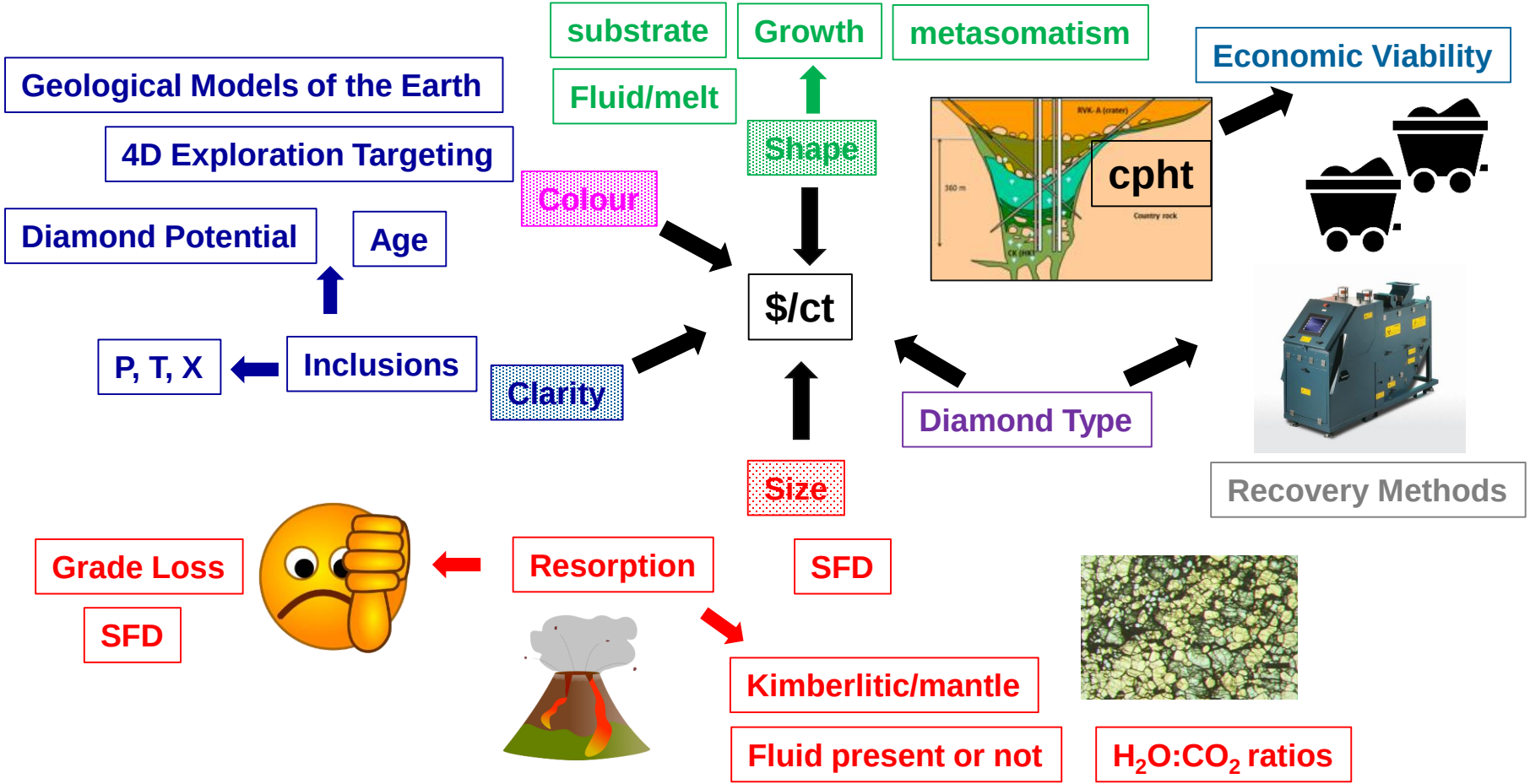
THE ART AND SCIENCE OF DIAMOND ANALYSIS

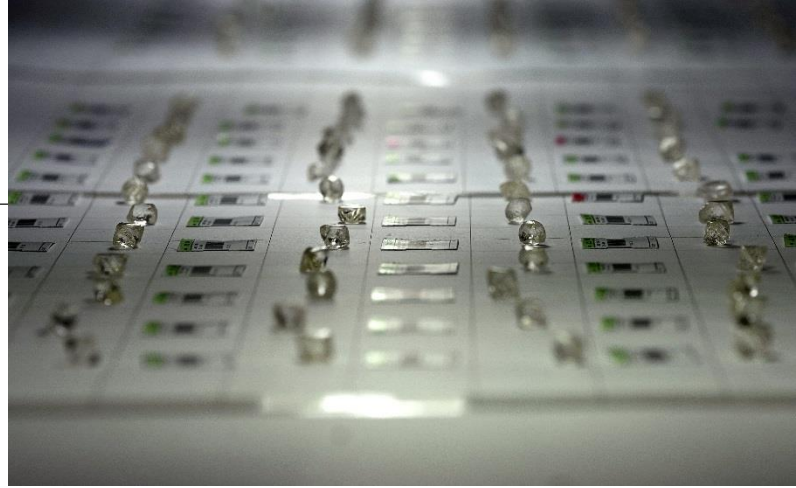
Ingrid Chinn & Samantha Perritt
De Beers Group Services

De Beers
Group of Companies

SAIMM: Diamonds Source to Use 2018 Conference


substrate
Growth
metasomatism
Economic Viability
Geological Models of the Earth
Fluid/melt
Shape
4D Exploration Targeting
Colour
cpht
Diamond Potential
Age
$/ct
P, T, X
Inclusions
Clarity
Diamond Type
Size
Recovery Methods
Grade Loss
SFD
Resorption
SFD
Kimberlitic/mantle
Fluid present or not
H_2O:CO_2 ratios

REVENUE



4 C's of **polished** diamonds:

Carat (size)

Colour

Clarity

Cut (shape/model)

Complexity in establishing $/ct and hence $/ton compared to commodities with unit prices

Further complexity in extrapolating revenue from small initial Deposit Assessment parcels of rough Stones unlikely to contain large high value diamonds

www.lookhuman.com

SIZE

Lognormal size distribution of diamonds is used to calculate **grade** from microdiamond samples

Mineralogy and Petrology
https://doi.org/10.1007/s00710-018-0566-y

ORIGINAL PAPER

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

Johann Stiefenhofer[1,2] · Malcolm L. Thurston[1] · David E. Bush[3]

