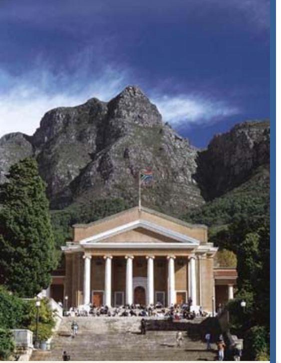

Addressing the elephant in the room: Integrating diamond breakage into kimberlite geometallurgy

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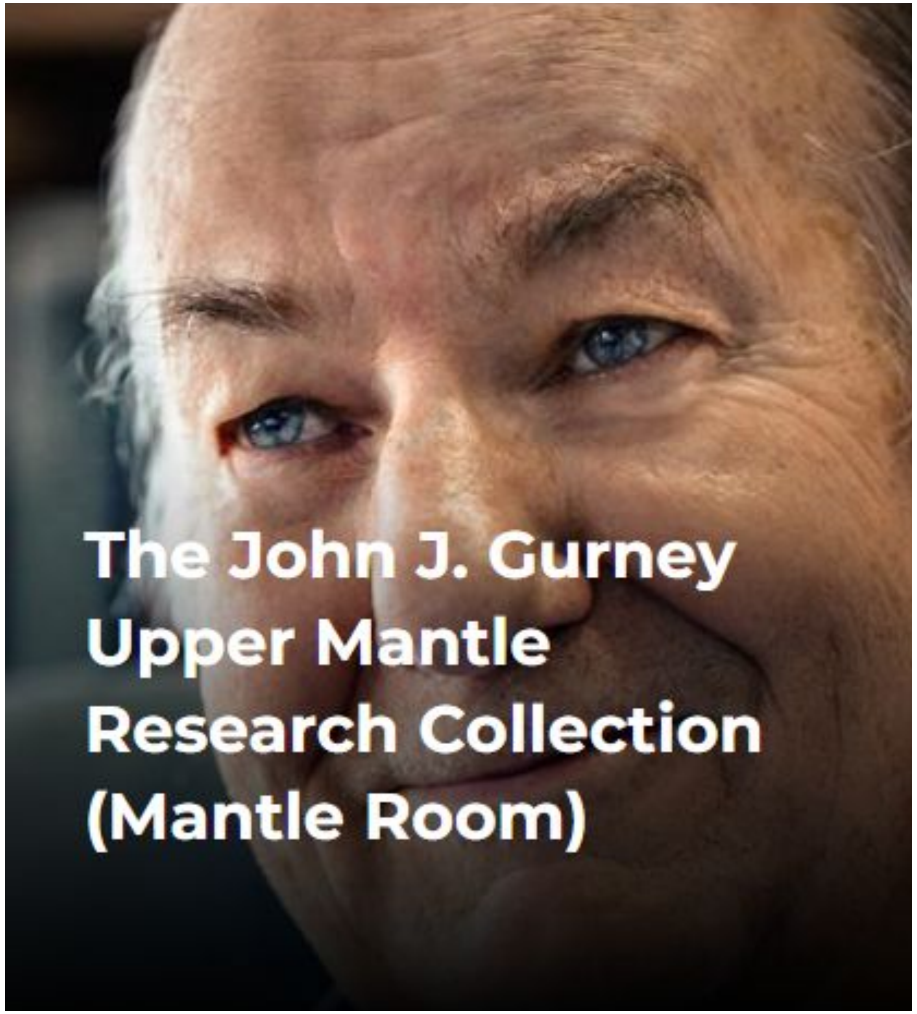
EBE UCT Engineering & The Built Environment

cimera



Southern Africa’s diamond landscape

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1866: ***First diamond (Eureka) was found by Erasmus Jacobs i6 on the farm De Kalk near the Orange River at Hopetown***

1871: ***Diamond rush peaks with Kimberley’s rich deposits***

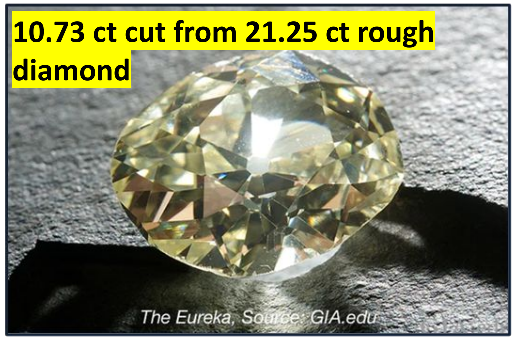
1888: ***Cecil John Rhodes founds De Beers Consolidated Mines***

1957: ***Lesotho makes its mark with the discovery of Letšeng, famous for its large (+10.8 carat) high value stones***

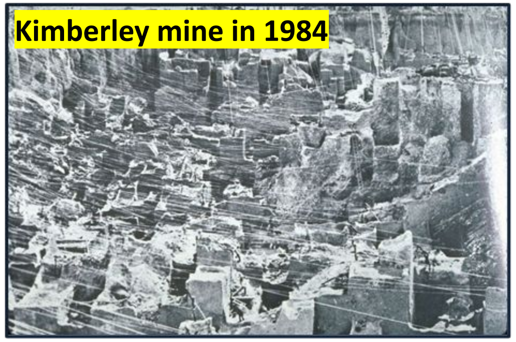
1967-70: ***Botswana's Orapa diamond field and Karowe are discovered, soon followed by Jwaneng in 1972, now the world’s richest diamond mine (US$20B in-situ value till 2020)***

1980: ***Venetia is discovered, and has become RSA’s largest diamond producer by volume***

2024: ***Karowe continues to shine with the discovery of the world’s second-largest diamond ever found (2,492 ct)***

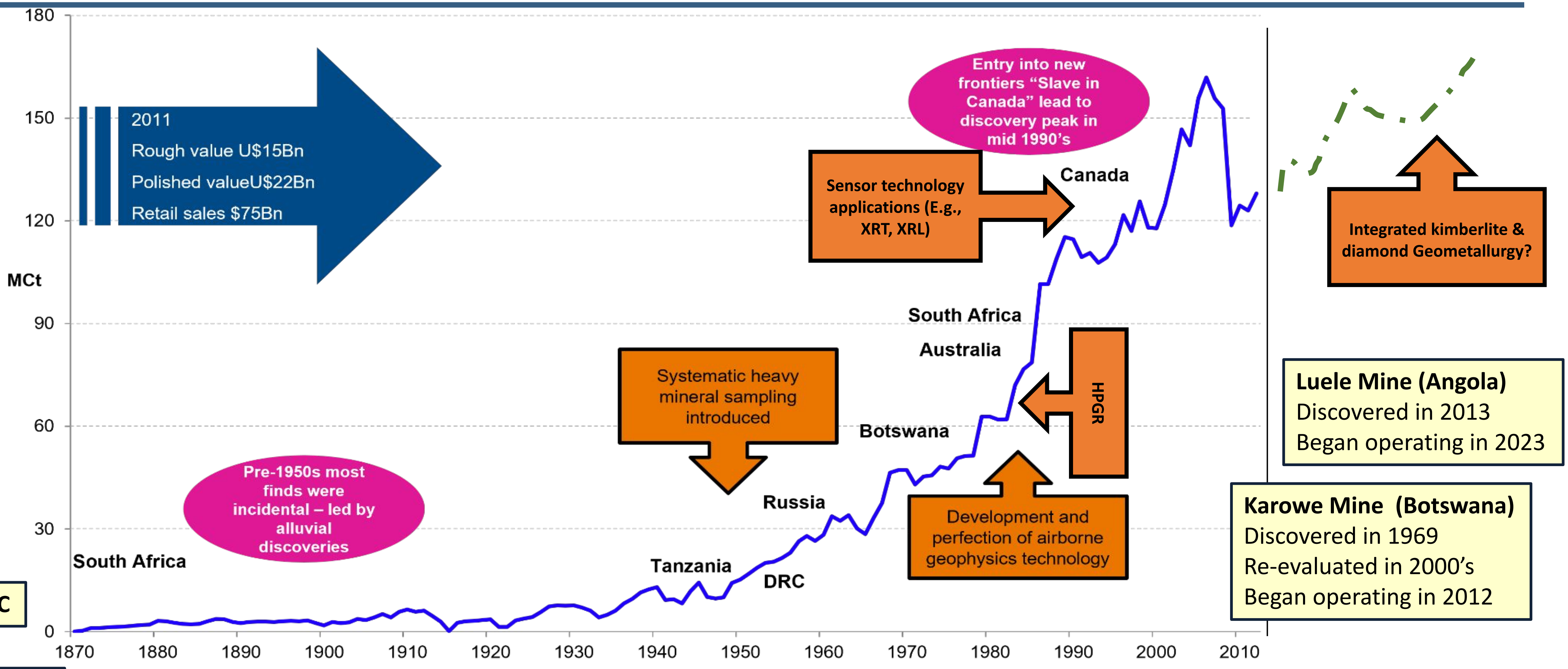


10.73 ct cut from 21.25 ct rough diamond



Kimberley mine in 1984

Trends in Global Diamond Production



Luele Mine (Angola)
Discovered in 2013
Began operating in 2023

Karowe Mine (Botswana)
Discovered in 1969
Re-evaluated in 2000's
Began operating in 2012

India ~400 BC

Brazil ~1725

(Original Image credit: I Chinn, De Beers)

Geometallurgy

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Geometallurgy definition: An approach / practice used to ***optimise the resource and manage the risk arising from ore variability*** through the mining value chain – ultimately centred on spatial ore body knowledge

Some key components of a GEOMET Model:

Input variables (principal features - characteristics)

- Geological and geochemical data
- Mineralogy and texture
- Alteration and related ore properties

Response variables (metallurgical parameters)

- Physical properties: density, SG, hardness, viscosity
- Processing behaviour: comminution response, metallurgical recovery

Results

- Model predictions

Prediction of rock strength (UCS) data using geotechnical logging data (RQD), Orapa diamond mine, Botswana (Lechuti-Tlhalerwa et al. (2018)

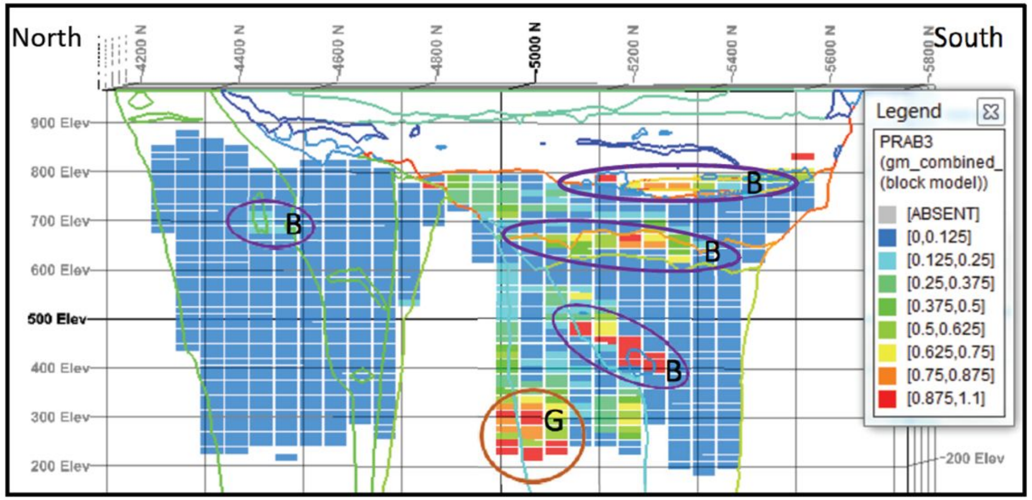

Figure 4. North-south vertical section showing geological outlines as lines and a block model colour-coded by estimated values of the probability of the UCS values in each block exceeding 80 MPa (a variable named PRAB3). Probabilities are presented as fractions (i.e. varying from 0 to 1). Basalt-rich zone are indicated with purple outlines and labelled as 'B', and granite-gneiss zone are outlined in orange and marked 'G'.

