Variation in diamond growth events recorded in Botswanan diamonds

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Introduction

The number of diamond-forming events recorded in the mantle beneath an individual diamond mine and the scale of these events, remains unknown, limiting the understanding of the geological processes that ultimately control diamond formation. In a first step towards constraining these parameters we report a study of diamond populations from the Orapa kimberlite cluster in central Botswana (Damtshaa, Letlhakane and Orapa mines) and the Jwaneng mine in southern Botswana, ~400 km to the southwest.

This study was conducted as part of an inclusion-bearing diamond collection campaign. Over a 4-year period run of mine production was examined from a total of 8 kimberlite pipes, with diamonds ranging in size from 0.12 to just under 1 ct.

Analytical Results

In total over 332 000 diamonds were characterised for their inclusion content. Inclusions were defined as a recognisable mineral (> 10 µm) for counting purposes. The inclusion abundance (Fig. 1) varies between diamond size fractions but on average Damtshaa has 2.1 to 4.9%, Letlhakane, 1.5 to 5.5%, Orapa 2.8 to 5.4% and Jwaneng 2.0 to 4.5% inclusion-bearing diamonds.

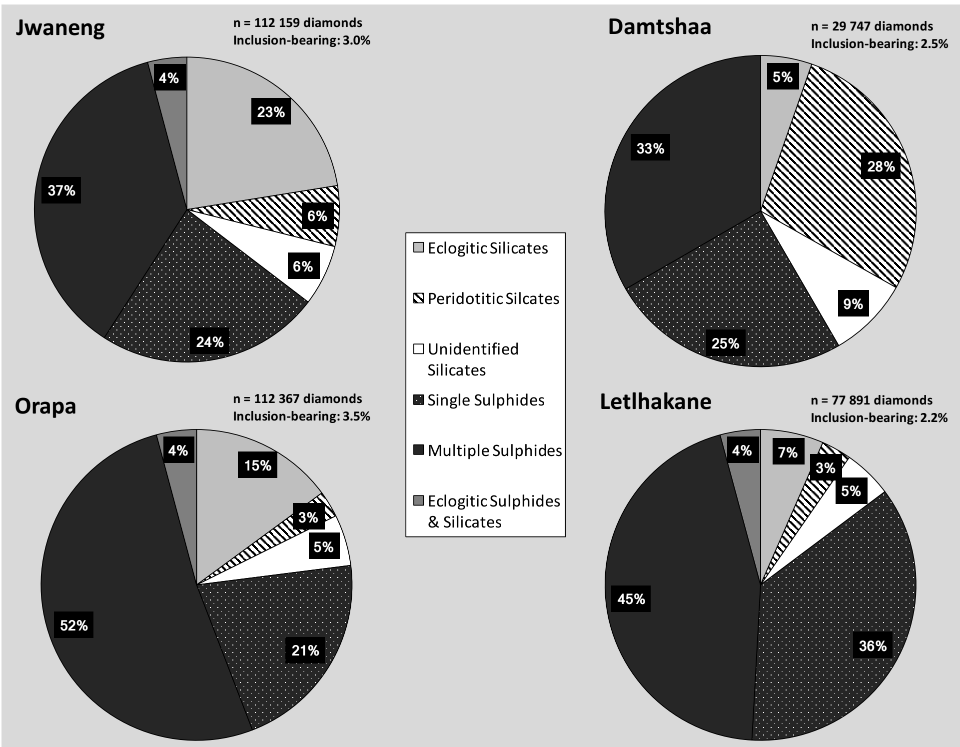

Fig.1: Average inclusion abundance for Jwaneng, Damtshaa, Orapa and Letlhakane diamond mines for 332 000 diamonds from 0.12 to 1 ct.

Eclogitic inclusions dominate the inclusion population at Letlhakane (80%), Jwaneng (83%) and Orapa (86%), while Damtshaa (20%) has a notably lower eclogitic inclusion abundance.
All diamond populations record colour variations with Orapa for example being characterised by several populations with different yellow-orange colours. A representative set of diamonds was selected from each mine for bulk diamond FTIR analyses (~1900 stones). All localities record marked variation in nitrogen abundance (10 to 1200 at.ppm) and nitrogen aggregation state (0-100 %N as B).

A set of inclusion-bearing diamonds were examined to determine their detailed growth history by cathodoluminescence (CL) imaging of central plates. To date > 145 diamonds have been characterised and FTIR traverses conducted. More than 70% record complex growth histories with up to 9 recognisable growth zones and multiple resorption events. Diamond growth zones were measured for C-isotope ratios from diamonds recording both simple and complex growth zonation. Carbon isotope ratios vary markedly; for example, $\delta^{13}C$ values range from -38.5 to -3.8 ‰ in Letlhakane and from -9.1 to -3.5 ‰ in Jwaneng, although larger ranges have been recorded in previous studies from Jwaneng (Cartigny et al. 1998; Deines et al. 1997).

