Microdiamond grade as a regionalised variable – some basic requirements for successful local microdiamond resource estimation of kimberlite

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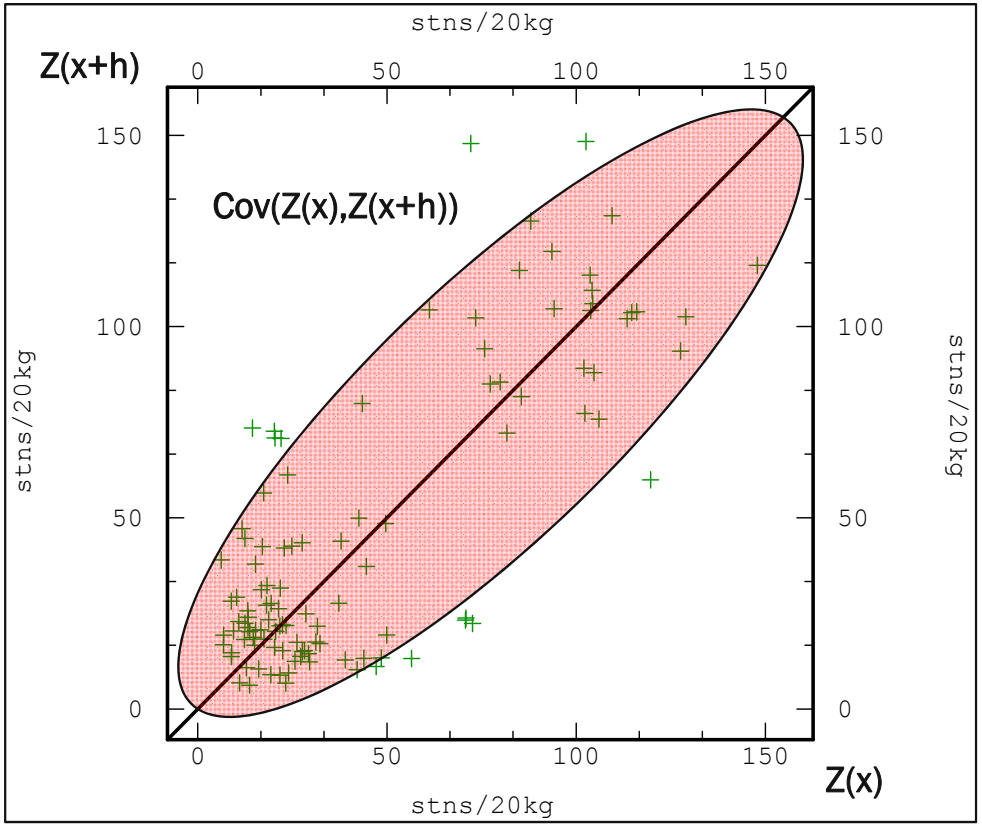
INTRODUCTION

- Large diameter drilling suffers from depth and technical limitations
- Most standard-sized core holes not suitable for the collection of macrodiamonds
- Microdiamonds are more abundant and can be recovered from drill core
- Five key parameters which are required to create a local resource estimate
  - Stationarity of data
  - Variography
  - Variance-support relationship
  - Consistency of the diamond size frequency distribution
  - Optimisation of the sampling
- Methods of comparing local block estimates based on micro- and macrodiamonds

STATIONARITY OF DATA

- The independence of the univariate and bivariate probability law from location x
- If Z(x)=microdiamond stone concentration, then it is a second-order regionalised variable if the following conditions apply.
  - E[Z(x)]=0
  - Var[Z(x)]=0
  - Cov[Z(x),Z(x+h)] independent of x
- Stationarity occurs at different scales
- Unimodal data histogram
- No trend in the data