Input variables
(principal features - characteristics)

Kimberlite lithologies

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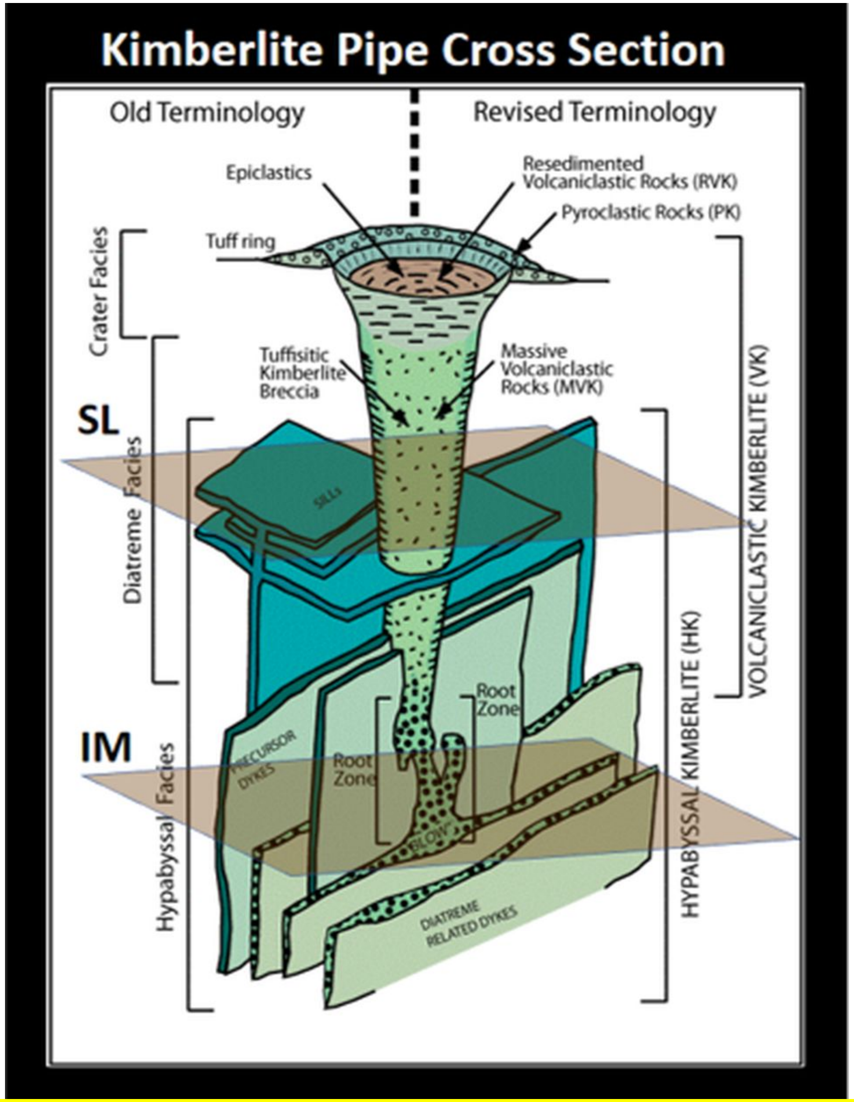
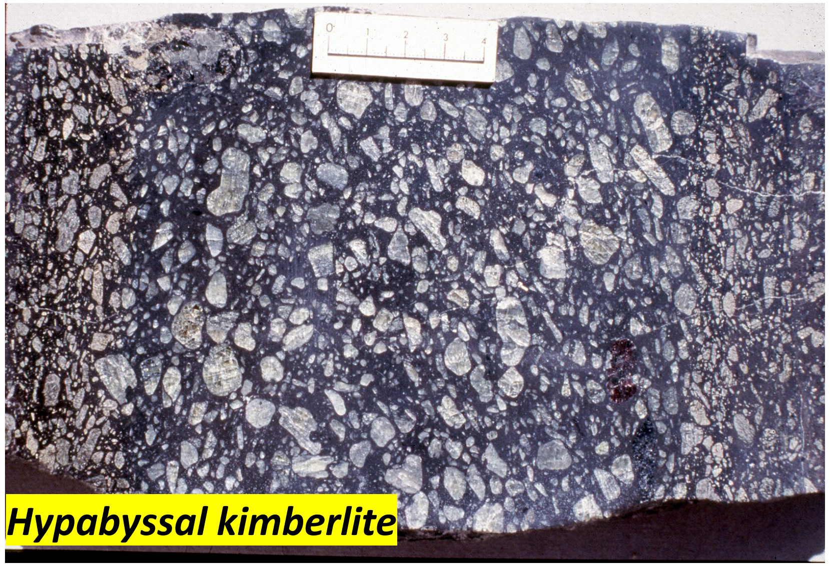
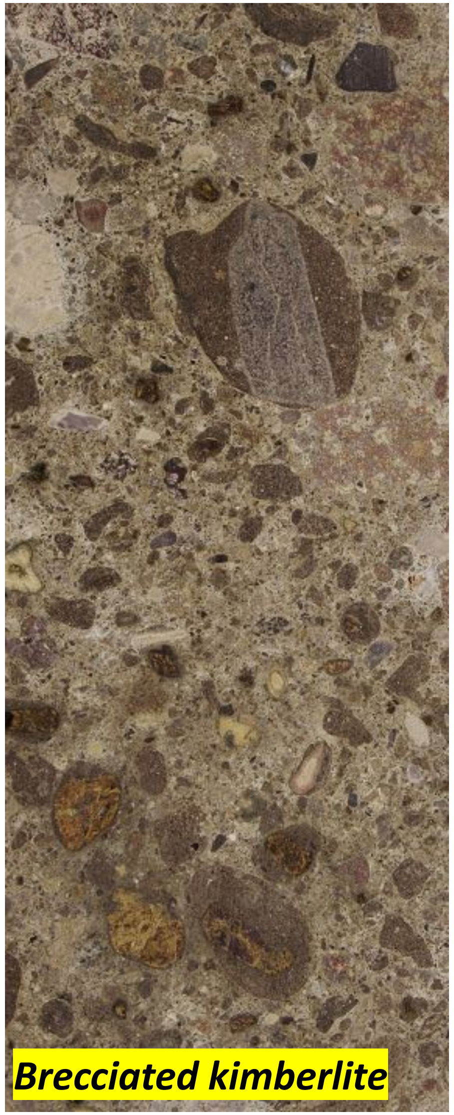


