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The Genesis of Blue Diamonds

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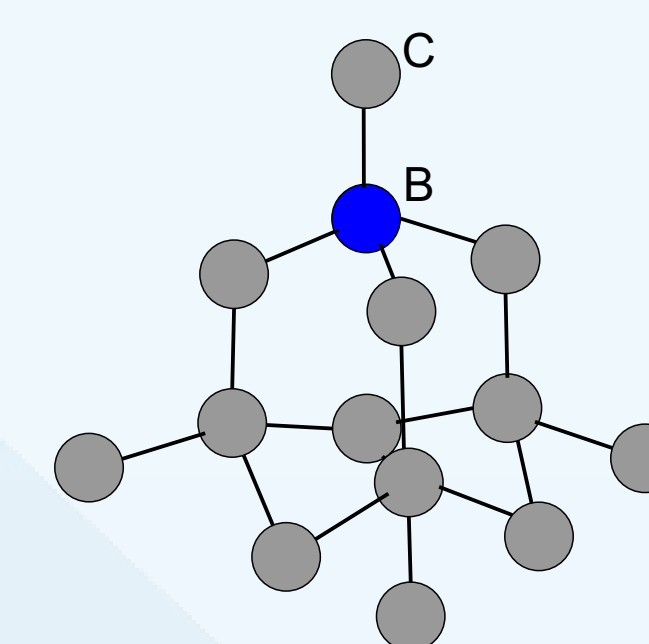
Introduction:

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 relatively unknown and the study of these boron-bearing diamonds brings new insights on this deep cycle.



Materials

Cullinan mine in South Africa

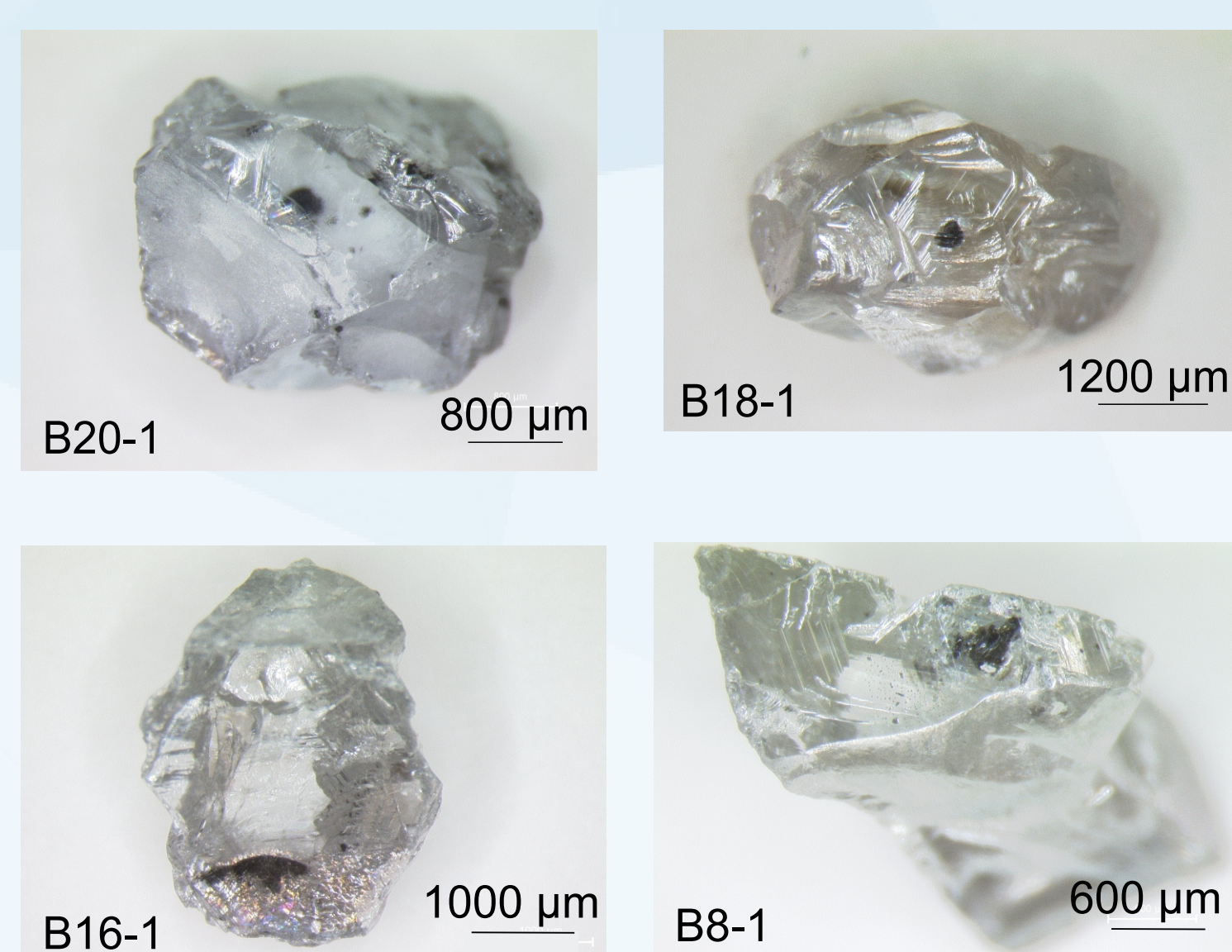
Boron: 0.22 to 0.38 ppm B

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)

