

The source of Pleistocene-Holocene volcanism in the Sredinny Range back arc, Kamchatka: constraints from trace elements and isotopic compositions.

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Contemporaneous volcanic activity in Kamchatka is a result of convergence of Eurasian and Pacific plates, the latter of which presently subducts at a rate of 8-9 cm/year. The northern boundary of this subduction zone is marked by the Bering transform fault zone. The Sredinny Range (SR) is located in the back-arc region some 400 km from the present trench and is one of the least studied regions in Kamchatka. Its northernmost part continues more than 200 km north of the present-day Bering transform zone. The active Benioff zone in the southern part of the SR (up to the latitude of Ichinsky volcano) is located at a depth of 350 km (Gorbatov *et al.*, 1997). In the north, however, subduction appears to have stopped (Avdeiko *et al.*, 2002; Trubitsin *et al.*, 1998; Davaille, Lees, 2004). North of Ichinsky, a prominent Holocene stratovolcano, geophysical data suggest that the subduction system is inactive. Nevertheless, recent radiocarbon and tephrochronological research found Holocene ages for numerous monogenetic centers and stratovolcanoes, both in the southern and northern parts of the Sredinny Range (Bazanova, Pevzner, 2001; Pevzner, 2004, 2006; Dirksen *et al.*, 2004). Published geochemical composition data of volcanic rocks from the SR is sparse and does not allow us to reconcile recent volcanic activity with the absence of convergent motion of the plates. The goal of this study is to document temporal and spatial compositional and isotopic variations of volcanic rocks from the SR in order to reveal cause and source of active volcanism in this area.

To achieve this goal, we analysed a collection of 120 volcanic rocks from a more than 200 km profile along the SR. Our new data characterize all regions of Quaternary back arc volcanism: Ichinsky volcano and its surrounding monogenetic lava field (stratigraphic units Q₃₋₄ of Pevzner, 2004), monogenetic centers around Achtang volcano and Esso village (Q₃), Kekuknaysky monogenetic lava field (Q₃₋₄), Alnej-Chashakondzha volcanic massif (Q₃₋₄), Sedanka monogenetic lava field and Titila volcano (Q₃₋₄), Gorny Institute volcano (Q₄), Ozernovsky monogenetic lava field (Q₃₋₄), monogenetic centers around Tekletunup volcano (Q₃). In order to discover possible temporal variations in the source composition, we also sampled the underlying stratified lava plateaus: Dvuh'urtochnoe plateau (3.64±0.07 Ma), Kruki Range (Q₁ or older), Left Ozernaya plateau (6.14±0.05 Ma – 6.09±0.04Ma), Right Ozernaya plateau (3.05±0.14 Ma – Q), plateau under Ichinsky volcano (0.94±0.03 Ma – 0.08±0.06Ma).

The trace element patterns of the Pleistocene-Holocene volcanic rocks combine subduction and within-plate-type signatures irrespective of the N-S location of the eruptive centers. Particularly, there is no geochemical change crossing Bering transform zone north of the active subduction zone. At the same time, we observe rocks with completely different geochemistry and mantle source mineralogy in the same region, and this difference is clearly related to the age of studied rocks. For example, Miocene-Pliocene Ozernaya river plateau rocks have very depleted HFSE concentrations (Nb = 0,65-1,87 ppm, Ta = 0,049-0,17 ppm, Hf = 1,17-1,89 ppm) and elevated Ba (300-961 ppm), Sr (400-1256 ppm), etc. (fig. 1, 2). Consequently, fluid-mobile Elements/HFSE ratios are rather high in these samples: Ba/Nb=221-1012, U/Nb=0,15-0,86, Th/Ta=2,94-18,18, etc. These older lavas are overlain by Q₃₋₄ monogenetic lava fields, which are distinct in having enriched trace element pattern with

