Sr-Nd ISOTOPIC COMPOSITION OF NEOGENE-QUATERNARY VOLCANIC ROCKS OF THE SREDINNY RANGE, KAMCHATKA: IMPLICATIONS FOR MAGMA GENERATION IN THE BACK-ARC

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Sredinny Range (SR) is the largest volcano-tectonic structure of the Kamchatka peninsula. It consists of the old (Cretaceous – Paleogene) metamorphic massif and volcanic belt, formed in Neogene-Quaternary (N-Q) times. Today, SR is about 400 km away from the contemporary trench. Benioff zone is located at 350-400 km depth in the southern part of SR, up to Khangar volcano latitude (Gorbatov et al., 1997), and is not traced further to the north (Gorbatov et al., 2000). Most of researches agree that Neogene volcanism in SR was caused by the subduction of the Pacific plate, when the active trench was located 200 km to the west from its' today position. In the Late Miocene-Pliocene time the subduction under SR was blocked due to the accretion of Kronotsk arc (Avdeiko et al., 2006; Legler, 1977; Shapiro, Lander, 2003 and others). A new subduction zone was formed near the eastern shore of Kamchatka; it causes a contemporary volcanic activity in the Eastern volcanic front (EVF) and Central Kamchatka Depression (CKD). Pliocene-Quaternary volcanism of SR is referred to as back-arc (Fedotov, Masurenkov, 1991).

From geomorphological point of view, SR can be divided in two parts: northern (SR_N) and southern (SR_S) (Fig. 1). Northern part of SR is a narrow volcanic range stretching to NE. Southern part is more complicated. There are at least two elements in its structure: (1) "eastern" flank stretching to NE, which is a structural continuation of the SR_N; and (2) "western" flank, stretching to NNE. It goes from Sredinny metamorphic massif to N-NE and is marked by large volcanic centers – Khangar, Ichinsky, Kekuknaisky, Ketepana. Between "eastern" and "western" flanks there are Anaunsky Dol, Uksichan and Bolshoy Chekchebonay volcanic massifs, which, probably, mark the intermediate, "central" flank of SR_S.

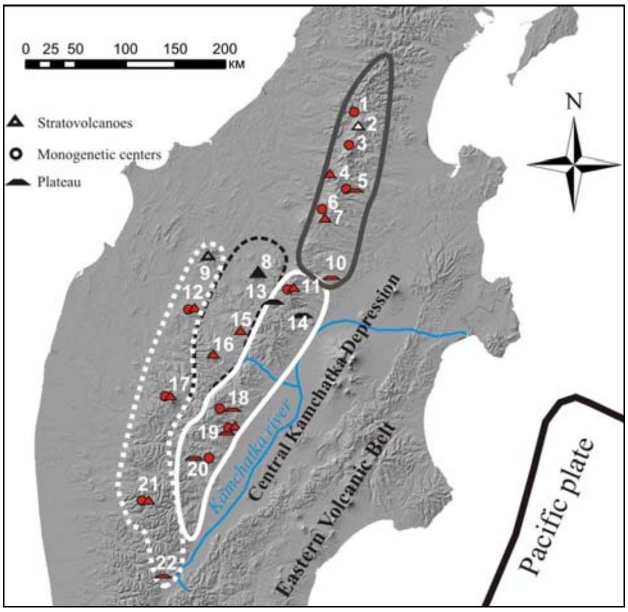

Fig. 1. Scheme of the Sredinny Range of Kamchatka with the sampling map. Numbers indicate sampled volcanic edifices: 1 – Tobeltsen cone; 2 – Spokoiny volc.; 3 – Nylgimelkin cone; 4 – Tekletunup volc.; 5 – Right and Left Ozernaya rivers plateau and Ozernovsky monogenetic lava field; 6 – Titila volc. and Sedanka monogenetic lava field; 7 – Gorny Institute volc.; 8 – Bolshoy Chekchebonay volc.; 9 – Bolshaya Ketepana volc.; 10 – Dvuh'urtochnoe plateau; 11 – Alney-Chashadondzha massif; 12 – Kekuknaisky massif; 13 – Bystrinsky ridge; 14 – Kruki ridge; 15 – Anaunsky Dol; 16 – Uksichan volc.; 17 – Ichinsky massif; 18 – plateau and monogenetic cones in Kozyrevka mt. area; 19 – Akhtang massif; 20 – Aga river and Kostina mt.; 21 – Khangar volc.; 22 – Urtinaya mt. Red symbols – volcanic edifices with Sr-Nd isotopic composition available (this research, literature, unpublished data); unfilled symbols – volcanoes yet not analyzed for Sr-Nd isotopic composition. Lines indicate proposed division of SR to the southern part (consisting from the "eastern" (white solid line), "central" (black dotted line) and "western" (white dotted line) flanks, and northern part (grey solid line).

This subdivision was confirmed by the geochemical data (major and trace elements). Within the northern part of SR typical island-arc rocks erupted in Neogene and hybrid type rocks in Quaternary time. By hybrid type we understand rocks with both elevated HFS and LIL element concentrations. This can be interpreted as a result of three-component (enriched mantle + depleted mantle + fluid) source interaction (Churikova et al., 2001; Volynets et al., 2010). Degree of source enrichment relative to N-MORB is estimated from HFSE concentrations. Hybrid rocks of the SR_N are characterized by the high degree of enrichment (up to 55 % of the enriched mantle in the source (Volynets et al., 2010)). In the SR_S, within its "eastern" flank there are as well Neogene island-arc-type rocks; during Pliocene-Quaternary times both island-arc and hybrid type rocks with the low degree of enrichment were erupted (up to 5-14 % OIB-type mantle in the source (Volynets et al., 2010)). "Western" flank of SR_S is most likely characterized by the enriched type of the mantle source during the whole time of this structure development starting from Late Miocene (from 10-14 % OIB-type mantle in Miocene to almost 50 % in Quaternary). Though, in Quaternary there are as well less enriched rocks (for ex. within Ichinsky massif - 5-15 % OIB-type mantle, (Churikova et al., 2001)). Pliocene Uksichan volcanic massif, Anaunsky Dol, and Bolshoy Checkchebonay massif are structurally positioned between the "eastern" and "western" flanks, and are subdivided as the 'central" flank of SR_S, but geochemically they are similar to the "eastern" flank rocks.

