The suitability of microdiamonds for local (blocked) resource estimation – opportunities and challenges

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Introduction

The suitability of microdiamonds for kimberlite and related-rock resource evaluation has been the subject of robust debate for many years. These debates have centred round the suitability of microdiamonds for global and zonal average grade calculations. The impact of mantle processes and geology on microdiamond-based estimation methods has already been addressed (Stiefenhofer et al., 2016), as well as key features of the microdiamond estimation process (Stiefenhofer et al., in prep.). In this paper the debate is taken a step further and the suitability of microdiamonds for use in local block estimates was investigated through analysis of key geostatistical properties.

Any variable, or function thereof, randomly distributed in space with a value at every point and a set of spatial coordinates, is considered a regionalised variable, micro-diamonds included. Our investigation focussed on the essential parameters which characterise a regionalised variable, and without which geostatistical applications would not be possible. These include the spatial attributes and structure, i.e. variography, of micro-diamonds, sample support size limitations, and consistency of the diamond size frequency in space.

Study results

Tests were undertaken to verify the relationship between micro-diamond sample support and stone grade variance, more specifically relating to point sampling. This required the calculation of non-adjacent sample covariance. The output was compared against a hand-calculated sample support up-scaling exercise using the real sample data, as well as the block dispersion variance following the kriging of a single 50x50x15m block using the same variogram input parameters. It should be noted that the sampling protocols are completely different for microdiamond sampling (point samples) compared to macrodiamond samples (continuous line sampling). The level of internal geological heterogeneity in the kimberlite is critical – higher variability will require more samples to reduce the variance of statistical parameters to acceptable levels. Following a continuous sampling exercise at Jwaneng Mine Centre Pipe, the data revealed a predictable decrease in variance with increasing sample support (sample length), as shown in Figure 1. Analysis also confirmed a stable size frequency distribution (SFD) with increasing depth in the Centre Pipe, as well as at other locations (Figure 2).

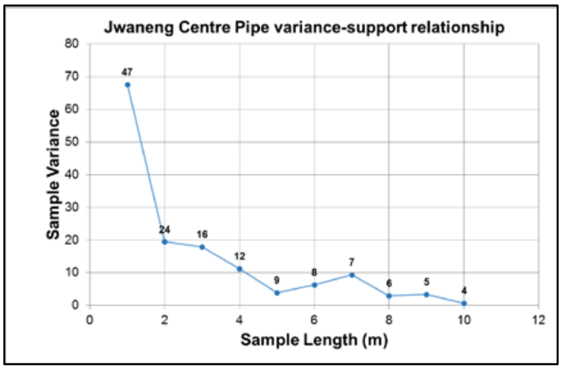

Figure 1: Variance-support relationship for microdiamond sampling within the Jwaneng Centre Pipe. Labels refer to the number of samples down the particular drillhole.

