Technological approaches to diamond exploration on the Thorny River prospect, South Africa

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Outline

- General Geology
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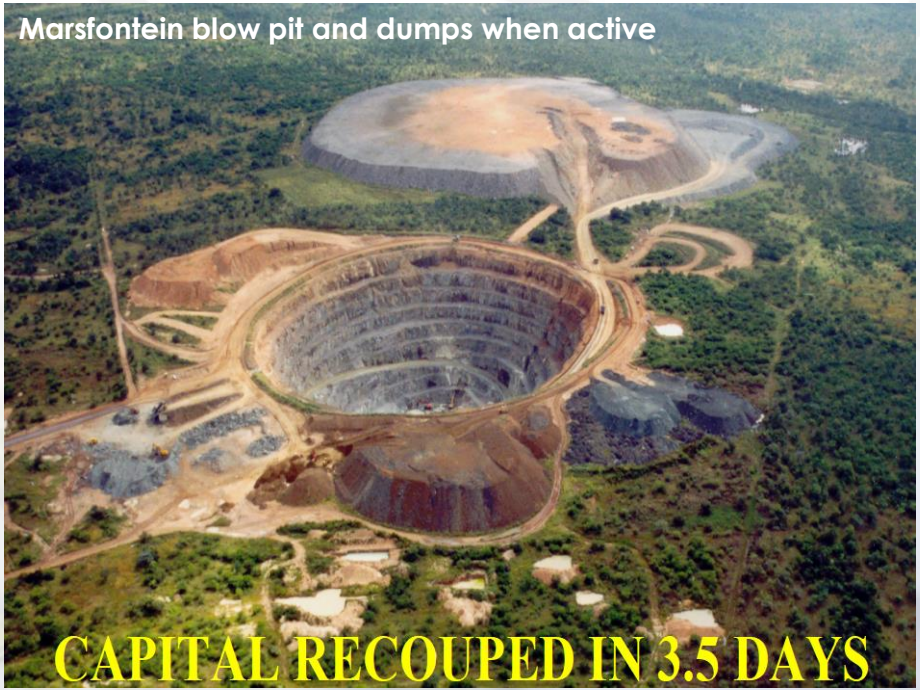


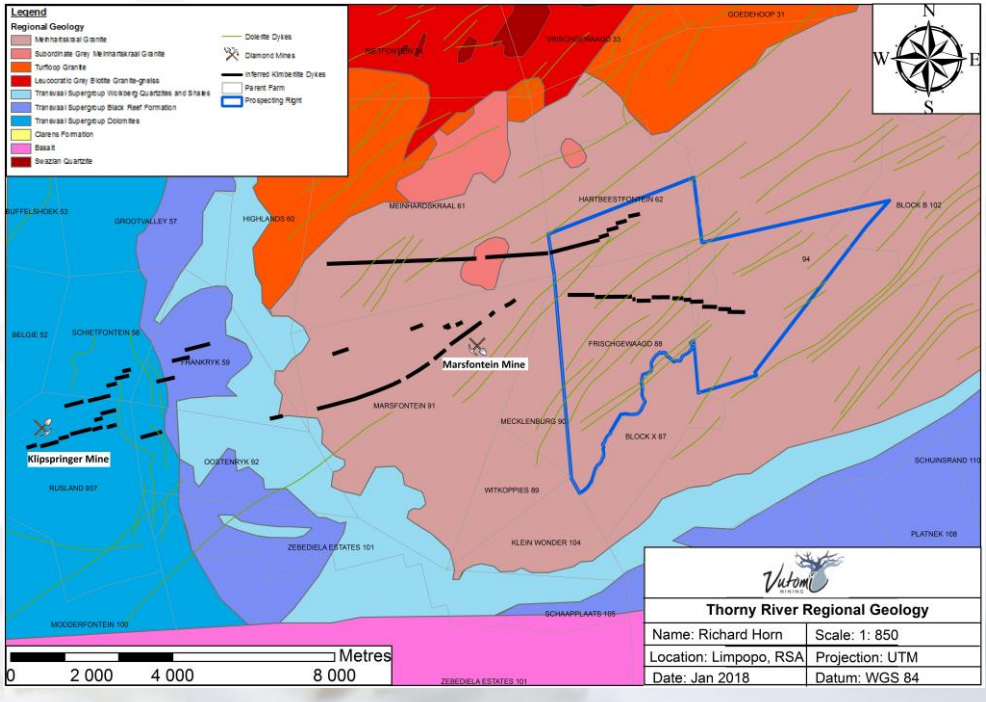
Reference: Allan, 1999

Introduction

Photo: Andreas Stelzer

General Geology

- The region is underlain by the **Kaapvaal craton**.
- In the vicinity of the Klipspringer mine, sediments of the Transvaal Supergroup occur. These comprise the Chuniespoort dolomites, basal Black Reef Formation and the pre-Black Reef units of the Wolkberg Group.
- In the east, the geology comprises exposed Archaean Turfloop and Meinhardskraal granites and Archaean granite gneisses. Remnants of ancient Greenstone belts occur to the north-east of the region.
- The **Zebedelia kimberlites** are intrusive into the Archaean Meinhardskraal granites and younger dolerites in the east, and the Transvaal Supergroup sedimentary rocks in the west.
- The kimberlites are classified as **Group 2** and are 155.1 +/-0.8 Ma in age.