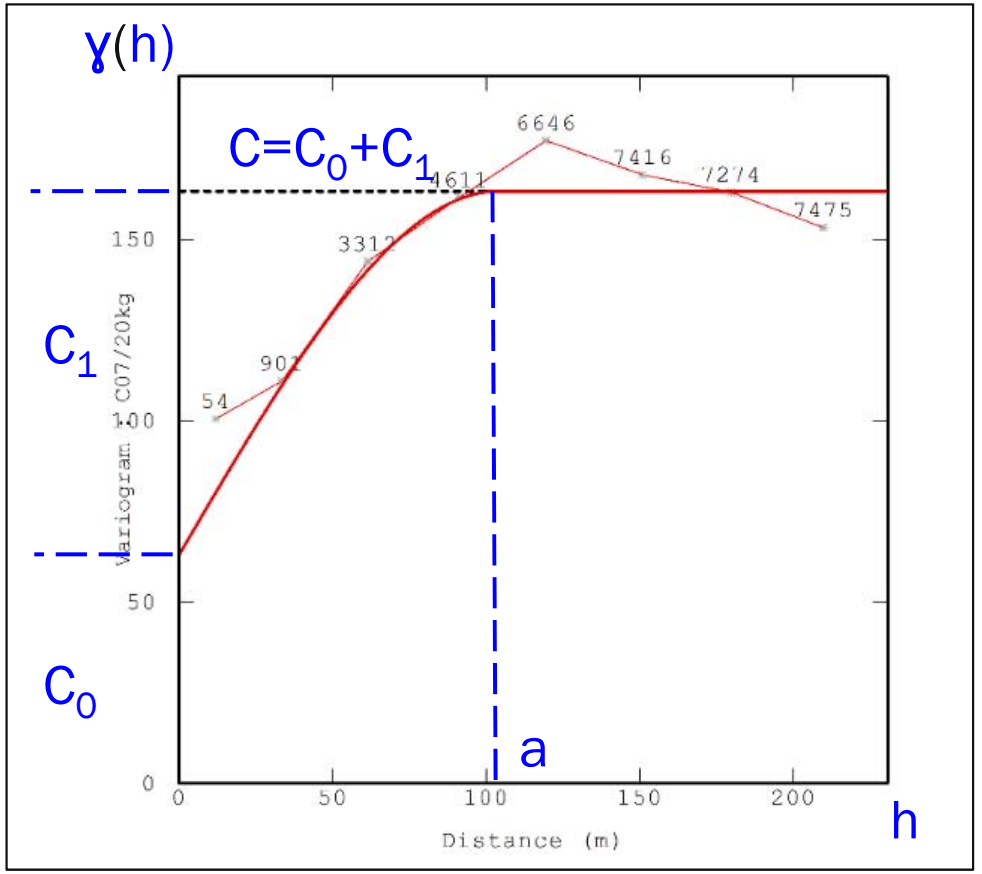
VARIOGRAPHY

- Under the intrinsic hypothesis (Matheron, 1971 & 1973):

$$E[Z(x+h)-Z(x)]=0 \quad \text{for all } x \text{ and } h$$

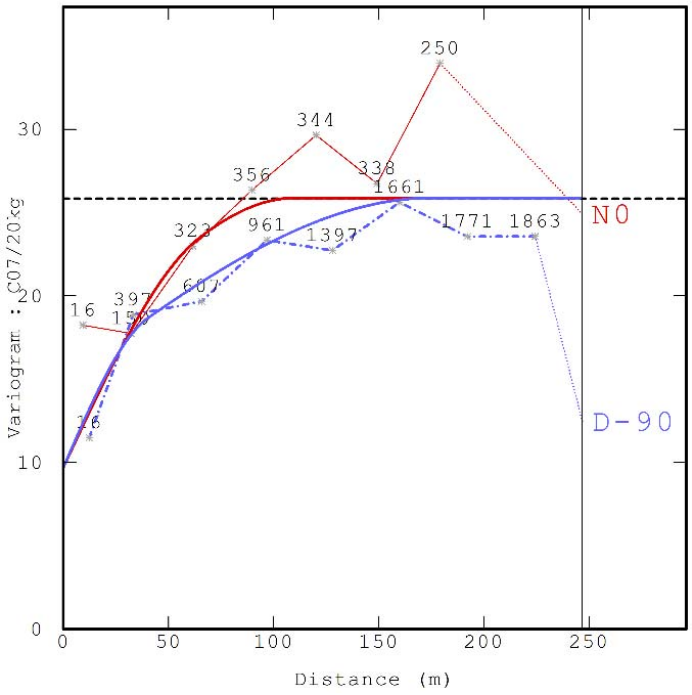
$$\gamma(h)=0.5\ \mathrm{var}[Z(x+h)-Z(x)]$$

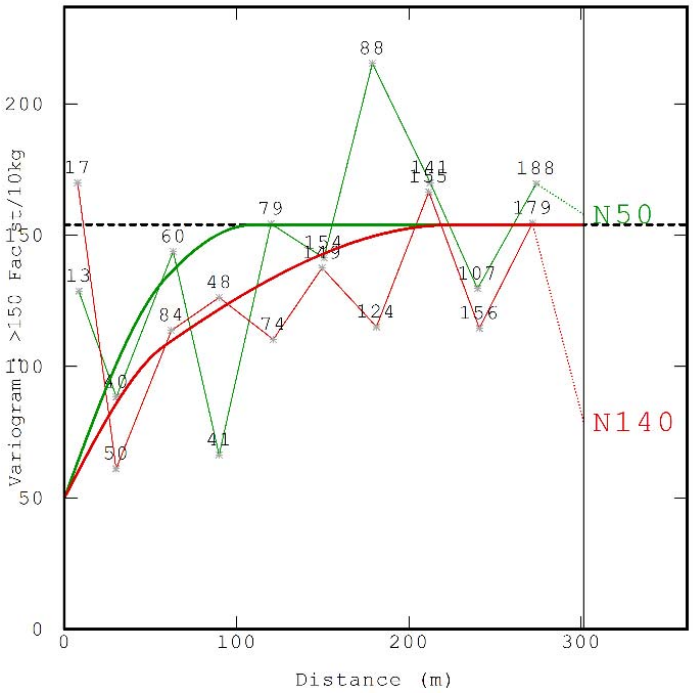
where $\gamma(h)$ is the variogram, depending only on h