We analyzed Sr-Nd isotopic composition in the representative set of 58 samples of volcanic rocks from virtually all parts of Sredinny Range. Together with the previously published data for 19 samples from the northern part of SR that gives us a unique in scope collection for a regional investigation of the sources of the back-arc volcanism in Kamchatka.

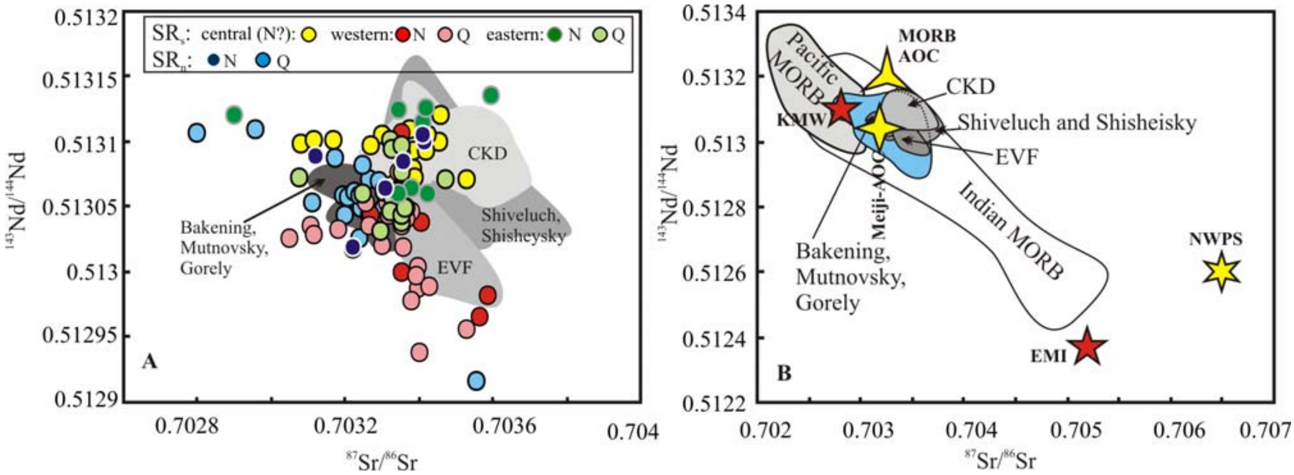

Fig. 2. Sr-Nd isotopic systematic of Miocene-Quaternary volcanic rocks of the Sredinny Range of Kamchatka compared to the previously published data for other volcanoes of Kamchatka (grey fields) (A) and to the potential sources (B). Data sources: Churikova et al., 2001; Class and Lehnert, 2012; Duggen et al., 2007; Portnyagin et al., 2007 and references therein; Portnyagin et al., 2015 and references therein. (A): see legend for SR samples at inset: N – Miocene-Pliocene rocks, Q - Quaternary. (B): SR – blue field. KMW – Kamchatka mantle wedge, NWPS – North West Pacific Sediments, MORB AOC – average altered MORB (Portnyagin et al., 2015 and references therein), EMI – enriched mantle (Zindler and Hart, 1986).

The results are presented at fig. 2. Studied rocks of different age form two fields which intersect with the majority of the previously studied rocks from EVF and CKD only partially (Fig. 2). We observe two trends in composition within the different age groups. Neogene rocks are characterized by slightly elevated (compared to primitive) $^{87}Sr/^{86}Sr$ at more or less constant $^{143}Nd/^{144}Nd$. Neogene rocks from the "central" and "eastern" flanks are similar to the Quaternary CKD rocks in isotopic composition with a slight shift towards Pacific MORB compositions. Neogene rocks from the "western" flank have lower $^{143}Nd/^{144}Nd$ at the same $^{87}Sr/^{86}Sr$ and thus form a separate trend towards the enriched source. Most SR Quaternary rocks at $^{143}Nd/^{144}Nd$ vs. $^{87}Sr/^{86}Sr$ diagram form clear trend from the compositions typical for Pacific MORB (Class, Lehnert, 2012) and Kamchatka mantle wedge (Portnyagin et al., 2015) towards the enriched source with elevated $^{87}Sr/^{86}Sr$ and unradiogenic $^{143}Nd/^{144}Nd$. The enriched character of this source is detected as well by the negative correlations of $^{143}Nd/^{144}Nd$ with Nb/Y, Ta/Yb and Ce/Pb ratios in the whole rocks.

Therefore, our large-scale regional investigation of the Sr-Nd composition of volcanic rocks of Sredinny Range has shown that this structure has a complex geological history, with various sources involved in magma generation in different structural parts of the Range in different periods of time. In Miocene-Pliocene times, when SR represents a frontal part of the active subduction zone, we observe typical island-arc rocks with slightly elevated Sr isotopes, most likely inherited from the fluid addition, and rocks with the enriched mantle signature in the western parts of SR, probably representing back-arc at those time.

In Quaternary times, the enriched mantle source signature becomes dominating in isotopic composition of the erupted rocks in the whole Range. This shift reflects a change in geodynamic environment caused by Kronotsky terrains accretion.

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