Evidence for multiple diamondite-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-micron, 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 IaA to pure IaB. 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. Whilst 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.

1. Introduction

Diamondites are polycrystalline mantle xenoliths that are associated with kimberlites. Their occurrence has been reported from a number of 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), sulphides (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 & 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 diamondites 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 & 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 other propose a much younger age, with
Nitrogen aggregation data provides a qualitative method to investigate the mantle residence time and temperature of diamonds (Evans and Harris 1989; Mendelssohn and Milledge 1995). Nitrogen is the most common substitutional impurity found in natural diamonds and forms the basis of their classification. Type I diamonds contain nitrogen, while Type II diamonds are nominally nitrogen free (<10 ppm as determined by Fourier Transform infrared (FTIR) spectroscopy). Nitrogen is relatively mobile in the diamond lattice at mantle pressure and temperature conditions. As a result the defects evolve over time from single nitrogen (C centres, Type Ib; Dyer et al. 1965), to pairs of nitrogen atoms (A centres, Type IaA; Davies 1976), to 4 nitrogen atoms tetrahedrally arranged about a vacancy (B centres, Type IaB; Evans and Qi 1982), in a process referred to as nitrogen aggregation. The first step in this progress (C to A centre aggregation) occurs quite rapidly (<1 Ma), while the second step (A to B centre) occurs much more slowly (over Ga). This A to B centre aggregation follows a second-order kinetics law (Chrenko et al. 1977), which means it can be used to estimate either the duration the diamond has resided in the mantle for, or the average temperature at which it resided (assuming the other is known). Platelets, planar interstitial carbon aggregates found on the {100} crystal planes (Humble, 1982), are the byproduct of B centre formation and show a linear relationship with B centre absorption (Woods, 1986). However, these features are prone to degradation during deformation and/or heating events (Woods, 1986).
In this study we provide the first documentation of the FTIR impurity characteristics of some of the diamond material that make up diamondites. We use this data, and the time and temperature relationship of nitrogen aggregation, to assess the temporal and depth constraints of diamondite formation, as well as investigate any indications of their deformation history.

2. Samples

A collection of 35 diamondites, held at the Department of Mineralogy and Petrography, Naturhistorisches Museum Vienna, Austria, were used in this investigation. Detailed descriptions of samples from this collection are provided by Kurat and Dobosi (2000) and Dobosi and Kurat (2002). Fragments of individual crystals were obtained from these samples by mechanically breaking small pieces off each sample. However, the transparency of the diamond crystals that form the diamondite can be highly variable, depending upon the concentration of included material (minerals and/or fluids; Figure 1). As a result, despite analyzing fragments from all 35 diamondite samples, only 10 of them yielded high quality FTIR spectra. The data presented below comes from 35 fragments of 10 of the diamondite samples (Table 1).

To determine the paragenesis of the diamondite samples, the garnet discrimination diagram of Aulbach et al. (2002) was used. Of the samples analysed, 5 are of websteritic and 2 of peridotitic paragenesis (Dobosi and Kurat 2010); 3 samples had an absence of silicates and are therefore classified as unknown (Table 1). As these samples were purchased from a gem dealer, the exact geographical origin of these
diamondite samples is unknown. However, previous workers (Kurat and Dobosi 2000) inferred them to be from southern Africa, as similar samples have been described from the Orapa, Jwaneng (Botswana) and Venetia (South Africa) kimberlites (Gurney and Boyd 1982; McCandless et al. 1989; Kirkley et al. 1991; Jacob et al. 2000).

3. Analytical technique

Infrared spectroscopic measurements were conducted at room temperature in transmittance mode on a Nicolet Nexus 650 Fourier Transform infrared spectrometer with Continuum microscope configured for the mid- to near-IR (Institute of Meteoritics, University of New Mexico) using the procedures employed by Mason et al. (2009). Both the IR objective and interior of the IR bench unit was in an atmosphere purged of H₂O and CO₂, which eliminated atmospheric absorption features. Data were collected over the mid-IR (400-4000 cm⁻¹) region using a Globar source, KBr beam splitter, and deuterated triglycerine sulfate (DTGS) detector. Approximately 256 scans were performed for each IR spectrum acquired at a resolution of 4 cm⁻¹. Background spectra were collected under the same analytical conditions before each analysis and used to calculate absorbance by dividing each sample spectrum and then taking the base-10 logarithm.