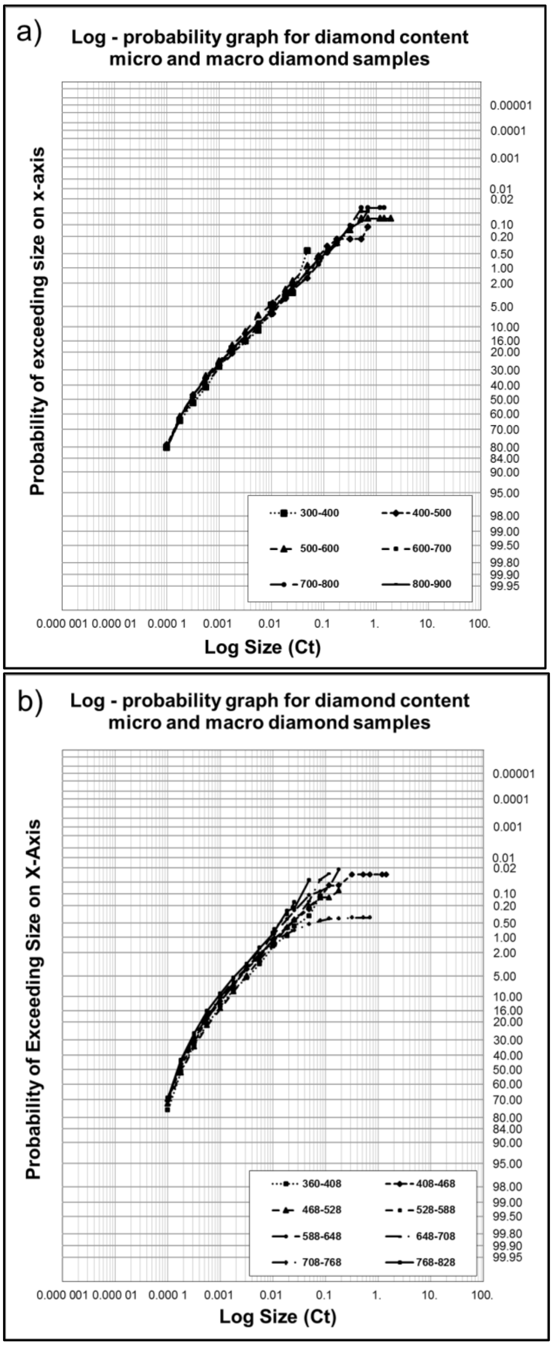

Figure 2: SFD's at 100m depth intervals for the Centre Pipe Volcaniclastic Kimberlite (a) and at 60m depth intervals for the Venetia K1 Dark Volcaniclastic Kimberlite (b). The variability observed at the upper (coarse) end of the curves is due to sample support constraints.

Successful variance-support analysis is a function of optimal micro-diamond sample support size which is in turn related to the stone density of the kimberlite under investigation. It is important to optimise the sample support size prior to any resource evaluation sampling. Data from such optimised micro-diamond sampling campaigns yield clear spatial structure, consistent with that of a regionalised variable. Studies conducted across four different kimberlite clusters (Snap Lake, Venetia K1, Orapa and Jwaneng) and eleven different lithologies revealed nugget effect proportions ranging from 21-65% and variogram ranges from 67-220m. An example is shown in Figure 3.

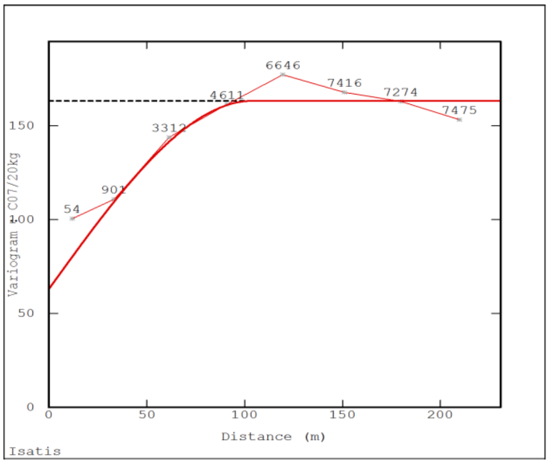

Figure 3: Omnidirectional variogram for the Southern Dark Volcaniclastic Kimberlite (SDVK) unit in the Orapa AK1 South Lobe. The range is 104m and the number labels refer to the number of pairs in the lags of the experimental semivariogram.

Z-star Mineral Resource Consultants have generated several "digital kimberlite" simulations using high-density micro-diamond point samples. The output was validated against the input data which consisted of real microdiamond samples (actual data). Thereafter, both micro and macrodiamond data sets were generated from the simulations and used to generate local estimates on a 50x50x16m block grid. The macrodiamond output was compared against real macrodiamond data obtained from large diameter drilling (actual data). As expected the large diameter data exhibited a better correlation to actual compared to the microdiamond data, although both correlations are significant (Figure 4). These exercises were performed for both high- and low-grade kimberlites. It was also possible to optimise the micro-diamond sampling such that a resource of an indicated level of confidence could be obtained.

