



Ultramafic-alkaline-carbonatite complexes as bimodal intrusions: Evidence from the Tikshezero complex, Northern Karelia, Russia

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Ultramafic-alkaline-carbonatite intrusive complexes are usually members of large igneous provinces (LIPs) where represent transitional chambers of alkaline magmatic systems. However, relationships between silicate and carbonatite parts of the complexes remain unknown (Gill, 2010; Philpotts, Aue, 2009; Woolley, Church, 2005, etc.). According to isotopic data, carbonatites were derived from the same mantle source as associated ultramafic-alkaline rocks; however, geochemical and experimental data indicate that carbonatites could not be derivatives of alkali magmas.

This problem is discussed by the example of the ~2 Ga age Tikshezero ultramafic-alkaline-carbonatite complex (Northern Karelia, Fennoscandian Shield) ascribed to the Mid-Paleoproterozoic Jatulian-Ludicovian LIP. This complex ~24 km² in area is hosted by Archean granite-gneisses and consists of three intrusive phases: (1) olivinites, wehrlites, clinopyroxenites, and subordinate gabbros, (2) alkaline rocks (ijolite-urtite, jacupirangite, nepheline syenites, etc.), and (3) carbonatites. Isotope data (Sr, Nd, and Os) showed that carbonatites were derived from the same mantle source as associated alkaline and ultramafic rocks. Ultramafics and foidolites form complementary spidergrams with weak or no Zr-Hf anomaly, whereas carbonatites have the strongest negative Zr-Hf anomaly suggests their independent evolution, did not consider with carbonatites.

Unlike most ultramafic-alkaline-carbonatite complexes around the world with stock-like or concentrically-zonal structure, the Tikshezero complex rather looks like lopolith which was intruded by large carbonatite body. Judging from geological and geochemical data, this situation resembles relationships of ferrogabbros and syenites in the bimodal syenite-gabbro complexes.

According to modern paradigm (Maruyama, 1994; Dobretsov et al., 2001; French, Romanowiz, 2015, etc.), formation of LIPs is explained by ascent of thermochemical mantle plumes, which are generated at the liquid outer core-mantle boundary due to percolation of core's fluids in overlying mantle. So, mantle plumes consist of two kinds of material, mantle rocks and core fluids, which in different proportions could be involved in melting of plume heads.

Study of plume-related magmatic systems of LIPs showed that the same plume heads can produce different parental melts in response to two types of melting: adiabatic and fluid-assisted, which is marked by scarce finds of "melt-pockets" in Sp lherzolite xenoliths in basalts and basanites (Downes et al., 2001; Ma et al., 2015; Ionov et al., 1996, etc.). The fluid-assisted melting was caused by excess CO₂-rich fluid that penetrated in cooled upper margin of the plume head from underlying zone of adiabatic melting and caused incongruent melting (Sharkov et al., 2017). Thus, subsequent adiabatic and fluid-assisted melting of mantle plume heads generates two different magma types: (1) ultramafic and alkaline magmas derived by adiabatic melting, and (2) carbonatites originated through incongruent melting. Due to the limited solubility of these fluids in newly-formed magmas, they were accumulated beneath the cooled margin of the plume head, percolated in it, and finally led to the appearance of large zones of incongruent melting and formation of bimodal silicate-carbonatite complexes.