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A new model for the evolution of diamond-forming fluids

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High-density fluids (HDFs, either melts or supercritical fluids) are trapped as myriads of sub-micrometer inclusions during the growth of fibrous diamonds and represent the medium in which these diamonds grew. Their chemical properties shed light not only on the genesis of fibrous diamonds, but perhaps on the formation of monocrystalline diamond as well.

The major-element composition of the HDFs varies between two carbonatitic (high- and low-Mg) end-members, rich in Mg, Ca, Fe and carbonate; a hydrous-silicic end-member, rich in Si, Al and water and a hydrous-saline one, rich in K, Na, Cl and water. High levels of potassium appear in all four types, range between 10-22 wt% in the carbonatitic and silicic compositions and reaching up to 32% in the saline ones (water- and CO2-free basis). Most of the analyzed diamonds are homogenous and show no radial evolution (i.e. no changes in the medium during diamond growth); some show limited radial evolution of a few percent in their major-element concentrations; and only in four diamonds (two from Kankan, Guinea, one from Brazil and one from Diavik, Canada) large variations were found. The data collected from such diamonds show contrasting evolution during growth and precludes the formation of the end-members from a single parental fluid. Recent trace-elements (Cs, Rb, K, Ba, U, Th, Nb, Ta and LREE) and isotopic (Sr, Nd and Pb) data also support more than a single source for the different fluids.

Based on HDF composition in diamonds from Africa, Brazil, Canada and Siberia and on the similarity of the HDFs to experimental near-solidus melt compositions of carbonated/hydrous peridotite and eclogite, we propose a new model for the evolution of HDFs. We suggest that the source rock for the high-Mg carbonatitic HDFs is peridotite, while the one for the low-Mg carbonatitic to hydrous-silicic compositions is eclogite. For most major elements, the saline HDF form a clear array that extends to the high-Mg carbonatitic compositions, suggesting involvement of saline fluids in the generation of the high-Mg carbonatitic HDFs. Saline fluids may also be the metasomatic agent that triggers the formation of the silicic to carbonatitic fluids in the eclogitic case. Either way, potassium and carbonate should be available during HDF generation. Possible scenarios include melting of carbonates or K-bearing phases in the source rock or interaction of such sources with carbonatitic and potassic melts/fluids. We prefer HDF formation by interaction of saline HDFs with carbonate-peridotite or eclogite. The saline component brings K, Cl and Ba as well as many of the incompatible trace elements that are highly enriched in all HDFs.

The extreme enrichment in the highly incompatible elements (with levels reaching up to several thousands the primitive mantle values) and the very steep REE patterns make the HDFs good candidates for producing the sinusoidal REE patterns observed in many garnet inclusions in monocrystalline diamonds. Such sinusoidal patterns may form when HDFs with steep REE patterns are introduced into LREE-depleted harzburgites. Unless garnet inclusions and their host diamond were formed in two separate events, this resemblance suggests the growth of monocrystalline diamonds from HDFs similar to those found in the fibrous diamonds.