Size dependence of **diamond value:**

813 ct Constellation sold for $63.11 million in May 2016 (**77 649 $/ct**)

1 109 ct Lesedi La Rona sold for $53 million in September 2017 (**47 777 $/ct**)

Caveats:

Diamond properties (and hence value) in a single deposit **vary with diamond size**

Optimisation of diamond recovery is very important, not only during mining but during deposit assessment

COLOUR

2018: Christie's sold a 20.49 ct Fancy Vivid Yellow for $5.6 million

2017: Sotheby's sold the 59.6 ct Pink Star for $71.1 million ($**1.19 million/ct**)

2014:Original 29.6 ct rough sold for $25.6 million ($864 865/ct)
2015: Blue Moon of Josephine (12.03 ct) sold for $48.4 million

Image by Christie's

Image by Sotheby's

Image from www.resourceclips.com

COLOUR: GEOLOGICAL CONTROLS (GROWTH AND MANTLE RESIDENCE)

Brown, pink, red and purple: **plastic deformation (e.g. Argyle mine)**

Yellow, orange/amber: nitrogen

Blue: boron & a lack of nitrogen

Green: irradiation

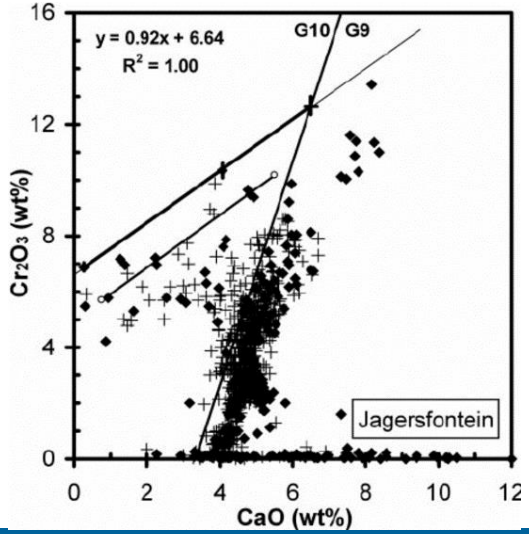
Image by R Weldon/GIA

Image by GIA

CLARITY

Inclusions decrease the value of diamonds, but provide geologists with valuable information about diamond formation processes