Kimberlite emplacement – ore genesis knowledge

Pyroclastic kimberlite

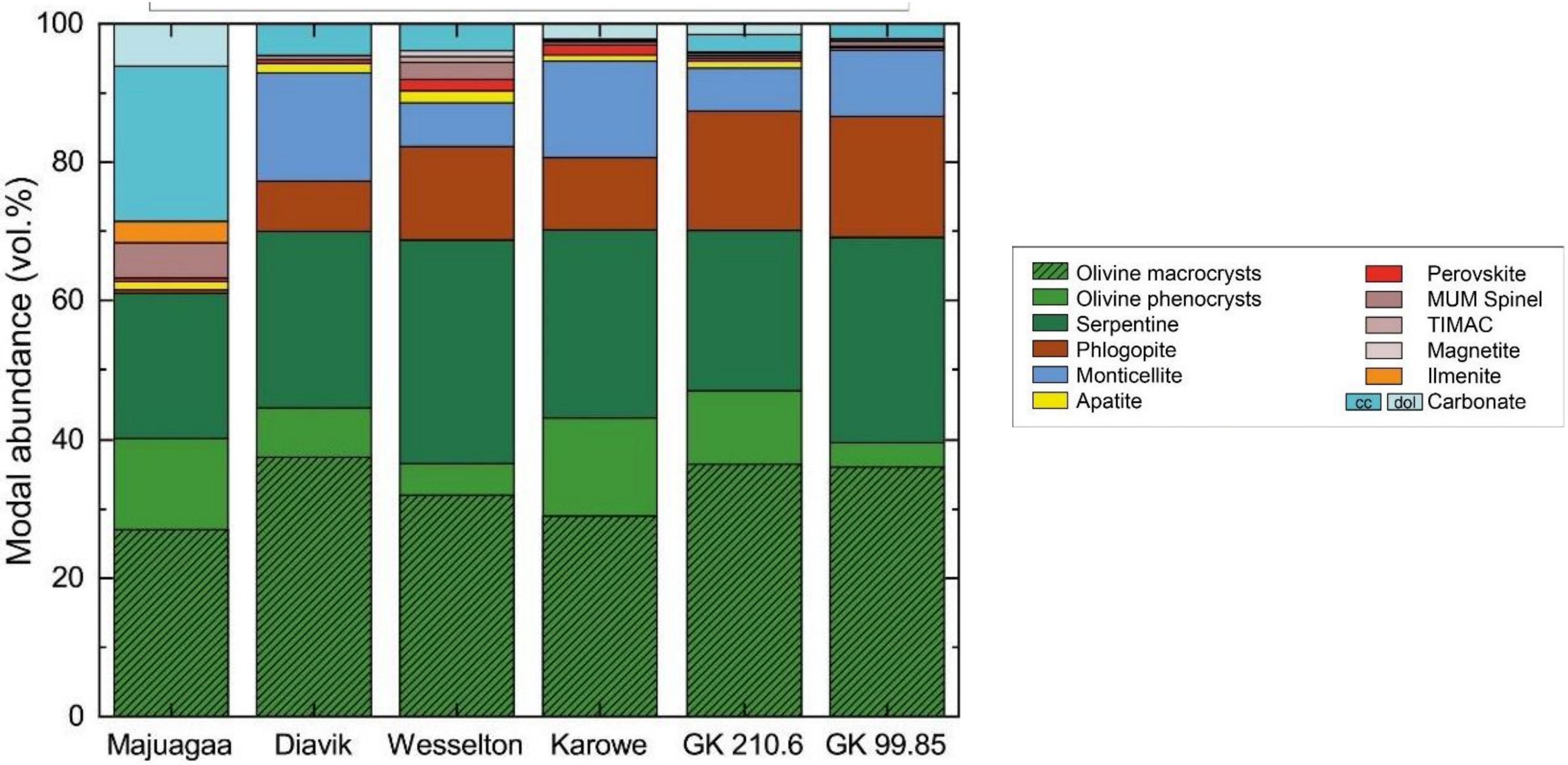


Hypabyssal kimberlite



Brecciated kimberlite

Kimberlite mineralogy



Variable kimberlite mineralogy

Zech et al. (2024) - IKC

Block model - $/ct diamond values

The Karowe kimberlite contains a number of kimberlite domains, each displaying noteworthy characteristics:

M/PK(S) and EM/PK(S) each have distinct diamond grades, size frequency distribution (SFD) models, average $/ct diamond values

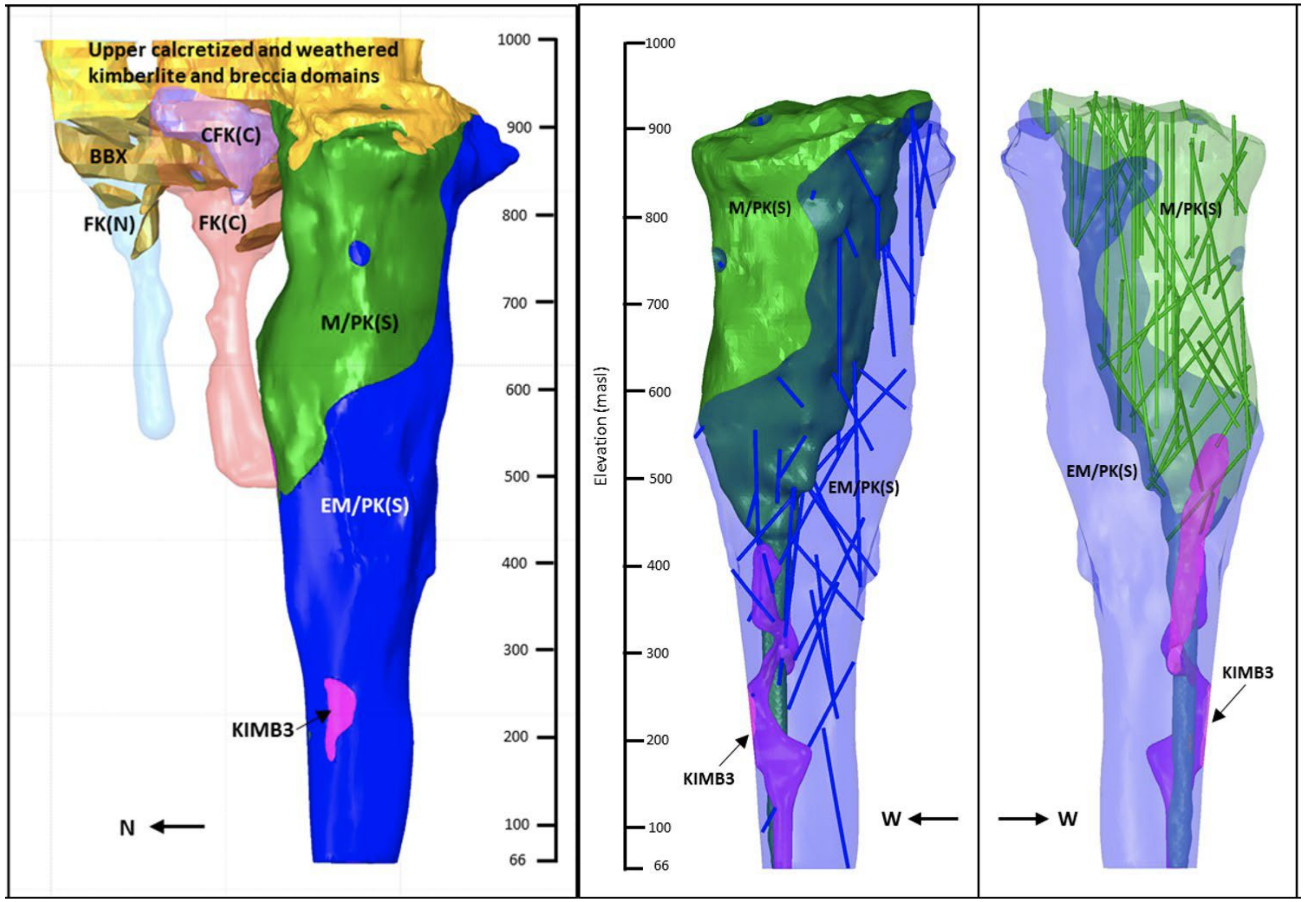
M/PK(S)

- *Grade of 10.8 cpht,*
- *average $/ct values of 707 $/ct*
- *Weight percent specials of 6.3 wt.%*

EM/PK(S)

- *Grade of 21 cpht,*
- *Average $/ct values of 828 $/ct*
- *Weight percent specials of and 8 wt%*

Kimberlite emplacement vs. diamond grade



Webb et al. (2024) – *IKC conference proceedings*

Response variables (metallurgical parameters)

Metallurgical parameters

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Historically:

- The diamond industry has operated with high levels of confidentiality
- Very little technical or processing data was shared publicly

Recent Developments:

- More industry publications have become available in the public domain

Response parameters:

- Overall throughput
- Overall equipment effectiveness
- Power consumption
- Water use
- UCS
- DMS

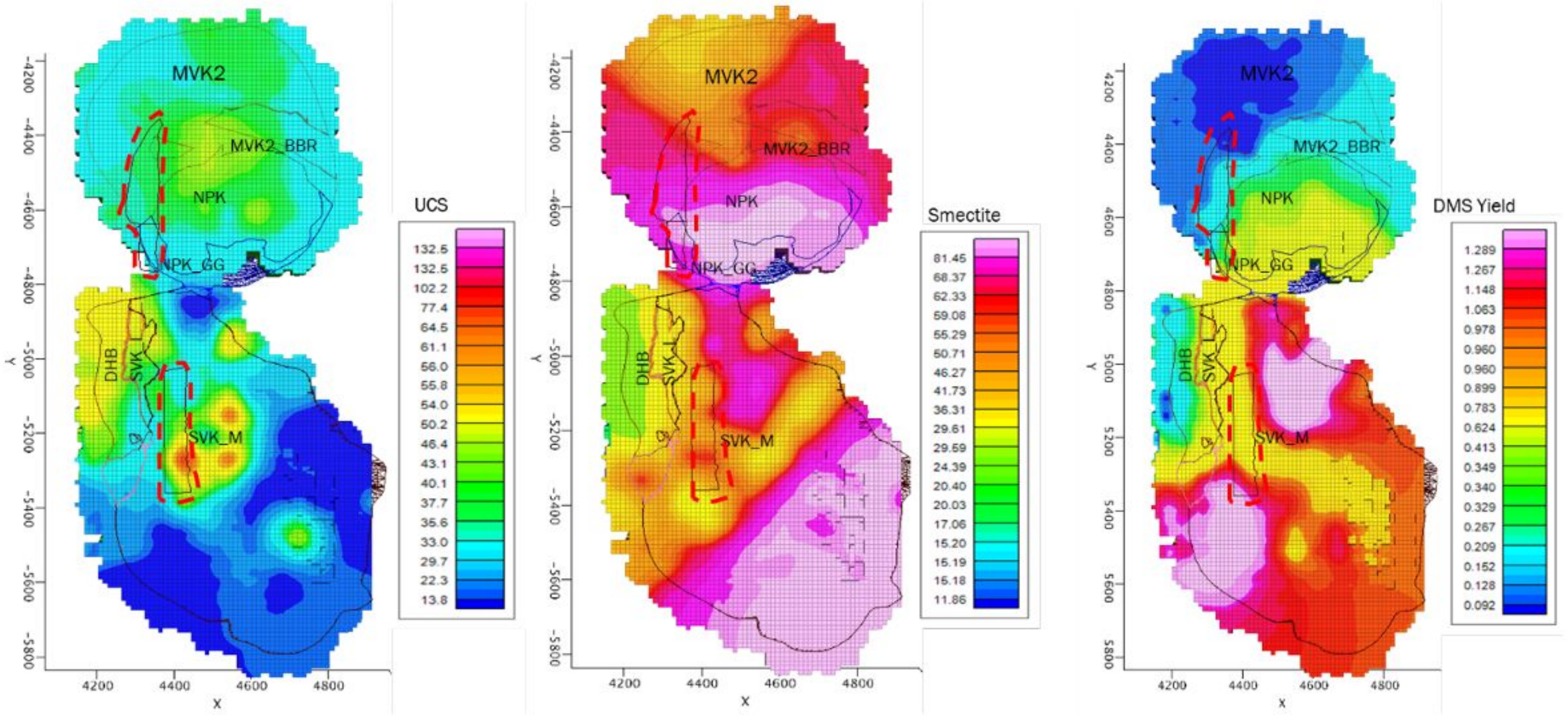

Figure 1. Cross section of the A/K1 resource showing heat maps of the various modelled geomet parameters.

