Olivine crystal size distributions in kimberlite

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**ABSTRACT**

Olivine is the dominant component in coherent kimberlite rocks and related pyroclastic rocks. Quantitative characterization of olivine crystals in kimberlite rocks may be used to better understand kimberlite emplacement and eruption. Here, we construct the first complete olivine crystal size distribution (CSD) for magmatic or coherent kimberlite using two-dimensional image analysis techniques with a new method for scale-integration. Crystal size and frequency data are collected from polished slabs and thin sections, normalized to the largest scale of observation, and stereologically corrected to create a complete CSD covering the full range of observed olivine crystal sizes.

Resulting CSDs show the following properties for olivine in crystal-rich interiors of intrusive coherent kimberlite in the A154N kimberlite pipe, Diavik, Northwest Territories: (1) 0.03–10.0 mm in diameter size range; (2) 46.7–51.2% modal crystal content; (3) modal% dominance by crystals >1 mm; (4) frequency dominance by crystals <1 mm; and (5) equant-axial crystal shapes that cannot be easily described by a single external morphology for any size fraction.

Measured size ranges and modal crystal content are consistent with previous reported data. Relative frequency and area ratios between crystals of different sizes and shape properties differ from previous assessments. Olivine CSDs are consistent with a power-law distribution over at least two orders of magnitude, and statistical parameters (power-law exponents, Inman parameters) suggest that apparent characteristic ranges are independent of crystal frequencies, modal abundance (area%), or sampling locale. These properties suggest olivine crystals may be a single population with a shared paragenesis, and not the end-product of a combination of two populations of olivine. On this basis, olivine CSDs and population parameters have the following uses: (1) to compare and discriminate among kimberlite facies and deposit types, and (2) to test models for olivine paragenesis.

**Keywords:** Olivine, kimberlite, crystal size distribution, image analysis, emplacement, diamond

**INTRODUCTION**

Olivine crystals are the most abundant mineral phase in coherent and fragmental kimberlite rocks. Olivine crystals can comprise between 5 and 90 vol% of kimberlite rocks and typically vary in size from ~0.03 to ~10 mm in diameter (Mitchell 1986; Scott Smith 1996). Properties of olivine crystals in intrusive, coherent kimberlite rocks (sensu Cas et al. 2008) are locally heterogeneous; modal%, size range, shape, relative abundance, and relationships between sizes appear to vary within and between single occurrences. However, these properties appear broadly similar among global occurrences of intrusive coherent kimberlite or “hypabyssal” kimberlite (sensu Mitchell 1986). Such properties likely reflect end products resulting from several processes, including initial equilibrium crystallization in the pre-existing mantle, disaggregation, transport, chemical corrosion, and new crystallization of olivine from the kimberlite melt. Accurate estimation of these properties at all scales is critical to the interpretation of kimberlite paragenesis and emplacement processes.

In this paper, we present the first complete olivine crystal size distributions (CSDs) for individual samples in intrusive coherent kimberlite using a single method. We characterize the population of olivine crystals in five samples of intrusive coherent kimberlite from dikes at the Diavik diamond mine, Northwest Territories, Canada, using a method consisting of manual tracing of olivine crystals and image analysis of the traced crystals. The data were collected at two overlapping scales of observation: (1) thin sections (12.5 × 28 mm; 4000 dpi), and (2) slabs (47 × 77 mm; 600 dpi). The two data sets were combined to create a single CSD of olivine crystals from the full size range, 0.025 to 12 mm in diameter. This study describes the properties of size, abundance, relative size ratios, and shape of the olivine crystals in samples of intrusive coherent kimberlite, and reports variances obtained using a manual tracing method. These properties are used to compare olivine populations in intrusive coherent kimberlite at Diavik to previous understandings of olivine CSDs in kimberlite...