Inclusion compositions form the basis of Mineral Chemistry Derived Diamond Potential (MCDDP) assessment of kimberlites



INCLUSIONS: DIAMOND GENESIS AGES FROM ISOTOPIC COMPOSITIONS


Image by SH Richardson

Early Sm-Nd analyses of garnet and cpx inclusion composites
(e.g. Richardson et al. 1984: 3.2 Ga model age for harzburgitic inclusions from Kimberley & Finsch)

Proof of xenocrystic origin of diamonds

Late 1990's Re-Os dating of individual sulphides: e.g. Pearson et al. 1998 (Koffiefontein)

Use of 13 ohm resistors in N-TIMS instruments at Vrije University to date individual silicate inclusions:
Harzburgitic ages of 2.95 and 1.15 Ga from Koornneef et al. (2017) vs previous "Bushveld" age of 2 Ga from inclusion composites from Venetia (Richardson et al. 2009)

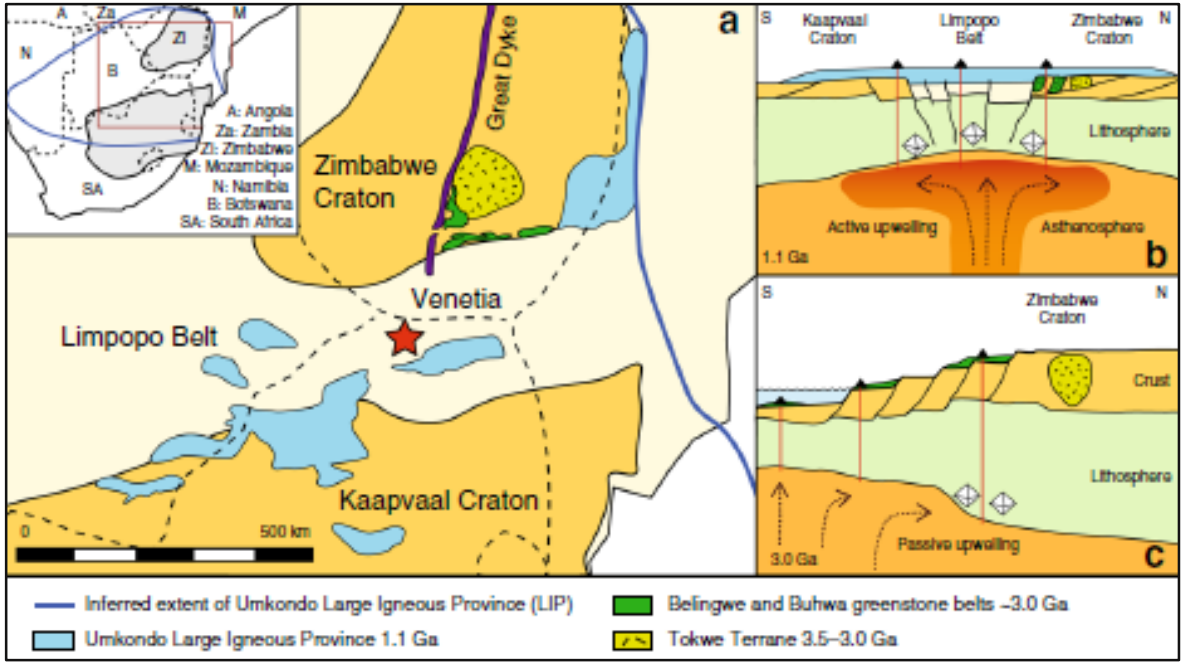
ARTICLE

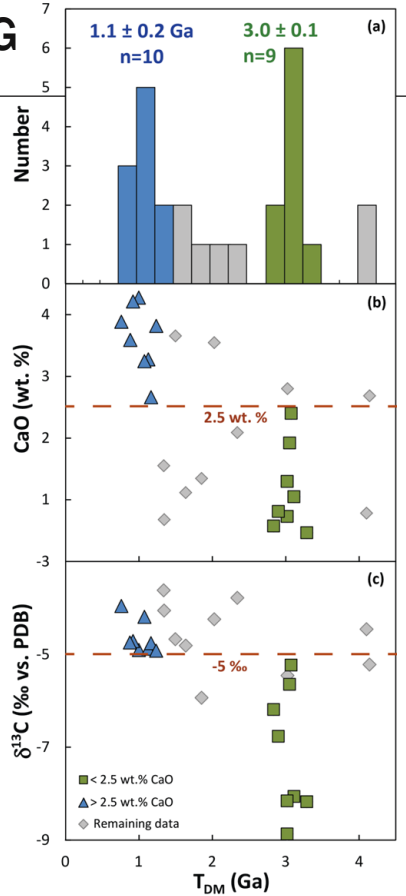
DOI: 10.1038/s41467-017-00564-x OPEN

Archaean and Proterozoic diamond growth from contrasting styles of large-scale magmatism

Janne M. Koornneef[1], Michael U. Gress[1], Ingrid L. Chinn[2], Hielke A. Jelsma[3], Jeff W. Harris[4] & Gareth R. Davies[1]

INCLUSIONS: DIAMOND GENESIS LINKED TO GEOLOGICAL SETTING





Images from Koornneef et al. (2017)

