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Petrogenesis of siliceous high-Mg series rocks as exemplified by the Early Paleoproterozoic mafic volcanic rocks of the Eastern Baltic Shield: enriched mantle versus crustal contamination

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The Early Paleoproterozoic stage in the Earth's evolution was marked by the initiation of global rift systems, the tectonic nature of which was determined by plume geodynamics. These processes caused the voluminous emplacement of mantle melts with the formation of dike swarms, mafic-ultramafic layered intrusions, and volcanic rocks. All these rocks are usually considered as derivatives of SHMS (siliceous high-magnesian series). Within the Eastern Baltic Shield, the SHMS volcanic rocks are localized in the domains with different crustal history: in the Vodlozero block of the Karelian craton with the oldest (Middle Archean) crust, in the Central Block of the same craton with the Neoarchean crust, and in the Kola Craton with a heterogeneous crust. At the same time, these rocks are characterized by sufficiently close geochemical characteristics: high REE fractionation ((La/Yb)N = 4.9-11.7, (La/Sm)N=2.3-3.6, (Gd/Yb)N =1.66-2.74)), LILE enrichment, negative Nb anomaly, low to moderate Ti content, and sufficiently narrow variations in Nd isotope composition from -2.0 to -0.4 epsilon units. The tectonomagmatic interpretation of these rocks was ambiguous, because such characteristics may be produced by both crustal contamination of depleted mantle melts, and by generation from a mantle source metasomatized during previous subduction event.

Similar REE patterns and overlapping Nd isotope compositions indicate that the studied basaltic rocks were formed from similar sources. If crustal contamination en route to the surface would play a significant role in the formation of the studied basalts, then almost equal amounts of contaminant of similar composition are required to produce the mafic rocks with similar geochemical signatures and close Nd isotopic compositions, which is hardly possible for the rocks spaced far apart in a heterogeneous crust. This conclusion is consistent with analysis of some relations between incompatible elements and their ratios. In particular, the rocks show no correlation between Th/Ta and La/Yb, (Nb/La)pm ratio and Th content, and eNd and (Nb/La)N ratio. At the same time, some correlation observed in the eNd-Mg# and (La/Sm)N-(Nb/La)N diagrams in combination with the presence of inherited zircons in the rocks does not allow us to discard completely the crustal contamination. Examination of Sm/Yb-La/Sm relations and the comparison with model melting curves for garnet and spinel lherzolites showed that the parental melts of the rocks were derived by 10-30% mantle melting at garnet-spinel facies transition.

Two stage model can be proposed to explain such remarkable isotope-geochemical homogeneity of the mafic volcanic rocks over a large area: (1) ubiquitous emplacement of large volumes of sanukitoid melts in the lower crust of the shield at 2.7 Ga; (2) underplating of plume-derived DM melts at the crust-mantle boundary, melting of the lower crust of sanukitoid composition, and subsequent mixing of these melts with formation of SHMS melts at 2.4 Ga. A simple mixing model showed that in this case the Nd isotope composition of obtained melts remained practically unchanged at variable amounts of contaminant (up to 30%).

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