(Gilika & van der Westhuyzen, 2023)

Metallurgical parameters

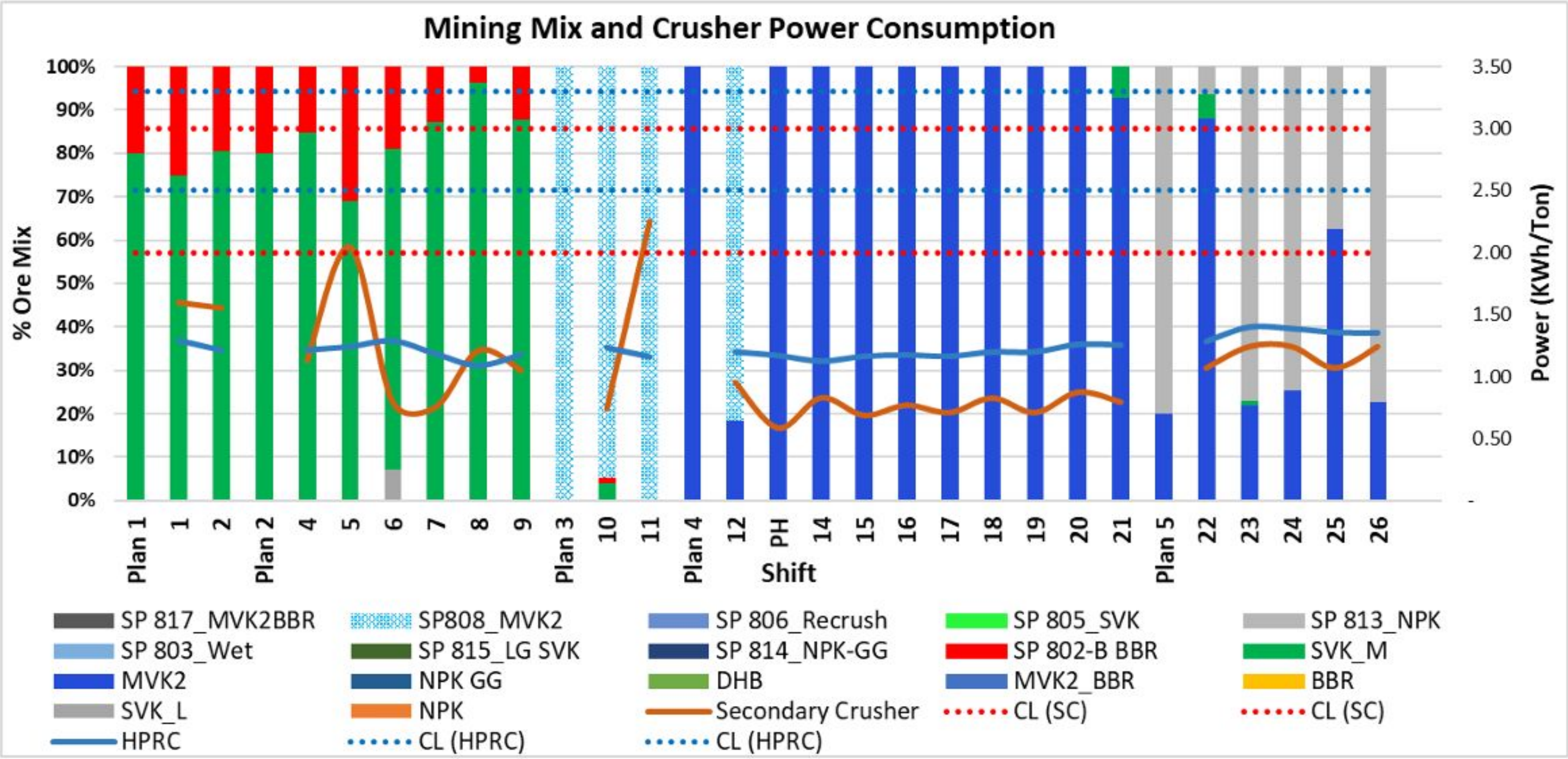

Figure 3. A reconciliation of the crusher power draw against the ore mix.

(Gilika & van der Westhuyzen, 2023)

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What about the diamonds?

Feature characteristics:
PSD, morphologies, inclusions, resorption?

Metallurgical response:
Recovery to DMS, breakage statistics?

What about the diamonds?

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Key questions:

- What energy is needed to liberate diamonds without causing breakage?
- Does the required energy vary with ore type, kimberlite characteristics, or diamond population (size, inclusions, morphology)? How do these diamond factors influence breakage risk?

Approach:

Breakage experiments: preliminary

- ***Ceramic diamond simulants*** *(used initially)*
- ***Synthetic concrete matrices*** *of varying strengths to mimic kimberlite ore*
- ***Drop-weight impact testing*** *replicated comminution circuit forces*

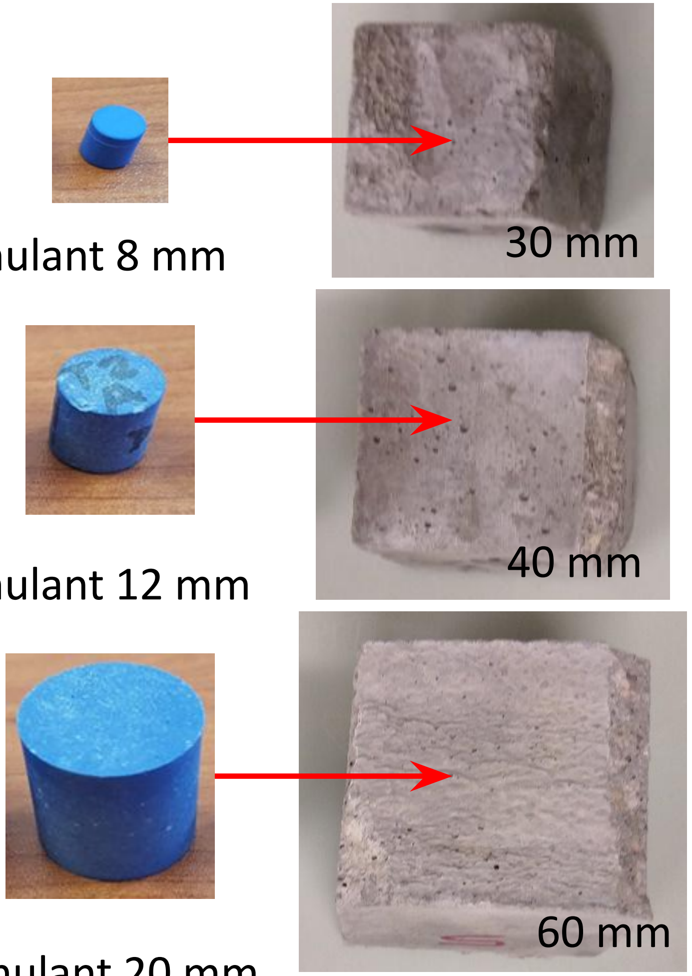
Diamond breakage characterisation

- *Diamonds from DMS concentrates*
- *Morphological characterisation*
- *Surface features*
- *Inclusions*
- *Breakage properties*

