End-member fluids for diamond formation and their possible sources

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Microinclusions in fibrous diamonds carry high density fluids (HDF) with compositions that vary between silicic, carbonatitic and saline end-members. Combining EPMA and FTIR data we can estimate the composition of each end-member. The silicic end-member composition (Udachnaya) comprises ∼90 wt% silicates, 4% carbonate, 4% water and minor apatite. The saline end-member (Diavik, Canada) carries 51 wt% alkali halides, 12% carbonates and 37% water. Klein-BenDavid et al. (in review) defined two carbonatitic end-members. The low-Mg one carries ∼75 wt% carbonates, 11% silicates, 5% halides, 2% apatite and 7% water; the high-Mg end-member carries similar proportions, except for the higher apatite: 78% carbonates, 9% silicates, 5% apatite, 2% halides and 6% water, but with much higher Mg/(Mg+Fe+Ca) ratio.

The volatile-free oxides proportions of the most silicic microinclusions in an Udachnaya diamond are: 69 wt% SiO_2; 14% Al_2O_3; 10% K_2O, 2% Na_2O, 1% CaO and P_2O_5 and minor FeO, TiO_2, MgO, and Cl. The saline HDF carries 73 wt% KCl, 12% NaCl, 7% CaO, 2.5% MgO, 2.5% BaO, 1.5% FeO and 1.5% SiO_2. In the low-Mg carbonatitic HDF calcium exceeds magnesium: ∼21 wt% CaO, 18% FeO, 12% MgO, 22% K_2O; 10% SiO_2, 8% Na_2O and minor TiO_2, Al_2O_3, P_2O_5 and Cl, while in the high-Mg end-member MgO is the main oxide: ∼29% MgO, 23% CaO, 7% FeO, 17% K_2O, 8% SiO_2, 9% Na_2O, 2% P_2O_5 and Cl and minor BaO, TiO_2, Cr_2O_3 and Al_2O_3 (all values were calculated on volatile-free basis).

Weiss et al., in a companion abstract, suggest that the four end-members form two arrays; one between the saline and the high-Mg carbonatitic compositions and the second between the silicic and the low-Mg carbonatitic ones. They further suggest that the first array represents a process that takes place in a peridotitic environment and the other in an eclogitic one. For example, the arrays may be formed by interaction of hydrous or saline fluids with carbonate-eclogite or with carbonate-peridotite. Safonov et al. (2007) suggested that a saline melt can interact with silicate minerals to form immiscible silicic melt that may later evolve into a carbonatitic HDF. In an ultramafic environment a saline melt may evolve along the array to high-Mg carbonatites without forming an immiscible silicate melt (Safonov, 2008).

The source of the saline fluid is not clear. It may be present as discrete halides or as a grain-boundary phase in the carbonate-bearing rock, or it may form deeper in the mantle and migrate upwards either as a saline melt, or as a hydrous fluid that is concentrated enough to preclude interaction with the mantle rocks it traverses.

A second alternative is to introduce the carbonate as the penetrating fluid in the form of carbonatitic melt. A third alternative involves the upward migration of CH_4 and heavier hydrocarbons. Such a fluid should be stable in eclogitic or peridotitic environments, as long as the oxygen fugacity is low enough. During ascent, such fluids migrate to more oxidized regions and eventually will react with the mantle rocks to form $C+H_2O$ (Luth, 1993; Malkovets et al. 2007) and later CO_2. In eclogitic rocks, the water will react to form a silicic HDF and the C may precipitate as diamond. In a peridotitic environment, at temperatures below the carbonate solidus, such water may leach and dissolve K and Cl from the rock and evolve into a saline HDF. Temperature increase or further diamond oxidation may initiate the formation of carbonatitic HDF's.