SUBLITHOSPHERIC DIAMONDS IN THE NEWS

GIA at the forefront of research into large Type IIa and Type IIb diamonds

Large gem diamonds from metallic liquid in Earth's deep mantle

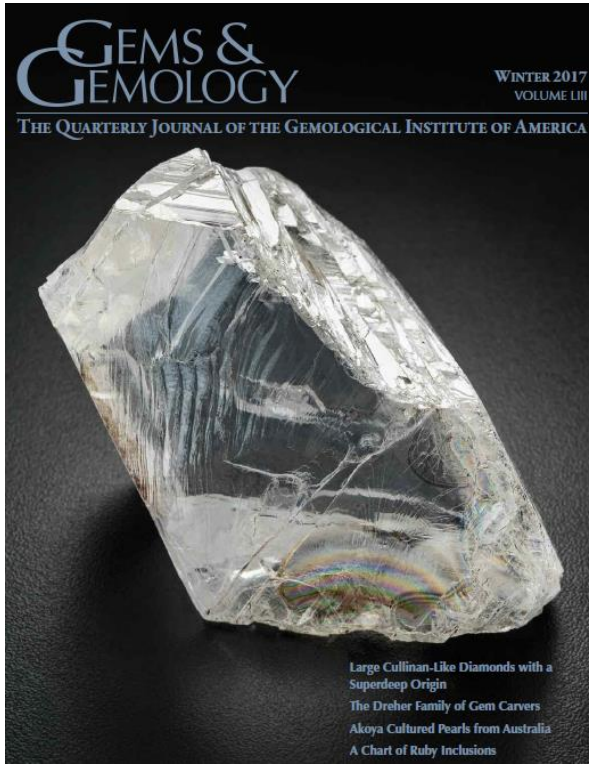
Evan M. Smith,[1*] Steven B. Shirey,[2] Fabrizio Nestola,[3] Emma S. Bullock,[4] Jianhua Wang,[2] Stephen H. Richardson,[5] Wuyi Wang[1]

Smith et al. (2016) Science 354: 1403-1405

THE VERY DEEP ORIGIN OF THE WORLD'S BIGGEST DIAMONDS

Evan M. Smith, Steven B. Shirey, and Wuyi Wang

Smith et al. (2017) Gems and Gemology 2017: 388-403



INCLUSIONS: OTHER RECENT WORK

Raman spectroscopy now routinely used to identify inclusions non-destructively

Fluid films around inclusions have been identified using Raman spectroscopy: implications for pressure estimates from elastic barometry, particularly important for eclogitic diamonds

Lithos 260 (2016) 384–389

Contents lists available at ScienceDirect

Lithos

journal homepage: www.elsevier.com/locate/lithos

Letter

First evidence of hydrous silicic fluid films around solid inclusions in gem-quality diamonds

Paolo Nimis [a,*], Matteo Alvaro [a,b], Fabrizio Nestola [a], Ross J. Angel [a], Katharina Marquardt [c], Greta Rustioni [b], Jeff W. Harris [d], Federica Marone [e]

