Application of the microdiamond technique in assisting diamond mining juniors to make rapid technical and economic decisions

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SAIMM “Diamonds: Source to Use”

13 June 2018
INTRODUCTION

• Frischgewaagt kimberlite dyke in Limpopo, RSA
  – Explored by Vutomi Mining (Pty) Ltd & Botswana Diamonds plc

• **Microdiamond analysis** (MiDA) technique,

• Combined with
  – *macrodiamond results* from two surface sampling programmes (SSP’s)
  – geological information (petrography)
  – size-frequency distributions of historical mining data
  ➢ Calculate total in-situ carat content (TCC) range

• To support the risk-based decision making required by Diamond Mining Juniors

• Optimize the resource development program budget

• Calculate a well constrained grade range
FRISCHGEWAAGT KIMBERLITE
THORNY RIVER PROJECT LOCATION

[Map showing the location of the Thorney River Project]
FRISCHGEWAAGT KIMBERLITE DYKE
HISTORICAL WORK DONE

- Previous Work Done by Vutomi
  - Several phases of drilling
  - Heavy Mineral Analysis by MSA
  - Kimberlite Indicator Mineral (KIM) Chemistry Analysis by UJ

Evaluation of Kimberlite Discoveries

- Indicator mineral Chemistry / Diamond Potential
- Prioritise kimberlites for evaluation
- Microdiamond Analysis (MiDA)
- Surface sampling
  - Macro diamond recovery
  - Diamond valuation
THE MSA GROUP – Diamond Exploration Lab

The MSA Group Diamond Analytical Services ISO17025 Accredited since May 2012

Accreditation No. T0544
SAMPLING RESULTS – MINCHEM (1)

- KIM Chemistry: 209 PERIDOTITIC GARNETS

A-C From Westerlund (2000)
SAMPLING RESULTS – MINCHEM (2)

• KIM Chemistry: 42 ECLOGITIC GARNETS

A-C From Westerlund (2000)
SAMPLING RESULTS – 2015 SSP

• 2015 Vutomi Surface Sampling Programme
  • 3,647 t material processed
  • 466 macrodiamonds recovered from surface sampling,
  • 236 carats
  • 6.5 cpht for the dyke sampled
  • Valued at $180/ct
SAMPLING RESULTS – 2015 SSP

• 2015 Vutomi Surface Sampling Programme

  • *In-situ grade estimation* required several *supporting estimates*
    – Mass of material sampled
    – Visual estimation of contamination & dilution
    – Compensating for scrubber oversize & processing losses

• Actual mass kimberlite processed **253 t**

• Calculated *in-situ grade* ~ **62 cpht**

• Low confidence in accuracy of grade

• But *size frequency distribution* still relevant for *grade modelling*
SAMPLING RESULTS - BOD

• 2017 Sampling carried out by Botswana Diamonds PLC (BOD)
  
  – Ground Geophysics
  – Percussion and core drilling
  – Petrographic analysis

• Group 2, coherent hypabyssal (magmatic) kimberlite (Robey, 2017).

• Compared with historical data from Marsfontein and Klipspringer

➢ indicate all dykes & blows probably part of same kimberlite complex
SAMPLING RESULTS - BOD

• 2017 Sampling carried out by Botswana Diamonds PLC (BOD)
  
  – Microdiamond analysis

Evaluation of Kimberlite Discoveries

• Indicator mineral Chemistry / Diamond Potential

• Prioritise kimberlites for evaluation

• Microdiamond Analysis (MiDA)

• Surface sampling
  – Macro diamond recovery
  – Diamond valuation
MICRODIAMOND ANALYSIS

• MSA established first MiDA lab in 2006 (SGS South Africa)
• Since 2016 custom-built facility operated by Min-Met Equipment (Pty) Ltd
• The only Caustic Fusion and MiDA lab in Africa
MICRODIAMOND ANALYSIS (continued)

• Synthetic diamond QC Spikes
• All stones screened, measured (X,Y,Z) described and weighed
• Diamonds stored on mineral cards and data captured
MICRODIAMOND RESULTS

- Microdiamond analysis
  - 160kg core
  - From 'Dyke Proper', 'Central Blow' and 'Second Blow'
  - **223 microdiamonds** recovered
  - 98% QC spikes recovered
  - Screened (Taylor sieves)

<table>
<thead>
<tr>
<th>Sample location</th>
<th>Sample ID</th>
<th>Sample Weight (kg)</th>
<th>Total # diamonds</th>
<th>Diamond Size Fractions (mm)</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.18</td>
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<tr>
<td>Dyke Proper (27.1kg)</td>
<td>B3017</td>
<td>10.6</td>
<td>9</td>
<td>0</td>
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<tr>
<td></td>
<td>B3018</td>
<td>10.45</td>
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<td>0</td>
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<td></td>
<td>B3019</td>
<td>6.05</td>
<td>7</td>
<td>0</td>
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<tr>
<td>Central Blow (58.2kg)</td>
<td>B3015</td>
<td>6.65</td>
<td>4</td>
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<td></td>
<td>B3016</td>
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<td></td>
<td>B3021</td>
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<td>59</td>
<td>0</td>
</tr>
<tr>
<td>Second Blow (75.16kg)</td>
<td>B3020</td>
<td>10.2</td>
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<tr>
<td></td>
<td>B3022</td>
<td>64.96</td>
<td>103</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>160.46</strong></td>
<td><strong>223</strong></td>
<td><strong>7</strong></td>
<td><strong>10</strong></td>
</tr>
</tbody>
</table>
PRELIMINARY GRADE ESTIMATION (1)

