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The segregation of carbonate and silicate melts in kimberlitic melt inclusions from Monastery mine, South Africa

EDMORE MARIMA[1], STEFFEN H BÜTTNER[1], AIDEN VAN HUYSSTEEN[1], CHRISTIAN SCHMIDT[2], ANTON DU PLESSIS[3], MUOFHE TSHIBALANGANDA[3] AND GEOFFREY H. HOWARTH[4]

[1]Rhodes University

[2]Deutsches GeoForschungsZentrum (GFZ)

[3]Stellenbosch University

[4]University of Cape Town

Presenting Author: edmoremarima14@gmail.com

The composition and evolution of kimberlitic magma has been proposed to form either as primary carbonatitic melts that during their ascent are contaminated by lithospheric silicate components, or by segregation of primary carbonated silicate melts in the kimberlite source. The highly dynamic and rapid magma transport and alteration of kimberlites during and after emplacement renders a distinction of these two avenues difficult in most kimberlites.

Millimetre-sized melt inclusions in ilmenite megacrysts from the 89 Ma Monastery kimberlite contain predominantly calcitic carbonate and Si-Mg-Fe-rich quenched melt in variable stages of devitrification and with variable amounts of perovskite, secondary ilmenite, spinel, phlogopite, serpentine, garnet and kassite.

X-ray tomography of ilmenite megacrysts shows a clustered or random distribution of melt inclusions with sphericities most commonly between 0.6 and 0.7. The sizes of melt inclusions range over more than four orders of magnitude from ~0.001 to ~26 mm^3, with the largest inclusions reaching ~6 mm in diameter. The size variation and the distribution of melt inclusions indicates their primary origin during the growth of their ilmenite hosts.

Two textural patterns are consistent with the separation of carbonate and silicate components in the liquid state: (1) The formation of large carbonate pools from calcitic emulsions in high-Mg silicate quenched melt concurrently with the segregation of Ti and Ca into garnet, kassite, or melt of similar composition. (2) Labyrinthic textures of highly interconnected materials in which calcium carbonate is separate from Fe-Mg-silicate in a concentric zone around a central carbonate pool indicate the unmixing of an initially homogenous melt. In the same inclusion, Ti, Ca, and K and minor CO_2 are segregated as kassite, perovskite, spinel, ilmenite, minor phlogopite, and calcitic carbonate along the margin of the melt inclusion. The formation of calcite emulsions in silicate quenched melt, consolidating to larger carbonate pools, is consistent with binodal melt separation, nucleation and growth. The labyrinthine segregation textures we interpret as spinodal unmixing of a primary carbonated silicate melt after the capturing of such melt as inclusions in the SCLM and preserved by quenching after the ascent of the Monastery kimberlite.