Sr-Nd isotopic composition of Shiveluch volcanic massif (Kamchatka)

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Shiveluch is one of the largest (up to 1000 km^3) and most active volcanic centers in Kamchatka, which occupies a unique geodynamic setting close to the edge of the subducting Pacific plate at the Kurile–Kamchatka and Aleutian arc junction. Volcanic massif has a long and complex eruptive history that started before 80 ka (Pevsner et al., 2014). It edifice includes the Late Pleistocene Old Shiveluch stratovolcano, partially destroyed by a large-scale sector collapse, and Young Shiveluch eruptive center, which has been active through the Holocene (Melekestsev et al., 1991). Among the Old Shiveluch rocks dominate andesite and basaltic andesites (SiO_2=53.5-63.8 wt. %; Mg# 0.52-0.57). High-Mg rocks (SiO_2=53.9-55.0 wt. %; Mg # $\geq$ 0.60) are relatively scarce (Gorbach et al., 2013). In contrast, Young Shiveluch has produced mainly high-Mg andesites (e. g., Volynets et al., 1997; Ponomareva et al., 2007).

Several hypothesis have been proposed regarding to the origin of Shiveluch magmas: 1) slab melting (Yogodzinski et al., 2001; Churikova et al., 2001; Münker et al., 2004); 2) two subducted slabs beneath Shiveluch which are responsible for variable magma compositions (Ferlito, 2011); 3) a highly depleted harzburgitic mantle source (Volynets et al., 1999); 4) low temperature mantle melting and large contribution from pyroxenite sources (Portnyagin et al., 2007; Portnyagin and Manea, 2008; Portnyagin et al., 2009; Nikulin et al., 2012). Melekestsev et al. (1991) proposed an extensive interaction of magmas with the lower crust. Published Sr-Nd isotope data were obtained for Holocene Shiveluch rocks so far (Ivanov, 2008; Volynets et al., 2000, Churikova et al., 2001). Here we report new isotope data for rocks representing all major Shiveluch units and spanning age interval from the initial Late Pleistocene to historic eruptions.

The Old and Young Shiveluch rock have Sr and Nd isotopic compositions which are typical for the Quaternary volcanic rocks of Kamchatka and overlap data for three volcanic zones of Kamchatka (Fig. 1a). $^{87}Sr/^{86}Sr$ isotope ratios vary from 0.703215 to 0.703676. $^{143}Nd/^{144}Nd$ range from 0.513123 to 0.513045 (εNd = 9.5-7.9) and correlate negatively with Sr isotope ratios. Compared with Kliuchevskoi and Bezymianny, Shiveluch rocks have lower $^{87}Sr/^{86}Sr$ but similar $^{143}Nd/^{144}Nd$. The similar range of isotope compositions of Old and Young Shiveluch rocks suggests that these rocks originate from a common source, not from two distinct sources for Old and Young Shiveluch magmas (Ferlito, 2011). The difference in major element composition of the Old and Young Shiveluch magmas is likely related to different crystallization histories and increased role of magma mixing on the most recent stage of Shiveluch activity (Gorbach et al., 2013). With exception of high-K basalts erupted 3600 ^{14}C BP, Sr isotope ratios correlate with major elements in Shiveluch rocks and increase with increasing SiO_2 (Fig. 1b). All Shiveluch rocks, including high -K basalts, exhibit a strong positive correlation between $^{87}Sr/^{86}Sr$ and K_2O (Fig. 1c), Th/La (Fig. 1d), Th/Ta and La/Sm.

The variability of Sr and Nd isotope ratios can reflect heterogeneous mantle source and/or crustal assimilation. In order to evaluate the potential effects of heterogeneous mantle source we calculated a mixing trend of the high-$^{143}Nd/^{144}Nd$ and low-$^{87}Sr/^{86}Sr$ Shiveluch basalts as depleted end-member and 3600 ^{14}C BP high-K basalts as end-member derived from enriched mantle source (Portnyagin et al., 2007). To simulate crustal assimilation, amphibole-mica schists of Khavyvenskaya Rise were chosen as possible assimilant. Although the crust composition under Shiveluch is unknown, Khavyvenskaya Rise amphibole-mica schists can be present in the basement of the Central Kamchatka depression and, in particular, under the western sector of Shiveluch (e.g. Avdeiko et al., 2001). The amphibole-mica schists have $^{87}Sr/^{86}Sr$= 0.70727, $^{143}Nd/^{144}Nd$=0.512968, K_2O=4.3 wt.%, Th/La= 0.46 (Tararin et al., 2007; 2010).