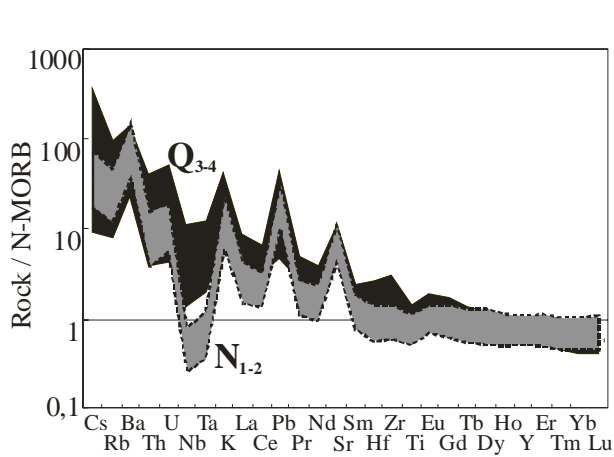
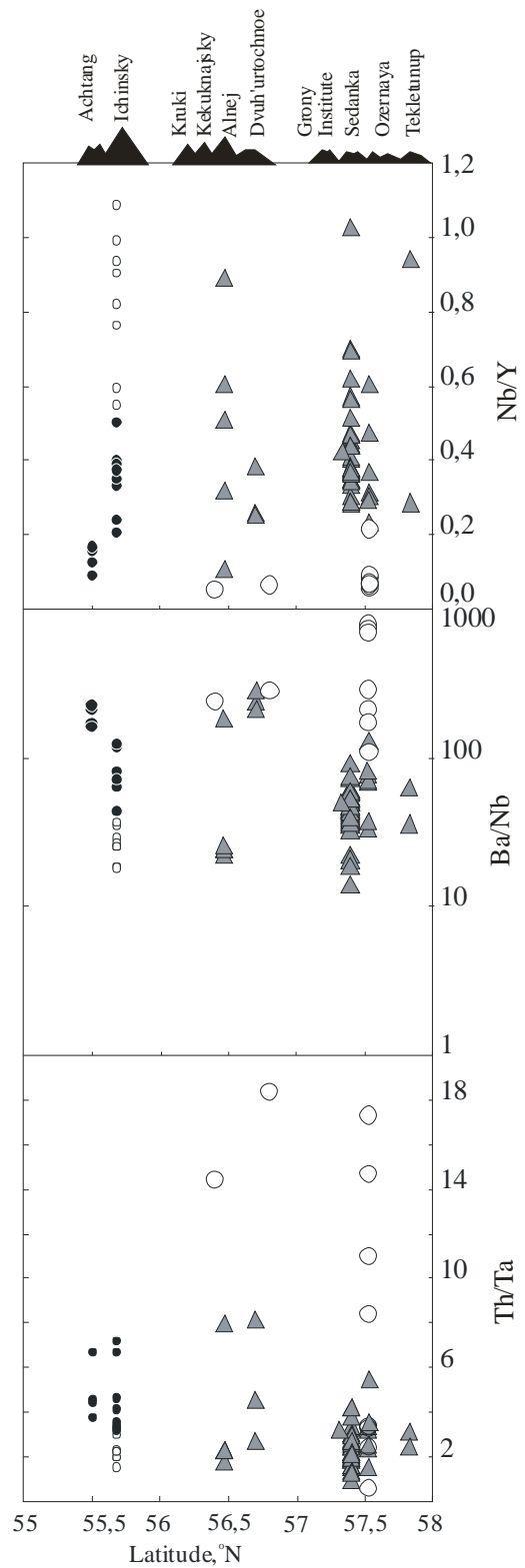


Figure 1 (top). Trace element distribution patterns in Late Miocene-Pliocene plateau lavas and Late Pleistocene-Holocene volcanic rocks. Concentrations are normalized to N-MORB after (Sun and McDonough, 1989). Order of elements after (Hofmann, 1988), with Cs and all REE added.

Figure 2 (right). Variations in Nb/Y, Ba/Nb and Th/Ta ratios in volcanic rocks from the south to the north of Sredinny Range. There is no regular changes at crossing Bering Fault transform zone latitude (57-57,5 °N). Miocene-Pliocene plateau lavas has lower Nb/Y and higher Ba/Nb, Th/Ta then Late Pleistocene-Holocene volcanic rocks.



