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Mantle helium traces in the Elbrus–Kazbek sector of the Greater Caucasus and adjacent areas

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ABSTRACT

The isotope composition of He contained in gas phase of subsurface fluids in the Greater Caucasus orogene and adjacent areas is revisited combining data obtained before 1998 with 54 new measurements. We report $^3He/^4He = R$ ratios (hereafter, *R*) in CO_2-rich springs from the vicinities of the Elbrus and Kazbek active volcanoes and CH_4-rich gases from mud volcanoes in eastern Georgia. The central segment of the orogene between Elbrus and Kazbek volcanoes differs from its western and eastern segments in the highest *R*-values exceeding 5×10^{-6} (~3.6 Ra). The halo of the elevated *R*-values extends northward, far from the Mt. Elbrus into the Scythian Plate, indicating the recent magmatic activity in this region as well. The origin of this halo is discussed along with temperatures of the mineral springs. The high *R*-values are also observed near Mt. Kazbek and further to the south, in mud volcanoes of eastern Georgia, indicating hidden magmatic activity.

1. Introduction

The Caucasian sector of the Alpine-Himalayan fold belt includes manifestations of two different types of present-day volcanic activity. One of them is the Pliocene–Quaternary calc-alkaline magmatic volcanism in the central segment of the Greater Caucasus orogene between Elbrus and Kazbek volcanoes and in the Lesser Caucasus orogene. The other type is recent mud volcanism locally manifested in foredeeps and intermountain depressions.

Volcanic activity of both types is accompanied by discharge of subsurface fluids that differ in their chemical and isotopic composition. Methane predominates in gases emitting from mud volcanoes, whereas CO_2-rich springs mark areas of magmatic activity. The abundance of such gas outlets in the Caucasus region facilitates the study of subsurface fluids aimed at revealing geological regularities in lateral variations of their gas and isotope compositions. One of the most informative features of subsurface gases is the isotopic composition of helium.

It is well known that the ratio of $^3He/^4He = R$ in the mantle is of order 10^{-5} whereas the so-called "canonic" crustal radiogenic ratio is three orders of magnitude lower (Mamyrin and Tolstikhin, 1984). The mantle-derived helium enters the crust along with magmatic melts. Helium released from the melts is mixed with the crustal helium and is dissolved in subsurface fluids. Subsequently, the helium migrates to the surface and further to the atmosphere. The data on the helium isotopic composition in natural gases offer opportunities to map hidden magmatic activity in regions lacking in surface manifestations.

The study of He isotopes in Caucasian gases began in the 1970s. Matveeva et al. (1978) summarized the data available at that time and supposed the existence of a zone of elevated *R*-values that crosses the Greater Caucasus. The subsequent data were considered in Buachidze and Mkheidze (1989), Polyak et al. (1996), and Lavrushin et al. (1996, 1998) and summarized in Polyak et al. (2000). The last work demonstrated a lateral variability of the *R*-values in subsurface fluids from different tectonic units of the region under consideration.

In this paper, the published data on the Northern Caucasus region are considered together with 54 new measurements of He isotopes in spring gases from the vicinities of Elbrus and Kazbek active volcanoes and in gases from mud volcanoes in eastern Georgia. This synthesis is aimed i) to reveal the features of the *R*-value distribution in CO_2-rich springs around Elbrus and Kazbek active volcanoes, ii) to specify isotopic composition of helium from CH_4-rich emanations of mud volcanoes, iii) to demonstrate decreasing *R*-values in spring gases in the eastern segment of the Greater Caucasus orogene, and, as a result, iv) to refine the contours of recent magmatism in the central segment of the orogene and adjacent areas.

Before going to interpretation of lateral changeability of the *R*-values in subsurface fluids, the reality of such variations should be tested by the repeated sampling of the same fluid manifestation. Otherwise, there is a chance to confuse spatial and temporal variations of the parameter.