References: Marshall & Campbell, 2018; Kiviets & Barton 1999

History

- De Beers sampled the area during the 1970-80's.
- Klipspringer discovered in 1987 by De Beers*.
- SouthernEra announced discovery of Marsfontein in 1995 and mined in JV with De Beers 1999-2000 with a **payback of less than 4 days**.
  - 970k tons produced 1.8M carats in 18-months
- **Three further blows discovered**: Sugarbird (which paid for the development of Klipspringer), Sugarbird Pass and Kudu.
- SouthernEra mined Klipspringer from 1998-2004 until the mine was placed on care and maintenance following flooding.
- Klipspringer has since been owned by Mwana Africa plc, ASA Resource Group plc and SLA Capital none of which have re-opened the mine.
  - The mine has **2.2M tons @ 73cpht** in its disclosed resource statement (BCOS of +1.2mm).


Underground at Klipspringer

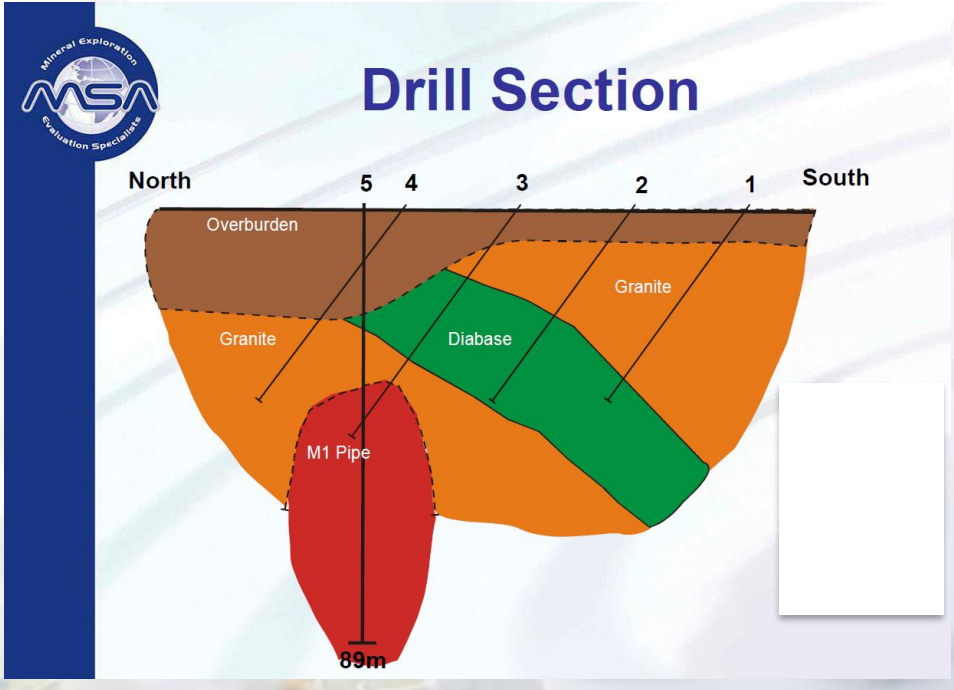

Marsfontein blow pit


Sugarbird blow pit

References: Scott, 2005; Allan, 1999; ASA Resources plc website

Strategy: to find another Marsfontein!

- Abundant kimberlitic indicators (particularly garnet, spinel and chromium diopside) present so loam sampling is a useful reconnaissance tool.
- Electromagnetics ('EM') produces good anomalies over the kimberlite.
- Blows tend to occur on the confluence of the kimberlite and dolerite dykes (ie. **structurally controlled**).
- These can be obscured by dolerite dykes.
- Requires **precision geological work** in these areas, including gravity, structural mapping, drone surveying, satellite imagery and drilling.

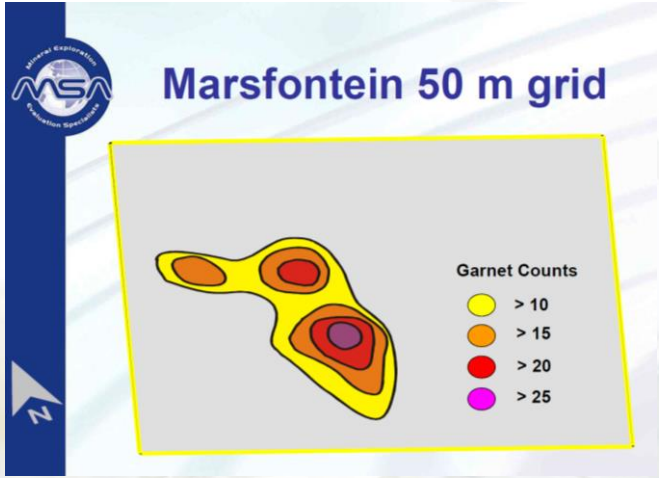


Reference: Scott, 2005

Technological Approaches

Soil Sampling

- Soil (loam) sampling a good first pass reconnaissance and follow-up exploration tool.
- **Abundant kimberlitic minerals**: garnet, spinel and chromium diopside proximal to the kimberlite.
- **Strong halo effect**: coarse grains don't tend to travel far.