[a] Department of Geosciences, University of Padua, Via G. Gradenigo 6, 35131 Padua, Italy
[b] Department of Earth and Environmental Sciences, University of Pavia, Via A. Ferrata, 1, 27100 Pavia, Italy
[c] Bayerisches Geoinstitut, University of Bayreuth, 95440 Bayreuth, Germany
[d] School of Geographical and Earth Sciences, University of Glasgow, Glasgow, G12 8QQ, UK
[e] Swiss Light Source, Paul Scherrer Institut, 5232 Villigen, Switzerland

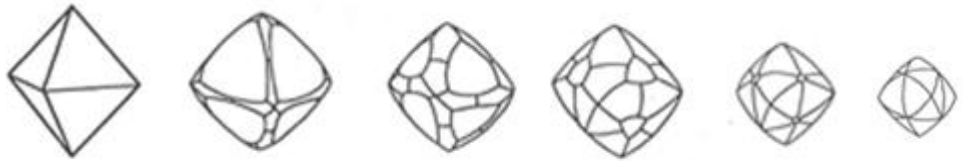
CUT (SHAPE/MODEL)

Diamond shape is affected by physical and chemical **growth conditions**

Competition between factors driving crystal nucleation and growth control the resultant outcome in terms of size, inclusion content etc.

Subsequent **resorption and/or etching** in the mantle and in the kimberlite or lamproite during transport to the surface may also modify the shape

During resorption considerable volume (grade) loss may occur

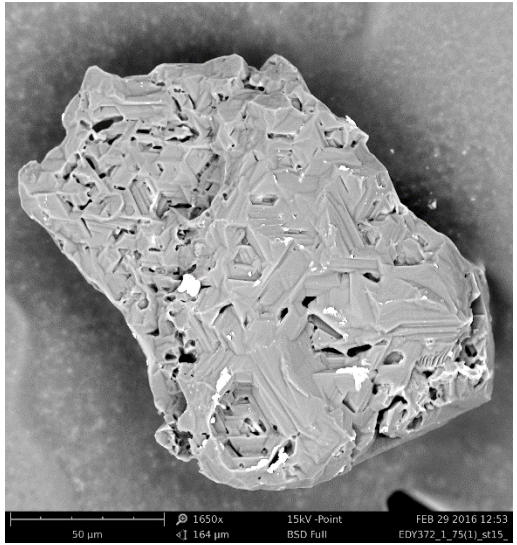


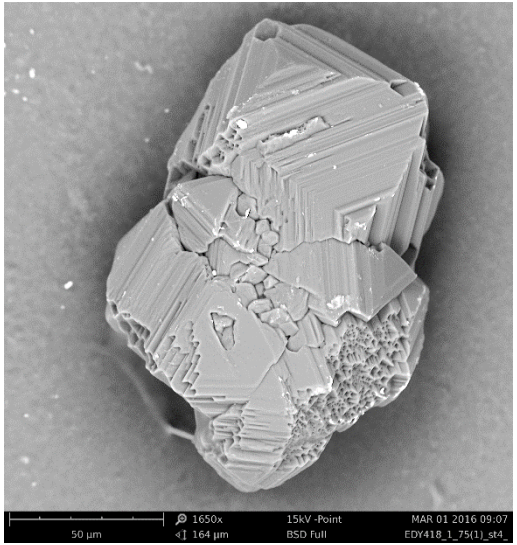
CUT (SHAPE/MODEL)

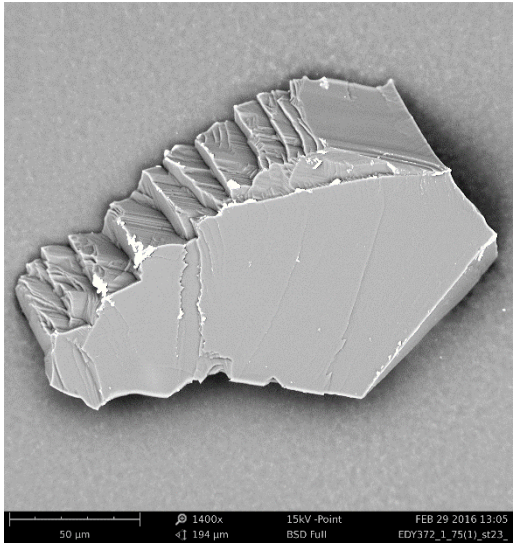
Characterisation of microdiamonds (SEM and FTIR): sweating the small stuff!