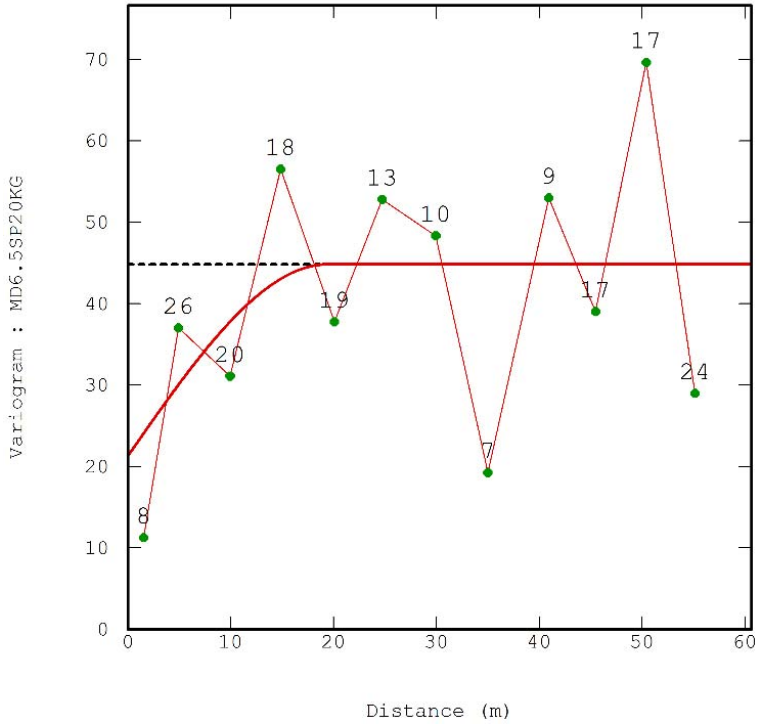


- The variance of the differences between sample values a distance h apart = variability between samples
- Closely related to the underlying geology
- Key input to the spatial interpolation process
- Microdiamond variograms can be produced from vertical drill grids as well as inclined drill holes for variably-sized datasets
- Trend in the data and the proportional effect prevent efficient variogram construction