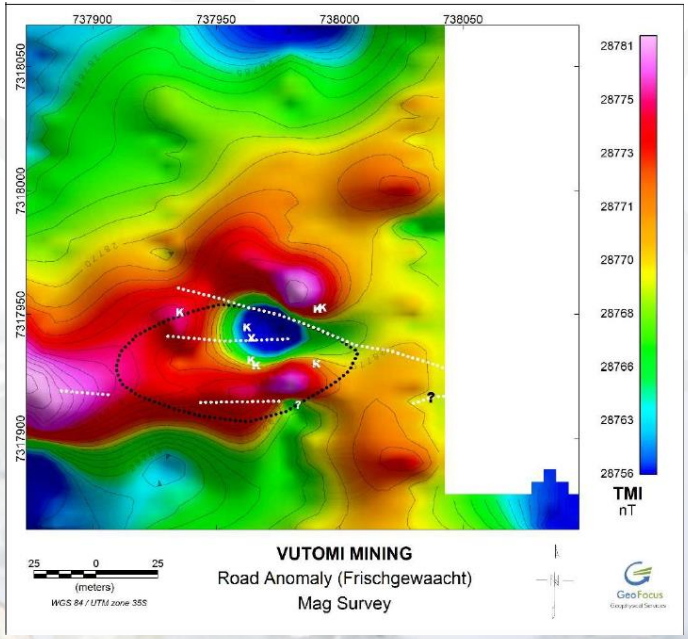


Eclogitic and peridotitic garnets, chromium diopside and spinel

Reference: Scott, 2005

Ground Geophysics - Magnetics

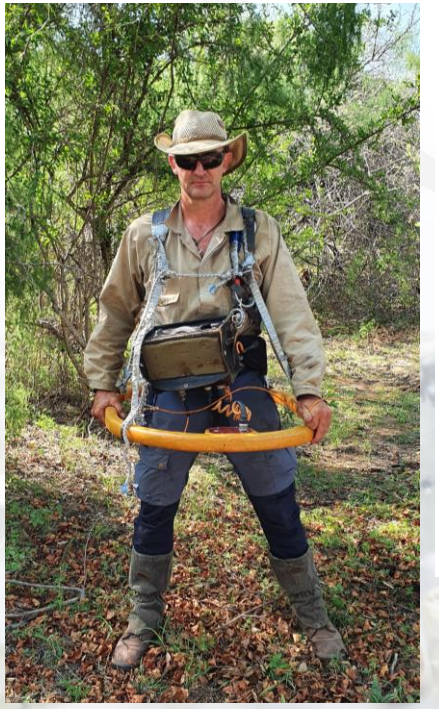
- Magnetics tend to chiefly **outline the dolerite** and not kimberlite dykes as the latter are only weakly magnetic.
- Magnetic susceptibility readings from drill core show that on average, the kimberlite has a susceptibility of 0.47SI with a maximum of 1.3SI
- Quick and relatively cheap technique.

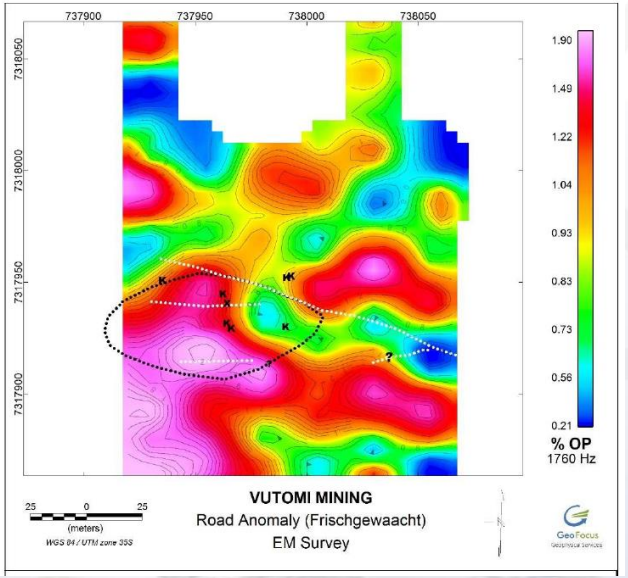


Reference: Geofocus, 2020

Ground geophysics – Electromagnetics

- Frequency Domain Electro-magnetics (Max/Min) will outline both dolerite and kimberlite dykes.
- Used in combination with magnetics, Max/Min is a useful tool in **delineating the kimberlite dykes**.
- This technique can acquire data over multiple frequencies at various coil spacing.
- Also a quick and relatively cheap technique.

