CHEMISTRY AND MINERALOGY OF EARTH’S MANTLE
Evidence for multiple diamond-forming events in the mantle†

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ABSTRACT

A collection of 35 diamondite samples (polycrystalline diamond aggregates, sometimes referred to as framesites), assumed to be from southern Africa, have been studied to investigate their infrared (IR) spectroscopic characteristics. Due to the abundance of sub-micrometer, interlocking diamonds (polycrystalline) with mineral and fluid inclusions within the diamond material affecting their transparency, only fragments from 10 of the samples provided high-quality data. The IR spectra showed a wide range of generally high-nitrogen concentrations (386–2677 ppm), with a full range of nitrogen aggregation states, from pure LaA to pure LaB. Platelet characteristics were interpreted as being regular (i.e., not having been affected by deformation and/or heating events), meaning the nitrogen aggregation data could be interpreted with confidence. Surprisingly, the platelet data showed a positive correlation between their intensity (integrated area) and peak position. The primary hydrogen band (at 3107 cm⁻¹) and secondary band (at 1405 cm⁻¹) are both often present in the samples’ spectra, but show no correlation with any other characteristic. There is also no correlation between the samples’ paragenesis (as defined by their garnet chemistry) and any of the IR characteristics. While we have no independent determination of the samples mantle residence age, nor the temperature they resided at, we infer that diamondite formation has occurred episodically over a large time frame in single and distinct growth events (as opposed to over a short time frame but over a large depth/temperature range). This idea is more in keeping with the theory that C-O-H diamond- (and diamondite-) forming fluids are the result of localized small volume processes. Interestingly, one sample contained fluid inclusions that exhibited a water:carbonate molar ratio (≈0.8), similar to the saline and silicic end-members of the monocrystalline diamond-forming fluid chemical spectrum.

Keywords: Polycrystalline diamond, framesite, infrared spectroscopy, nitrogen aggregation, C-O-H mantle fluids

INTRODUCTION

Diamondites are polycrystalline mantle xenoliths that are associated with kimberlites. Their occurrence has been reported from several kimberlite pipes in southern Africa [Venetia, Premier, Jwaneng, Orapa; see Dobosi and Kurat (2002)] and Siberia (Mir, Aikhal; Sobolev 1977). They consist predominantly of randomly oriented diamond crystals of varying sizes (Kurat and Dobosi 2000), along with varying amounts of silicates (garnet, clinopyroxene), oxides (magnetite, rutile, ilmenite), sulfides (pyrrhotite), native metals (iron), and Fe-carbides as intergrowths and inclusions (Dobosi and Kurat 2002; Gurney and Boyd 1982; Jacob et al. 2000, 2004, 2011; Kirkley et al. 1991). These minerals can help define a formation paragenesis (source rock affinity). In monocrystalline diamonds, peridotitic and eclogitic parageneses are most prevalent, with a small number classified as websteritic (Stachel and Harris 2008). While polycrystalline diamonds are relatively understudied compared to monocrystalline samples, websteritic and eclogitic, and parageneses dominate (see Mikhail et al. 2013 and references therein).

Some workers argue the crystallization histories of diamon- dites are distinctly different from monocrystalline diamonds (see Heaney et al. 2005 for a review) and several different theories have been proposed to account for their formation at specific localities. Some invoke a subduction component (Burgess et al. 1998; Honda et al. 2004; Mikhail et al. 2013), while others are less convinced by the contribution of crustal material and rely more upon upper mantle melts/fluids that contain a carbonatitic component (Kurat and Dobosi 2000; Jacob et al. 2000; Maruoka et al. 2004; Gautheron et al. 2005). At present, no formation age data has been obtained from diamondites. Some of the aforementioned studies loosely connect their diamondite samples’ formation to ancient episodes of monocrystalline diamond growth (e.g., Honda et al. 2004), while others propose a much younger age, with formation occurring only shortly before kimberlite emplacement (e.g., Jacob et al. 2000).

Nitrogen aggregation data provides a qualitative method to investigate the mantle residence time and temperature of