DE BEERS GROUP

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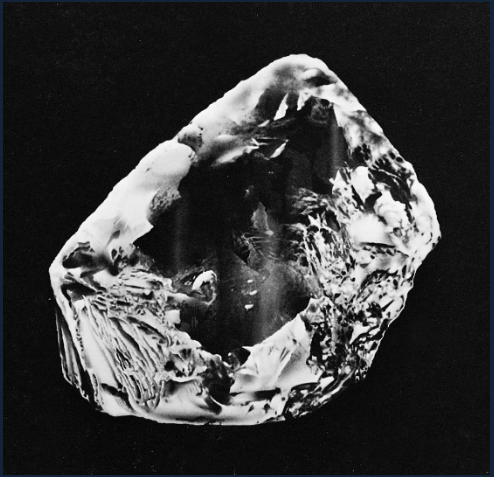
DECIPHERING THE HISTORY OF CLIPPIR DIAMONDS FROM THEIR MORPHOLOGY & SURFACE FEATURES

Ingrid Chinn



The Cullinan, 3106 ct

12TH INTERNATIONAL KIMBERLITE CONFERENCE
YELLOWKNIFE, 8-12 JULY 2024

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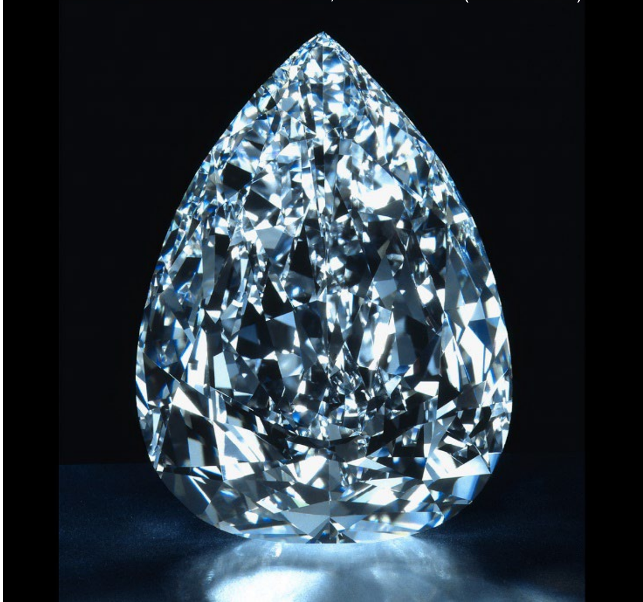

De Beers Millenium Star, 203.04 ct (ex 777 ct)

1. Smith, EM., et al. (2016) Science, 354 (6318), 1403-1405. https://doi.org/10.1126/science.aal1303

CONTEXT

- 32 years' experience in the description of diamond morphology and surface features, and the interpretation of Fourier Transform Infrared (FTIR) spectra and Cathodoluminescence (CL) images.

- Exposure to Type I and Type IIa diamond **populations** (from microdiamonds to several ct) from Exploration projects and operating mines around the world.

- Type II diamonds of all kinds; I have had recent access to 2-10 ct (and a few larger) brown Type IIa gem diamonds from current and past De Beers mines.

- All the Type IIa diamonds in this presentation were identified by FTIR spectroscopy, not a screening device based on UV fluorescence (e.g. Yehuda).

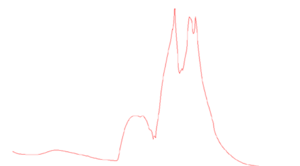
"The 616", courtesy of De Beers Group

CRITERIA USED TO CLASSIFY CLIPPIR-RELATED SUBLITHOSPHERIC DIAMONDS

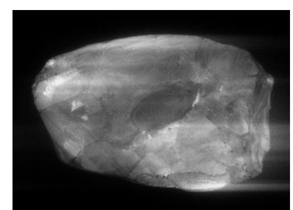
- **Morphology**: irregular, highly resorbed, often with low relief surfaces, evidence of extreme deformation, diamonds often consist of aggregates (more than one nucleation centre).

- **Inclusions:** rare, commonly black in colour, not visually identifiable as one of the common lithospheric inclusions of the peridotitic or eclogitic paragenesis.

- **FTIR spectrum:** Type IIa or highly aggregated (Type IaB,) with platelet degradation (but see Terminology & Caveats).

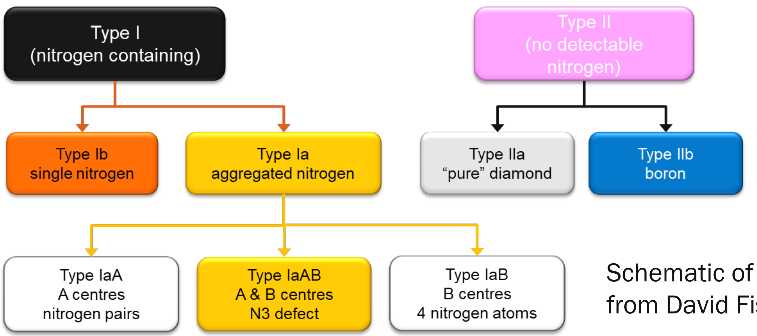


- **CL**: evidence of extreme plastic and/or brittle deformation, growth zoning is absent or more complex than for lithospheric diamonds, some show mosaic structure with individual grains misaligned with respect to each other as a result of deformation.