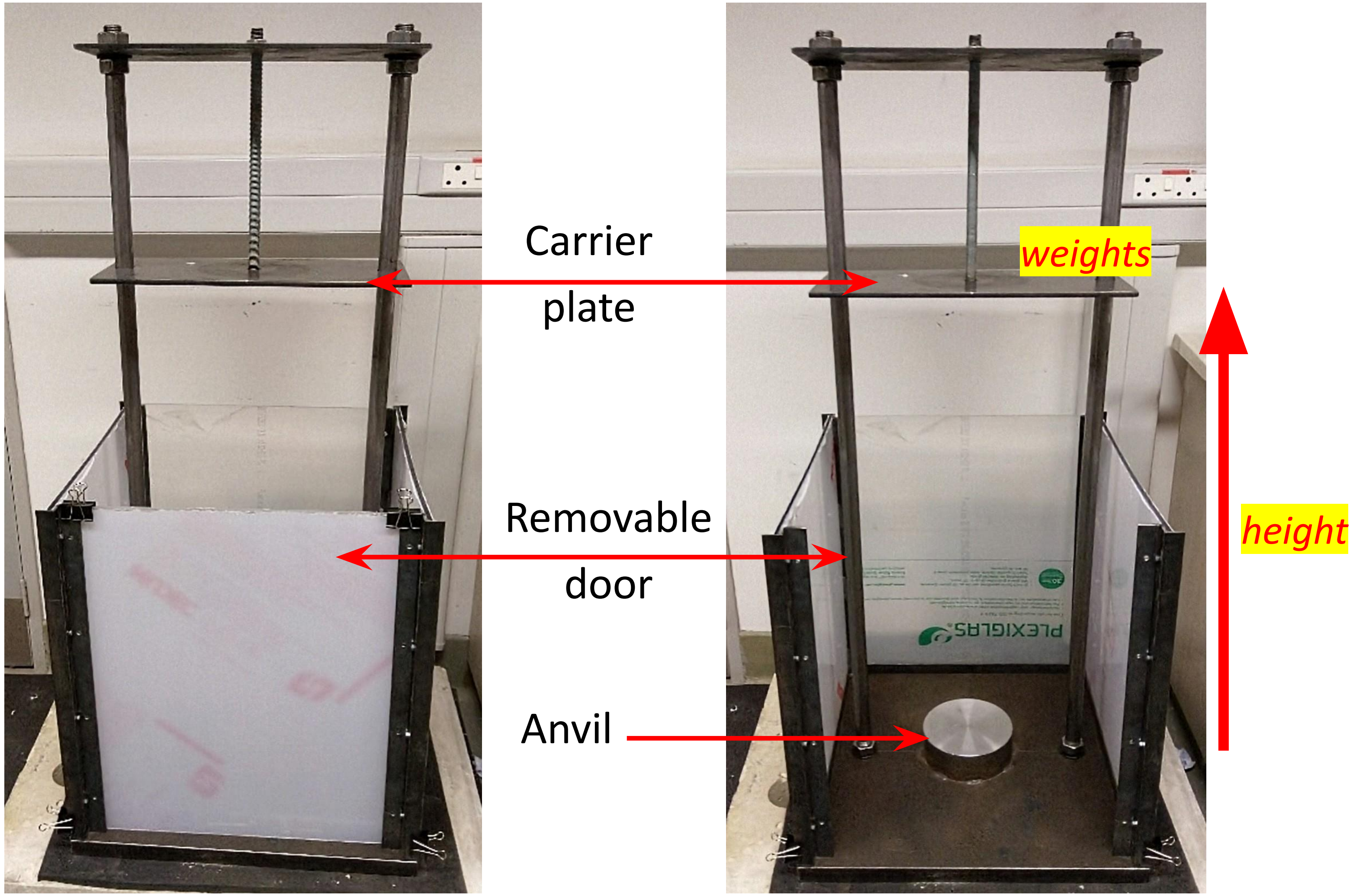
Breakage testing

Drop-weight testing

Proxy ore

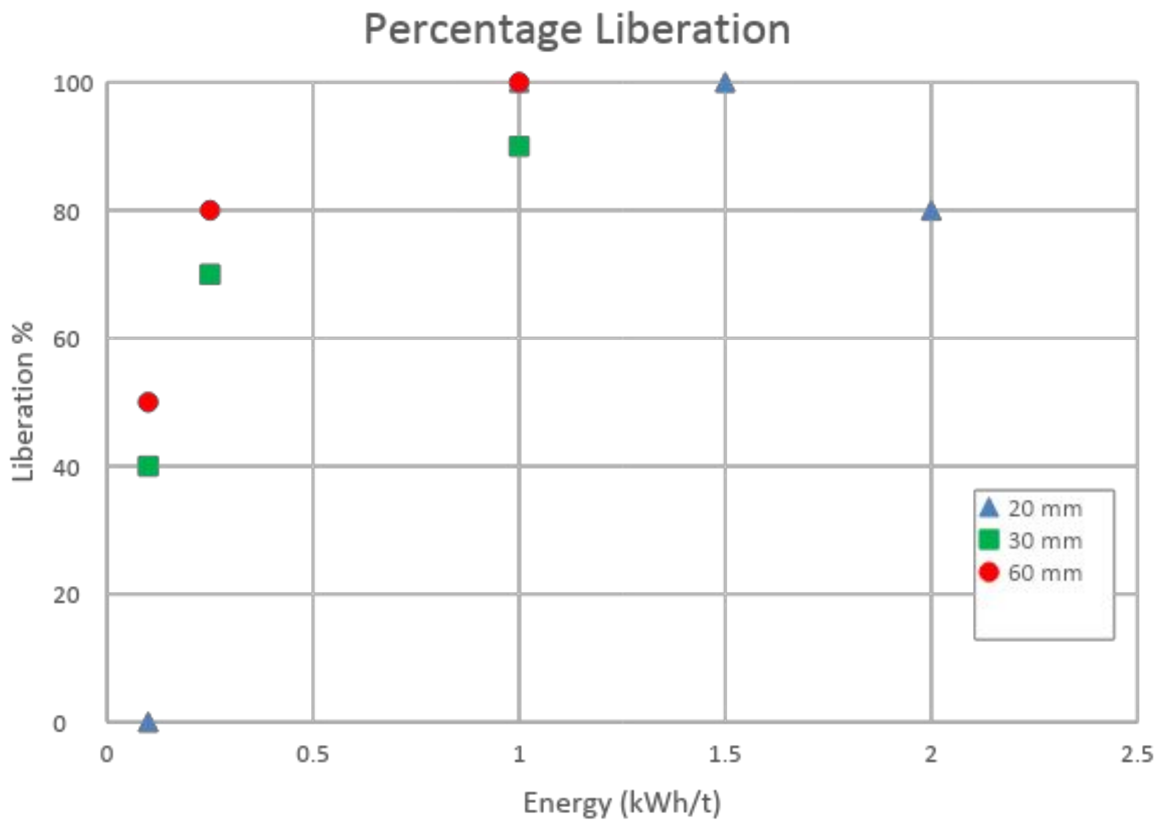


concrete matrix of 77 Mpa

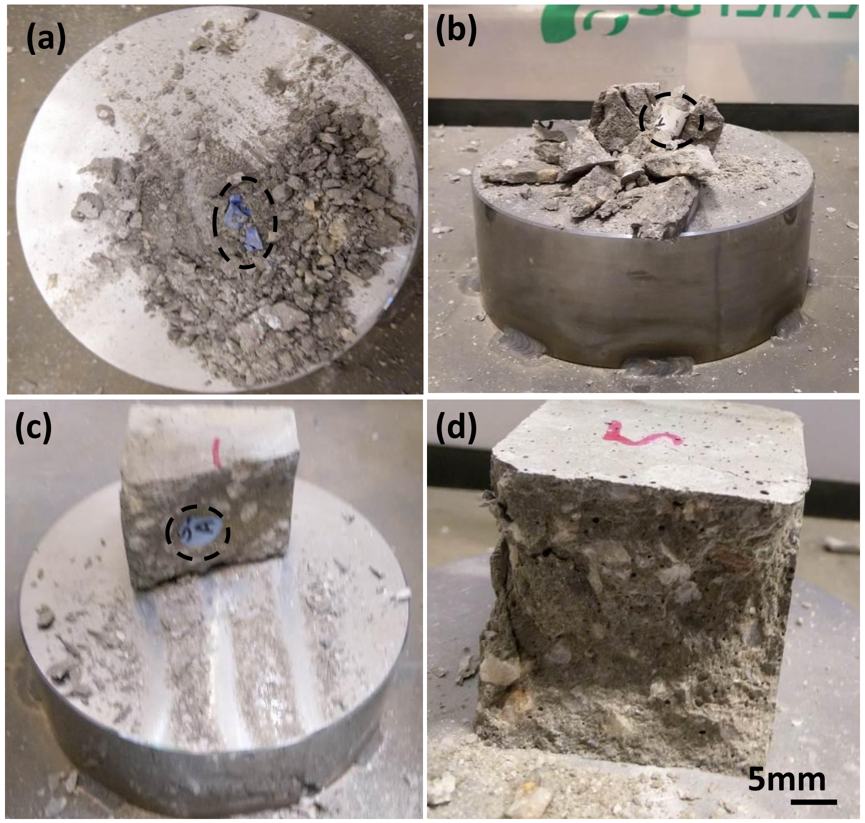


Energy levels adjusted by drop-weight height

Liberation of simulants from matrix

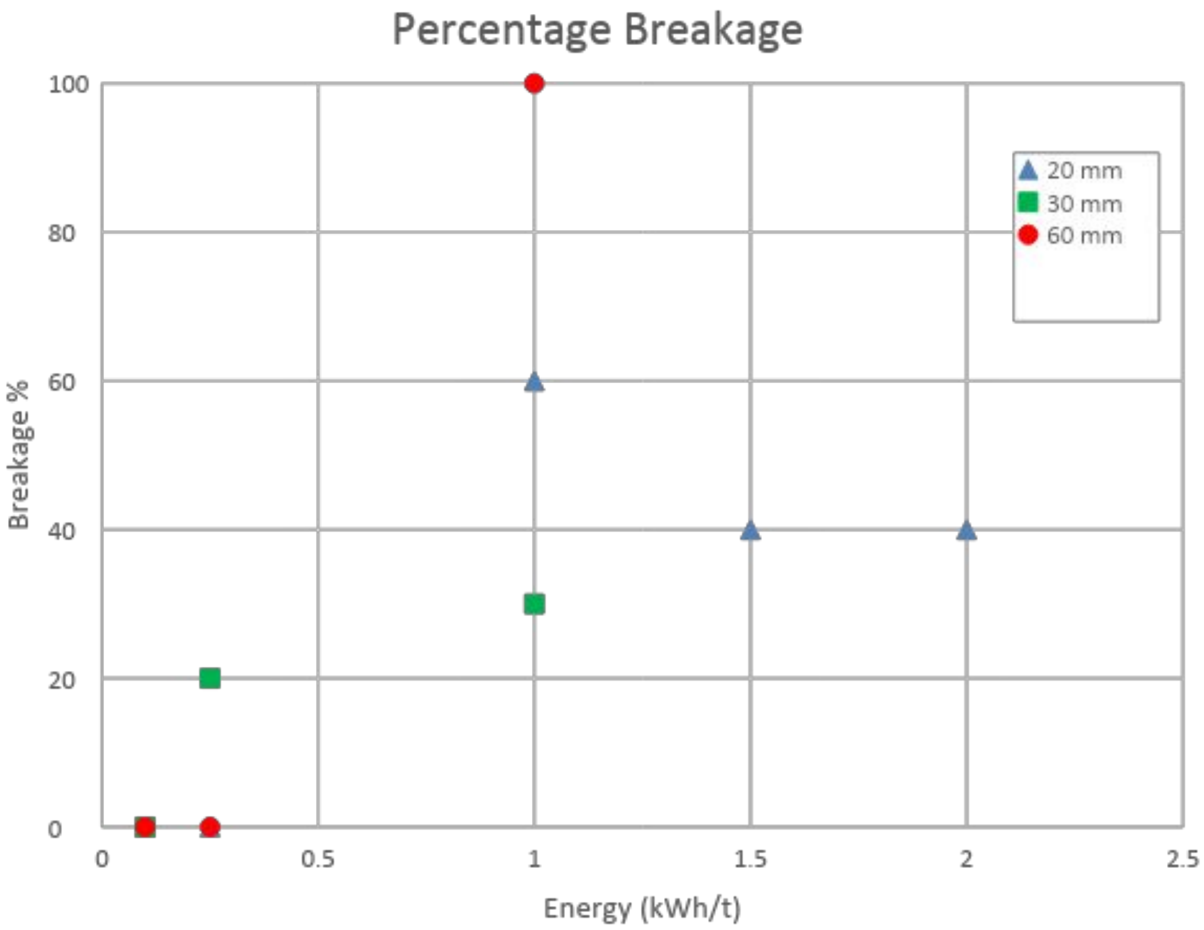


Optimal energy levels → Host rock fragments, simulant remains intact → Efficient liberation with minimal loss



(a) Full liberation – broken simulant
(b) Full liberation – intact simulant
(c) Partial liberation
(d) Complete retention within host matrix

