

Phase relations in the eclogite-carbonate-chloride system at 7.0-16.5 GPa: implications to mantle fluids and diamond inclusions

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Recent studies of fluid inclusions in diamonds and other mantle minerals indicate that chloride can be important in the mantle fluids. Complex chloride-carbonate-water fluids have been detected in many diamonds worldwide; however nature and speciation of these fluids are poorly constrained. Melting phase relations have been determined in a model chloride-carbonate-bearing eclogite at 7.0, 10.5, and 16.5 GPa and 1200-1800°C using multianvil technique. Starting composition was simplified Mid-Ocean-Ridge basalt in the system SiO₂-Al₂O₃-MgO-CaO. 4 wt.% CO₂ was added in the form of MgCO₃ and CaCO₃ and 3.56 wt.% Cl was added as NaCl and KCl.

The typical silicate phase assemblage coexisting with partial melts at 7.0-10.5 GPa is garnet-clinopyroxene-kyanite-stishovite. At 16.5 GPa kyanite and clinopyroxene were not stable and corundum was observed with garnet and stishovite. Unknown Cl-free Al-rich phase (carbonate?) was detected at 16.5 GPa. It has an approximate formula, recalculated to one carbon atom (calculated from electron microprobe analyses deficit), Mg_{0.3}Al_{3.0}Si_{0.7}O₅CO₃. KCl and NaCl crystals were stable in low temperature runs coexisting with magnesite and Ca- and Mg-bearing carbonatite melt. Melting of chloride produces chloride-carbonate melt immiscible with carbonatite. High temperature runs at 1600-1800°C reveal homogenous Si-rich carbonate-chloride partial melts. Although melting sequence of chloride and carbonate was found to be similar with that in peridotite-carbonate-chloride system (Litasov and Ohtani, 2009) melt compositions were significantly different. For example, at 7 GPa and 1550°C melt composition was (wt.%): SiO₂=50.3, Al₂O₃=8.5, MgO=3.7, CaO=10.6, Na₂O=1.5, K₂O=4.0, CO₂=17.5, Cl=4.9, O(-)=0.9. This composition correspond to Si-rich endmember of silicate-carbonate-bearing sequence of fluid inclusions in diamonds at Si,Al (silicate) - Mg,Fe,Ca (carbonate) - Na,K (chloride) triangle (e.g. Klein-BenDavid et al., 2007).

Chlorides were stable 100-200°C above the solidus. This fact indicates that melt composition in chloride-carbonate peridotite can be effectively controlled by the presence of water. In the anhydrous environments a low-fraction of Cl- and alkali-poor Ca-Mg-rich carbonatite melts can be formed and migrate from the source, whereas under the hydrous conditions, chloride can be dissolved into water to form alkali-rich chloride-carbonate brine-like melts. At higher temperatures (1400-1600°C) two immiscible carbonatite and chloride-carbonate liquids may coexist. The composition of carbonatite and chloride-carbonate melts is consistent with that of melt inclusions in fibrous/cloudy diamonds worldwide. Typical trends of melt evolution upon cooling and formation the melts included in diamonds may involve formation of immiscible Si-rich carbonatite and Si-rich chloride-carbonate melts from homogenous Cl-bearing kimberlite or carbonatite. The results are also applicable for carbonate and chloride stability and dynamics during deep subduction.