, fully-crystalline, coarse-grained, weakly differentiated massive rocks, mainly consisting of olivine, mafic labradorite, monoclinic pyroxene, and titano-augite. According to petrochemical data, they are more related to mid oceanic ridge basalts than to island arcs. The content of SiO_2 in these flows varies in the range of 49-51% and that of MgO varies within 6-8%. The $^{143}Nd/^{144}Nd$ parameter varies in the range of +0.51703 to +0.52304, and the $^{87}Sr/^{88}Sr$ parameter – from 0.7036 to 0.7042. By all these characteristics, these are typical continental basalt strata, the genetic relation of which to mantle plumes is doubtless.

The third and last magmatic activity of the Samtskhe-Javakheti volcanic highland, which took place from mid-Pleistocene to Holocene (0.35-0.025 Ma; Chang et al., 2013) is a classic example of a “hot spot” (Okrostsvaridze, 2011). As a result of this magmatic activity, the Abul-Samsari linear volcanic ridge was formed, which stretches in the S-N direction for 40 km with an 8-12 km width and containing more than 20 volcanic edifices. According to the Sr and Nd isotopic parameters ($^{143}Nd/^{144}Nd$ = +0.52504; $^{87}Sr/^{88}Sr$ = 0.0421), the magmatic source of this ridge was the mantle reservoir; formation of its volcanic edifices occurred from the southern to the northern direction over time. At the same time, volcanic activity decreased. To the south of the Abul-Samsari ridge, the highest (elevation 3305 m) and oldest (0.35-0.30 Ma) volcano Didi Abuli (Big Abuli) is located. To the north, the heights and ages of volcano edifices gradually increase. Further north, the youngest volcano Tavkvetili is located (elevation 2583 m, age 0.025-0.30 Ma). Unlike other volcanoes, it still has a crater. One can see from this brief description that the Abul-Samsari ridge shows all the signs that characterize an intraplate volcanic ridge.

Discussion

If we assume the results obtained, then the history of geological development of the region becomes more interesting because of a close genetic relation between a Paleozoic granite-gneiss crust (Artvini-Bolnisi platform), Paleogene volcanic arc formations (Akhaltsikhe depression), and the products of Pliocene-Quaternary mantle activity (Samtskhe-Javakheti volcanic highland). Such a circumstance makes it possible to reconstruct an important geological process in the future, such as thermochemical interaction of mantle plumes and a subduction zone.

In addition, as the modern studies show, as a result of thermochemical interaction of mantle plumes and lithosphere, important metallic ores are formed. A newly-formed powerful hydrothermal system accumulates associations of Cu-Ni-Pt, Fe-Pt, Au-As, Ag-Sb, Sb-Hg, and other metals at the barriers of basaltic strata. It should be noted that such an accumulation of metals is observed in the upper horizons of the Goderdzi suite, which forms the basis for their study in detail.

As for the problem of the Javakheti mantle plume generation, maybe it is a marginal manifestation of the northern flow of the Eastern Africa mantle plume.

Conclusion

Based on the results of petrologic, petrochemical, and isotopic studies, we believe that all three stages of the formation of the Javakheti volcanic highland were related to the activity of a mantle plume; therefore, it is possible for the highland to be viewed as a relatively small-scale magmatic province. This consideration is confirmed by the following important factors of mantle plume manifestation within the highland: super/mega volcanoes – magmatic activity forming the Goderdzi suite; continental flood basalts – dolerite flows of Javakheti volcanic plateau; intraplate linear volcanic ridge – Abul-Samsari volcanic ridge.

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