Percentage breakage



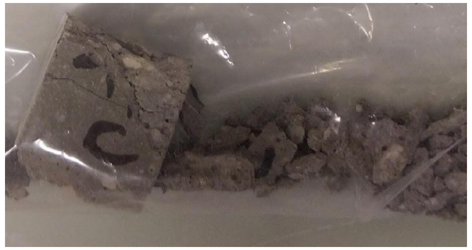
Excessive impact energy → Breakage of both simulant and host matrix → High diamond breakage risk

simulant 8 mm

Low energy

simulant 12 mm

Medium energy



High energy

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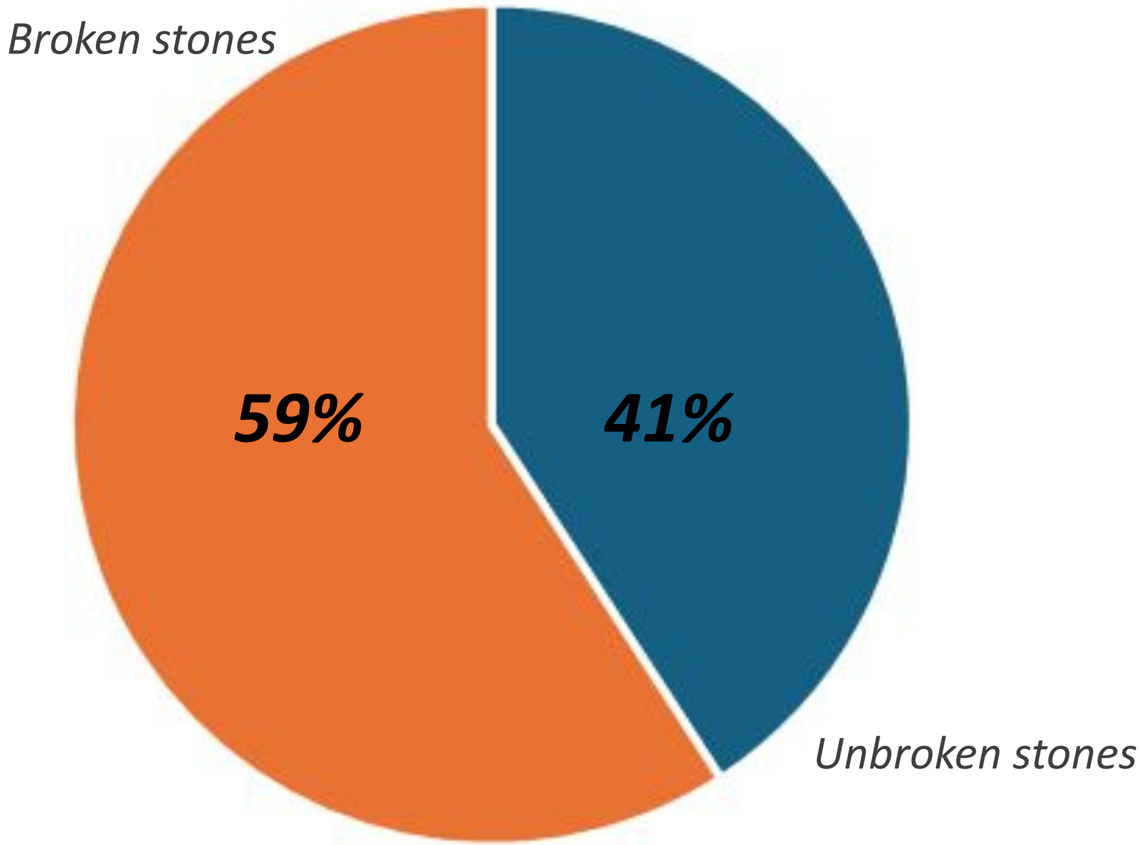
Diamond breakage characterisation

Diamond breakage characterisation



Diamond parcel statistics:

Location: *DMS from Roberts Victor (South Africa)*

Diamond size: *micro- and small diamonds (~3mm)*

Total count: *6223 stones*

Total broken: *3684*

Total intact: *2544*

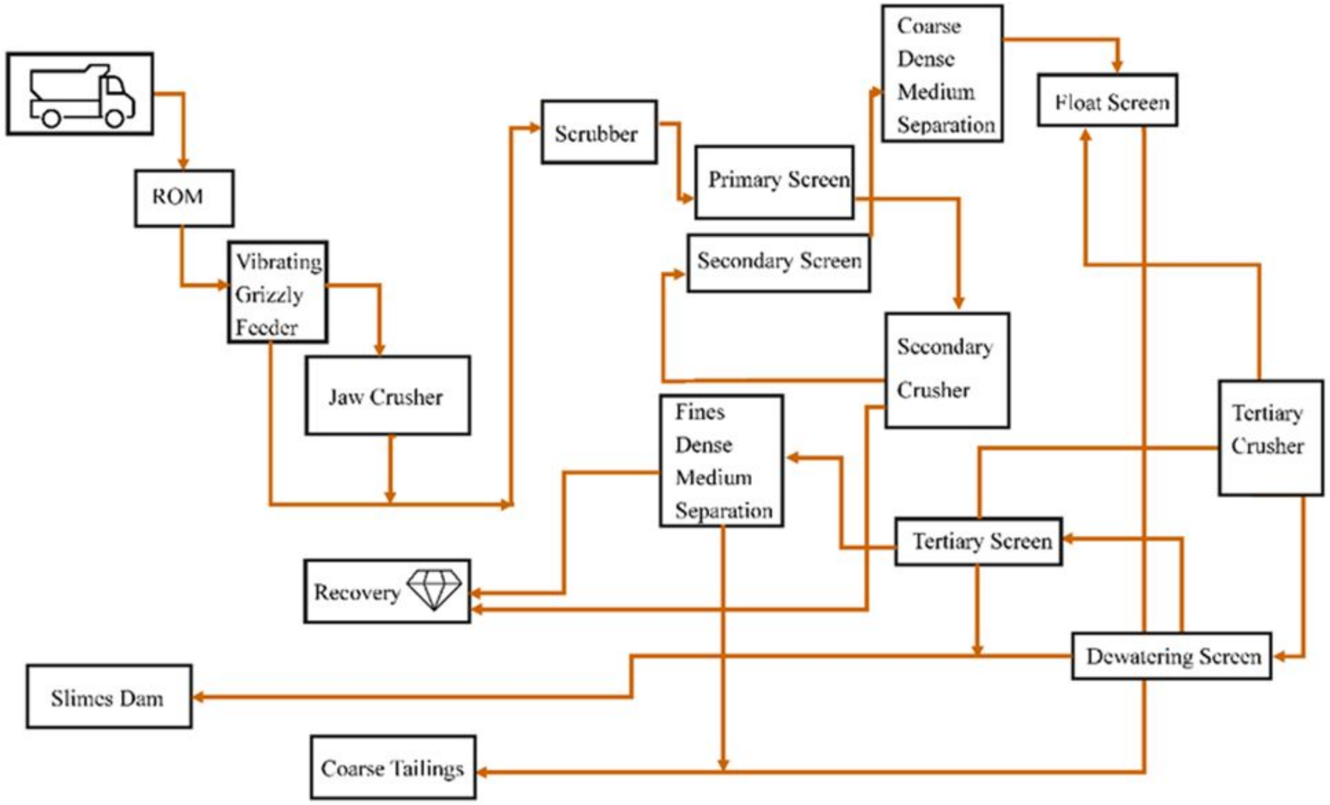
Morphologies: *Octahedra, THH, Dodecahedra, Macels & aggregates*

Colour: *colourless-yellow-brown*

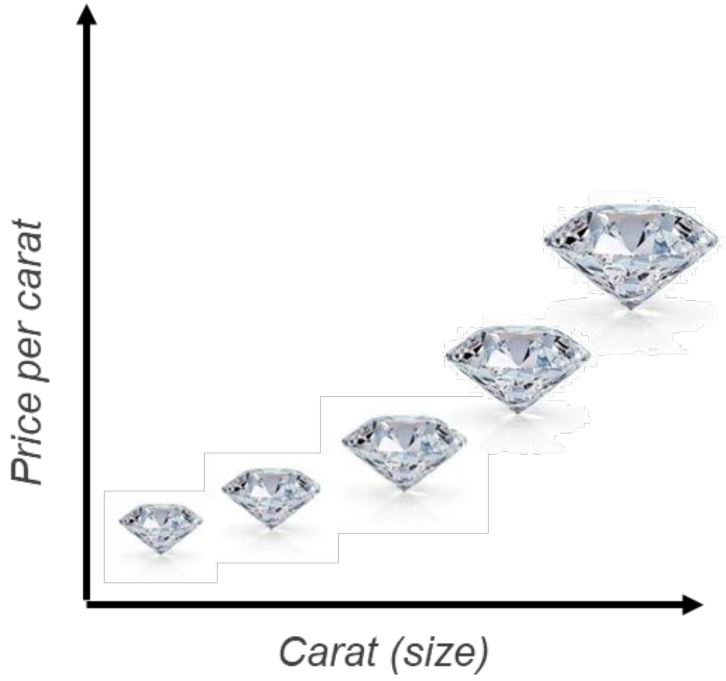
Inclusions: *dominated by graphite*

Historical diamond extraction processes

Conventional comminution technologies are aimed at diamond liberation, not 'diamond protection'

