Variations of olivine abundance and grain size in the Snap Lake kimberlite intrusion, Northwest Territories, Canada: A possible proxy for diamonds

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The Snap Lake kimberlite is located approximately 220 km north-east of Yellowknife in the Northwest Territories of Canada (Fig.1). The kimberlite occurs as a complex inclined hypabyssal intrusion that on average dips 15° to the north-east. A striking feature of the Snap Lake intrusion is the abundance and size of altered olivine macrocrysts. It has long been contended that olivine macrocrysts are derived from disaggregated mantle xenoliths. Since the specific gravity of fresh olivine is close to that of diamond (3.37 g/cm^3, Deer et. al.,1992, compared to 3.51 g/cm^3, Field, 1997) it may be expected that some form of hydraulic equivalence existed between the two mineral types, provided they were both present as free grains in a low viscosity medium. This investigation aimed to test this hypothesis and to investigate how an understanding of the size distribution of a common mineral (olivine) could assist in understanding the distribution of an extremely rare one (diamond).

Previous investigations of the Snap Lake kimberlite (Mogg et al., 2003) identified the presence of a dominant main hypabyssal-facies kimberlite and minor breccias within the Snap Lake intrusion. Recent detailed mapping by one of the authors (TMG) has recognized four main lithofacies within the “main intrusion". Two of these are locally developed and relatively minor breccia units within the dyke, often closely associated with zones of complexity in intrusion geometry. The other two are crystal-rich and crystal-poor varieties whose relative proportions are highly variable.

For this investigation olivines were examined in a drill core and in two channel samples (a series of grab samples taken vertically through the intrusion). This study involved three distinct steps. First digital photographic images from a scanned drill core and polished slabs were image-analysed to determine 2D olivine size distributions in samples of roughly 64 cm^2 positioned vertically through the intrusion. Secondly, a physical sample was subjected to X-ray Computed Tomography (XCT) analysis and a serial grinding (SG) exercises to determine the 2D and 3D characteristics of olivine grains from the same sample. Thirdly, macro diamond size distributions for 75 bulk samples (averaging 60 metric tons in mass) were examined and compared to olivine size distributions.

A summary of the data collected for the drill core is presented in Fig.2. This data demonstrates that in the chosen sections, olivine is mostly ungraded in the central parts of the intrusion, but that the upper portion generally has lower olivine concentrations and the olivines are on average of a smaller size in this upper region. The largest olivines occur near, but not at the base of the intrusion. The 2D olivine size distributions in the three measured sections demonstrate relatively weak grading and sorting characteristics. This is a curious feature since olivines are dense particles being transported in a low-viscosity melt, albeit that the high concentration of olivine grains (typically 20 to 40 percent) will have substantially increased the viscosity of the intruding magma (Smith, 2000).

