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Diamond-forming fluids

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Examination of diamonds from Botswana, South-Africa, Zaire, Brazil, Siberia, and Canada revealed a variety of fluids: hydrous melts rich in silica and alkalis, carbonatitic melts rich in magnesium and calcium, brine rich in chlorine and alkalis and sulfide melts rich in iron and nickel. Carbonatitic melts were found together with all other fluids. They may form one component of an intermediate composition trapped in an individual inclusion, trapped as carbonatitic inclusions along with another fluid in separate micro-inclusions in the same diamond, or in one diamond while the other fluid is trapped in other diamonds of similar morphology originating from the same kimberlite. Hydrous melts, brine and sulfide melts were never detected together in any single diamond and no mixing lines were observed between these three end-members.

The carbonatitic melts in most diamonds are similar in composition. They carry ~33% CO₂, 13% MgO, CaO and K₂O, 6-7% FeO, Na₂O and SiO₂, 2% H₂O, Cl, TiO₂ and P₂O₅, variable amounts of BaO and no Al₂O₃. A clear continuous array extends from the carbonatitic melt composition toward the hydrous-silicic end-member. Another array connects the carbonatitic melt with the brine end-member. Micro-inclusions carrying sulfide melts were found together with carbonatitic melt inclusions in Yubileinyan diamonds.

Various fluids may be formed from parental carbonatitic melts by carbonate crystallization and separation of residual melt into two immiscible fluids: brine and hydrous-silicic melt. Compositional variation along radial profiles in some diamonds also indicate introduction of fresh carbonatitic melt into a more evolved brine or hydrous-silicic melt.

The micro-inclusion-bearing diamonds clearly grew from the fluids they trapped. Diamond growth from carbonatitic melts was demonstrated in many laboratory experiments and was achieved even at pressures and temperatures as low as those recorded by most natural diamonds. Many single crystal diamonds may have grown from similar fluids: metasomatic interaction with melts or fluids is evident in the trace element patterns of many mineral-inclusions in diamonds. It may be explained by interaction of these minerals with fluids similar to the diamond-forming fluids.

The trace element chemistry of the diamond-forming fluids is similar to that of kimberlites. Hypabissal kimberlites are also rich in volatile, but to a much lesser degree than the diamond-forming fluids. Kimberlites must have released part of their volatiles during ascent, which means that the original melt at depth must have been richer in volatile components. It is possible that while the diamond-forming fluids are the results of a cooling parental melt at depth, kimberlites represent evolution of similar parental melt during decompression and ascent.

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Noble gas and halogen composition of mantle fluids in Canadian diamonds

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Mantle fluids trapped in microinclusions in diamonds are important for tracing the evolution of volatile elements in the mantle. In principle, diamonds from different regions of the globe, formed at different time periods, can be used to extend the noble gas and halogen record of the mantle back through geological time. We have characterised the noble gases (Ar, He) and halogens (Cl, Br, I) in microinclusions in diamonds from the Panda and Snap Lake kimberlites, Slave Craton, NW Territories, Canada. These two kimberlites are in close proximity, within about ~200 km of each other, but differ in age by nearly 500 Ma (Panda = 53.2 ± 3.8 Ma [1]; Snap Lake = U-Pb age of 535 ± 11 Ma [2]).

Panda diamonds show a narrow range of ³He/⁴He = 5.4-6.5 Ra and high ⁴⁰Ar/³⁶Ar values of 17,000-36,000 similar the MORB value. Snap Lake diamonds show a larger range in ³He/⁴He (4-9 Ra) and He concentrations, which seem to be related to the colour of the diamond. ⁴⁰Ar/³⁶Ar of Snap Lake are variable, and extend to lower values (<10,000) consistent with mixing between air and mantle Ar sources. The air component is most likely derived from blank during furnace heating steps. However, Ar isotopes in Panda diamonds do not conform with air-mantle mixing and contain a mantle-derived component with a high ³⁶Ar concentration.

Panda diamonds show a ⁴⁰Ar*-Cl correlation (⁴⁰Ar*/Cl = 5.8-7.8 × 10⁻⁴ mol), indicating that excess ⁴⁰Ar is dissolved in a brine in the inclusions. The halogen ratios of Panda diamonds are variable: Br/Cl = 1.8-8.8 × 10⁻³ mol; I/Cl = 10.3-26.9 × 10⁻⁶; but similar to the range determined for other Canadian diamonds. Experiments are ongoing to determine the halogen composition of Snap Lake diamonds.

Mantle fluids in diamonds from Panda and other Canadian kimberlites can be subdivided into two trends based on their Br/Cl-K/Cl systematics. One trend has a MORB-like Br/Cl but variable K/Cl, and the other characterised by high and variable Br/Cl values but with a relatively constant K/Cl close to the chondritic value of ~1. It is tentatively suggested that these trends correspond to the carbonatitic-hydrous silicic (constant Br/Cl) and carbonatitic-brine fluid (variable Br/Cl) end-member arrays of mantle fluid compositions reported by Klein-BenDavid et al. [1].

Reference

- [1] Klein-BenDavid O., Izraeli E.S., Hauri E. and Navon O.
Lithos (in press).