TERMINOLOGY & CAVEATS *(DIAMOND TYPE)*

- **Type II diamonds** have lower nitrogen than can be detected by FTIR.
- They originate from within the lithosphere, the transition zone, and lower mantle.
- Not all **sublithospheric diamonds** are **Type II**. Some are Type Ia, usually with **low nitrogen** contents and a high degree of nitrogen aggregation, i.e., **Type IaB.**
- Some sublithospheric diamonds have **high nitrogen** contents (up to 2528 ppm)[1] and are not always fully aggregated (**Type Ia**, Monastery and Juina).[1,2]
- Most, **but not all**, CLIPPIR diamonds are Type IIa[3].



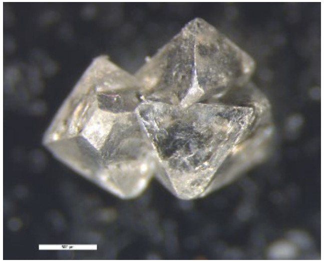
Schematic of diamond Type and colour from David Fisher, De Beers Group

1. Palot, M., et al. (2017) Chemical Geology, 466: 733-749. https://doi.org/10.1016/j.chemgeo.2017.07.023
2. Rudloff-Grund, J., et al. (2016) Lithos 265: 57-67. https://doi.org/10.1016/j.lithos.2016.09.022
3. D'Haenens-Johansson, UFS., et al. (2017) International Kimberlite Conference: Extended Abstracts. Vol. 11.

TERMINOLOGY & CAVEATS *(MORPHOLOGY, SHADES OF IRREGULAR)*

DB

- Some **sublithospheric** diamonds have **octahedral** morphology and do not show extreme resorption or irregular morphology[1].



Diamond aggregate from Candle Lake C29/C30 kimberlite, courtesy of Perry Ksyniuk, Adamas Minerals Corp. Scale bar: 0.5 mm.

- Mixed habit cuboid and octahedral **growth sector zonation** seen in Type Ib-IaA **eclogitic** diamonds* may produce "irregular" morphologies, but these are different from the **irregular** morphology associated with CLIPPIR diamonds.

* *e.g., from North Arrow Mineral's Naujuut Q1–4 kimberlite and Orapa*[2].

Images shown in this presentation are of uncut **brown Type IIa gem quality diamonds,** not of any large colourless Type IIa diamonds. Based on morphology, surface features and inclusions they are presumed to be sublithospheric.

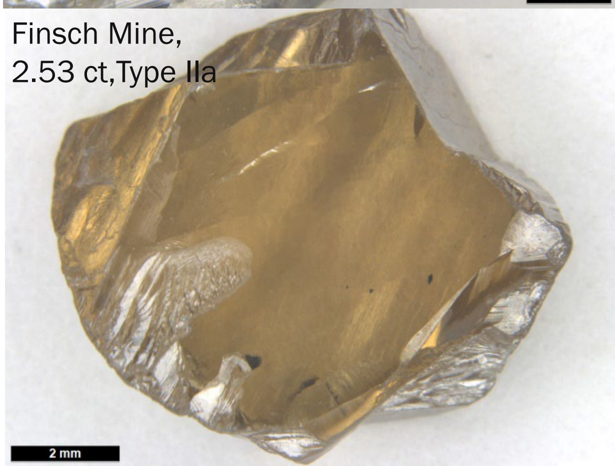
1. Pezzera, A., et al. (2024) Canada.12th International Kimberlite Conference, Extended Abstract 12IKC-139.
2. Timmerman, S., et al. (2018) Mineralogy and Petrology 112. Suppl 1: 209-218. https://doi.org/10.1007/s00710-018-0592-9

INCLUSIONS: RARE, BUT DO EXIST

- Mostly black
- Some in annealed fracture planes

Finsch Mine, 8.55 ct, Type IIa

Finsch Mine, 2.41 ct, Type IIa



Finsch Mine,
2.53 ct,Type IIa

Finsch Mine, 1.92 ct, Type IIa

OCCURRENCE OF CLIPPIR-RELATED SUBLITHOSPHERIC DIAMONDS

Kimberlites		CROLS	Lamproites
Cullinan	Venetia[1]	Finsch[1]	Prairie Creek[4]
Jagersfontein	Meya dykes[2]	Voorspoed[1]	
Koffiefontein	Victor[3]		
Monastery			
Letšeng & satellite			
Mothae			
Kao			
Karowe			
Jwaneng			
Orapa			
Letlhakane			

Esperanza Diamond:
8.52 ct Type IIa recovered in 2015. Image courtesy of Crater of Diamonds State Park.

Maiko Star:
102.39 ct cut from 271 ct Type IIa recovered from Victor Mine in 2018.