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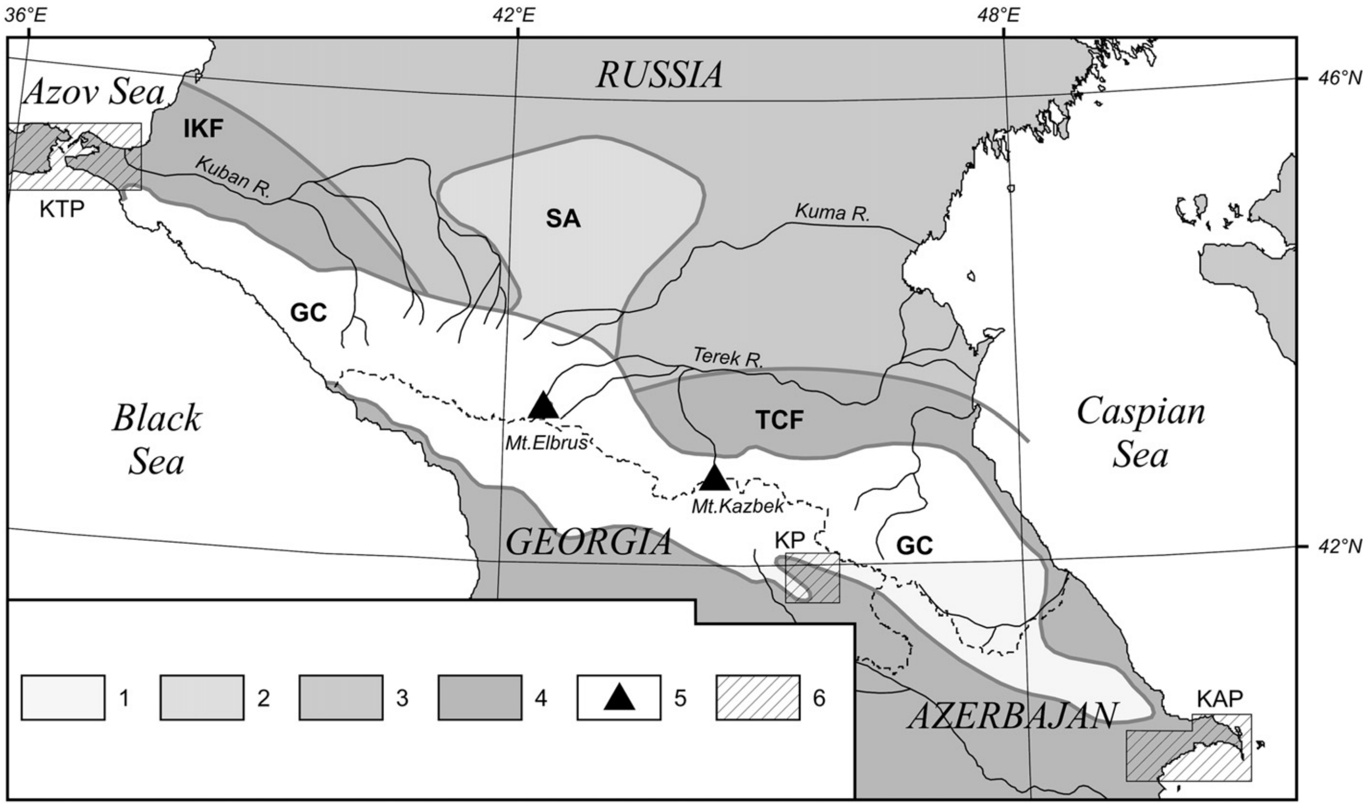

Fig. 1. Tectonic scheme of Caucasus (from Milanovsky and Koronovsky, 1973, simplified). Legend: (1) Alpine orogene of the Greater Caucasus, GC, (2) epi-Hercynian Scythian Plate, (3) Stavropol Arch of the plate, SA, (4) foredeeps (Indol-Kuban, IKF, and Terek-Caspian, TCF), (5) centres of recent Ca-alkaline volcanism, (6) provinces of mud volcanism (Kerch-Taman, KTP, Kakhety, KP, and Kura-Apsheron, KAP).

Therefore, the repeated sampling of selective manifestations was an additional aim of our research.

2. Geological setting

The Northern Caucasus region includes the Alpine anticlinorium of the Greater Caucasus and the epi-Hercynian Scythian Plate (Fig. 1). The anticlinorium represents a large orogene resulted from continental collision that was responsible for thrust deformations, vertical movements and NNW- and NNE-trending strike-slip faulting (Zonenshain and Le Pishon, 1986; Philip et al., 1989; Koronovsky, 1994). The plate is separated from the orogene by the Indol-Kuban (in the west) and the Terek-Caspian (in the east) foredeeps, and is subdivided into the western Azov-Kuban and eastern Terek-Kuma basins by the Stavropol Arch. The arch shows positive anomaly of terrestrial heat flow attributed to unexposed magmatic intrusions (Polyak and Smirnov, 1968).

The central segment of the Greater Caucasus was rejuvenated by Pliocene–Quaternary volcanism. Milanovsky and Koronovsky (1973) described its manifestations in detail. The manifestations are grouped in the Elbrus and Kazbek volcanic areas, around the eponymous

Fig. 2. Mt. Elbrus, view from NNE (photo by V. Lavrushin).