The IR spectra were deconvoluted using the excel version of the DiaMap software (Howell et al. 2012a, b). Uncertainties on each component are as such; nitrogen content and aggregation state – ± 10%, platelet intensity [I(B')] – ± 20%, platelet band position and height – ± 1cm⁻¹, hydrogen-related band heights at 3107 and
1405 cm\(^{-1}\) ± 1 cm\(^{-1}\). While all of these uncertainties are very conservative, the reason for the large uncertainty on \(I(B')\) is due to the exceptionally large platelet features that occur in some of the spectra and how variations in the baseline can significantly affect the result. Reproducibility of this dataset is however maintained by the standardizing effect that the DiaMap software has on spectral deconvolution (Howell et al. 2012a, b).

4. Results

The data obtained from the FTIR spectra for all the samples are presented in Table 1. The range of nitrogen concentrations within the sample set is large and consistently above the average nitrogen abundance seen for monocrystalline diamonds (ca. 200-300 ppm; Cartigny, 2005). For example, Dia020 has the lowest nitrogen abundances of 386 ppm, and sample Dia073B has the highest nitrogen abundances of 2677 ppm (Table 1). In general, multiple analyses of the nitrogen content from different fragments of the same sample provide data that are within uncertainty of each other. Overall nitrogen aggregation states (expresses as the % B-centers) vary from 0 to 100% (Table 1). Two of the samples show nitrogen aggregation states between 0 and 8.6% (Dia070 and Dia068), the remaining samples show aggregation states with >40% B-centers present, and samples Dia057 and Dia075 show fully aggregated nitrogen (100% IaB; Figure 2). We observe no relationship between garnet paragenesis and the nitrogen aggregation state of the diamond from these diamondites.
When the primary hydrogen-related band was observed at 3107 cm\(^{-1}\), the secondary band at 1405 cm\(^{-1}\) was also observed. Some additional bands were observed at 2924 and 2855 cm\(^{-1}\) in samples Dia019 and Dia066, which may also be related to hydrogen (Woods and Collins 1983). The intensity of the primary hydrogen band shows no correlation with any of the other impurity data, but it is important to note that this feature does not provide quantitative data regarding hydrogen concentration due to the possibility of non-IR-active hydrogen also being contained within the diamond (Connell et al. 1998).

Finally, despite sample selection being based on optical transparency, one spectrum (Dia066_2) revealed clear evidence of fluid inclusions (Figure 3). The strong hydrous band (between 2750 – 3700 cm\(^{-1}\)) and weaker carbonate band (1420 – 1500 cm\(^{-1}\)) can provide semi-quantitative concentration data (see method of Navon et al. 1988; their Table 1, which was followed here). In Dia066_2 there is approximately 104 ppm H\(_2\)O and 33 ppm CO\(_2\) within the fluid inclusions, which provides a molar ratio \([\text{H}_2\text{O} / (\text{H}_2\text{O} + \text{CO}_2)]\) of \(~0.76\).

5. Discussion

As highlighted in the introduction, no dating of diamondite formation has yet been accomplished. The primary objective of this study is to measure the nitrogen concentration and aggregation states of fragments of diamondite samples to investigate their mantle residence age - average temperature relationship. To do that, we first must assume that the diamond samples analysed have grown via octahedral growth (spiral / dislocation growth; Sunagawa 2005).
age/temperature relationship utilized below is based upon factors (i.e. activation energies, platelet formation rates) that have only been quantified specifically for octahedral diamond growth. Importantly, the available data for these samples show open cavities to contain octahedral or stepped-octahedral diamond crystal faces (Kurat and Dobosi 2000; Dobosi and Kurat 2010).