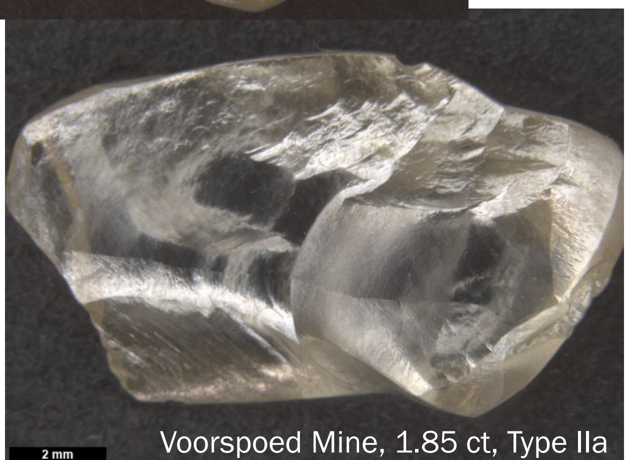
Images by Sotheby's

1. This presentation
2. Jakubec, J. 2024 PDAC presentation: Meya Project: a source of Sierra Leone's large Type IIa diamonds.
3. https://www.diacore.com/102.39-carat-d-colour-flawless-oval-diamond.php
4. https://www.arkansasstateparks.com/parks/crater-diamonds-state-park/history/famous-finds

MORPHOLOGY: AGGREGATES

Finsch Mine, 3.22 ct, Type IIa

Finsch Mine, 1.84 ct, Type IIa



Voorspoed Mine, 1.85 ct, Type IIa

Voorspoed Mine, 2.17ct, Type IIa

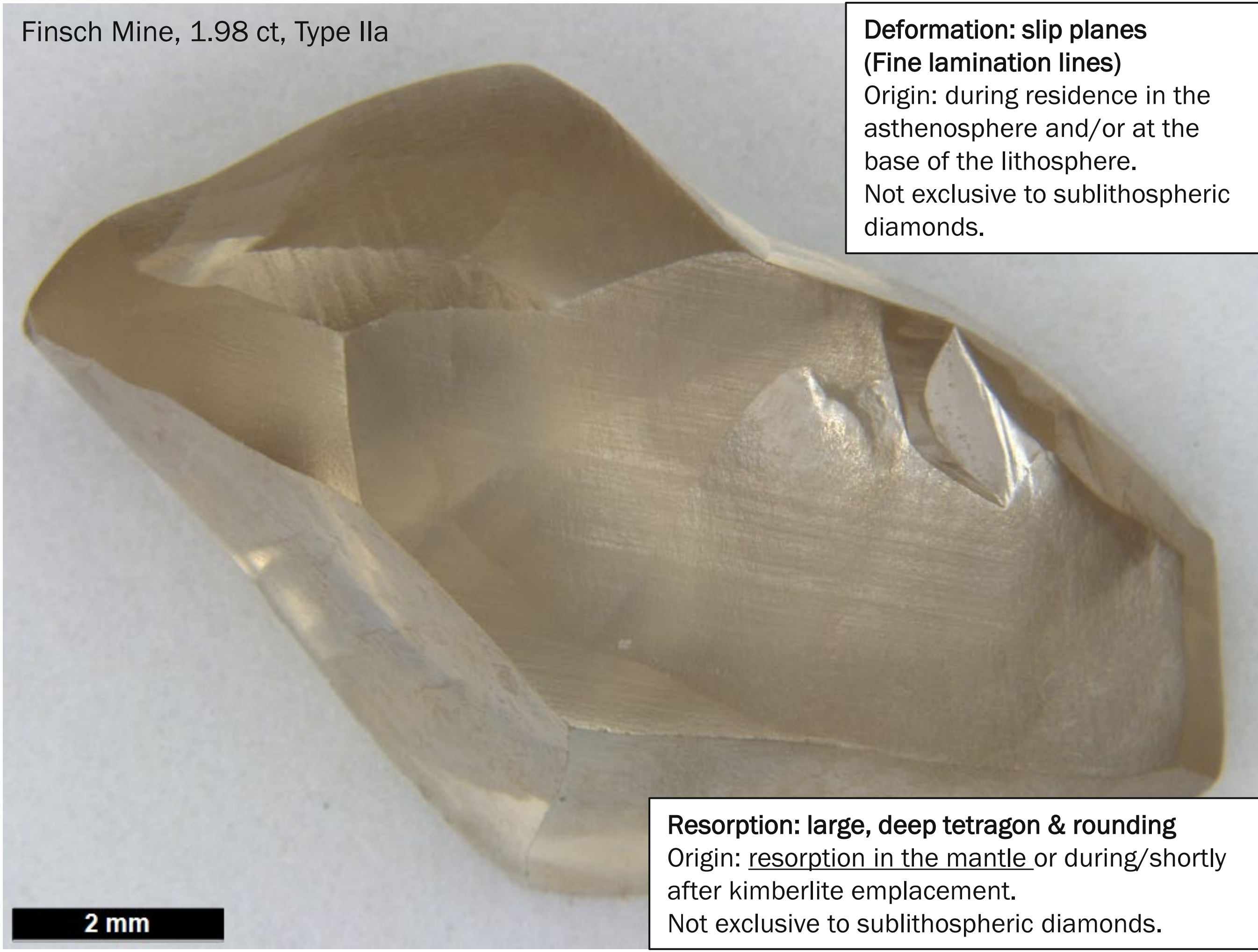
PLASTIC DEFORMATION: SLIP & TWINNING

Wide lamination lines
Origin: during residence in the asthenosphere and/or at the base of the lithosphere.

Finsch Mine, 1.99 ct, Type IIa

Slip is **not exclusive** to sublithospheric diamonds, but wide lamination lines may be more common than fine lamination lines in sublithospheric diamonds.

