

# Fluid release in carbonatitic systems and its implication for carbonatite magma ascent, compositional evolution and REE-mineralization

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Carbonatites form from volatile-rich magmas that release fluids during their ascent from the mantle into the crust (Fig. 1A). Worldwide, four types of fluid inclusions are identified in carbonatite (Fig. 1B): vapour-poor H<sub>2</sub>O-NaCl fluids with up to 50 wt.% salinity (type I), vapour-rich H<sub>2</sub>O-NaCl-CO<sub>2</sub> fluids with <5 wt.% salinity (type II), multi-component fluids with high salinity (<80 %) and without CO<sub>2</sub> (type III); and multi-component fluids with high salinity (<80%) and high CO<sub>2</sub> (type IV). A review of all available fluid inclusion studies on carbonatite indicates continuous fluid release from deep to shallow-level intrusions, while our modelling approach provides evidence that carbonatite magmas generally exsolve a H<sub>2</sub>O-Na-K-CO<sub>3</sub>-SO<sub>4</sub>-Cl brine (type I), which separates into immiscible fluids of types II and III or evolves into fluids of type IV [1, 2]. This enables rough quantification of the fluid composition released from a carbonatite melt during ascent [1]. Experimental studies [3] show that in particular Na- and K-bearing fluids are of importance for an efficient REE transport. Fluid immiscibility is related to rapid pressure release during fast, forceful and discontinuous magma ascent, which we envisage as a “pneumatic jackhammer” process (Fig. 1C). The proposed model explains the apparent absence of shallow-level carbonatite magma chambers, and describes fenitization induced by fluids released during magma ascent and final cooling [4]. Moreover, it is in agreement with abundant brecciation induced by magma ascent and emplacement, as observed in the field. The frequently observed brecciation of associated silicate rocks and diverse country rocks, and related xenolith load in carbonatites, highlights the potential of chemical interaction between carbonatite magmas and diverse host rocks. Such contamination processes influence the mineralogical and geochemical evolution of these magmas and the potential for late-stage REE mineralization, with major implications for exploration of REE-deposits in carbonatitic systems.

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