Another key assessment that must be made before interpreting the nitrogen data is whether the nitrogen aggregation data have been affected by crystal plastic deformation, which Rubanova et al. (2012) have shown is present within samples from the same collection. The exact affects of plastic deformation on the nitrogen aggregation process are unknown. Some have postulated that it enhances the rate at which aggregation occurs (Evans 1992), while others suggest it would break up the B centers into other defects (Byrne et al. 2012) thereby reducing the quantified aggregation state. Either way, to have confidence in our interpretations of the nitrogen aggregation data in terms of their age – temperature relationship, we must rule out interference of this process by plastic deformation. To do this, we use the platelet data.

With the exception of Dia068 and Dia070 (both predominantly IaA), all of the samples exhibit significant platelet development (Figure 3). Due to the high nitrogen concentrations and aggregation states, very large platelet features are often present. Figure 4 shows a “regularity” plot (after Woods 1986) of absorption due to B centers (μB) against intensity (integrated area) of the platelet band [I(B‘)]. The general trend of the data is in keeping with regular samples as defined by Woods (1986).
This implies that the platelets, formed during the A to B center aggregation process, have suffered no subsequent degradation (by either heating and/or deformation processes). This means that we can interpret the nitrogen aggregation data with confidence that the nitrogen aggregation states have not been altered by deformation during residence in the mantle. While this might initially appear contradictory to the work of Rubanova et al. (2012), who reported samples from this same collection exhibited significant crystal plastic deformation, they also showed that highly deformed diamond grains could be in contact with others exhibiting little or no sign of deformation. While this would appear to confirm that differential stresses are not homogeneously distributed throughout polycrystalline materials (Callister 1985; Kalidindi et al. 2003), it cannot be ruled out that there was an additional growth event that occurred after deformation. It is also important to note that crystals containing inclusions and other defects are more susceptible to the effects of deformation. The grains analysed in this study were chosen for their optical transparency and therefore less likely to contain inclusions. In summary, we do not rule out that the diamondites that our fragments have been taken from could have been subject to plastic deformation. However, the regular characteristics of the platelet data (after Woods, 1986) suggest that nitrogen impurity characteristics of these grains have not been obviously affected by plastic deformation, and therefore allow for some qualitative interpretation to be performed on them with reasonable confidence.

More detailed interrogation of the platelet data provides an interesting result. Sumida and Lang (1988) showed that larger $I(B')$ values are indicative of the
platelets having a greater total area per unit volume, while Clackson et al. (1990) showed that the B’ band occurring at lower wavenumbers was indicative of the platelets having a larger mean radius. The platelet data in this study (Figure 5) show that the intensity and position of the band’s maximum exhibit a positive correlation, i.e. the larger intensities occur at high wavenumbers. This means that the larger population densities contain platelets of smaller sizes. This result appears to contrast with samples studied by Woods (1986) that showed no dependence of the I(B’) values on the peak position.

5.1 Nitrogen Aggregation Characteristics

The nitrogen concentrations of the studied diamondites range from 386 to 2677 ppm, while their levels of nitrogen aggregation show the full range from 100% IaA to 100% IaB. These nitrogen concentrations are relatively high compared to the average values for P and E-type monocrystalline diamonds (200 and 300 ppm respectively; Cartigny 2005), but are comparable to fibrous diamonds and diamondites globally (average = 600-800 ppm; Mikhail et al. 2013 and references therein). The largest variation in nitrogen concentration between fragments from the same diamondite sample is 916 ppm for sample Dia073B and Dia073W (where B and W refers to the black and white appearance of these fragments). Such a large range for the nitrogen concentration within a single sample is not atypical for diamond because there is no statistically significant average, i.e. the internal range of nitrogen contents within single diamonds can be anywhere between <10 and >5000 ppm; Boyd et al. 1987; Bulanova et al. 2002; Fitzsimons et al.,1999; Harte et
al. 1999; Hauri et al., 2002; Howell et al. 2012b; 2013; Mikhail et al. accepted; Smart et al. 2012; Wiggers de Vries et al. 2012). Interestingly, the nitrogen aggregation states for these samples are fairly consistent despite the large range of nitrogen concentrations within some samples (Table 1). It is clear when these nitrogen data are plotted against each other (Figure 2), the samples fall into two discernable groups; one with low aggregation levels (Dia068 and Dia070) and the other with more developed aggregation states (40 – 100% IaB). While two samples (Dia057 and Dia075) exhibit 100% IaB aggregation and could be classified as a third group, the analytical uncertainties on the data mean they overlap with the upper end of the second group.