VARIOGRAPHY



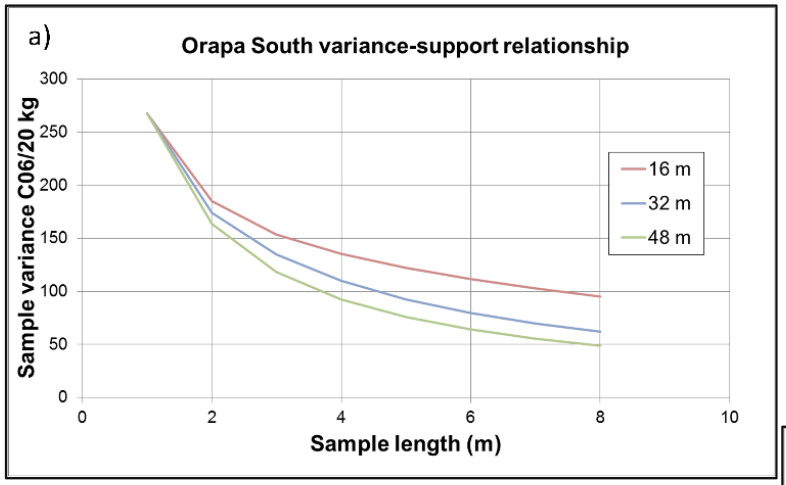




Nugget effect and range not dissimilar to macrodiamond variograms

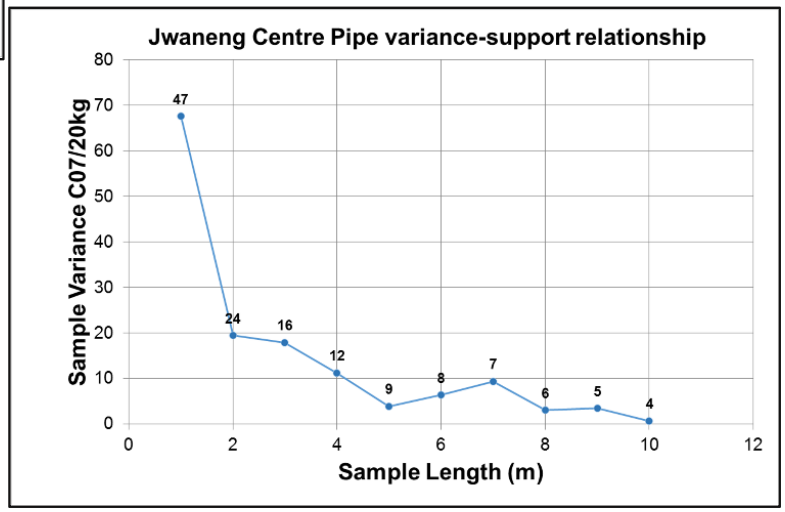
CHANGE OF SUPPORT AND THE VARIANCE-SUPPORT CURVE

- The variability of results as a function of the sample dimensions
- Variance decreases with increasing sample support
- Point sampling format for micro-diamonds requires non-adjacent sample covariance formulation
- Variance-support relationship can be demonstrated for micro-diamond point samples, line samples in real data and simulations



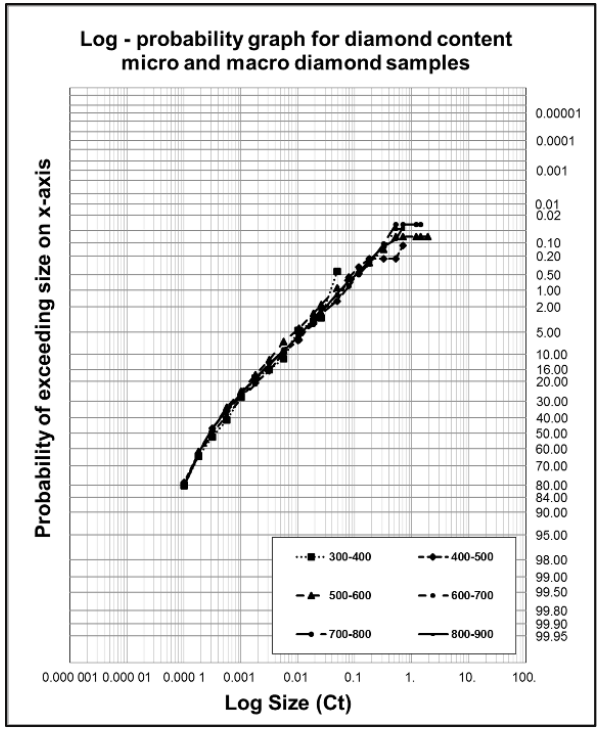
Non-adjacent covariance support curves for 16m, 32m, 48m

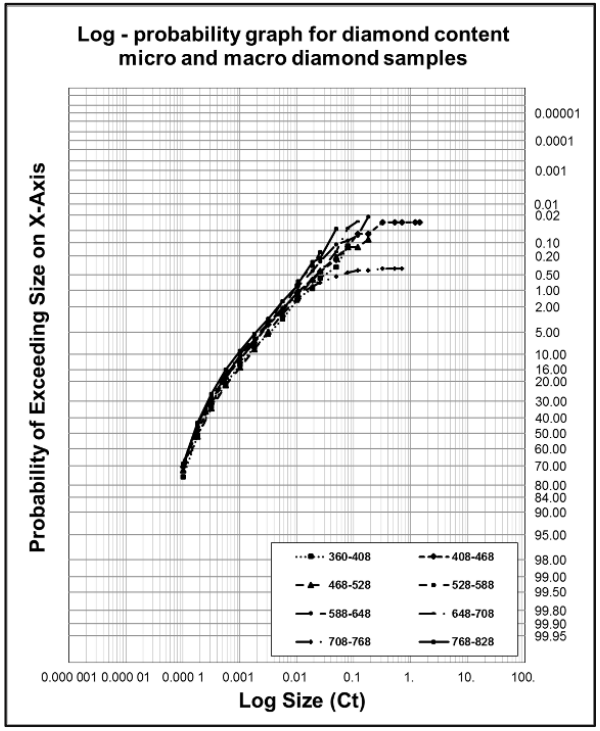
Adjacent covariance for continuous line sampling down a single borehole