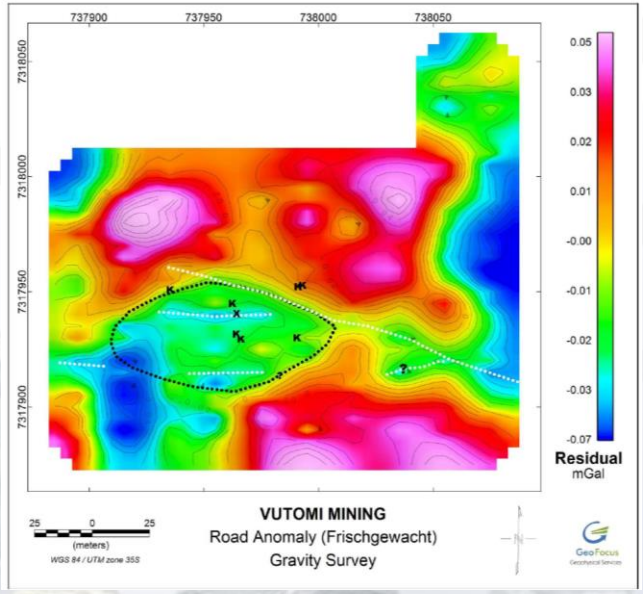




Reference: Geofocus, 2020

Ground geophysics - Gravity

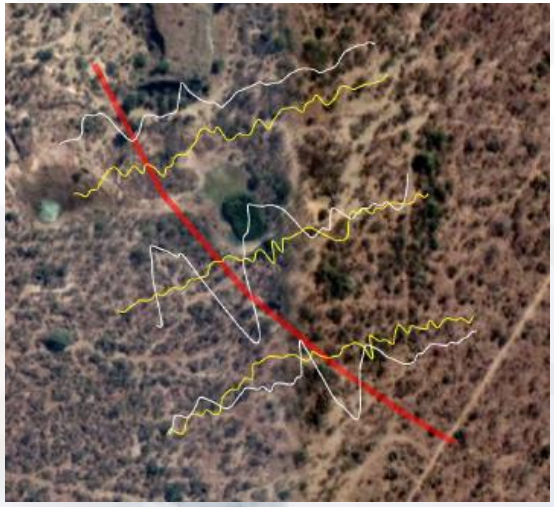
- Gravity is used where we believe there is a **kimberlite blow**.
- Blows tend to produce gravity lows.
- It is a more time consuming and complex technique and thus more costly so is restricted to specific targets.



Reference: Geofocus, 2020

Ground geophysics - GPRS

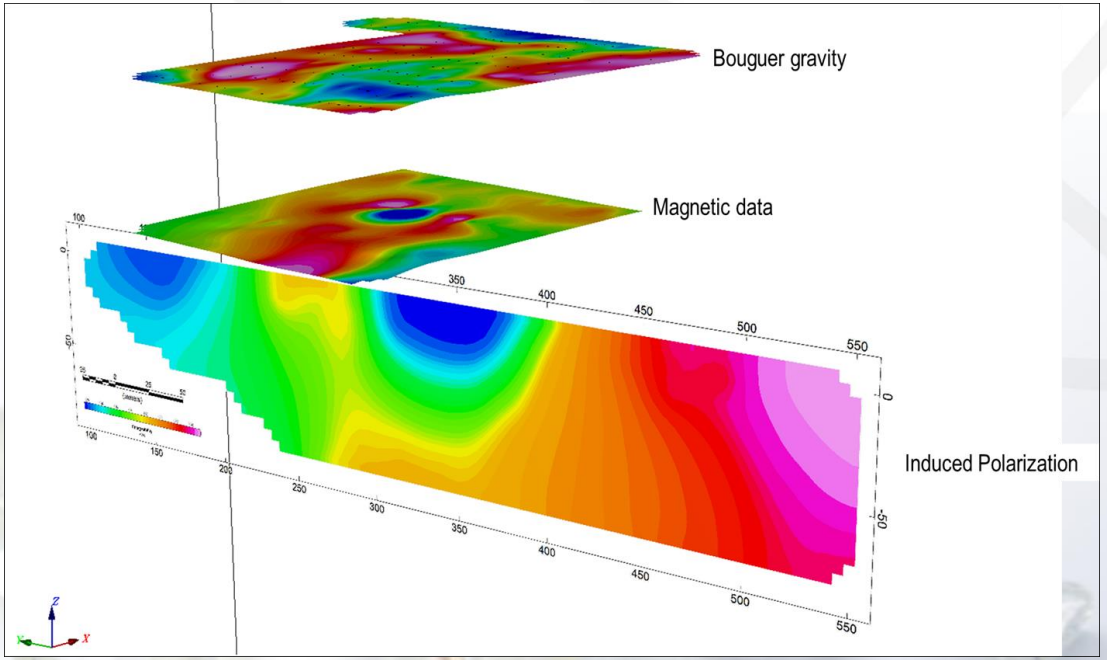
- A Ground Penetrating Radar System ('GPRS') was used to delineate the channels on the **Marsfontein sheet gravels**.
- Quick and relatively cheap.
- As the channels are relatively shallow, a higher frequency antenna would probably be required for better definition.



References: Geofocus, 2020; Diamexstrat Botswana, 2021

Ground geophysics – Induced Polarisation

- Induced Polarisation ('IP')was tested on the property by the **Council for Geoscience** ('CGS').
- IP is a geophysical imaging technique used to identify the **electrical chargeability** of **subsurface materials**.
- It is particularly focused on the chargeable materials being clays (viz. **weathered kimberlite**)
- Still work in progress.