A diamond’s nitrogen concentration and aggregation state are related to each other by the duration and average temperature at which they have resided in the mantle (Chrenko et al. 1977; Evans and Harris 1989; Mendelssohn and Milledge 1995). Isotherms are lines that correlate these two nitrogen characteristics for a fixed age and temperature. The dark grey area shown in Figure 2, which includes the data from the six samples with varied aggregation levels (42 – 94% IaB), is bound by two isotherms; the possible variations of age and temperature used to calculate these upper and lower bounds are shown in Table 2. It is clear from the values calculated in Table 2 that nitrogen aggregation is far more sensitive to temperature than age (220 - 245°C variation over 3 Ga). If we assume a relatively hot geotherm (42 mW/m² surface heat flow; Stachel and Harris 2008), these temperatures equate to approximately 170 – 180 km at 3 Ga, and 240 – 270 km at 1 Ma. A cooler geotherm would require much greater depths to achieve these temperatures.
It is not really possible to constrain the time–temperature conditions of the two diamonds with 100% IaB aggregation states. As there is no aggregation beyond the B center stage, it cannot be determined how long they have been fully aggregated for; the calculation assumes that diamond is removed from the mantle as soon as it reaches a 100% IaB aggregation state, therefore both age and temperature determinations (when the other factor is fixed) represent minimum values. A relative comparison between these two samples and the six intermediate samples suggests that the fully aggregated samples either resided at slightly higher temperatures than the other samples (and therefore greater depths), or they have resided in the mantle for a longer period of time. Nevertheless, as these values are minimums, the differences could be much more pronounced.

As three fragments from the two samples with low aggregation levels have a value more than 0% IaB it is possible to calculate isotherms that bound the data (light grey area in Figure 2). The time and temperature values for these isotherms are shown in Table 2. Using the same geotherm as previously, these temperatures correspond to approximate depths of 135 – 160 km at 3 Ga (generally within the graphite stability field), and 180 – 215 km at 1 Ma.

In summary, the nitrogen FTIR characteristics recorded in these 10 diamondite samples cover the full range of aggregation, from pure IaA to pure IaB. These data can be interpreted in two ways. If it were assumed that all the diamondites formed at a similar time, then they would have had to grow and reside at different depths within the mantle with a relative depth range of 45 to 90 km between these samples.
Alternatively, if the diamondites all resided at similar depths in the mantle, then they would have to have formed during multiple events over a large period of time (possibly up to 3 Ga). These two outcomes imply different things about diamondite forming fluids; the exact conditions that result in diamondite formation (pressure, temperature, oxygen fugacity, carbon supersaturation, impurities) can either occur fairly simultaneously over a large vertical profile, or alternatively, occur multiple times over a large time frame. We acknowledge the two possibilities are discrete variables; more likely, a combination of both of these factors can produce diamondites at different times and depths.