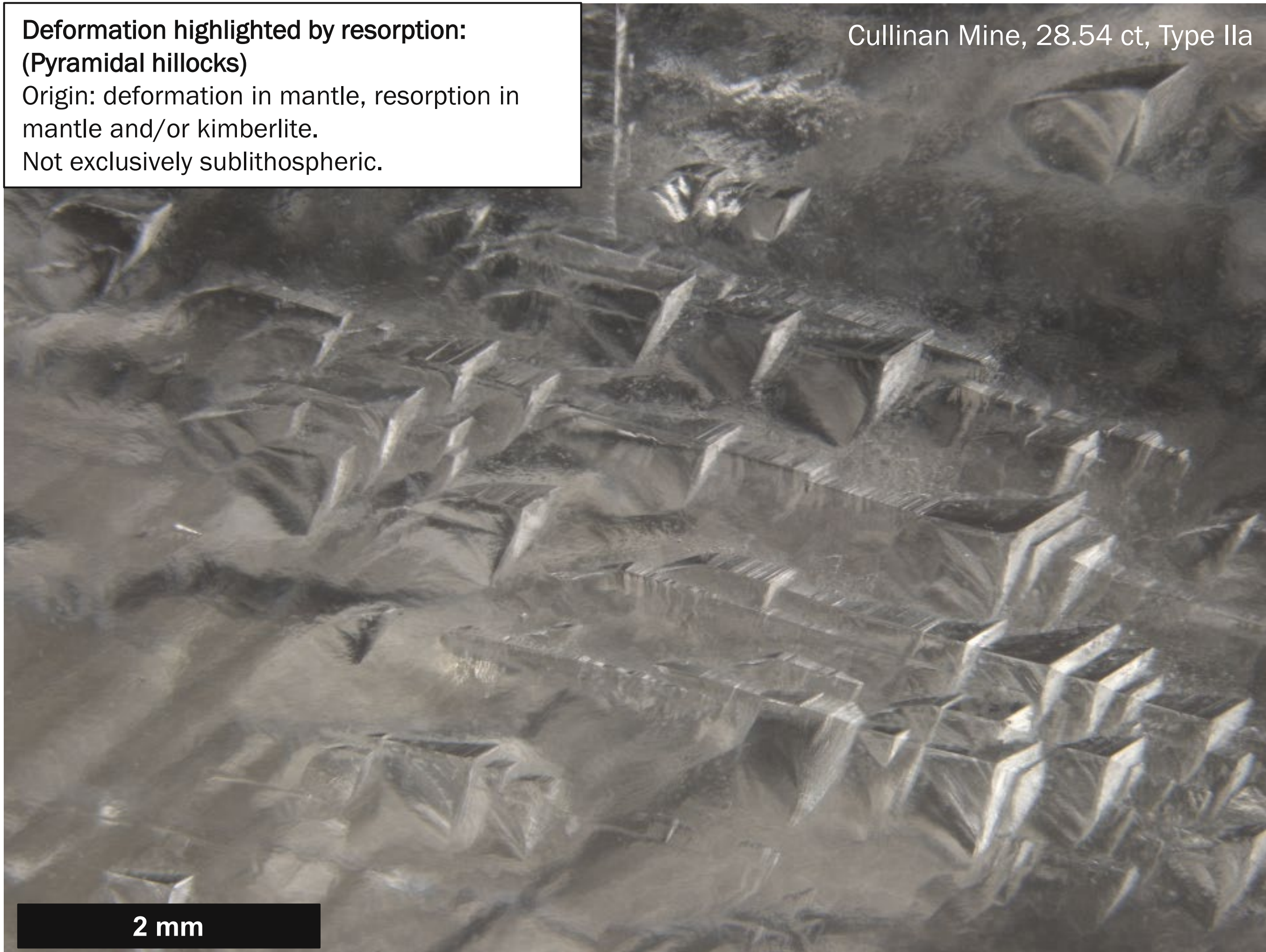
Deformation: slip planes
(Wide lamination lines)
Origin: during residence in the asthenosphere and/or at the base of the lithosphere.
Not exclusive to sublithospheric diamonds.


Finsch Mine, 1.98 ct, Type IIa
Deformation: slip planes (Fine lamination lines)
Origin: during residence in the asthenosphere and/or at the base of the lithosphere.
Not exclusive to sublithospheric diamonds.
Resorption: large, deep tetragon & rounding
Origin: resorption in the mantle or during/shortly after kimberlite emplacement.
Not exclusive to sublithospheric diamonds.
2 mm


Deformation: slip and twinning
Origin: during residence in the asthenosphere and/or at the base of the lithosphere. Slip is not exclusively sublithospheric, but deformation twinning may be characteristic of sublithospheric diamonds.
Voorspoed Mine, 2.95 ct, Type IIa
2 mm

Deformation highlighted by resorption: (Pyramidal hillocks)

Origin: deformation in mantle, resorption in mantle and/or kimberlite.
Not exclusively sublithospheric.



RESORPTION: LOW RELIEF SURFACES, VERY COMMON

Origin: during mantle residence and/or emplacement.

