The Genesis of Blue Diamonds

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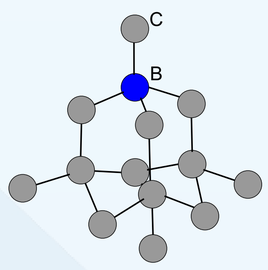
Introduction:

Blue diamonds are among the **rarest** type of gems : **<0.1%** of the extracted diamonds. Mainly from South Africa (Cullinan mine) and India (Kollur mine), ± Central Africa, South America and Borneo.Their **blue color** is due to **trace amounts of boron** in the lattice structure and the near absence of nitrogen, thus defined as **type IIb** diamonds [1].



It is proposed that blue diamonds are of **ultra-deep origin**, from the lower mantle, and exclusively formed in **subduction settings** [2].

Boron would be inherited from **slab dehydration** and carried to **lower mantle** (>660 km) in dense hydrous silicate minerals (DHMS).

→ Boron cycle in the mantle is realtively unknown and the study of these boron-bearing diamonds brings new insights on this deep cycle.

Materials

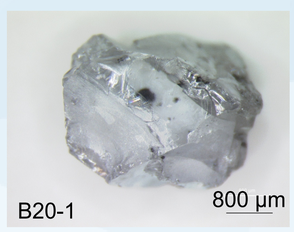
Cullinan mine in South Africa

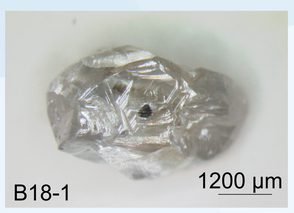
Boron: 0.22 to 0.38 ppm B

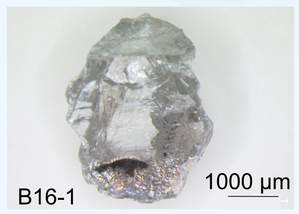
Four diamonds:

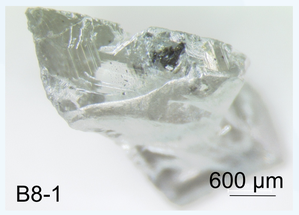
1 x3 mm for ~0.10 ct

- Two with primary inclusions
- Two with primary and secondary inclusions









Methodology: *in situ investigations*

Boron content measurement:

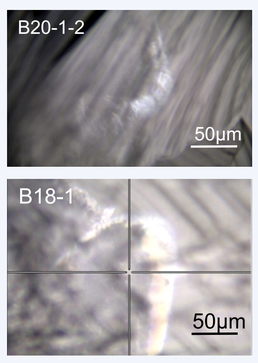
- Infrared spectroscopy (FTIR)

Mineral phase identification:

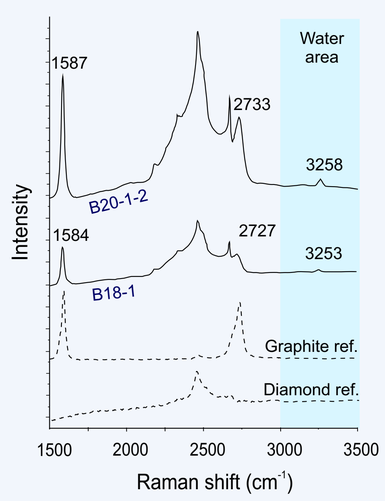
- µ-raman spectroscopy (532 nm)
- Synchrotron X-Ray diffraction