Diamond shape classification and characterisation of etch and resorption features

Natural and recovery-related breakage can be distinguished



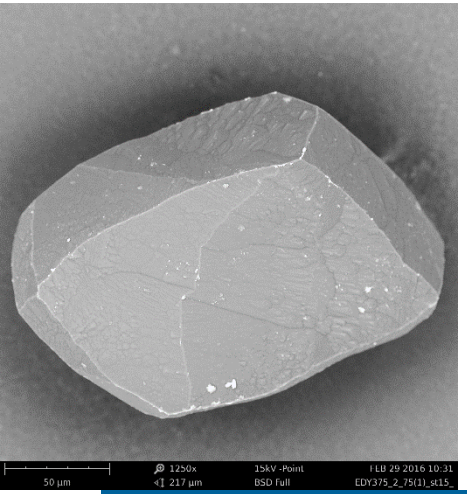


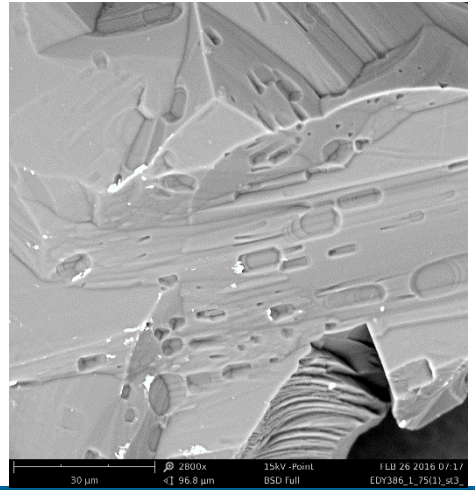


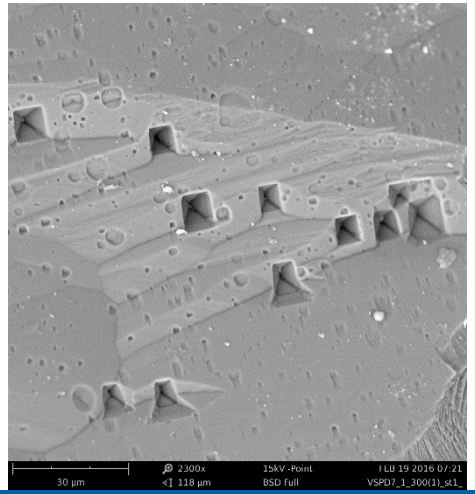
RESORPTION (AND ETCHING) OF DIAMOND

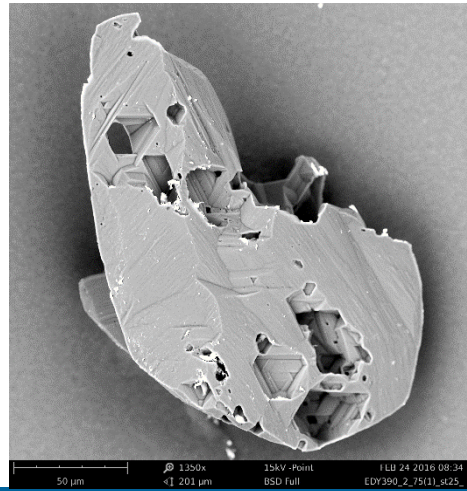
Collaboration with Professor Yana Fedortchouk at Dalhousie University

Distinction between mantle and kimberlitic resorption
Information on fluid/melt presence and composition,
Implications for kimberlite emplacement conditions

