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Relationships between diamond populations and geology from the AK06 kimberlite, Botswana

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The AK06 kimberlite

The AK06 is a tri-lobate kimberlite situated in Botswana 25 km south of the Orapa Mine and 15 km from Letlhakane, with a subcrop surface area of 4.4 hectares at 1012 m above sea level. At 100 m depth the kimberlite has a modeled maximum area of 6.9 ha. The petrographic and geochemical analyses of Stiefenhofer and Opperman (this volume) show that the North and Centre lobes are similar, whereas the South lobe shows very different characteristics including shape, mineralogy, degree of alteration, density and hardness. Zircon ages for the North, Centre and South lobes (Appleyard, 2005 & 2006) are within error at 88 ± 5 Ma, 93 ± 3 Ma and 93 ± 2 Ma respectively. Cross-cutting kimberlite relationships indicate that the smallest North lobe erupted first, followed by the Centre lobe, and then the volumetrically dominant South lobe (Stiefenhofer, 2007).

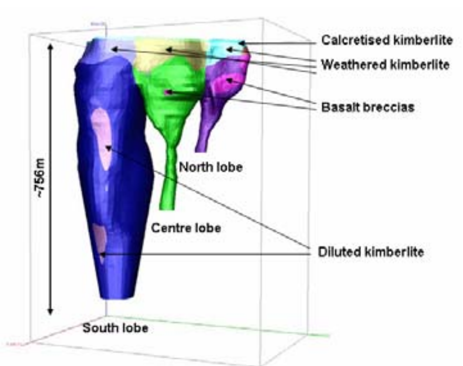

Figure 1: Geological model of the AK06 kimberlite, looking southwest (modified from Opperman, 2007).

Samples

Diamonds recovered from the first phase bulk sampling Large Diameter Drill (LDD) boreholes from each of the lobes were studied in an attempt to relate their characteristics to the kimberlite geology. Detailed morphology, colour and surface feature characteristics were obtained for a total of 561 diamonds ranging in size from the -6+5 to -21+19 DTC sieve classes. One hundred and ninety diamonds were examined from borehole LDD011 (North lobe), 178 from LDD007 (Centre lobe) and 193 from LDD006 (South lobe).

Inclusions

Visual identification of inclusions was hampered by severe etching and corrosion of a large proportion of the diamonds, particularly from the South lobe. Unidentified black inclusions and sulphides of undetermined paragenesis were the most commonly observed inclusions. A single eclogitic garnet was identified, and two chromite inclusions are representative of the peridotitic paragenesis.

Morphology and diamond type

Most of the diamonds from AK06 crystallised as octahedra, with those from the North and Centre lobes showing considerable secondary resorption to rounded dodecahedra. Etched octahedra are more prevalent than dodecahedra in the South lobe (Figure 2). The morphological trends observed in the macrodiamonds appear to be mirrored in the microdiamonds. Dodecahedra comprise 38% of the microdiamonds from a Centre lobe sample and only 14% of a sample from the South lobe (H Williams, pers. comm.). Few cuboid diamonds were identified, but 30, 21 and 5% of the diamonds from the North, Centre and South lobes respectively exhibit development of subordinate cubic faces and/or were derived by resorption of cubic morphologies. Aggregates of more than one crystal are slightly more common in the South lobe.

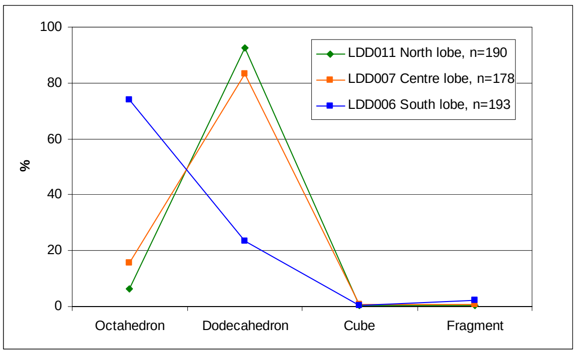

Figure 2: Main morphology of diamonds from AK06.

Nitrogen-free Type II diamonds with irregular, highly resorbed morphologies were found in significant numbers only in the South lobe. The Type II diamond distribution is highly variable and nugget-like within boreholes. The apparent absence of significant numbers of Type II diamonds from the North and Centre lobes may reflect the more limited sampling from these lobes.

Borehole LDD015 from the South lobe had the highest prevalence of Type II diamonds at 30.54 ct, which relates to 25% of the total carat weight for this borehole. Yet only four of the thirty-two 12 m sampling intervals contained significant numbers of Type II diamonds. Three of the Type II-bearing intervals produced the highest carat weights per sample from this borehole, and the fourth interval produced the fifth highest carat weight per sample.

Colour

All three lobes are dominated by colourless and very pale yellow diamonds, with decreasing abundance of brown and grey colours (Figure 3).