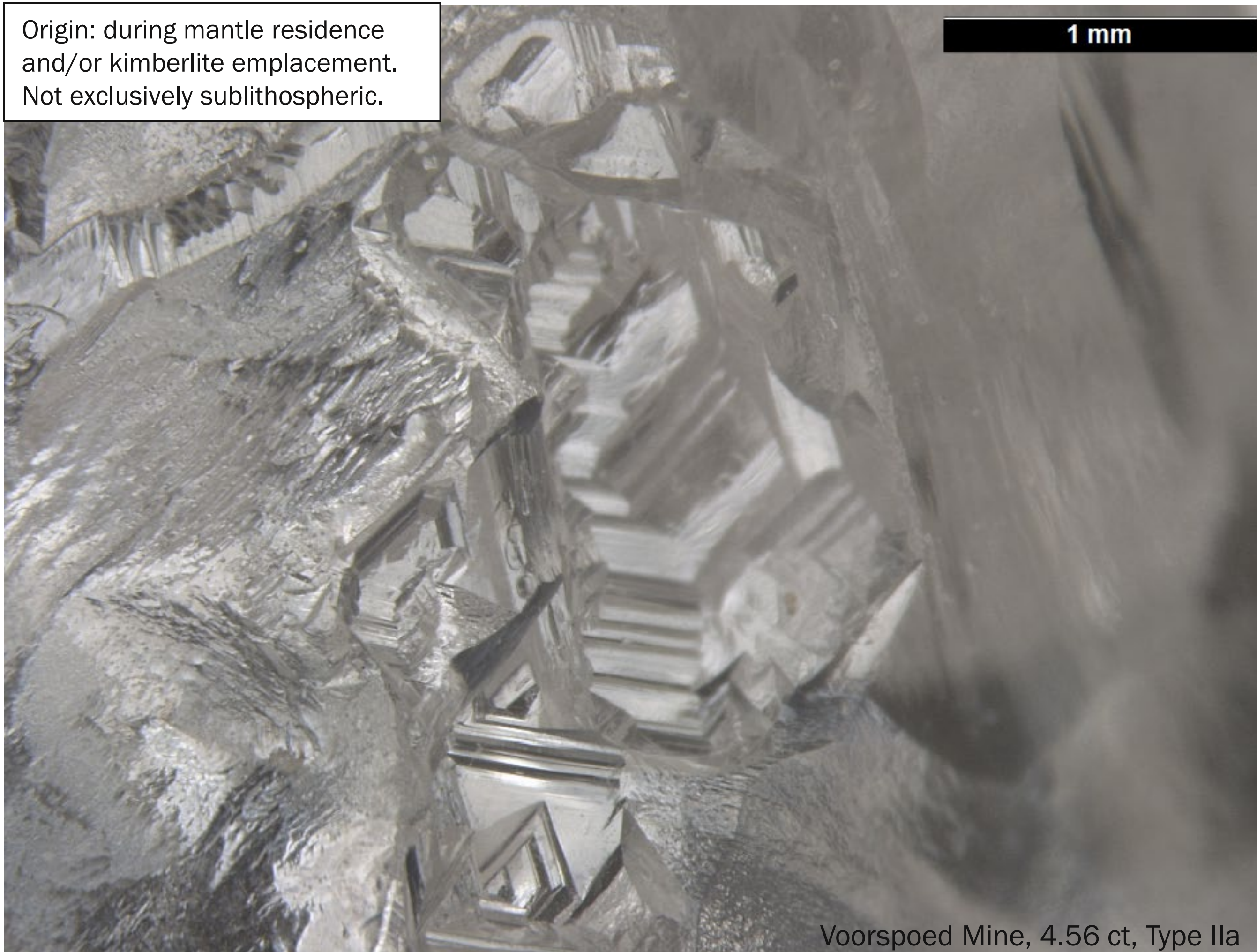
Voorspoed Mine, 7.33 ct, Type IIa

This type of low relief surface is not commonly associated with lithospheric diamonds, possibly suggesting derivation in unusual circumstances - sublithospheric?

SURFACE FEATURES: RESORPTION – TRIGONS

Origin: during mantle residence and/or kimberlite emplacement. Not exclusively sublithospheric.

Origin: during mantle residence and/or kimberlite emplacement. Not exclusively sublithospheric.



