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Plume-related magmatic systems and their roots: Evidence from large igneous provinces and mantle xenoliths in basalts

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The evolution of large igneous provinces (LIPs) throughout the Earth's history was determined by a change from Archean and early Paleoproterozoic thermal plumes derived from depleted mantle to the thermochemical plumes rooted at the core-mantle boundary (CMB). The thermochemical plumes originated for the first time at ~2.3 Ga and caused a cardinal transition from high-Mg basalts and komatiites to geochemically-enriched Fe-Ti basalts and picrites that formed Phanerozoic-type LIPs. Our attention is mainly focused on the second (Phanerozoic) type of LIPs, as exemplified by the Mid-Paleoproterozoic Jatulian-Ludicovian LIP in the Fennoscandian Shield, the Permian-Triassic Siberian LIP, and the late Cenozoic xenolith-bearing flood basalts of Syria ascribed to the Afro-Arabian LIP. These xenoliths are similar to mantle xenoliths found in plume-related (within-plate) basalts around the world and bear important information about plume composition and processes proceeding in a plume head.

We suggest that these xenoliths represent the fragments of the upper cooled rim of the mantle plume head, above the zone of adiabatic melting. The green series (peridotites, mainly lherzolites) sampled a matrix of the solidified rim, while the black-series xenoliths occurred as veined wherlite, hornblende clinopyroxenite, kaersutite hornblendite, and phlogopitite represent crystallized high-density melt/fluid previously existing in a plume matter as intergranular phases. When plume head reached its buoyancy level and adiabatic melting began, these phases were degassed and fluid components were partially dissolved in a newly-formed basaltic melt providing its geochemical features (the matrix itself mainly represented by depleted lherzolites). Residual fluids percolating through overlying cooled rim caused secondary melting (melt pockets) and formation of the black series rocks resembling alkali basalts.

As known, LIPs are made up of two major types of basalts (alkali and tholeiitic), which are commonly considered as derived by different-degree mantle melting at different depths. However, we suggest that their formation was determined by fluid regime in the plume heads. Depending on the concentration and composition of these fluids, especially their alkali contents, a newly-formed melt can occur on different sides of a critical plane of silica undersaturation (Yoder and Tilley, 1962) and acquire alkalic or tholeiitic composition regardless of PT-parameters.

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