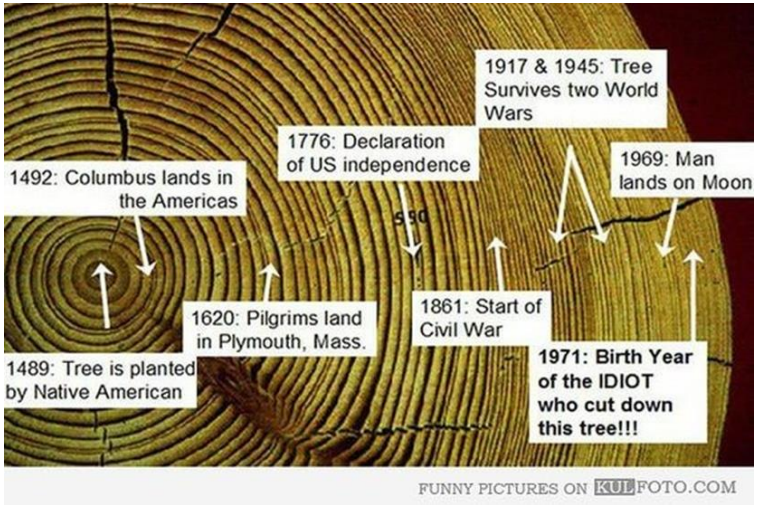


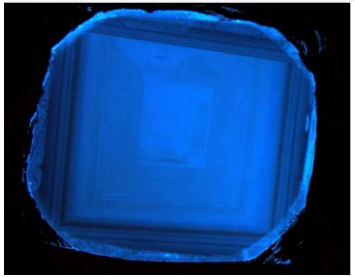


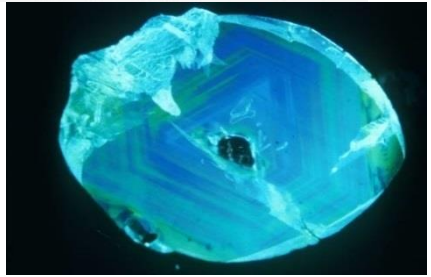


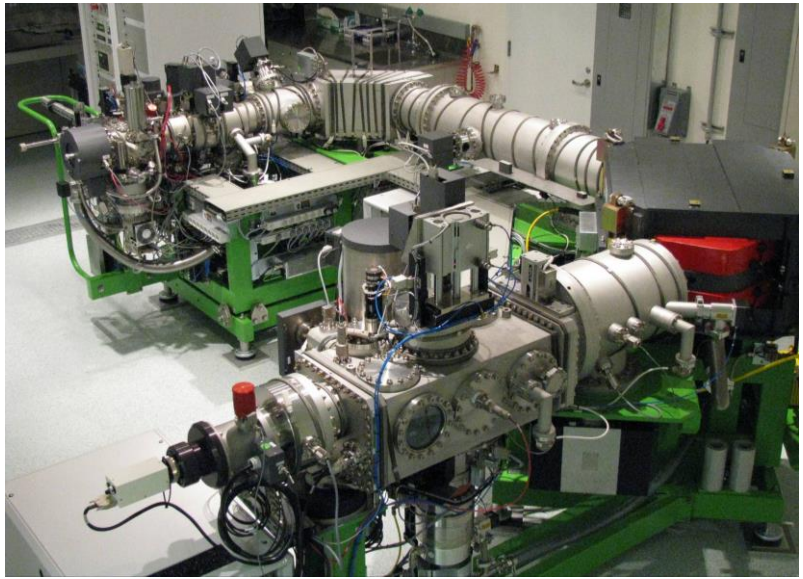


CATHODOLUMINESCENCE AND SIMS



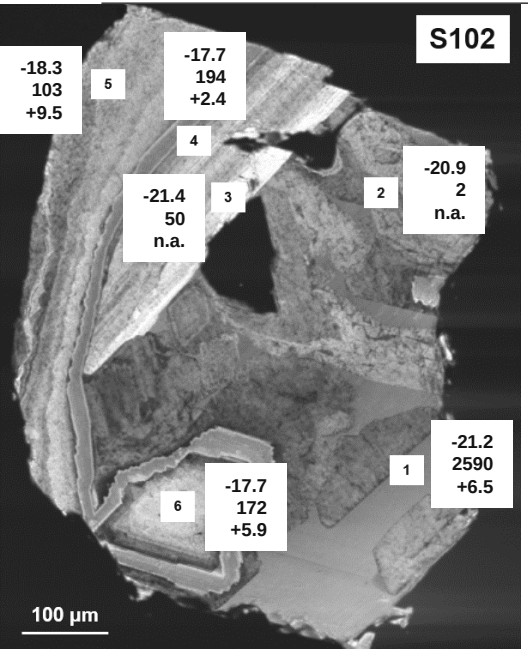






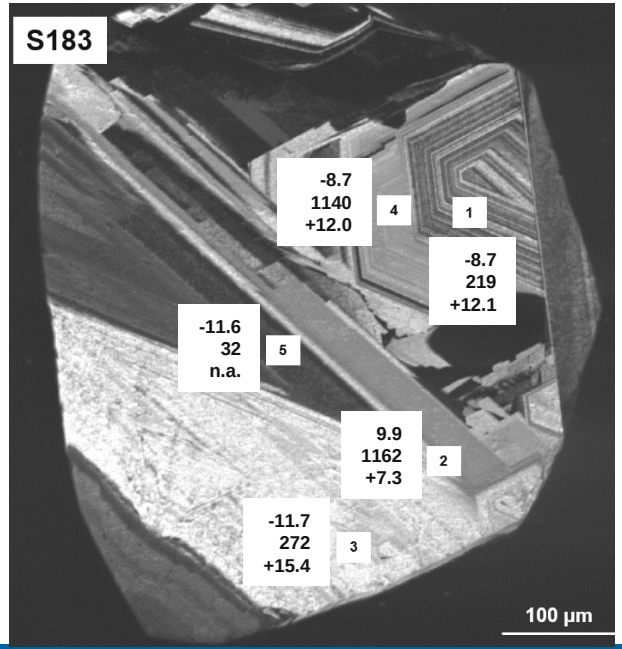
CATHODOLUMINESCENCE AND SIMS

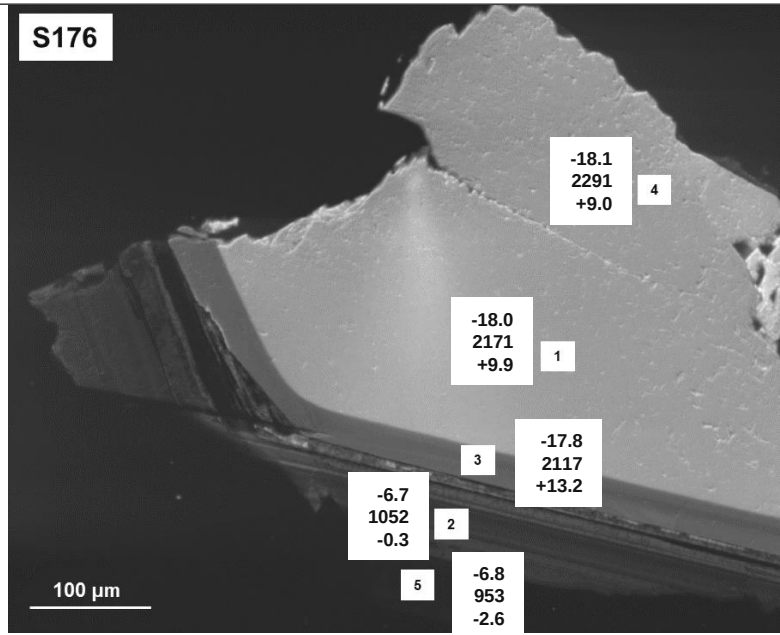
CANADIAN CENTRE for ISOTOPIC MICROANALYSIS



Analysis key

$\delta^{13}C$ ‰
[N] ppm
$\delta^{15}N$ ‰





MULTIPLE DIAMOND POPULATIONS AND SIGNIFICANT COMPLEXITY

SIMS isotope analyses allowing for modelling of **fluids** responsible for diamond formation

Earth and Planetary Science Letters 473 (2017) 44–51

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

www.elsevier.com/locate/epsl

Carbon isotope fractionation during diamond growth in depleted peridotite: Counterintuitive insights from modelling water-maximum CHO fluids as multi-component systems

T. Stachel*, T. Chacko, R.W. Luth

Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB, T6G 2E3, Canada

substrate

Growth

metasomatism

Economic Viability

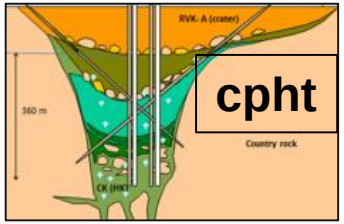
Geological Models of the Earth

Fluid/melt

4D Exploration Targeting

Shape

Colour



Diamond Potential

Age

$/ct

P, T, X

Inclusions

Clarity

Diamond Type

Size

Recovery Methods

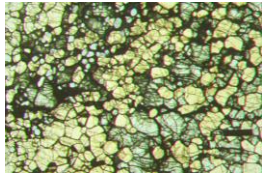
Grade Loss

Resorption

SFD

SFD

Kimberlitic/mantle



Fluid present or not

H_2O:CO_2 ratios