○ N₁₋₂ plateau basalts ○ Icha WPT (Churikova et al., 2001)
 ▲ Q₃₋₄ volcanic rocks ● SR IAB (Churikova et al., 2001)

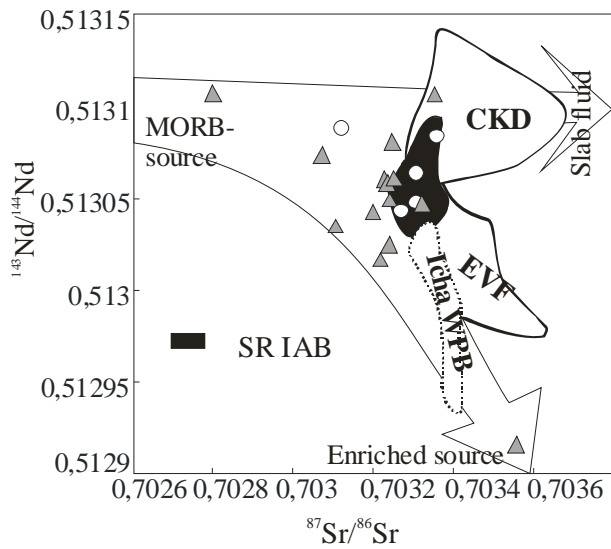


Figure 3. Isotopic composition of Sr and Nd in Sredinny Range volcanic rocks in comparison with previously reported values for Eastern Volcanic Front (EVF), Central Kamchatka Depression (CKD), Sredinny Range rocks of island-arc type (SR IAB) and within-plate type rocks from Ichinsky area (after (Churikova et al., 2001; Dorendorf et al., 2000 a,b). Symbols like in Fig.2.

elevated HFSE content (Nb=7-17 ppm, Ta=0,4-1,076 ppm, Hf=3,09-4,06 ppm) and lower fluid-mobile/HFSE ratios (Ba/Nb=34-80, U/Nb=0,04-0,09, Th/Ta=1,53-3,37, etc.; Fig. 1, 2). N₁₋₂ plateau lavas also differ from younger rocks by their low La/Yb (2,5-6 compared to >7 in Q₃₋₄ lavas), Nb/Y (0,05-0,22 versus 0,25-1,03 in Q₃₋₄ lavas, Fig.2). At the same time, the isotopic composition of Miocene-Pliocene and Pleistocene-Holocene basalts is more or less uniform, close to N-MORB (Fig.3): most samples have ⁸⁷Sr/⁸⁶Sr in a narrow range between 0,703074 and 0,703359; ¹⁴³Nd/¹⁴⁴Nd from 0,513018 to 0,513106 and also a rather small range in Pb isotopes: ²⁰⁶Pb/²⁰⁴Pb=18,10 to 18,26; ²⁰⁷Pb/²⁰⁴Pb=15,417 to 15,486; ²⁰⁸Pb/²⁰⁴Pb=37,676 to 37,928.

The uniformity of geochemistry of the younger SR rocks irrespective of their location north and south of the Bering transform zone suggests a uniform mantle source and subduction input in Quaternary time. Trace element patterns and isotope composition indicate three components in magma generation below the Sredinny Range back arc: (1) N-MORB-type mantle, depleted to different extents, (2) enriched OIB-type mantle and (3) a slab fluid which imparts a typical signature of fluids derived from subducted oceanic crust. Miocene-Pliocene volcanic rocks are most likely produced by high-percentage melting (~20 %) of extremely depleted mantle, induced by fluid addition from the slab at that time. By contrast, relative HFSE enrichment in Late Pleistocene-Holocene volcanic rocks is a result of melting deeper and hotter convecting mantle mainly by decompression. The subduction signature in these younger rocks is inherited from an earlier subduction system, which terminated in Late Miocene times.

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