CONSISTENCY OF THE DIAMOND SIZE FREQUENCY DISTRIBUTION

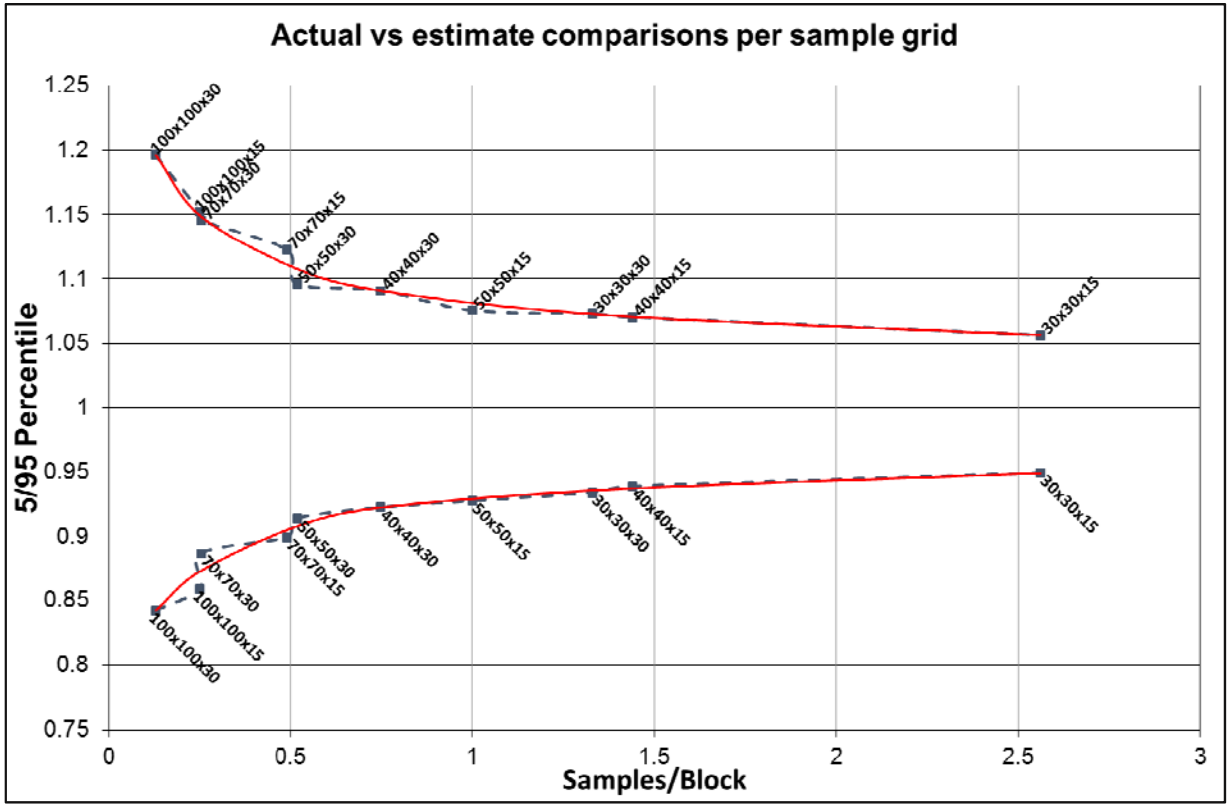
- The SFD defines the relationship between micro- and macrodiamonds
- Geological homogeneity is a key requirement
- Individual microdiamond sample support insufficient for comparison – grouping of data is required
- Small number of stones in upper sieve classes
- Trends or changes in SFD must be investigated
- Statistical vs. geological outliers





SAMPLE OPTIMISATION

- Customisation of a sampling campaign for the geology, stone density and diamond size frequency of each individual kimberlite
- Shareholder risk appetite
- De Beers uses an annual production increment, accurate to within 15%, 90% of the time.
- Representative, phased sampling.
- Margin of error required for failed holes, etc.