Voorspoed Mine, 4.56 ct, Type IIa

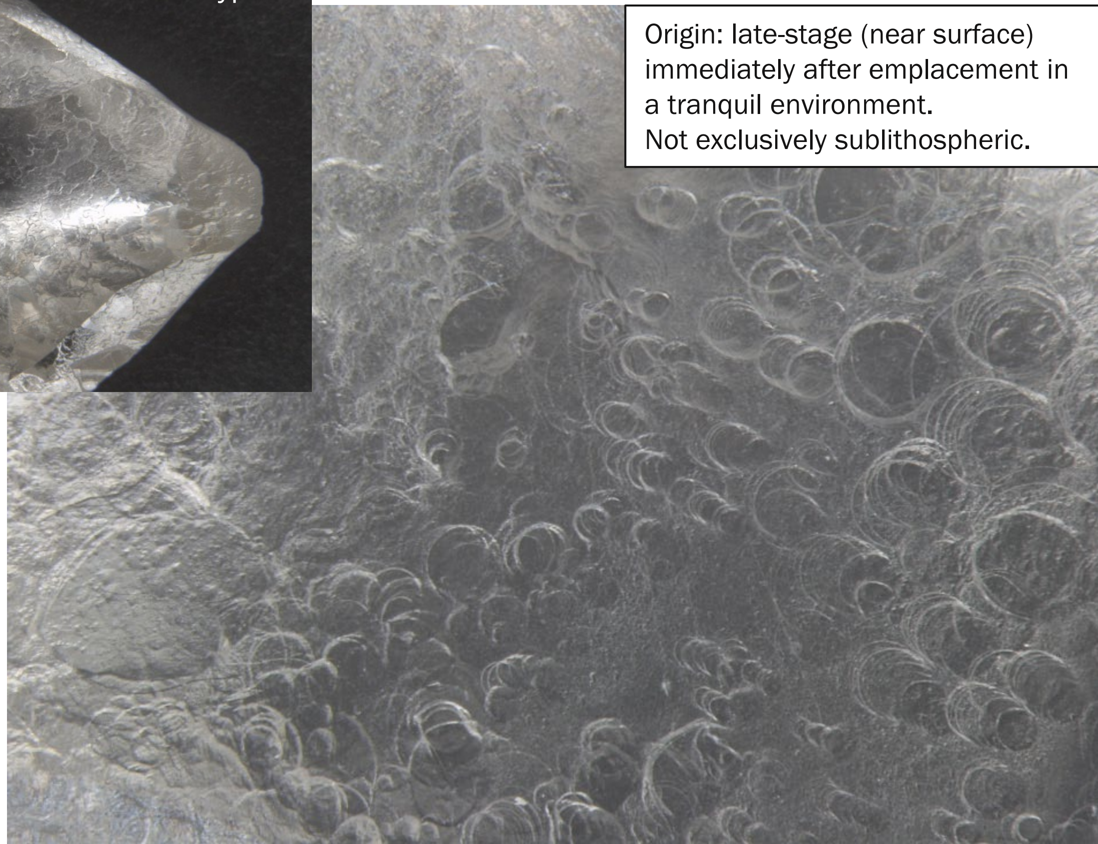
SURFACE FEATURES: RESORPTION – TETRAGONS & FROSTING

Origin: late stage: during and/or post-emplacement.
Not exclusively sublithospheric.

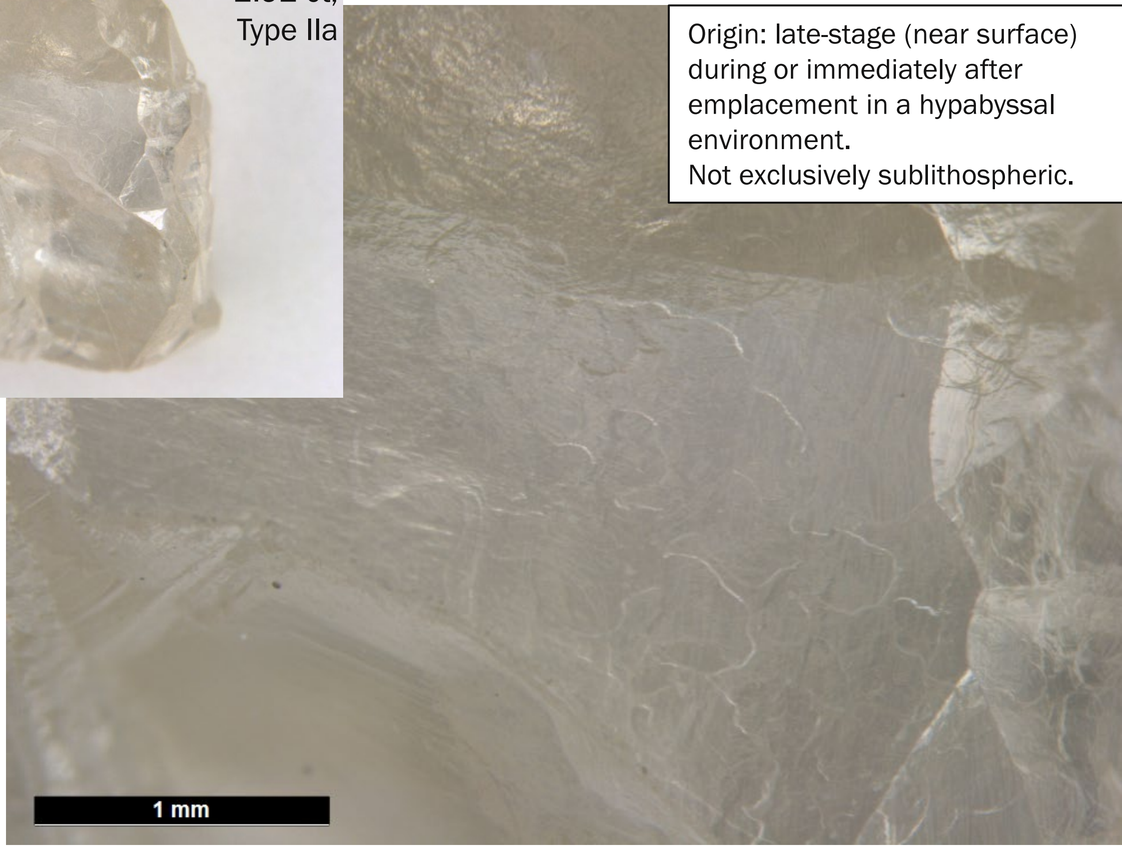
Cullinan Mine, 48.69 ct, Type IIa

RESORPTION: MICRODISK PATTERN

Origin: late-stage (near surface) immediately after emplacement in a tranquil environment.
Not exclusively sublithospheric.



