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Mantle metasomatism in the Kaapvaal Craton lithosphere: constraints on the composition of the metasomatic agent from fluid inclusions in MARID-type xenoliths

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The emplacement of both group I and group II kimberlites in the Kaapvaal Craton of the Kimberley region in South Africa is associated with an intense metasomatic alteration of the country rocks as evidenced by a diverse suite of xenoliths sampled by the kimberlites mainly comprising metasomatized peridotites and minor MARID-type xenoliths. These are characterized by hydrous potassic silicates and LILE-HFSE-rich titanates. Because the metasomatic agent is not preserved in these rocks its composition has to be inferred from that of the metasomatic assemblages. Here we present for the first time data on fluid inclusions from two MARID-xenoliths sampled by group-I kimberlites of the Kimberley cluster. They provide direct evidence for the nature of the metasomatic fluids involved in kimberlite-related metsomatism. The xenoliths contain phlogopite+K-richterite+diopside+ilmenite±rutile±apatite±zircon. Fluid inclusions with 4-10 μm in size were found in diopside, K-richterite and zircon and contain L+V+one-to-several daughter phases. Investigations with the freezing and heating stage indicate two different chemical systems for the fluids: (1) H_2O-NaCl dominant fluids found as L+V+S inclusions in zircon together with abundant needle-like apatite, rutile and phlogopite solid inclusions. The fluid inclusions in part occur along zircon host-rutile/apatite inclusion grain boundaries which indicates that the fluids were trapped during zircon growth. They contain 30-32 mass% NaCl and show a density of 0.87-0.94 g/cm3. Halos of tiny fluid inclusions, however, indicate that most if not all zircon inclusions are decrepitated during ascent from depth and/or superheating during entrainment of the xenoliths into the kimberlite. Using EMPA, enstatite and a SiO_2 polymorph were identified in opened fluid inclusions exposed at the surface of polished thin sections. Because these phases were exclusively found in the fluid inclusions, they are considered daughter crystals. The enstatite composition is identical to that found in the matrix of other MARID xenoliths. Projection on a 40 mW/m2 geotherm of Ca-in-opx temperatures yields ∼950°C/∼4 GPa which are thought to be P and T of MARID-crystallization and fluid entrapment; (2) H_2O-CaCl2 dominant fluids trapped in diopside and K-richterite as tubular to rounded L+V inclusions. These inclusions have 35-45 mass% CaCl2 and densities of 0.51-0.98 g/cm3 without any evidence for significant NaCl. During heating all inclusions of this type show a solid with Tm in the range 0-30°C which is consistent with the solid being CaCl2 x 6 H_2O. This study provides physical evidence for the presence of saline brines during metasomatism associated with kimberlite emplacement on the Kaapvaal Craton and contributes to the growing body of evidence for the important role of Cl in kimberlite evolution and diamond genesis.