As with the bulk diamond data, the diamond plates recorded marked variation in nitrogen content (< 10 to 1400 at.ppm) and nitrogen aggregation (0-100 %N as B). FTIR core to rim traverses reveal marked variability. Individual plates can be relatively homogeneous with N-content within ± 50 at.ppm, while others record marked changes in nitrogen content and aggregation states (Fig. 2) at the boundaries between individual growth zones (changes in N-content up to 500 ppm and N-aggregation from 5 to 95 %N as B). Isotherms calculated for mantle residence times based on recently published diamond formation ages (0.25, 1.0, 2.3 Ga) at Letlhakane show varying conditions for diamond precipitation for the diamonds with complex growth (Timmerman et al. 2017).

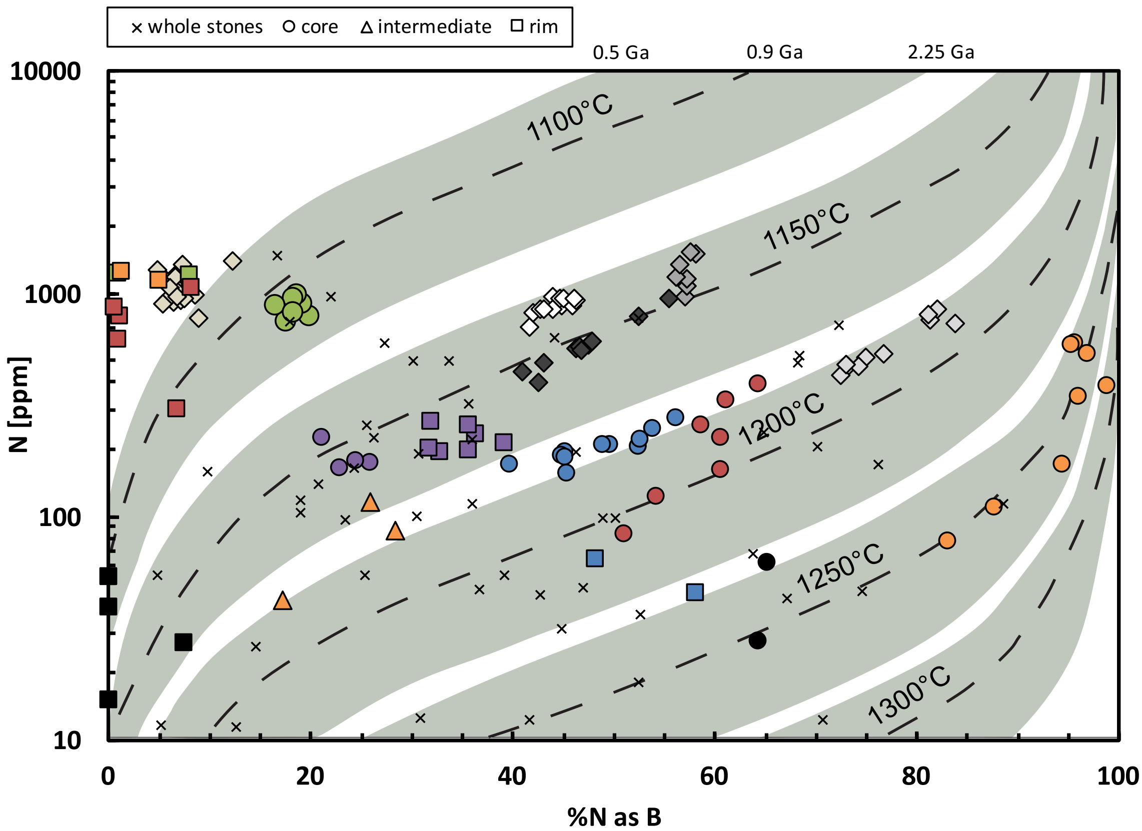

Fig. 2: Comparison of nitrogen content [ppm] vs nitrogen aggregation [%B] of FTIR data from Letlhakane of bulk stones (x) with traverses on individual plates subdivided into homogeneous growth (rhombus); and complex growth: core (circle), intermediate (triangle) and rim (rectangle). The different colours mark individual samples, isotherms are calculated for 0.5, 0.9 (dotted line) and 2.25 Ga mantle residence time accounting for diamond formation at 1.0 and 2.33 Ga and kimberlite eruption 93.1 my ago.

The integrated datasets establish that Orapa, Letlhakane and Jwaneng record multiple diamond growth events and have a limited number of unique characteristic growth events at each locality. This raises the question whether different diamond-forming events record evolution of diamond-forming fluids over time or are distinct events with new fluid input. On-going inclusion dating studies are designed to answer this question.

References

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