Trace-element patterns of diamond: Toward a unified genetic model

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Quantitative trace-element analyses of >40 elements in >500 diamonds have been carried out by LAM-ICPMS, using a multi-element-doped cellulose standard; detection limits range to low-ppb levels for many elements [1]. The trace-element patterns of polycrystalline (framesite, diamondite) and fibrous/particulate diamonds are consistent with crystallisation directly from kimberlitic-carbonatitic melts, which show significant compositional variation from locality to locality. However, many fibrous/particulate diamonds show an abrupt change in trace-element patterns as crystallisation proceeds. Large decreases in Nb/Ta and Zr/Hf are difficult to explain by fractional crystallisation, but can be modelled as the result of liquid immiscibility: a separation into broadly hydrous-silicate and carbonatite fluids. The ubiquitous development of pronounced negative Y anomalies (relative to Ho-Dy) may reflect the separation of fluoride phases or immiscible fluoride melts; microinclusions with positive Y anomalies are observed during ablation of diamondites. Despite significant variation from one deposit to another, nearly all monocrystalline diamonds show low LREE/HREE, Ba/MREE and Sr/MREE, as well as low Nb/Ta and Zr/Hf, suggesting that they have crystallised from the hydrous-silicate member of the proposed immiscible-liquid couple. Modelling of the conjugate Mg-rich "carbonatite" fluid shows it would have extremely high LREE/HREE and Sr. The reaction of this fractionated carbonatitic fluid with chromite + olivine + opx can produce subcalcic Cr-pyrope garnets with "sinuous" REE patterns and high Sr contents, which are a characteristic inclusion in diamonds of the peridotitic paragenesis. We therefore suggest that the development of immiscibility during the evolution of low-volume melts of the kimberlite–carbonatite spectrum produces conjugate fluids, one of which crystallises most monocrystalline diamonds, and the other of which interacts with mantle harzburgites to produce the most ubiquitous inclusions in peridotitic diamonds. Preliminary comparative studies show little difference in the trace-element patterns of peridotitic and eclogitic diamonds from single localities. This implies limited interaction between fluid and wall rock, which in turn suggests high fluid/rock ratios during diamond crystallisation.