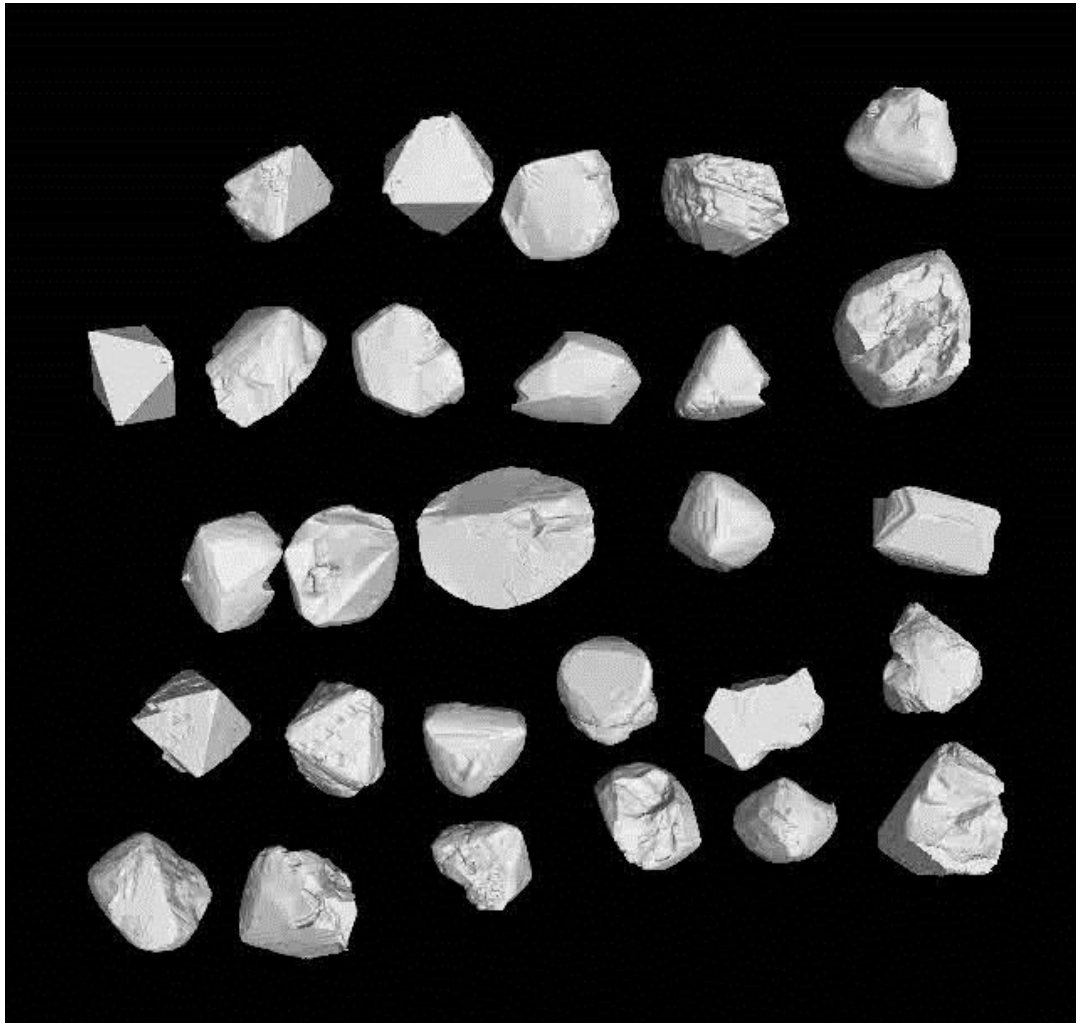


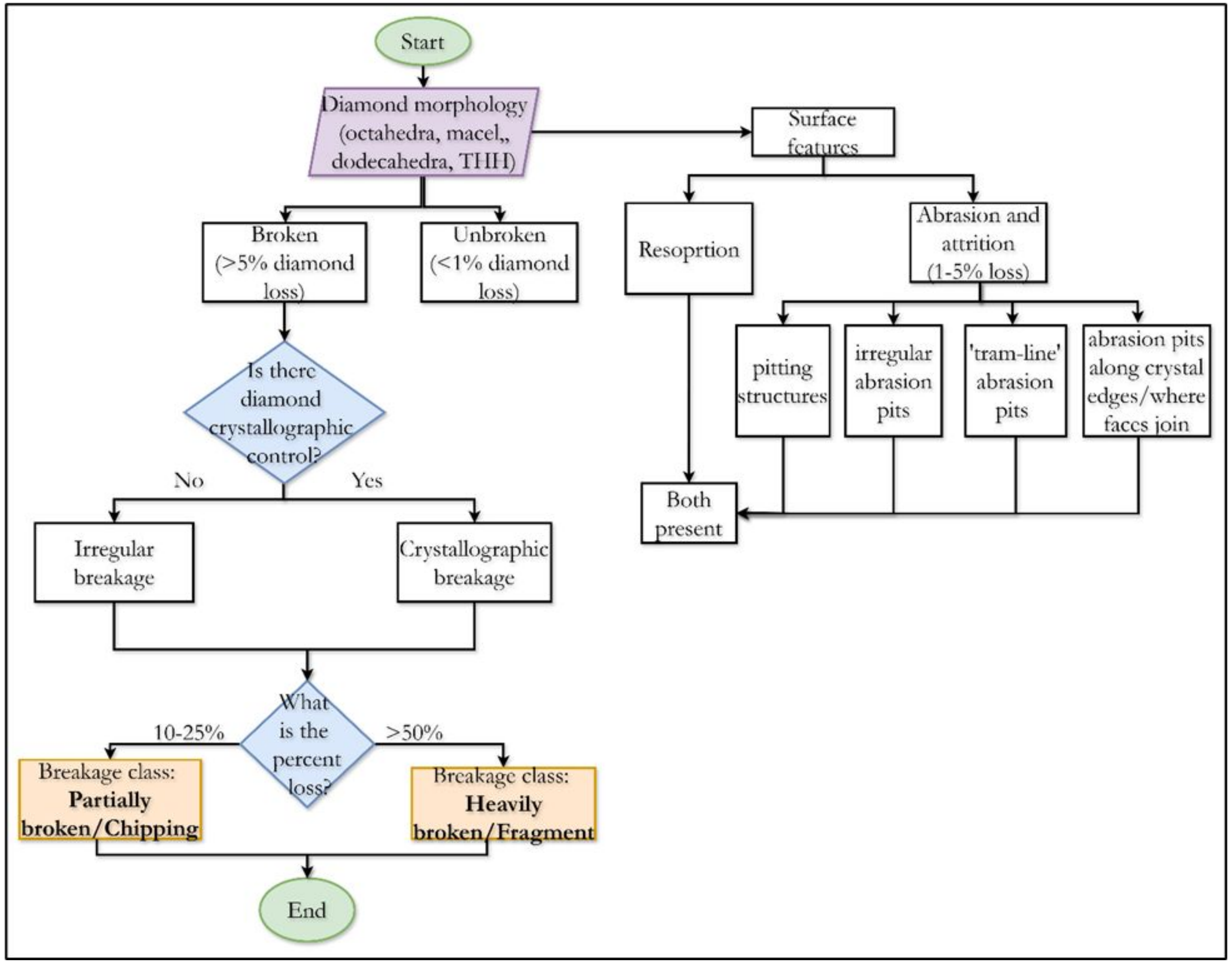
A historical diamond processing flowsheet



