Mixing of Saline and Carbonatitic Fluids To Form Peridotitic Panda Diamonds

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Diamonds containing fluid inclusions provide the most direct samples of upper mantle fluids. In eclogites, diamond can form by pH drop during fluid-rock interaction. However, in peridotites, the cause of the chemical evolution of the fluids and minerals, including the wide range of observed salinities involved, are still unclear. Here we used new experimental calibrations of the Deep Earth Water model involving organic and inorganic complexes of the major rock-forming elements to show that fluid mixing can cause diamond formation in the peridotitic environment.

Models of the saline and carbonatitic fluid inclusion compositions consistent with the chemistry of measured solid inclusions in Panda diamonds were used to simulate the irreversible, chemical mass transfer when a carbonatitic fluid infiltrates harzburgite containing a saline fluid at 950°C and 4.5 GPa. Simultaneous oxidation of aqueous hydrocarbons in the peridotitic fluid and reduction of the organic acid anion formate as well as bicarbonate in the carbonatitic fluid during mixing and reaction with harzburgite resulted in the formation of diamond, olivine, and garnet, and increases in the logfo_2 and pH. Olivine was predicted to become more Fe-rich and garnet more Ca and Fe-rich with reaction progress, in agreement with reported temporal trends in the composition of mineral inclusions from octahedral cores to coated rims on Panda diamonds. Aqueous phase concentrations of all elements changed consistent with measured trends in fluid inclusion compositions from saline to less saline. For comparison, we also simulated a saline fluid infiltrating a harzburgite containing a carbonatitic fluid. Diamond again formed, but the compositional trends of the silicate minerals and the trend of salinity with reaction progress were all in the opposite direction to data from the Panda diamonds. Overall, our study strongly suggests that mixing of fluids containing carbon from both reduced and oxidized sources, and simultaneous reaction with harzburgite can cause precipitation of diamond, without the need for triggering by temperature or pressure changes, while adding Ca and Fe to the sub-lithospheric mantle.