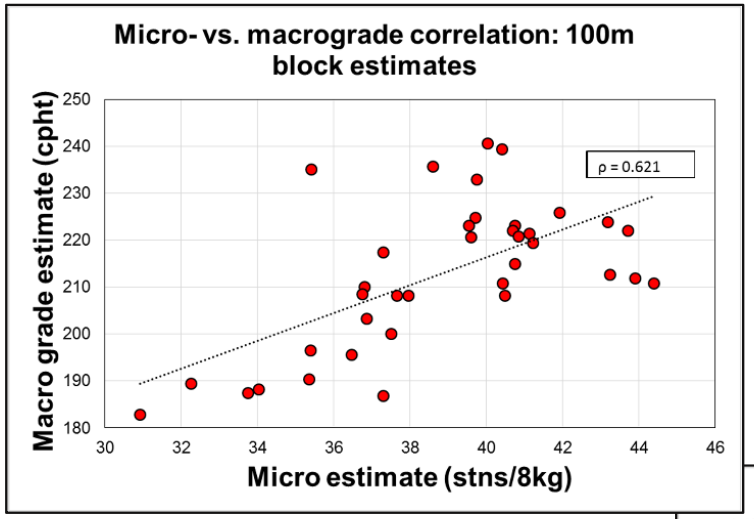


COMPARISON OF LOCAL MICRO- AND MACRODIAMOND ESTIMATES

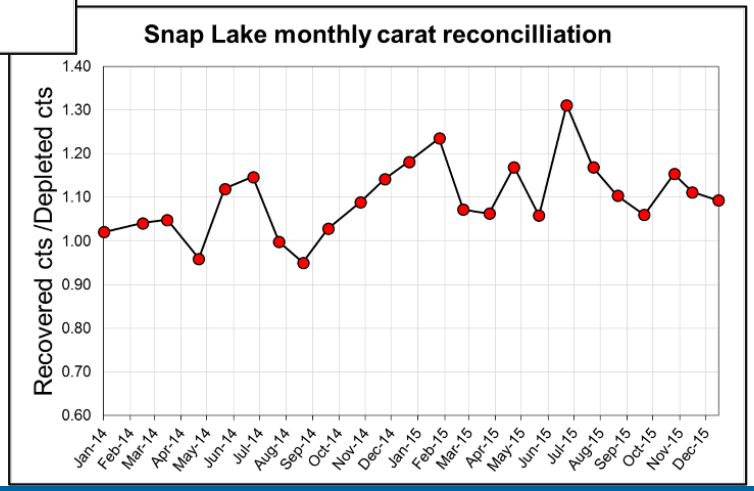
- Methods of comparison
  - Mining results
  - Overlapping micro-and macro-diamond sampling datasets from which two separate local estimates are created and comparisons made at block level, mining bench level, preferred cash-flow period, etc.
  - Simulation-based comparisons
- Comparing estimates at a block level are dependent on many variables. Understand the influence of each
- Local macrodiamond estimates are NOT beyond reproach
- Micro-macro estimate comparisons are made against an annual production increment, accurate to within 15%, 90% of the time, NOT on a block-by-block basis.

MINING RESULTS – SNAP LAKE

- Micro diamond-based resource estimate
  - Surface drillholes
  - UG grab samples
  - UG mini-bulk samples (100-400 t)
  - 100 m x 100 m block estimates
- Indicated resource
- Block estimates for micro vs macro grade comparison were generated independently



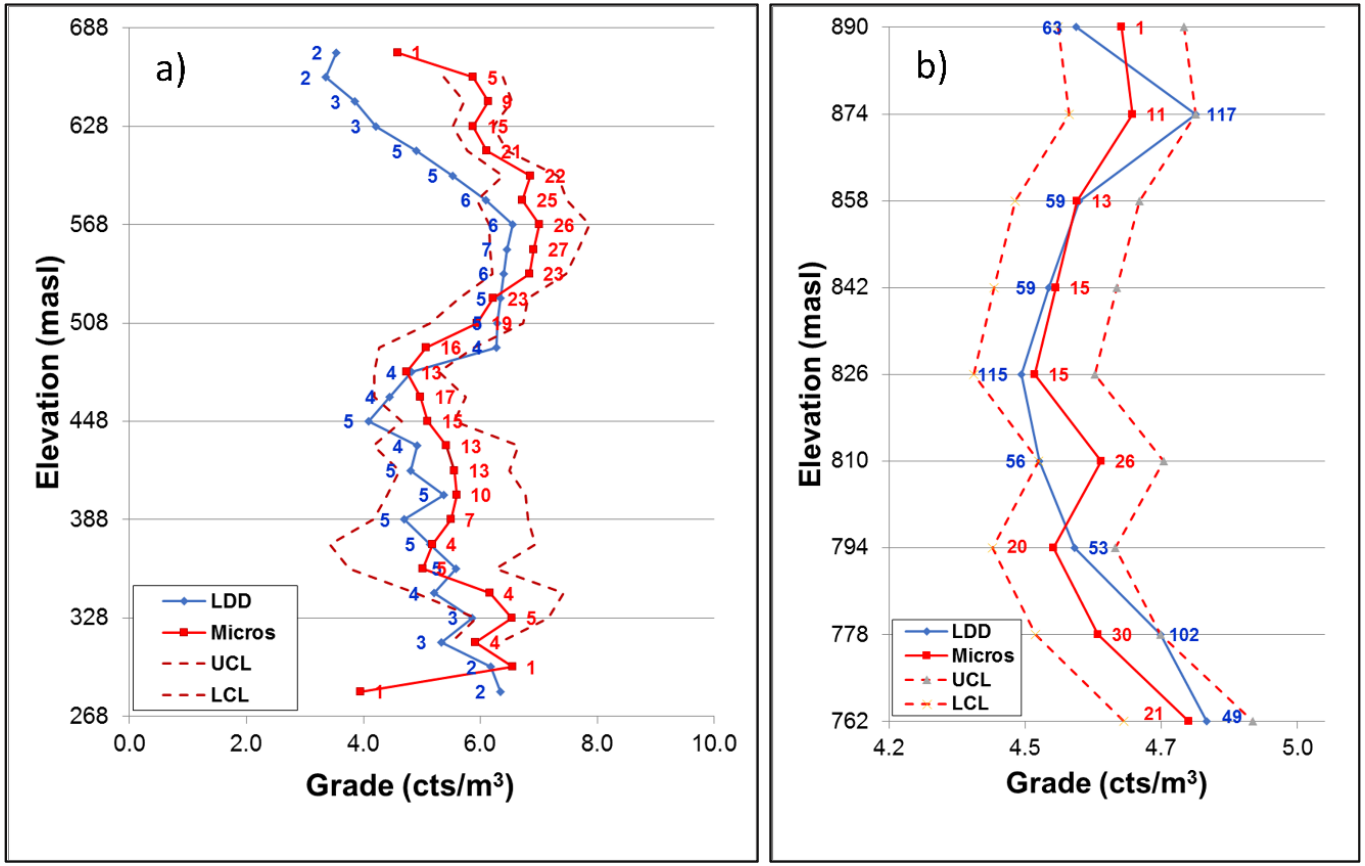
Microdiamond estimate at 150 micron bco, macro diamond grades at +3DS