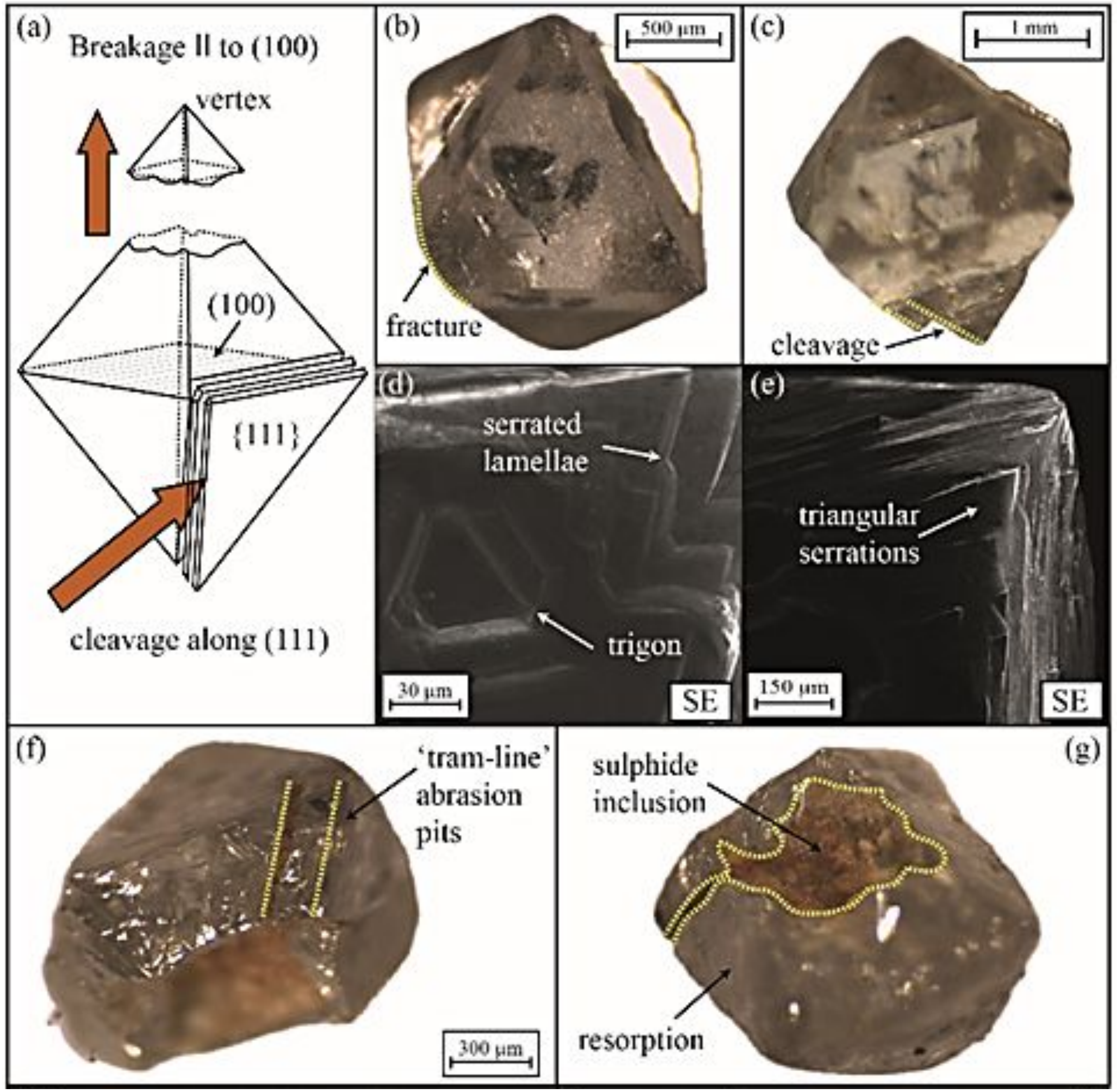
Size reduction impacts revenue

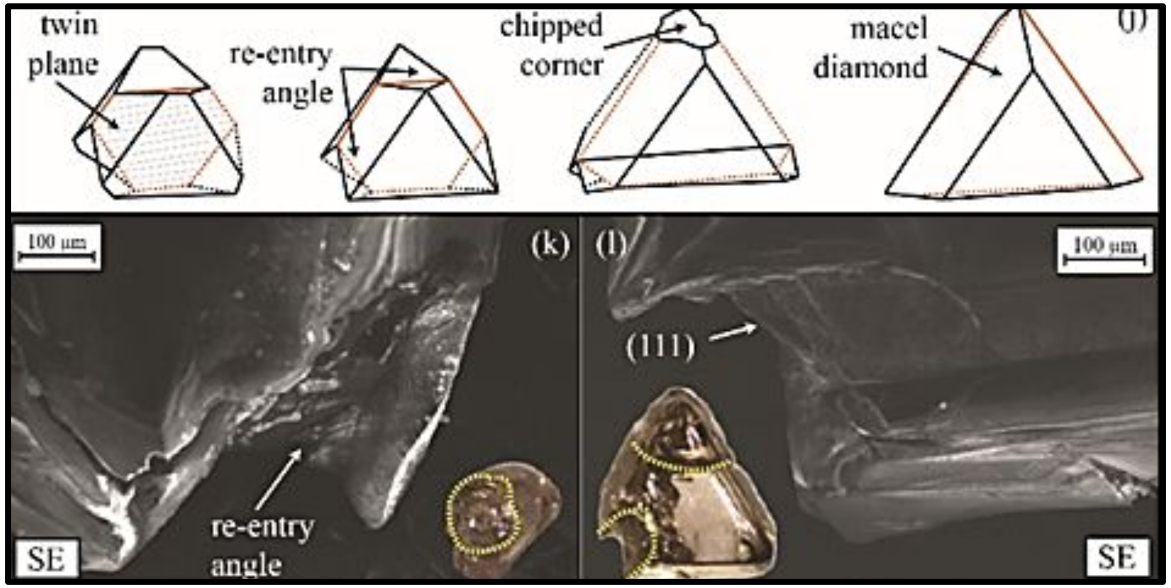
Diamond breakage classification

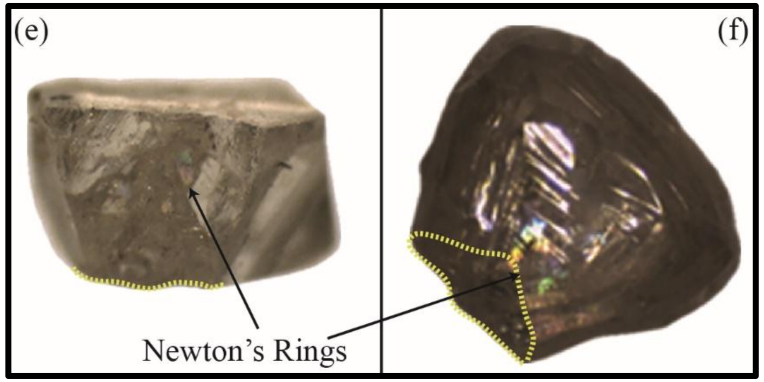




Breakage of octahedra & macels



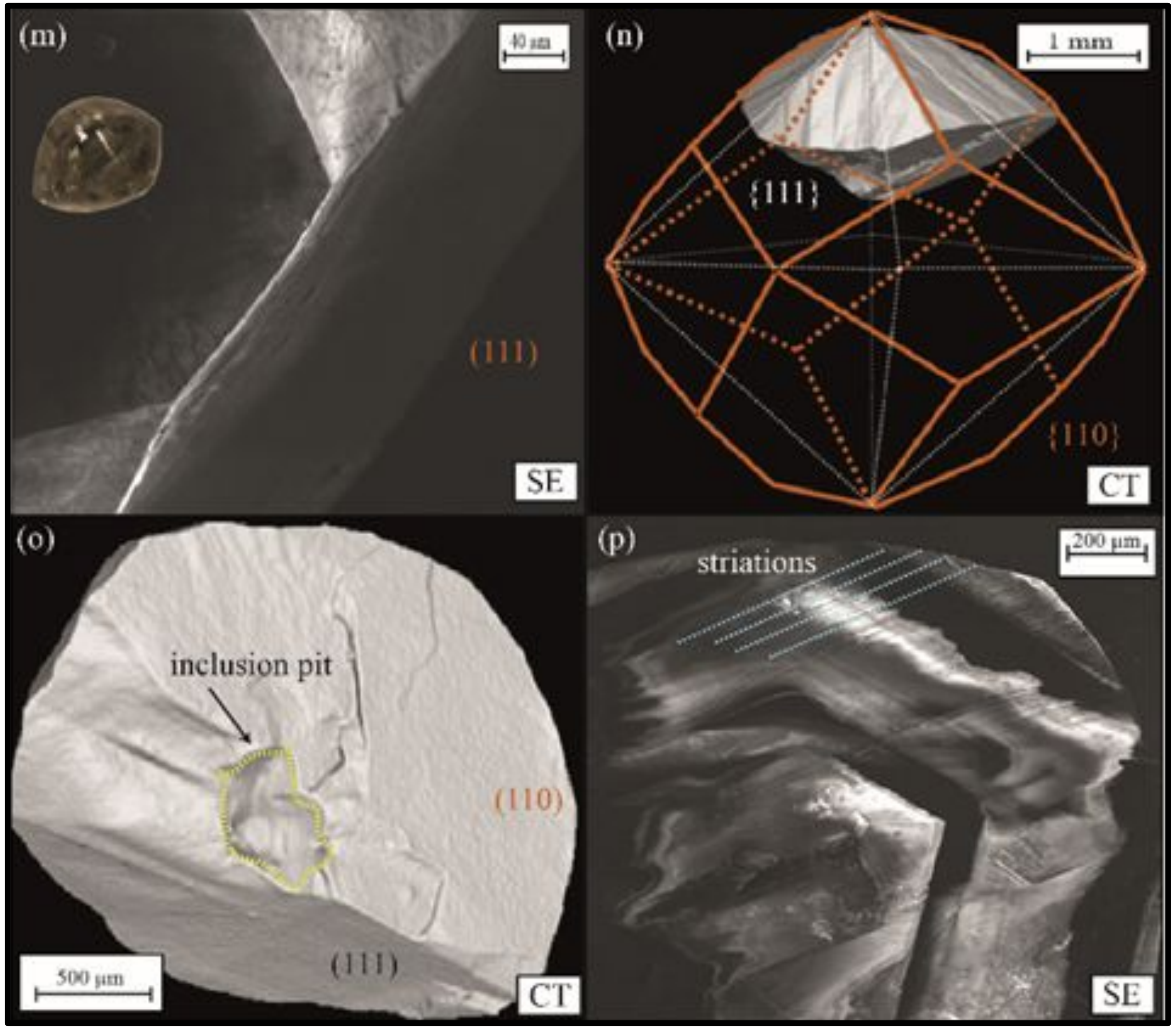




(Burness et al. 2024)

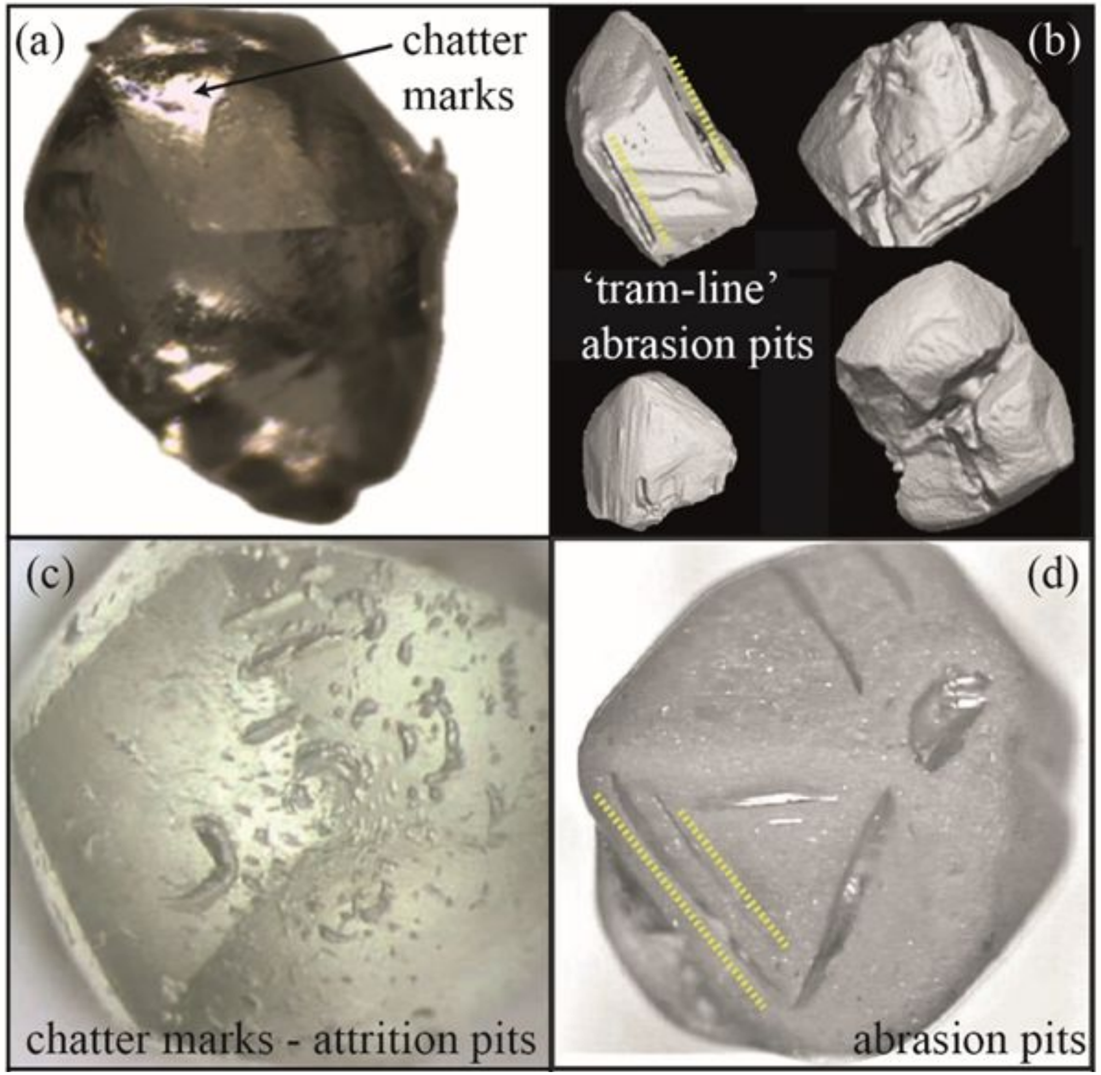
Breakage of secondary habits

THH and Dodecahedra



(Burness et al. 2024)

Diamond abrasion & attrition



Similar features identified on alluvial diamonds (e.g., Harris et al., 2022).

(Burness et al. 2024)

Implications

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Impact energy matters:

- *Too low → poor liberation & recirculation of ore*
- *Too high → diamond damage.*
- *Critical energy thresholds define a "safe window" for optimal liberation*

Breakage types linked to forces:

- *Impact → chipping/fragmentation/severe breakage*
- *Shear/Attrition → abrasion*
- *Compression → HPGR tests required…*

Inefficient circuit consequences:

- *Increased recirculation → higher wear, energy use, and risk of diamond damage*
- *Lower throughput and reduced overall recovery*
- *Goal: Optimise circuit, reduce recirculation, and preserve diamond value.*

Geometallurgy must include diamond breakage to manage value-based risk
Spatial variability: Diamond type, crystal structure, and inclusions affect breakage risk