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Problem of origin of alkali and tholeiitic basalts in LIPs

Evgenii Sharkov, Maria Bogina, and Alexey Chistyakov
Institute of Geology of Ore Deposits, Petrograpgy, Mineralogy and Geochemistry RAS, Petrology, Moscow, Russian Federation (sharkov@igem.ru)

Many researchers believed that the alkali and tholeiitic basalts, the main components of the most LIPs, are derived from a common source (hypothetical “average mantle”) at different PT-parameters and at various degrees of partial melting: alkali basalts are generated at higher depths and lower melting degree than tholeiitic basalts (Hirschmann et al., 1998, 1999; Johnson et al., 2005 and references therein). However, there is no any “average mantle” within the Earth: only “dead” lithosphere and active mantle plumes exist here, and it is necessary to seek another explanation for origin of these contrasting melts.

It is generally accepted that mantle xenoliths in plume-related alkali Fe-Ti basalts, in contrast to diverse lithospheric mantle xenoliths in kimberlite and lamprophire diatrems, are characterized by remarkable similarity in all occurrences around the world both in continents and oceans. We suggest that these xenoliths are fragments of the upper cooled margin of the mantle plume heads above zone of adiabatic melting, i.e. represent the proper plume’s material (Sharkov et al., 2017). They consist of depleted spinel peridotites (mainly lherzolites) with veins of “black series” rocks, which are composed mainly of hydrous minerals (kaersutite, phlogopite), and also olivine, clinopyroxene, ilmenite, etc., derived from high-density melt/fluid. In other words, the mantle plume heads are made up of two independent materials: depleted mantle peridotites and specific water-bearing fluids enriched in Fe, Ti, alkalis, REE and other incompatible elements. These fluids likely existed in the ascending mantle plume as intergranular material and were released due to decompression degassing during plume head ascent and propagation. Adiabatic melting of the plume head material (depleted peridotites+geochemical-enriched fluids) resulted in formation of enriched basaltic melts, while excess fluids penetrated in the cooled plume head margins and caused incongruent melting with formation of the “black series” parental melts.

All of these agree well with conception of thermochemical mantle plumes generation at the core-mantle boundary due to impregnation of overlying mantle peridotites in fluids released from the outer liquid iron core (Maruyama, 1994; Dobretsov et al., 2001; Zhao, 2004; French, Romanowicz, 2015). This likely caused mantle decompaction and its ascent in form of thermochemical mantle plume composed of mantle peridotites and core-related fluids.

We suggest that the appearance of two major types of the mantle-derived magmas (alkali and tholeiite basalts) presumably was not related to different PT-parameters in the adiabatic melting zone but resulted from the content of the core-related fluids in the plume heads. Depending on the concentration and composition of the fluids (especially alkali content) in each case, a newly-formed melt can occur on different sides of the critical plane of silica undersaturation (Yoder and Tilley, 1962) and can acquire alkalic or tholeiitic composition. Alkali Fe-Ti basalts and picrites were the first generated melts and received the highest concentrations of fluid components, while later generated tholeiitic melts were depleted in these components; only replenishment of fresh plume material in the plume head can change the situation.