

Kimberlite emplacement conditions through experimentally produced reaction rims on ilmenite macrocrysts

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ABSTRACT

Kimberlites, the primary hosts of diamond deposits, are enigmatic igneous rocks derived from the mantle and emplaced into ancient cratons. However, the nature of the primary kimberlite melt remains a subject of debate, limiting our understanding of ascent and emplacement processes. This study aims to enhance our understanding of kimberlite crystallization and emplacement by focusing on the mantle-derived oxide minerals entrained within kimberlites during their ascent. These mantle minerals, which are in disequilibrium with the kimberlite magma, develop various reaction textures, including secondary rims. Natural kimberlite samples show ubiquitous reaction rims on ilmenite, with mineral compositions, particularly Ti-bearing phases (i.e., perovskite, titanite, or anatase), varying across different kimberlite lithologies. To investigate the effect of kimberlite crystallization conditions on the stability of ilmenite, textures, and composition of the reaction rims, we conducted experiments in a piston-cylinder apparatus at 1050–1200 °C and 0.5–2.5 GPa using natural ilmenite grains and synthetic kimberlite melts with varying SiO₂/CaO ratios. Our experiments revealed that ilmenite dissolution in kimberlitic melts consistently produced rims of perovskite around ilmenite. Titanite appeared only when at least 6 wt% of granodiorite was added to a kimberlite composition, representing assimilation of crustal rock by the kimberlite magma. Additionally, lower water content affecting the degree of melting favored the stability of Ti-bearing phases (perovskite and titanite) to higher temperatures. Our results confirm that reaction rims on ilmenite form during the magmatic stage of kimberlite emplacement at temperatures of 1050–1200 °C and depths corresponding to 15–75 km (0.5–2.5 GPa), in agreement with the previous estimates for kimberlite crystallization temperatures. We demonstrate that the presence of titanite in the rims of ilmenite from some diatreme volcanoclastic kimberlite lithologies is an indicator of crustal assimilation.

Keywords: Ilmenite, kimberlite, reaction rims, volatiles, perovskite, titanite, piston-cylinder experiments, crustal assimilation