Carat grade (ct/m^3) = 1000 x (stones/20kg) x (macro diamond stone size/microdiamond-macrodiamond ratio) x density

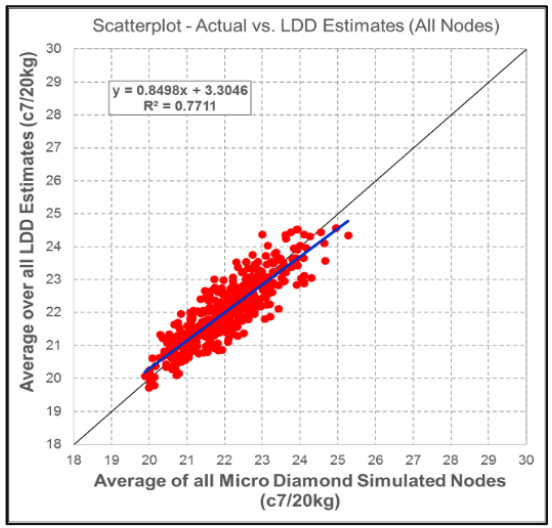
MICRO-MACRO ESTIMATE OVERLAP ZONE

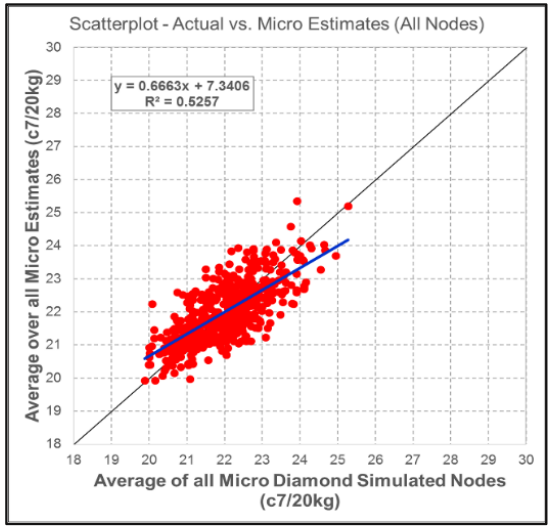
- Micro-macro overlap zones have been created on all of the major De Beers Operations.
- Quality of the micro-macro correlation is a function of sample variance, geological homogeneity, resource confidence, quality of the sample optimisation, and quality of the local estimation parameters.
- Microdiamond samples are smaller with higher grade variance
- Whenever possible, additional infill sampling is undertaken to test the optimisation studies.