Reference: Khoza, 2021

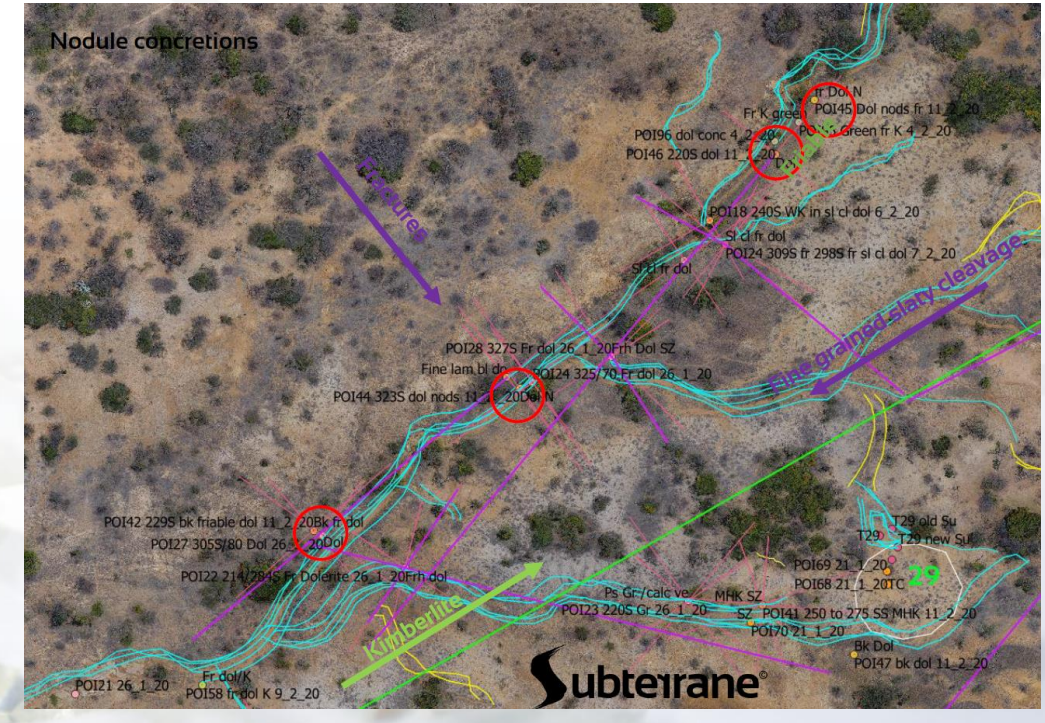
Drone Surveys

- Detailed drone surveys undertaken over much of the property.
- The aim of these surveys was to:
  - Provide **accurate georeferences** for groundwork, such as drilling and geological mapping.
  - Assess vegetation anomalies.
- The tool was also helpful in the production of videos for **public relations** purposes.

Reference: Shelton, 2018

Precision Structural Mapping

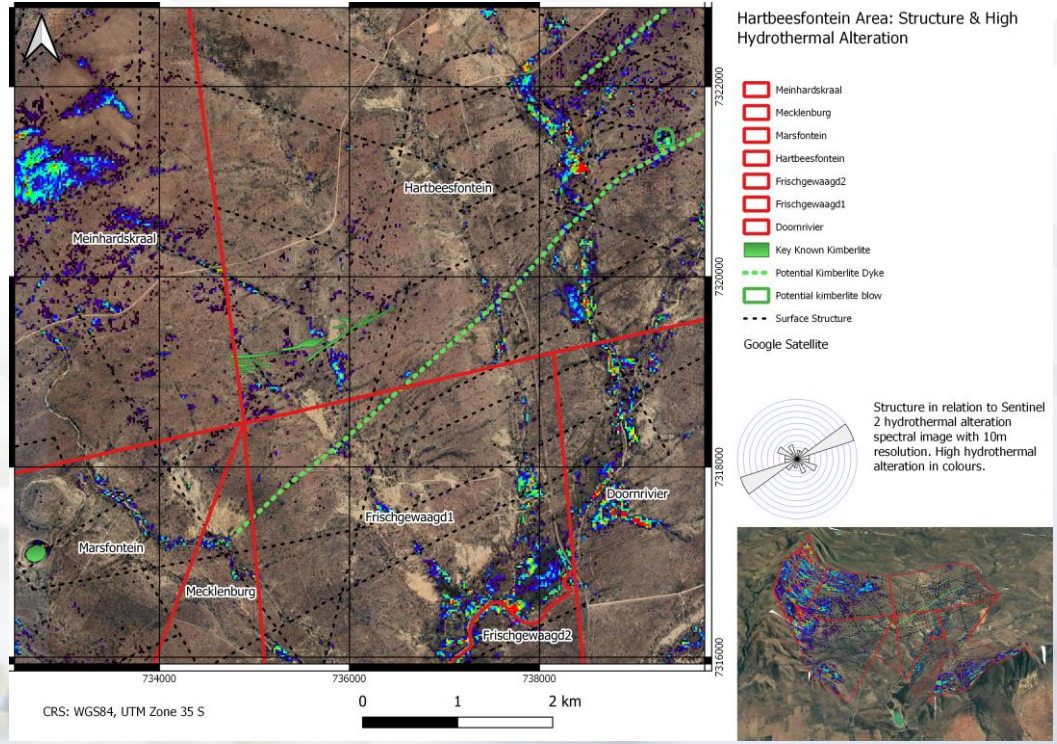
- Subterrane of the UK uses a combination of **precision field structural geological measurements** in combination with detailed ground geophysics to identify targets.
- Targets are defined as buried or partially buried (potential) blows.
- This is still very much work in progress and has been considerably delayed due to Covid related travel restrictions.



Reference: Subterrane, 2018

Spectral analysis

- Terramodelling Services of Canada used **machine** and **deep learning** to delineate spectral anomalies from European Space Agency Sentinel 1 / 2 and ASTER data.
- The following were assessed:
  - Structure
  - Topography
  - Elevation and displacement
  - Hydrothermal alteration
  - Epidote and chlorite alteration
  - Radon affected vegetation
  - Ferrous and ferric oxide spectra
  - ASTER mica and serpentine spectra
- Satellite and UAV spectral analysis, combined with machine and deep learning, has **fundamentally changed the remote sensing landscape** in the last 5-years.