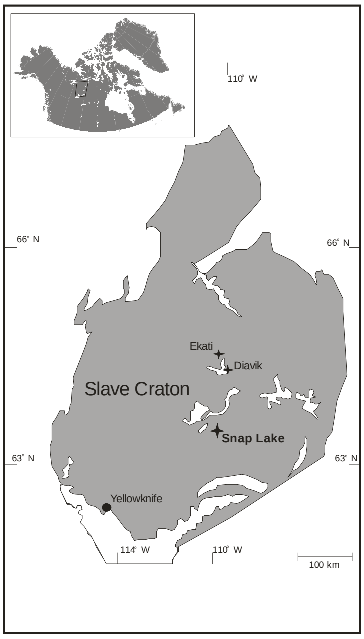

Fig 1. Locality map

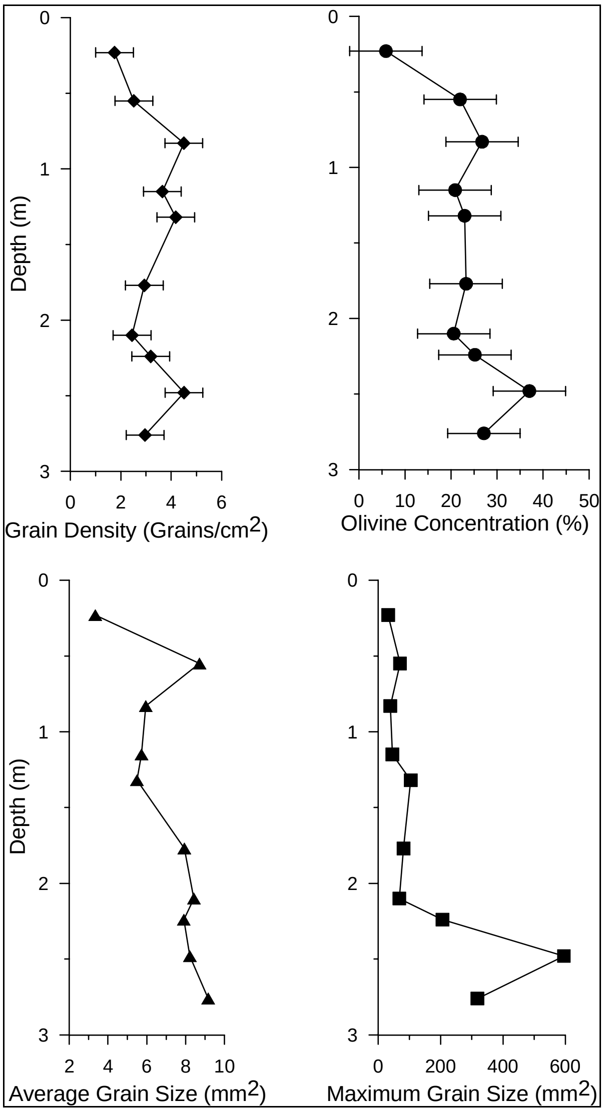

Fig. 2. Olivine variations in drill core.

The main purpose of the XCT and SG exercises was to demonstrate that measurements of olivine grains in 2D can be used to estimate their 3D character, so that 2D data could then be compared directly with diamond size distributions at many locations along the intrusion. This was achieved by comparing 2D area statistics with 3D volume statistics using a cumulative distribution graph (Fig.3).

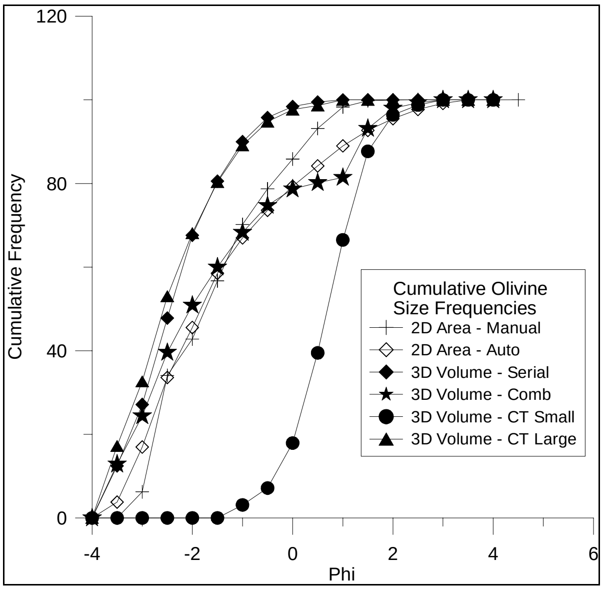

Fig.3. Comparison of 2D area and 3D volume data for olivines.

There is considerable variability in the diamond sizes between the 75 bulk samples. The bulk of the diamonds were retained on sieves below +13 diamond sieve (< 4.5 mm diameter aperture). There is no ready explanation for this diamond variability, and it was postulated that olivine size distributions might provide some insight if hydraulic equivalence could be assumed or demonstrated.

A direct comparison of all olivine and diamond data is made utilizing the plotting techniques demonstrated in Fig.3 and is presented in Fig.4. This shows that both olivines and diamonds display considerable, but not identical size distribution variations. Overlap occurs, but it breaks down at larger sizes. This lack of correlation at larger sizes may in part be due to under representivity of diamonds due to sample size or it may reflect different initial size maxima in the mantle host rocks.