5.2 Chemistry of diamondite forming fluids

While the focus of this study was on the nitrogen FTIR characteristics of the diamond material that make up diamondites, one analysis showed clear evidence of containing fluid inclusions. The molar ratio of \( \text{H}_2\text{O}:\text{CO}_2 \) of \(~0.76\) is in keeping with values measured in fluid inclusion rich fibrous diamonds (occurring either as fibrous cubes or fibrous coats on octahedral cores) studied by Navon et al. (1988; from Jwaneng, DRC and unknown), Schrauder and Navon (1994; Jwaneng), Tomlinson et al. (2005; DRC) and Klein-BenDavid et al. (2006; 2007; Diavik). These values, which indicate a higher water proportion, have the same basic characteristics as the silicic and saline end-member monocrystalline diamond-forming fluids (which have a \( \text{H}_2\text{O}:\text{CO}_2 \) mole ratio of 0.9 - 0.5, while the carbonatitic end-member has values <0.5; Klein-BenDavid et al. 2007)
Interestingly, trace element patterns in diamondites (from the same sample batch as our samples) show evidence for similar parental fluid compositions to those observed in fibrous diamonds (based on major and trace element abundances; see Rege et al. 2008). These data suggest similar fluid-compositions are responsible for the formation of both diamondite and fibrous diamonds. In support of this, highly porous fibrous cubes have been observed in diamondites (Kurat and Dobosi 2000).

Conversely, the average carbon isotope values of diamondite and fibrous diamonds are completely distinct, where these diamondites and all fibrous diamonds show a mean δ¹³C values of -18 and -5 ‰ respectively (see Mikhail et al., 2013 and references therein). Therefore, a better understanding of how polycrystalline diamonds fit in to diamond growth mechanism model of Sunagawa (1990, 2005) would help to tie all these discrete aspects of their formation into the bigger picture of not just monocrystalline diamond formation, but of C-O-H rich melts / fluids in the mantle (age, temperature, oxygen fugacity, source of the diamond-forming carbon etc.).

6. Implications

The mantle residence time for the 10 diamondites shown here can be interpreted as being highly variable. An alternative interpretation is that they resided over a large depth range. Considering their formation is from small-scale melt processes, this would probably require multiple growth events occurring over a large depth range at the same time. As the first interpretation requires multiple growth events over a large time frame, it is clear that the data indicates that diamondite formation has
occurred in multiple events. This would mean the formation histories of
diamondites might be more akin to the formation of monocrystalline diamonds,
both in terms of time (from the nitrogen aggregation data) but also in terms
fluid chemistry (from the fluid inclusions). Constraining the relationship, or lack
thereof, between monocrystalline diamonds (specifically gem quality) and
diamondites could be useful to the mining industry by being able to predict the
potential grade of a kimberlite. For example, is there any significance in the fact that
Orapa (Botswana), one of the world’s most productive diamond mines, produces a
high proportion of non-profitable diamondites (Gurney and Boyd 1982)?

Constraining this relationship will most likely be best achieved by performing
detailed, in situ geochemical analyses coupled with temporal constraints on
diamondites from known geographical localities, where multiple data are available
for other diamond-types.

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8. References cited


Mendelssohn, M.J., Milledge, H.J. (1995) Geologically significant information from


Figure Captions:
Figure 1: Representative images of diamondite from this study showing some important features. (a) Sample Dia063 shows translucent and opaque regions in the same sample where the translucent regions contain a lower abundance of intergrowths and inclusions. (b) Sample Dia074 is almost totally translucent whereas (c) sample Dia073 mostly resembles a rock in appearance (i.e. totally opaque), however upon breaking the sample some fragments were more opaque than other, this lead us to use the extensions B (black) and W (white) to denote the overall transparency.

Figure 2: A plot of nitrogen concentrations vs. aggregation state for all the analyses recorded in this study. The light and dark grey areas are each defined by two isotherms that are calculated for the mantle residence ages and corresponding temperatures stated in Table 2. The isotherms are calculated using the equation

\[ T(°C) = \frac{-E}{R} \ln \left( \frac{\left( \frac{C_0}{C} - 1 \right)}{-E/R - 273.15} \right) \]

where \( T \) is the average mantle residence temperature, \( t \) is the mantle residence time in seconds, \( C_0 \) is the total nitrogen concentration of the diamond, \( C \) is the nitrogen concentration in the form of A centres, \( E \) is the activation energy and \( R \) is the gas constant (where \( -E/R = -81160 \)), and \( A \) is the Arrhenius constant \((2.94 \times 10^5 \text{ s}^{-1} \text{ ppm}^{-1})\).