Reference: Terramodelling, 2020

Drilling – RC Percussion

- Reverse Circulation ('RC') drilling follows positive sampling and ground geophysical work.
- Both angle and vertical holes were drilled.
- The diameter of the holes was 140mm and a continuous 1m sample was taken and bagged.
- Portions of these samples were washed and geologically logged.
- **Kimberlitic indicators** and **diamonds** were recovered from select samples down to +0.3mm following screening, separation using Tetrabromoethane (TBE') and hand sorting.

Percussion drill chips from various rock types

Reference: Georoc, 2020

Drilling - Core

- Core drilling was carried out where there was a requirement for more detailed geological data.
- The core was subjected to detailed **independent petrographic work**.
- Samples from the core were also taken for **microdiamond analyses**.

Reference: Georoc, 2017

Bulk Sampling

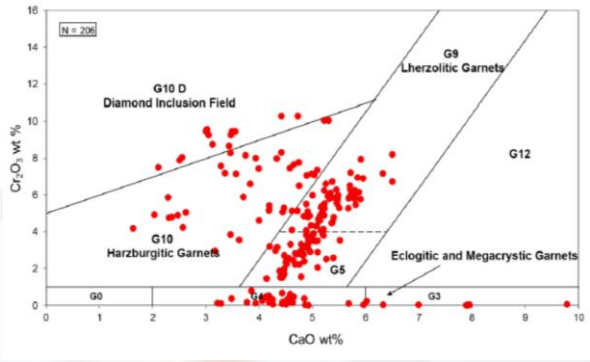
- Bulk sampling was undertaken in an area where the kimberlite dyke swelled.
- The purpose of the bulk sampling was to produce sufficient macro diamonds for **preliminary grade** and **valuation models**.
- The samples were processed at an independent bulk sampling plant which included crushing, scrubbing, screening, dense media separation ('DMS'), X-Ray and grease recovery.
- The area was **fully rehabilitated** on conclusion of the exercise.

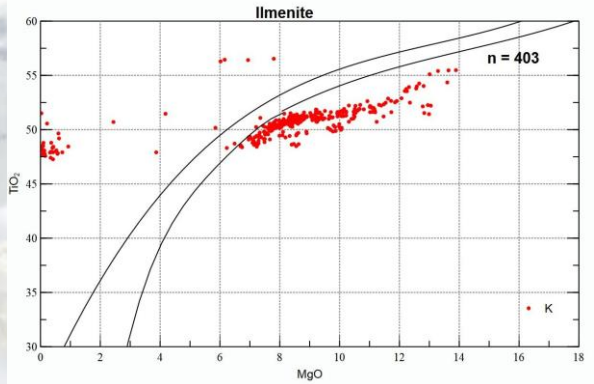
Reference: Vutomi, 2017

Results

Mineral Chemistry

- Around 54% of garnets fall into the G9/G5 category (garnets that originate from lherzolites and websterites).
- 19% fall in the G10 field (garnets originating from harzburgites) and **7% garnets in the G10D (diamond inclusion) field**.
  - The G10D garnets, plotting within the diamond inclusion field, indicate the possibility of **peridotitic diamonds** sampled by the kimberlite from which this sample has been taken.
- 20% of the garnets (with Cr_2O_3 less than 2%) fall in the G3 and G4 (eclogitic and megacrystic garnet) fields.
  - There is a population of eclogitic Group 1 garnets which suggests the source may also contain **diamonds** of **eclogitic origin**.
- Recent work by Tappe suggests that the kimberlite could be a **hybrid Group 1 / 2 variety**.

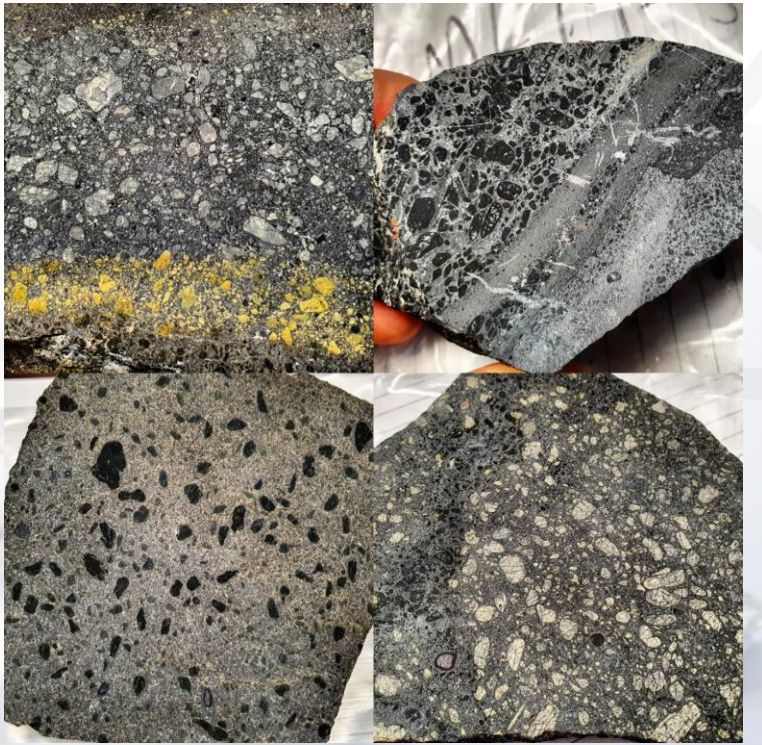




References: Marshall & Campbell, 2018, Tappe 2021

Petrography

- All kimberlite samples are **Group 2 variety, coherent hypabyssal kimberlites** with mineralogies dominated by calcite and phlogopite but with accessory apatite and in some samples monticellite, clinopyroxene and richterite amphibole. Fine grained perovskite and opaques are also present.
- All kimberlite samples can be classified as **apatite-bearing calcite phlogopite kimberlites**.
- For comparison, the Marsfontein pipe has two kimberlite phases – a monticellite phlogopite phase and a phlogopite monticellite phase.
- Where the dyke gets wider variable mineralogy is seen, with the crystallization of accessory clinopyroxene, amphibole richterite and monticellite.