RESORPTION: SMOOTH SCULPTURED SURFACES/TIDELINES



Origin: late-stage (near surface) during or immediately after emplacement in a hypabyssal environment.
Not exclusively sublithospheric.

RESORPTION: SHALLOW DEPRESSIONS

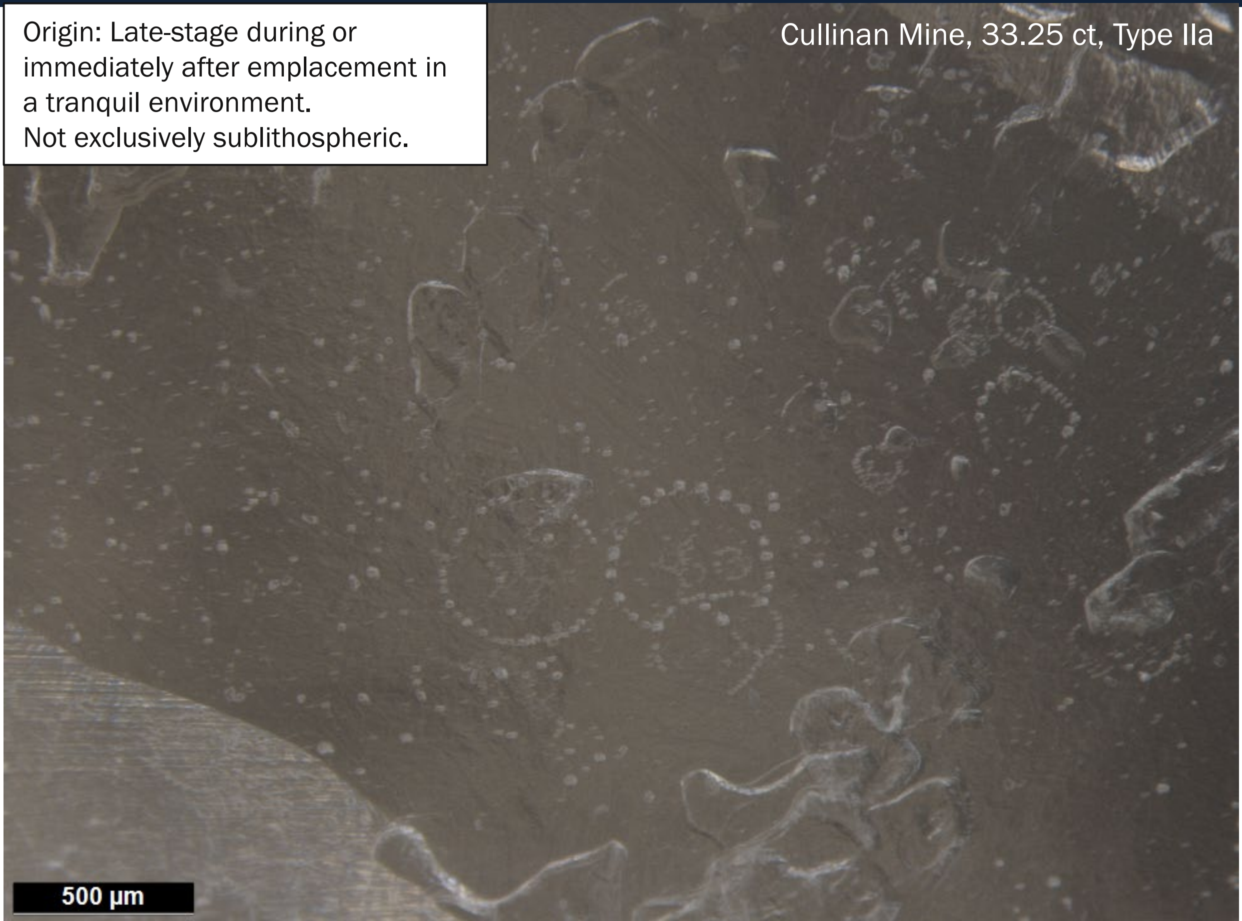
DB

Origin: late-stage during or immediately after emplacement in a hypabyssal environment.
Not exclusively sublithospheric.