Figure 3: IR spectra from samples Dia066_2, Dia068_3 and Dia073W_1, showing a range of nitrogen concentrations, aggregation states (labeled A and B), platelet intensities (labeled B'), hydrogen bands (labeled C-H) and evidence of fluid
inclusions (labeled OH and CO$_3$). Each full spectrum is presented on the same absorbance scale, just offset from one another. The two insets of samples Dia066_2 and Dia073W_1, are presented at different scales, to highlight the fluid components and nitrogen characteristics respectively.

Figure 4: Regularity plot (after Woods 1986) showing absorption due to B centers ($\mu_B$) vs. the integrated area of the platelet band ($I(B')$). The black line shows the regular trend as defined by Woods (1986). Some representative analytical uncertainties are shown.

Figure 5: Graph showing the intensity vs. the peak position of the platelet band. The data show a positive relationship indicating that the larger population densities contain platelets of smaller sizes.

Table Captions:

Table 1: FTIR data for the samples in this study; nitrogen concentration (ppm), aggregation state (% IaB, i.e. proportion of the total nitrogen in the diamond in the form of B centers), height of the H band at 3107 cm$^{-1}$, integrated area of the B’ platelet band (cm$^{-2}$), and the wavenumber position of the B’ band maximum. Each analysis for a given sample was performed on a different diamond fragment of the given sample. The data used to assign paragenesis can be found in Dobosi and Kurat (2010). The IR spectra were deconvoluted using the excel version of the DiaMap software (Howell et al. 2012a, b). Uncertainties on each component are as such; nitrogen content and aggregation state $\pm$ 10%, platelet intensity [$I(B')$] $\pm$ 20%,
platelet band position and height – ± 1 cm⁻¹, hydrogen-related band heights at 3107 and 1405 cm⁻¹ – ± 1 cm⁻¹.

Table 2: Calculated mantle residence temperatures for defined ages that produce the isotherms that bracket the light and dark grey areas in Figure 2.
<table>
<thead>
<tr>
<th>Sample</th>
<th>Paragenesis</th>
<th>N total (ppm)</th>
<th>% IaB</th>
<th>H@3107 (cm⁻¹)</th>
<th>I(B') (cm⁻²)</th>
<th>PLATELET position (cm⁻¹)</th>
</tr>
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<tbody>
<tr>
<td>Dia019_7</td>
<td>Peridotitic</td>
<td>2011</td>
<td>91.4</td>
<td>3.8</td>
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<td>Dia020_6</td>
<td>Websteritic</td>
<td>386</td>
<td>54.8</td>
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<td>1362</td>
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<tr>
<td>Dia020_8</td>
<td></td>
<td>411</td>
<td>56.3</td>
<td>2.0</td>
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<td>1362</td>
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<tr>
<td>Dia022_1</td>
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<td>861</td>
<td>78.8</td>
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<td></td>
<td>857</td>
<td>78.3</td>
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<td>1368</td>
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<tr>
<td>Dia022_7</td>
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<td>Dia057_3</td>
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<td>Dia066_2</td>
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<tr>
<td>Dia066_5</td>
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<td>1.2</td>
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<td>1.4</td>
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| Dia075_1  | 1591 | 100.0 | 3.5 | 793 | 1369  
| Dia075_2  | 1372 | 100.0 | 2.7 | 720 | 1368  
| Dia075_3  | 1493 | 100.0 | 2.3 | 783 | 1368  
| Dia075_4  | 1385 | 100.0 | 3.3 | 781 | 1369  
| Dia075_5  | 1767 | 100.0 | 2.5 | 988 | 1369  
| Dia075_6  | 1714 | 100.0 | 1.8 | 990 | 1369  

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