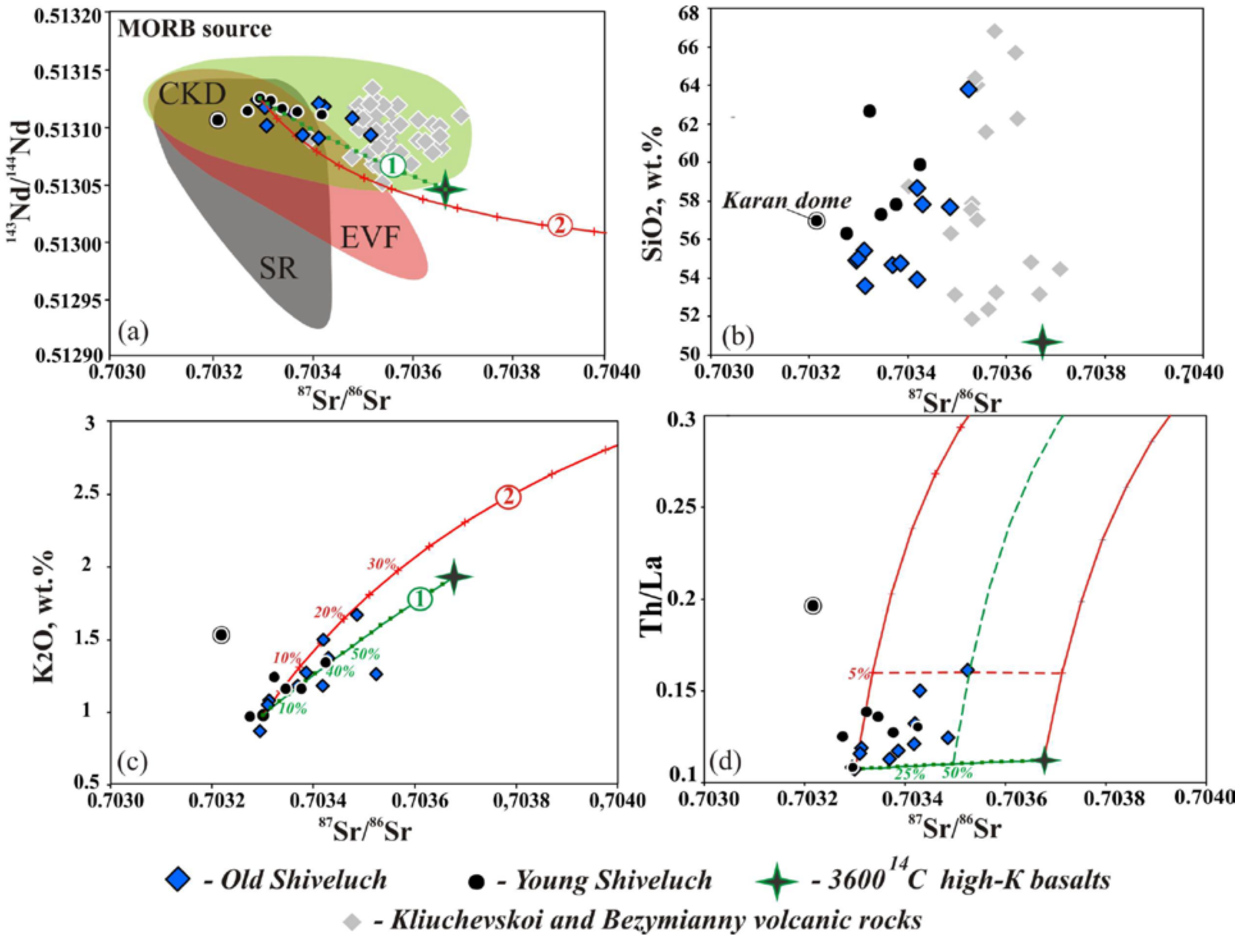

Fig 1. Sr-Nd isotope systematics (a) and variations of $^{87}Sr/^{86}Sr$ vs. SiO_2, K_2O and Th/La (b-d) in Shiveluch rocks. Fields of Sredinny Range (SR), Eastern Volcanic Front (EVF); Central Kamchatka Depression (CKD) are shown after Churikova et al., (2001). On fig. (c) и (d) possible trends of amphibole-mica schists assimilation and mixing with mantle-derived high-K basalts are shown. The amphibole-mica schists composition are after Tararin et al. (2007; 2010).

The results of our modeling are shown in Fig. 1. Variations in Sr-Nd isotopic ratios and K_2O contents in Shiveluch rocks can be well explained by either mixing with high-K 3600 ^{14}C end-member or by assimilation of crustal rocks (trend 1 and 2 in Fig. 1a, c). The systematics of $^{87}Sr/^{86}Sr$ and Th/La ratios allows discriminating the effects of magma mixing and assimilation. This model suggests that both mixing with high-K basalts (up to 50 %) and crustal assimilation (less than 5 %) could contribute to the geochemical and isotopic variations of Shiveluch magma. Assimilation of about 2% of marly rocks is suggested for the Karan dome andesites, whose composition differs from typical Shiveluch compositions (Fig. 1a-d).

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