Cullinan Mine, 23.63 ct, Type IIa

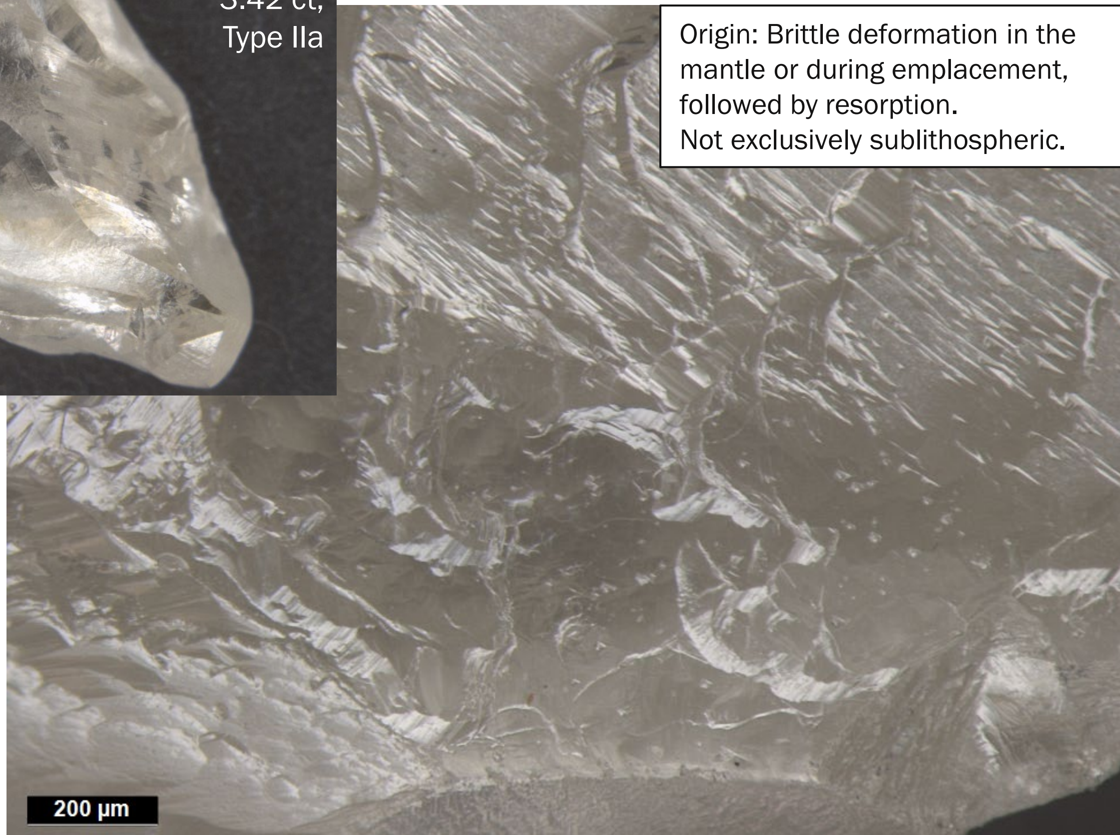
RESORPTION: NECKLACE PATTERN

Origin: Late-stage during or immediately after emplacement in a tranquil environment.
Not exclusively sublithospheric.



RESORBED BREAKAGE SURFACE

Origin: Brittle deformation in the mantle or during emplacement, followed by resorption.
Not exclusively sublithospheric.



SUMMARY

- CLIPPIR diamonds owe their irregular resorbed morphology to a combination of some being complex aggregates and the effects of plastic deformation (slip and twinning) at extreme strain rates in a dynamic environment. High pressures and temperatures, and low nitrogen contents may also contribute to the particular resorption style.

- Natural brittle fracture has also affected some of the CLIPPIR diamonds, also during growth.

- While their primary origin is sublithospheric, there is compelling evidence[1] for mantle residence at an intermediary level at the base or deep in the lithospheric mantle, prior to eruption to the surface of the earth.

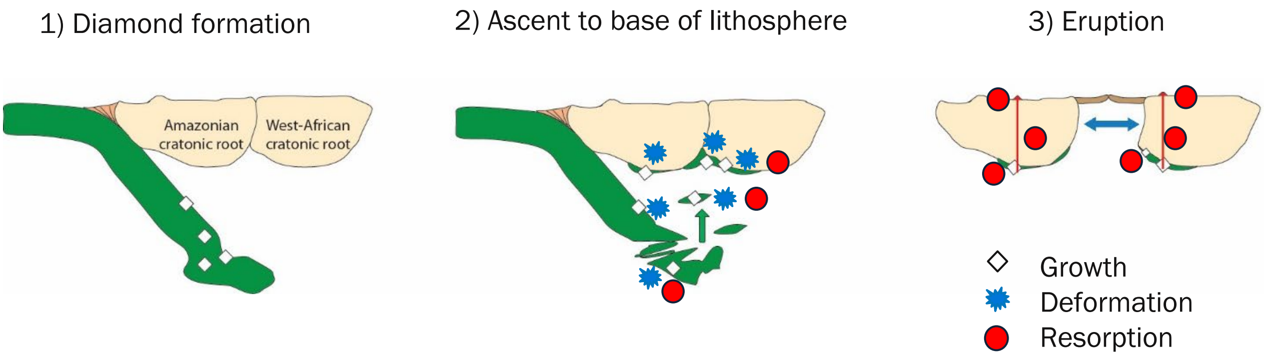
- Overprinting of surface features derived during late-stage emplacement (frosting, shallow depressions, necklace pattern) are commonly seen.

- **Multiple sub-populations** of CLIPPIR diamonds show subtle differences in colour, shape, inclusion content and deformation features at individual localities.

- CLIPPIR diamonds occur in kimberlites, CROLs and lamproites.

1. Timmerman S. et al. (2023) Nature 623: 752-756. https://doi.org/10.1038/s41586-023-06662-9

REFERENCE TO MODEL OF TIMMERMAN ET AL. (2024)



Growth: primarily in the asthenosphere, minor recrystallisation and annealing of fractures (with or without inclusions) may occur at the base of the lithosphere.

Deformation: plastic and brittle deformation in the asthenosphere and at the base of the lithosphere, brittle deformation also during emplacement of the kimberlite?

Resorption: in the asthenosphere, at the base of the lithosphere, during and shortly after kimberlite emplacement.

1. Timmerman S. et al. (2024). 12th International Kimberlite Conference Extended Abstract No. 12IKC-Key04.

ACKNOWLEDGEMENTS

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Petra Diamonds