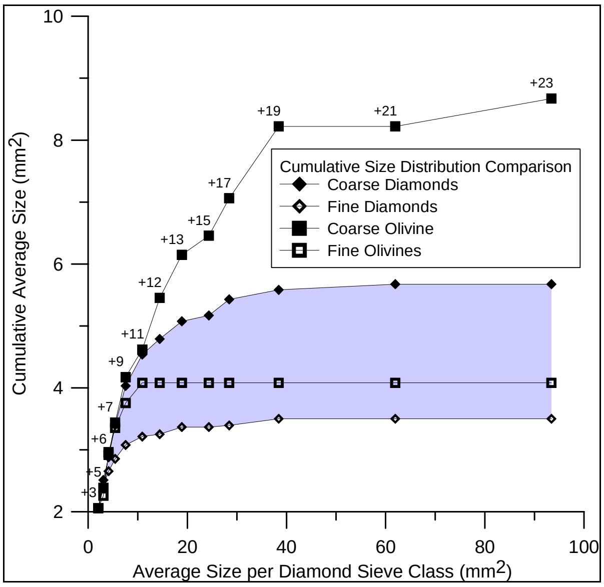

Fig.4. Cumulative size distribution comparison of ranges of olivine and diamond distributions.

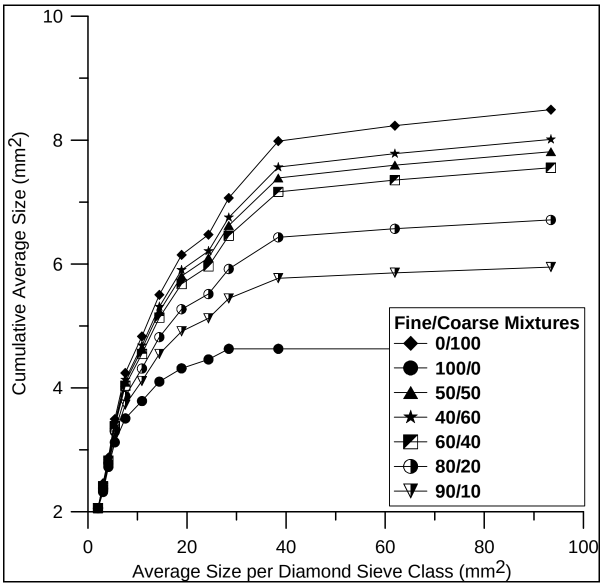

Fig.5. Cumulative olivine distributions of calculated mixtures of fine and coarse olivine distributions.

To investigate the spatial nature of diamond distributions in the intrusion, a series of successive samples taken in the 5280 SOD tunnel were examined. This showed that coarser diamond distributions occurred in samples where the hanging wall contact was not sampled, and that a finer distribution resulted where the footwall was not exposed in the sample, suggesting that considerable grading of diamonds occurred in the intrusion. To test whether the weak grading of olivine apparent in the three measured sections could be used to predict this diamond distribution variation a series of mixtures of coarse- and fine- olivine distributions were calculated (Fig. 5). If the finer diamond distributions are to be produced, more than 60 percent of the intersection would need to have the finer-grained olivine distribution. This cannot be explained simply by the weak size-grading of olivine that has been demonstrated in the three measured sections presented above. In these sections the proportion of fine-grained distribution is considerably less than half. Detailed mapping of a test panel (TP-02) area showed that considerable lateral variation in the relative proportions of crystal-rich and crystal-rich kimberlite occur. Here portions of the intrusion can consist of 60 percent crystal-poor kimberlite. This offers a viable alternative explanation that can explain the variations in diamond size distribution.

It can be concluded that both olivine and diamond sizes vary considerably across the Snap Lake kimberlite intrusion. Diamond size variations are difficult to explain because of their low concentrations and therefore the scale at which they are measured. Olivines, by contrast are common and therefore provide an insight into how diamonds sizes may vary on a local scale. The case study presented here suggests that olivine size variations are influenced by at least two main factors, firstly by (weak) grain size grading within single batches of magma, but also more impotantly by different batches of magma that may have completely different olivine (and diamond?) size distributions and abundances.

References

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