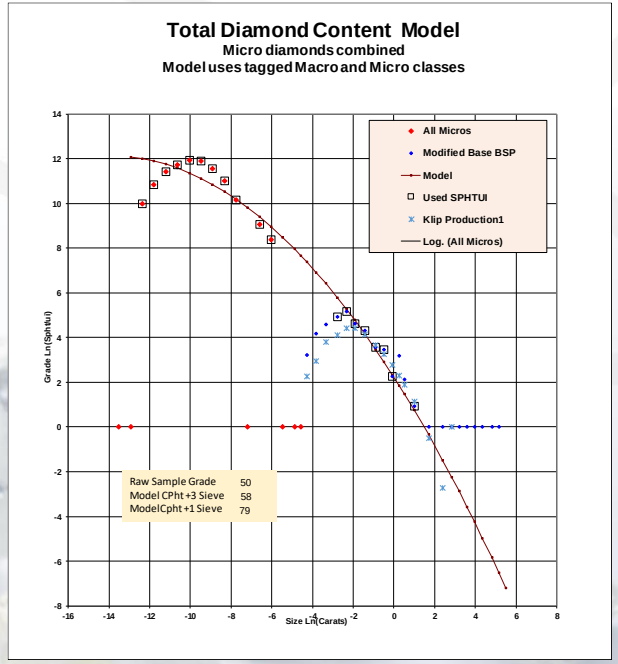


References: Robey, Mishra, 2017

Diamonds: Macro & Micro

- Select core samples were taken for microdiamond work and processed at an independent laboratory.
- A trench was excavated for the recovery of macrodiamonds and processed at an independent bulk sample processing facility.
- Micro-macrodiamond modelling was performed to derive a **Total Content Curve**.
- The macro diamonds were described and **valued**.

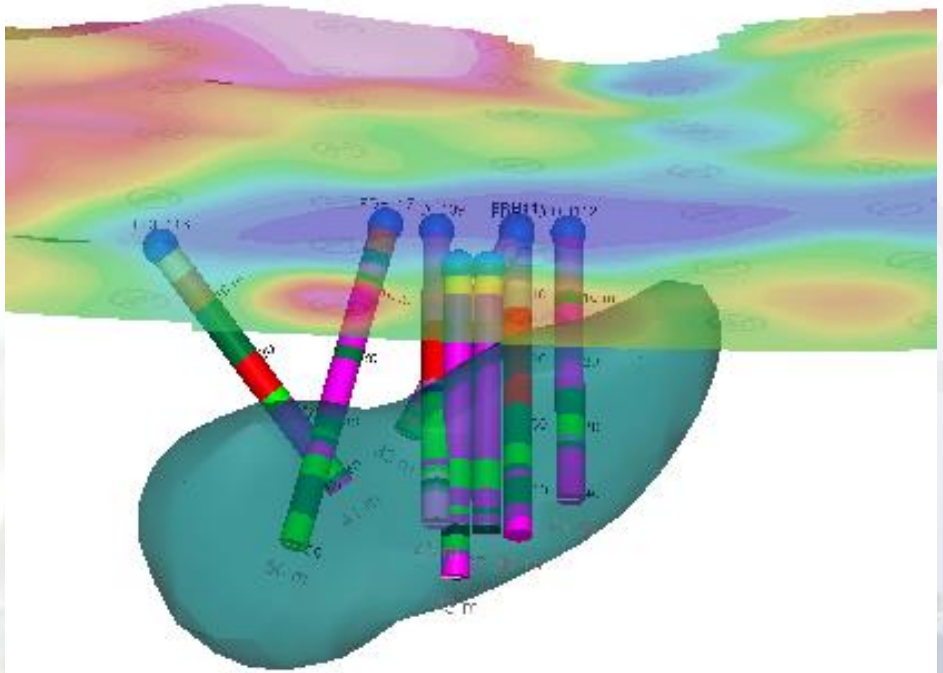
+9 Diamond Sieve



References: Coward, Ferraris, 2017

Geological Modelling

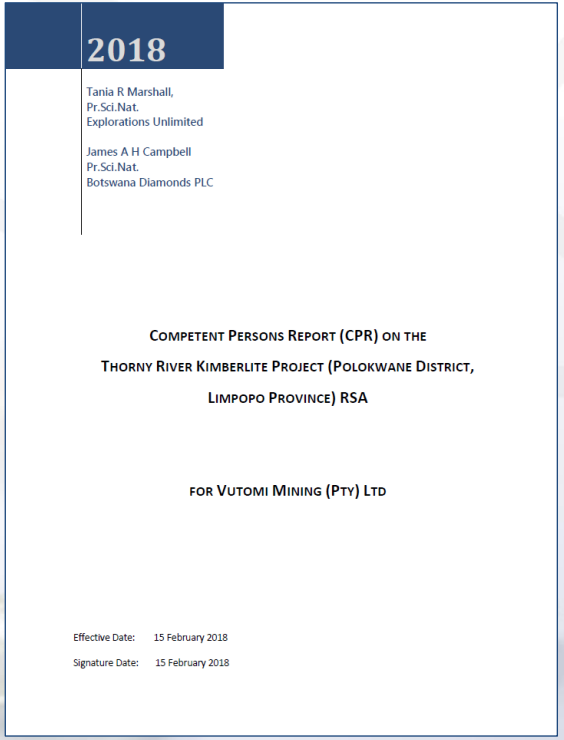
- Detailed ground geophysical work supplemented by drilling results has enabled kimberlite modelling using **Inversion** and **Forward Modelling Techniques**.
- Estimated volume so far of 72,000m^3.
- This work is being expanded to cover both the River and River Extension blows.
- This technique has **significant advantages** over just using the drill data especially due to the complexity of the kimberlite root zone structures and uses all available data.