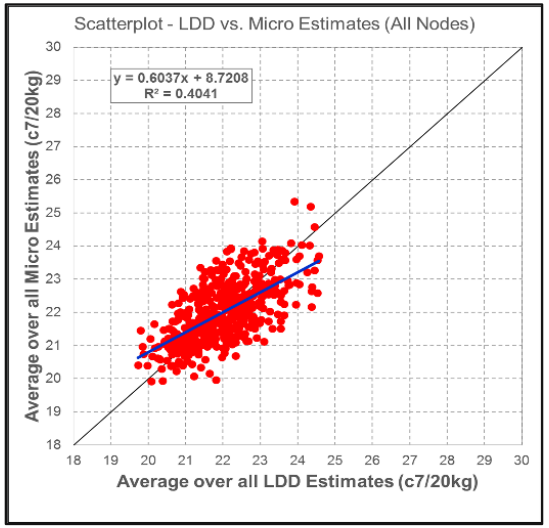


SIMULATION-BASED COMPARISONS

- Digital kimberlite simulations constructed from high-density microdiamond point samples (0.25x0.25x1m)
- Simulations validated against real input microdiamond data
- Micro- and macrodiamond datasets generated from the simulations
- Local estimates: 50x50x16m
- Microdiamond estimates significantly correlated to the actual block estimates

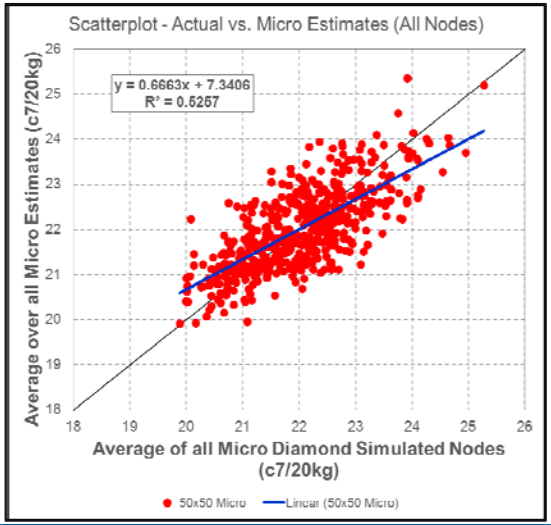


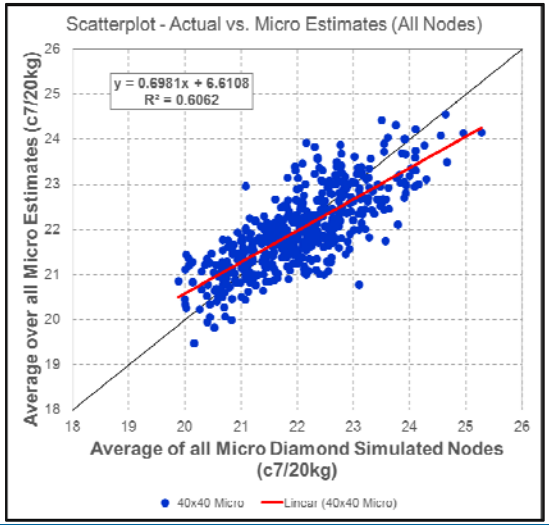


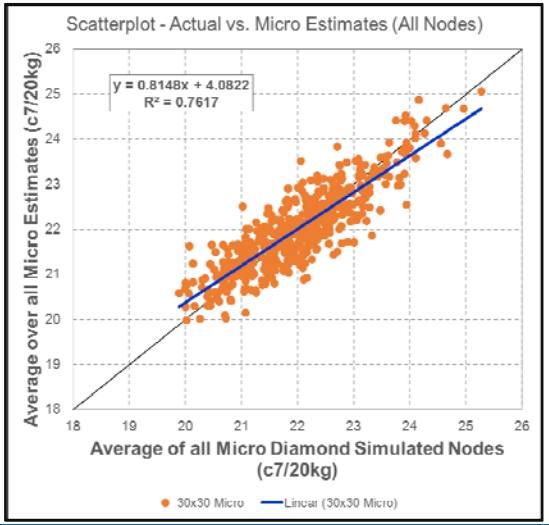


SIMULATION-BASED COMPARISONS

- Upscaling of microdiamond samples to represent LDD samples
- Simulation across entire diamond size frequency range
- High and low-grade kimberlites simulated
- Local estimates: 50x50x16m; 40x40x16m; 30x30x16m
- Increased sampling in the horizontal or vertical dimension for better block-by-block correlation?







CONCLUSIONS

- No reasons found why microdiamonds cannot be used for local estimation purposes
- Possible to assign a resource classification to deeper parts of a kimberlite not accessible through traditional LDD
- Basic precautions required:
  - Robust geological model
  - Prior agreement regarding the level of confidence required
  - Sample support size and drill grid optimisation required (higher sample variance)
  - Provision for macrodiamond sampling to assess integrity of the size frequency distribution as well as diamond revenue
  - Demonstrable stability of the size frequency distribution
  - Careful analysis of the individual microdiamond samples
- Sample optimisations are not universally applicable, but kimberlite-specific
- De Beers uses an annual production increment for micro-macro comparisons

THANK YOU