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Reactive porous flow in deep crustal mushes, and early evolution of primitive magmas in a continental rift: the Oldoinyo Lengai volcanic area example

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Carbonatites, abnormally carbon-rich magmatic rocks, are thought to form by low-degree partial melting of a relatively carbon-poor mantle followed by protracted differentiation and immiscibility. However, the nature of parental magmas, and the characteristics of the early stages of differentiation that shape the subsequent crystal and liquid lines of descent remain poorly constrained. In order to provide new constraints, deep crustal cumulative xenoliths from Oldoinyo Lengai (East African Rift), the only active volcano erupting carbonatite magmas, were characterized. Xenoliths are composed of olivine, diopside, phlogopite, amphibole, and accessory minerals. One remarkable feature is the presence of diopside and phlogopite oikocrysts enclosing olivine chadacrysts. The second remarkable feature is that most olivine-hosted melt inclusions contain no shrinkage bubbles and a Mg- nephelinite major element composition (7-10 wt.% MgO after corrections for post-entrapment crystallization). The absence of shrinkage bubbles implies that the concentrations of volatile components (mainly, CO_2, H_2O and S) were not compromised by well-known post-entrapment volatile loss into the bubbles. Based on these melt inclusions, the minimum volatile concentrations in Mg-nephelinite melts (early stage of differentiation) at Oldoinyo Lengai are 20-130 ppm S, 390-4500 ppm F, 50-540 ppm Cl, up to 6074 ppm CO_2, and 1.16 ± 0.15 wt.% H_2O. According to the calculated CO_2-H_2O saturation pressures, the crystallization of olivine from Mg-nephelinite melts occured at >12 km below the surface. Primitive Mg-nephelinite melt inclusions have higher H_2O content (up to 1.5 wt.% H_2O) than Mg-nephelinite lavas from other volcanoes from the North Tanzanian Divergence (0.2-0.5 wt.% H_2O), suggesting that the lithospheric mantle source beneath the Oldoinyo Lengai is more hydrated than the mantle beneath the North Tanzanian Divergence or different degrees of melting. We present a model in which dissolution features observed in olivine chadacrysts, together with the LREE enrichments in olivine grains, are the consequences of reactive porous flows in the crust. We provide constrains on the major element composition of the parental magmas of carbonatite series and demonstrate with MELTS models that phonolites and natrocarbonatites from Oldoinyo Lengai can be produced by protracted differentiation of Mg-nephelinitic melts.