Model of the River blow

Competent Persons Report ('CPR')

- Published in February 2018.
- "Based on the exploration results to date, exploration targets have been highlighted with the following potential:
  - The undiluted raw in-situ grade of the kimberlite dyke sample is estimated between **46-74 cpht** (1mm bcos). By contrast, the micro macro models return a range of total content model grade that falls between 54 to 88 cpht at bottom cut off size of +3 DTC diamond sieve (1mm).
  - Wide range of modelled diamond values at **USD120-220/ct** (at 1mm bcos).
  - Potential volumes of some **450,000 – 470,000m^3**. Using the estimated 2.6g/cm^3 density calculated by Vutomi, this may reflect target tonnages of over some 1.2MT to 100m depth."
- **Considerable work** has been done post this report.



2018

Tania R Marshall,
Pr.Sci.Nat.
Explorations Unlimited

James A H Campbell
Pr.Sci.Nat.
Botswana Diamonds PLC

COMPETENT PERSONS REPORT (CPR) ON THE
THORNY RIVER KIMBERLITE PROJECT (POLOKWANE DISTRICT,
LIMPOPO PROVINCE) RSA

FOR VUTOMI MINING (PTY) LTD

Effective Date: 15 February 2018
Signature Date: 15 February 2018

Reference: Marshall & Campbell, 2018

Conclusion

Conclusion

- Modern diamond exploration requires the application of **advanced** and **complimentary technologies**.
- These are informed by the area's **geological model**.
- In this case, we are looking for **buried** or **partially buried kimberlite blows**.
- The level of precision required is high as the targets are often small: size does not necessarily matter here.
- Why has only one blow (Marsfontein) been discovered in the Nkumpi Valley?
  - Are there more blows to be found?
- Only with the **creative** and **precise application** of several technologies supported by strong field observations will we found out.
- And of course, **patient shareholders** …

The Nkumpi Valley: home to another Marsfontein?

Acknowledgments

Photo: John Shelton

Acknowledgements

- My Vutomi colleagues: John Shelton, Linesh Lutchmansingh & Dennis Kekana
- Explorations Unlimited: Prof Tania Marshall (Competent Persons Report).
- Geofocus: Bjorn Harvemann & Gavin Selfe (geophysical surveys).
- Subterrane: Andrew Long (detailed structural analysis).
- Terramodelling: Louis Fourie & Pieter du Plessis (spectral analysis).
- Diamexstrat Botswana: Mike Shaw (geophysical survey)
- Georoc Drilling: Corne Fondse (drilling)
- Council for Geoscience: Dr David Khoza (IP survey)
- University of Johannesburg: Prof Sebastian Tappe (mineral chemistry).
- Dr's Jock Robey & Gargi Mishra (petrography).
- Interlaced: Dr Stephen Coward (diamond modelling).
- QTS Kristal Dinamika: Ray Ferraris (diamond valuation).
- Historic papers and presentations: James Allan, Keith Scott, Kiviets & Barton

Thank You

Questions & Discussion

Photo: Andreas Stelzer

About the Author

- James Campbell is Managing Director of Botswana Diamonds plc (a diamond development company active in Botswana, South Africa and Zimbabwe and listed on London AIM and Botswana Stock Exchange). He has spent over thirty-five years in the diamond industry in a variety of leadership roles both in major and junior companies.
- Previous roles include Non-Executive Director of Shefa Gems; Chief Executive Officer and President of Rockwell Diamonds Inc; Non-Executive Director of Stellar Diamonds plc; Vice President - New Business for Lucara Diamond Corp, Managing Director of African Diamonds plc; Executive Deputy Chairman of West African Diamonds plc and Director of Swala Resources plc and Bugeco sa.
- James also worked at De Beers for over twenty years; his roles included General Manager for Advanced Exploration and Resource Delivery and the Executive Chairman Nicky Oppenheimer's first Personal Assistant.
- James holds degrees in Mining and Exploration Geology from the Royal School of Mines (Imperial College, London University) and an MBA with distinction (and top student prize) from Durham University. He is a Fellow of the Geological Society of South Africa, Institute of Mining, Metallurgy and Materials, South African Institute of Mining and Metallurgy and Institute of Directors of South Africa. He is also a Chartered Engineer (UK), Chartered Scientist (UK) and a Professional Natural Scientist (RSA).
- James is also chairman and founding director of Common Purpose South Africa NPC (a not-for-profit organization that develops leaders who can cross boundaries and is synonymous with the terms 'cultural intelligence' and 'leadership beyond authority'). CPSA celebrated its twentieth anniversary in 2020. He was also a director, trustee and chairman of the Joburg Ballet for almost fifteen years.

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