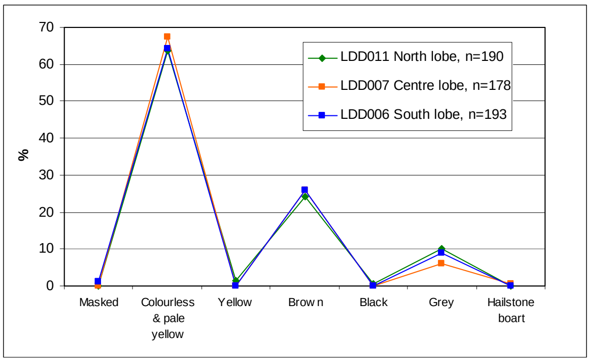

Figure 3: Colour distribution of diamonds from AK06.

Deformation

Fine lamination lines resulting from plastic deformation were identified on 47 and 42% of the diamonds from the North and Centre lobes respectively, in comparison to 7% of the diamonds from the South lobe. Plastic deformation of diamonds may be accompanied by the development of brown colour. The proportion of brown diamonds is indistinguishable between the lobes at 24, 26 and 26% for the North, Centre and South lobes respectively.

Lamination lines were identified on 65 and 61% of the brown diamonds from the North and Centre lobes respectively, compared with 2% of the brown diamonds from the South lobe. This may not be a true reflection of the deformation levels in the South lobe, as lamination lines are generally identified on dodecahedral surfaces which are considerably more prevalent among diamonds from the North and Centre lobes (e.g. Figure 4).

Figure 4: Dodecahedral diamond from the Centre lobe.

Resorption and etching

Unlike the abundant rounded dodecahedra of the North and Centre lobes, the South lobe is characterised by highly etched octahedra and octahedral aggregates (e.g. Figure 5). Experimental oxidation data of Fedortchouk *et al.* (2007) suggest that resorption of diamonds in the North and Centre lobes may have occurred in a fluid-saturated environment, yielding rounded dodecahedra; whereas the oxidation of diamonds in the South lobe occurred without the presence of a free fluid phase. The octahedra from the South lobe also show a high prevalence of diamonds with knoblike asperities and ribbing (Table 1). These surface features are often associated with surface graphitisation on diamonds, and have commonly been found on diamonds recovered from eclogitic xenoliths (Robinson, 1979).

Figure 5: Typical etched diamond from the South lobe.

Radiation damage

Green spots and surface stains (from α-particle damage caused by decay of radiogenic nuclides) are most common on diamonds from the upper 48 and 60 m of the North and South lobes, and this may reflect the depth of penetration of ground water in these boreholes. In contrast, radiation staining is most prevalent in the Centre lobe diamonds studied which are derived from a depth interval of 180 to 204 m. Core logging of the corresponding pilot borehole (Opperman, 2007) indicated the presence at this depth of the highly porous Ntane Sandstone Formation which may have served as an aquifer, facilitating transport of radiogenic nuclides.

Diamond crystallisation and evolution

Based on the similarity of primary diamond characteristics (colour and crystallisation form) from the North, Centre and South lobes, the kimberlite pulses are believed to have sampled similar eclogitic and peridotitic lithologies and depth intervals. The Type II diamonds are thought to have originated from unusual mantle source rocks which were not sampled extensively, or by all the kimberlite pulses.

Diamonds from the South lobe appear superficially to be very different from the majority of the North and Centre lobe diamonds, but this difference is largely ascribed to late-stage effects of graphitisation, etching and corrosion in a fluid poor regime in the South lobe. Circumstantial evidence, e.g. degree of crustal xenolith resorption, and the presence of textures interpreted as sintering of pyroclasts (Stiefenhofer and Opperman, this volume) suggests that the South lobe may have been emplaced at a higher temperature than the North and Centre lobes.

Geological control on the source of diamonds within different kimberlite facies allows for better interpretation of the crystallization history and subsequent modification (deformation, resorption and etching) of diamond populations within the context of mantle sampling and kimberlite eruption processes.

Table 1: Summary of diamond characteristics.

Lobe	North	Centre	South
Colour	%	%	%
Masked	0	0	1.0
Colourless & pale yellow	63.7	67.4	64.2
Yellow	1.6	0	0
Brown	24.2	25.8	25.9
Black	0.5	0	0
Grey	10.0	6.2	8.8
Hailstone boart	0	0.6	0
Morphology			
Octahedron	6.3	15.7	74.1
Dodecahedron	92.6	83.1	23.3
Cube	0.5	0.6	0.5
Fragment	0.5	0.6	2.1
Surface Features			
Trigons	66.3	56.2	96.9
Hexagonal pits	31.1	23.6	31.6
Triangular/round plates	1.1	1.7	3.1
Shield/triangular laminae	19.5	21.9	75.1
Serrate laminae	4.2	15.2	65.8
Tetragons	36.8	32.0	9.8
Terraces	38.4	36.0	15.5
Long hillocks	97.4	98.9	66.3
Short hillocks	98.4	95.5	59.6
Flat triangular hillocks	41.1	36.0	15.5
Ribbing	1.1	1.1	25.9
Fine lamination lines	47.4	41.6	6.7
Discrete lamination lines	8.9	7.3	0.5
Corrosion sculpture	1.6	30.3	45.1
Shallow depressions	2.1	15.2	12.4
Fine frosting	24.7	15.7	8.3
Rut	33.2	39.9	17.6
Knoblike asperities	0.5	1.1	56.5
Radiation staining/spots	8.4	4.5	3.6
n	190	178	193

Acknowledgements

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