Results

Inclusions I

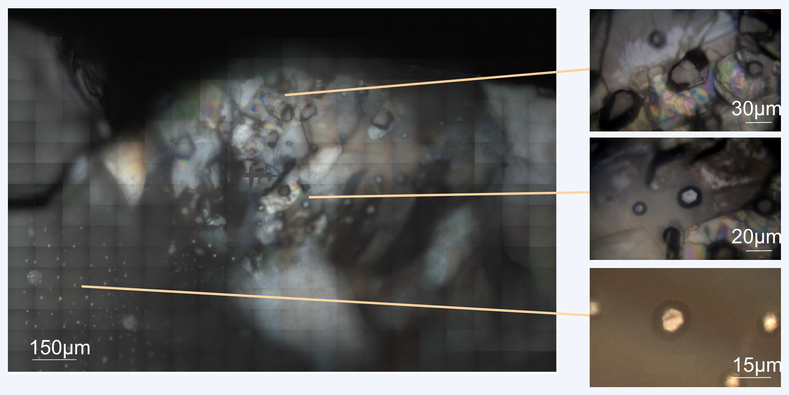


Contemporaneous to the diamond growth or at least trapped during the growth



+ Inclusions of CaSiO3-walstromite

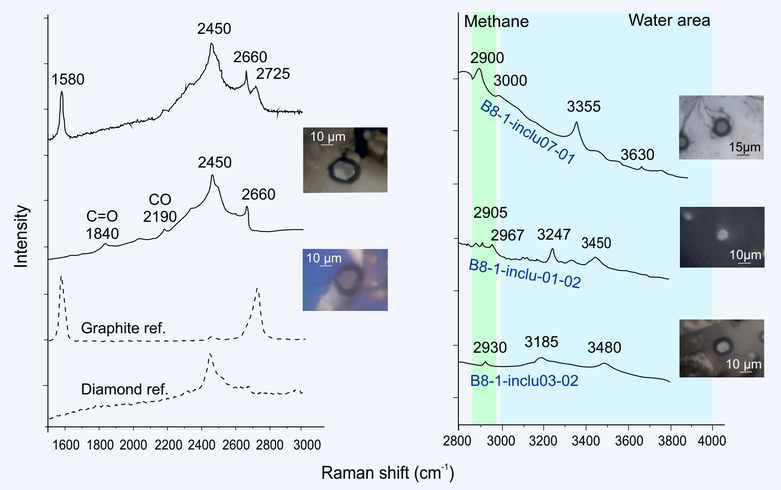
Inclusions II



Healed fractures: **Post-growth event**

Two-phase inclusions

Central Hexagonal Mineral — **Outer Colorless Halo**



+ Ilmenite ($FeTiO_3$)

A unique water-C- rich fluid present in both primary and secondary inclusions

Discussion

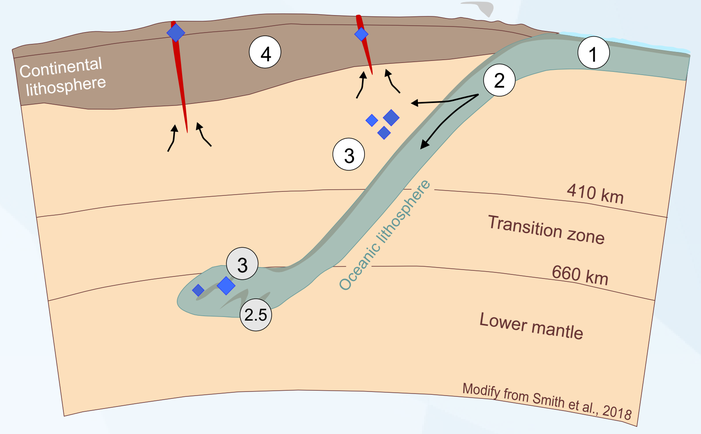
Forming fluid: Primary and secondary inclusions may be the witness of a **H_20-$C_{graphite}$ parent fluid**

Mineral assemblage: Inclusion of Ilmenite : **Eclogitic paragenesis at lithospheric depth**

Inclusion of walstromite (retrogressed Ca-Perovskite (CaTiO3); >9 Gpa): **Sub-lithospheric depth**

Boron: inherited from sea water through the subduction zone : H_20 + $C_{organic}$ + boron, available in the lithosphere after **slab dehydration**: **Data suggest a deep recycling of marine fluids that may be the the parents of blue diamonds**

We suggest that blue diamonds are not exclusively ultra-deep and may form at any depth in the mantle, from lithosphere (>150km) down to the lower mantle (~750 km), in subduction-related B-C-H_2O-rich fluids.



1: Seawater (H2O + C + B) throught subduction

2: Water and boron release during slab dehydration

or serpentinite to DHMS and 2.5 DHMS breakdown and realease boron [2]

3: Growth of B-bearing diamond

4: bring to surface throught kimberlite eruption

Acknowledgment:

We thank GEOTOP, FRQNT international internship scholarship and the Diamond Conference Young Researcher Award for their funding. The SEM facility of IMPMC is supported by Région Ile de France Grant SESAME 2006 NOI-07-593/R, INSU-CNRS, INP-CNRS, UPMC, and by the French National Research Agency (ANR) Grant ANR-07-BLAN-0124-01. We thank M. Guillaumet for his assistance during FTIR measurements, and Christophe Sandt and Ferenc Borondics from the SMIS beamline at SOLEIL synchrotron for their support during Raman mapping. We thank Ludovic Delbes, Philippe Rosier and the cellule projet from IMPMC for their assistance during the preparation for XRD experiments.

References

[1] Gaillou, E., Post, J. E., Rost, D., & Butler, J. E. Boron in natural type IIb blue diamonds: Chemical and spectroscopic measurements. American Mineralogist, 97 (1), 1-18 (2012). [2] Smith, E. M., Shirey, S. B., Richardson, S. H., Nestola, F., Bullock, E. S., Wang, J., & Wang, W. Blue boron-bearing diamonds from Earth's lower mantle. Nature, 560 (7716), 84-87 (2018).