• Preliminary Grade Estimation by Ferreira
  
  – **Mida** results together with **macrodiamonds from 2015 SSP**
  – Preliminary grade estimation
  – Early stage exploration evaluation to determine if further work is warranted
  – Modelling done with various methods
    
    • Using avg stone density,
    
    • size distribution using all size classes and
    
    • size distribution excluding two +0.6mm microdiamonds
  – Combined sample “Central Blow” and “Second Blow” (133kg)
  – Estimated grade range **20 – 270 cpht** at BCOS of 0.6 mm
TOTAL DIAMOND CONTENT MODEL

Range: 20 – 270 cpht

Uncertainty in grade due to

- Small sample size
- Low stone counts
- Nature of distribution of stones in size classes

Note: The upper end of the estimated grade range is supported by the result of 2015 SSP (207t surface sample, 236 ct)

From Ferreira (2017)
REFINEMENT OF GRADE ESTIMATION (2)

- Refinement of Preliminary Grade Estimation by Petersen
  - Modelling repeated using empirical data
  - Insufficient +1-3mm stones from 2015 SSP to anchor model
  - historic total content data used as proxy to bridge micro- and macrodiamond datasets
  - Grade refined to 78 cpht with a range of 64 – 113 cpht at BCOS +1mm

From Petersen (2017)
BOD 2017 SURFACE SAMPLING

• Surface Sampling Programme by BOD in November 2017
  • 42 m trench along strike of Frischgewaagt dyke
  • 305 dry tons of kimberlite and host rock
BOD 2017 SURFACE SAMPLING

- Aim to provide additional confidence to 2015 macrodiamond results
  - processing accurately known quantity kimberlite
  - recover stones 1-3mm size fraction (link up the MiDA – macro models)
  - refine the grade estimate
  - estimate the true total diamond content (TTC)
  - recover sufficient diamonds for valuation (inform the financial model)
BOD 2017 SURFACE SAMPLING

- Surface Sampling Programme Macrodiamonds
  - 512 macrodiamonds recovered
  - 62 carats
  - Recovered diluted grade of 20.7 cpht

- +11 Diamond Sieve
- +9 Diamond Sieve
GRADE ESTIMATION (3)

- Grade estimation using 2017 SSP data (Peterson, 2017)
- Biggest uncertainty in calculating **in-situ kimberlite grade** is **dilution** of kimberlite sample.
- Uncertainty in contact between weathered kimberlite dyke and host rock
  - gradational boundary of kimberlite,
  - parallel faulting during dyke emplacement

From Petersen (2017)
GRADE ESTIMATION (3 continued)

- External dilution calculated: planned vs actual size sample
- Proportion of kimberlite: estimated volume of kimberlite
  volume of excavation

From Petersen (2017)
GRADE ESTIMATION (4 continued)

• Determine actual quantity of kimberlite mined (Coward)
• Combine undiluted grade with
  – Metallurgical process efficiencies
  – modelled SFD

➤ Undiluted in-situ **Total Content** grade range of **46-74 cpht**
  (at BCOS of +1 mm) (Coward, 2018)

• Published resource grade of nearby Klipspringer Mine
  **49 cpht** (at BCOS of +1 mm) (Bartlett, 2012).
MACRODIAMONDS vs MICRODIAMONDS

- Valuation of 83 diamonds (54.32 ct) by QTS Kristal Dinamika (Ferraris & Bouquet, 2017)
- Crystal shapes compare well with microdiamonds
FTIR of MICRODIAMONDS

- Fourier transform infrared spectroscopy (FTIR analysis)
- Type II microdiamonds present
- Type 0.150mm microdiamonds
SUMMARY

2014 HMA & MinChem
209 Gar
18% G10D

2015 SSP (Vutomi)
3647 t
466 macros / 236 ct
6.5 cpht

In-situ grade (estim)
62 cpht

2017 SSP (BOD)
305 t
512 macros / 62 ct
20.69 cpht

2017 CF & MiDA
160 kg
223 MiDA’s

Initial Grade
Estim (Ferreira)
20 - 270 cpht

Recoverd (diluted) grade
20.69 cpht

Refined Grade
Estim (Petersen)
78 cpht
(range 64-113 cpht)

In-situ Grade
46 - 74 cpht
(at BCOS +1mm)

Adjust for dilution, processing losses and diamond SFD (Coward)
CONCLUSION

• MiDA is highly recommended by MSA for first stage cost effective evaluation of kimberlites
  – Establish whether newly discovered kimberlite body (dyke or pipe) is barren or diamondiferous
  – Helps prioritise targets for bulk sampling or “walk away” decision
  – Diamond content estimation of different phases/domains
  – Characterisation of micro populations
  – Should sufficient diamonds be recovered, the size frequency distribution (SFD) from microdiamond data can be modelled to predict macro diamond grade
CONCLUSION (continued)

• Early project evaluation using MiDA combined with
  – Geological information (spatial distribution, petrography, mineralogy)
  – Historical diamond size frequency distributions (e.g. Klipspringer)
  – Early stage diamond population characterization

• Provide a better understanding of targeted orebody

• With limited macrodiamonds recovered from surface sampling, can achieve fairly constrained grade range of 46-74 cpht (at BCOS of +1 mm)

• Optimize greenfields and brownfields exploration budgets
CONCLUSION (continued)

• BOD 2017 SSP yielded insufficient macrodiamonds for valuation and resource estimation (62.88 ct)

BUT

• Combined with MiDA data the total carat content (TCC) range could be calculated (46-74 cpht)

• This project illustrates how microdiamond analysis was crucial for a preliminary valuation

• Further work: to narrow the grade range
  – additional bulk sampling needs to take place;
  – will supply the required 500 carats to be valued
  – to establish an inferred resource estimate.
Thank you