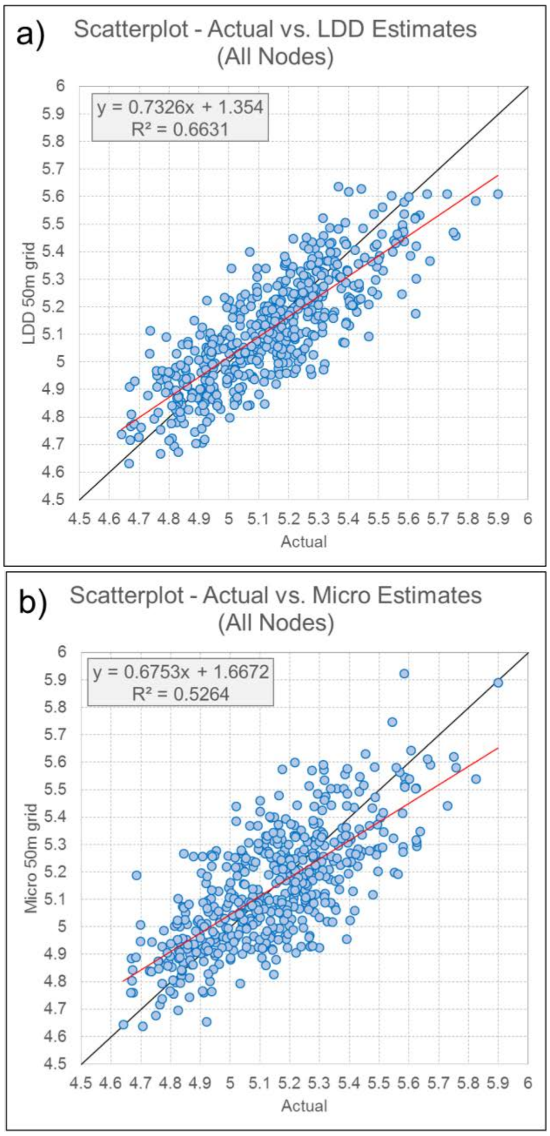

Figure 4: Actual block value vs. LDD (a) and actual block value vs. micro-diamond estimates (b). Both correlations are significant. An LDD sample contains on average 2,016 stones (96 micro-diamond samples) compared to only 21 stones in a single microdiamond sample. Actual and estimated block grades have been converted from stones/20kg to carats/m^3.

Conclusions

Our analysis yielded no reason why micro-diamonds should not be considered for local block resource estimation, provided some precautions are adhered to. These are:

- A valid and robust geological understanding of the pipe emplacement and lithologies;
- The required degree of confidence in the resource estimate must be agreed upon prior to any sampling. This should include the maximum variance which can be tolerated in the anticipated monthly or quarterly cash-flows;
- The sample support size and indeed also the sampling layout must be optimised for both the kimberlite under investigation and the level of risk acceptable to all stakeholders;
- Provision for some macro-diamond sampling to assess the integrity of the size frequency distribution beyond micro-diamonds and into the commercial diamond sizes; and
- Demonstrable stability in diamond size frequency, both across the pipe as well as at depth. A robust geological model will contribute significantly towards this goal. Failure to achieve this will result in a failed resource estimate.

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References

Stiefenhofer J, Thurston ML, Rose DM, Chinn IL, Ferreira JJ (2016) Principles relating to the use of micro-diamonds for resource estimation: 1 – The impact of mantle and kimberlite processes. CIM Journal 7(4) http://dx.doi.org/10.15834/cimj.2016.26

Stiefenhofer J, Thurston ML, Rose DM, Bush DE (in prep.) Principles relating to the use of micro-diamonds for resource estimation: 2 – Case studies to illustrate micro-macro diamond estimates.