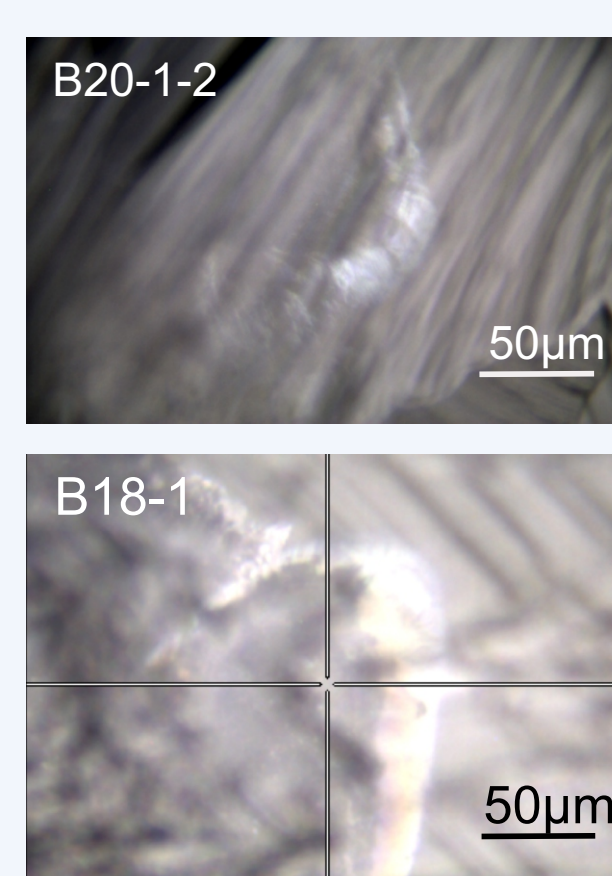
Mineral phase identification:

- μ-Raman spectroscopy (532 nm)

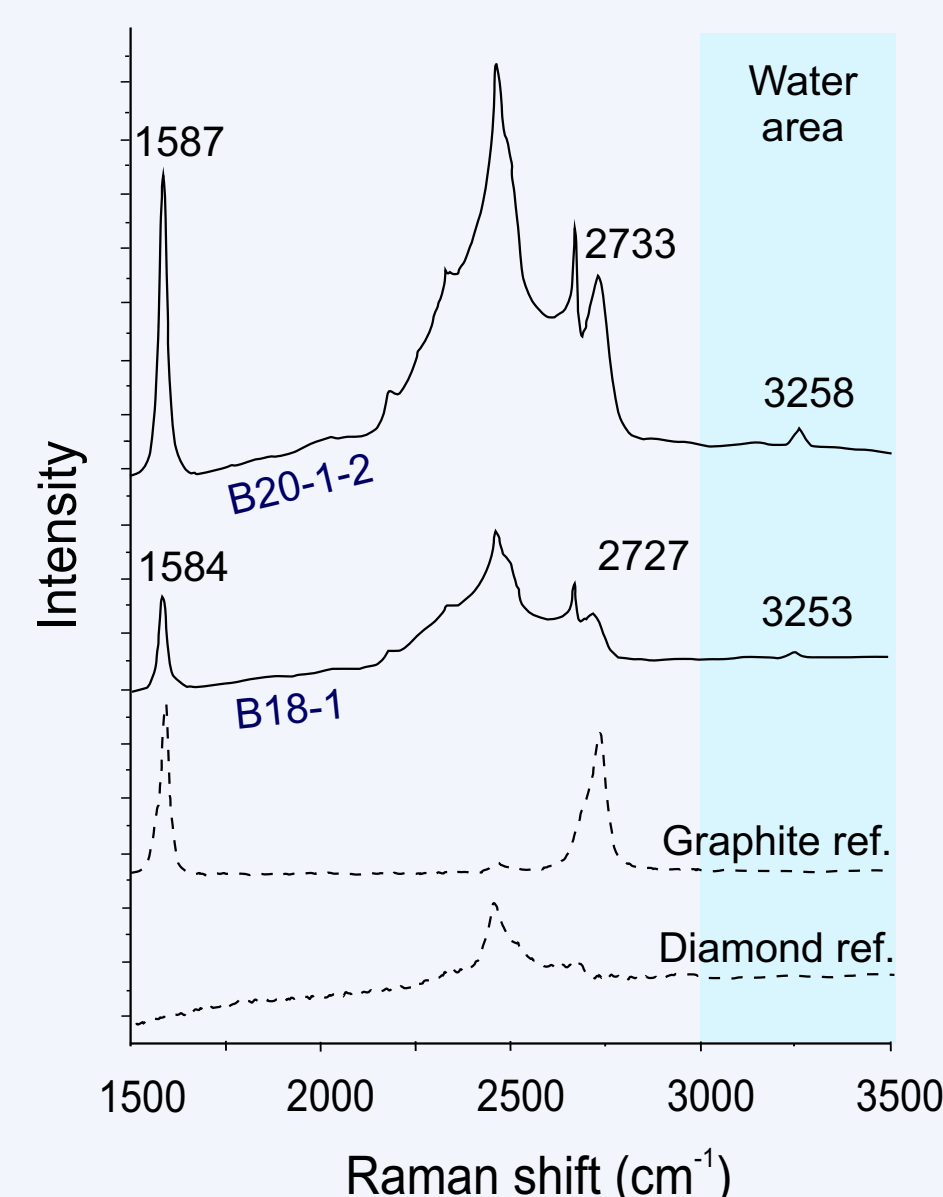
- Synchrotron X-Ray diffraction

Results

Inclusions I

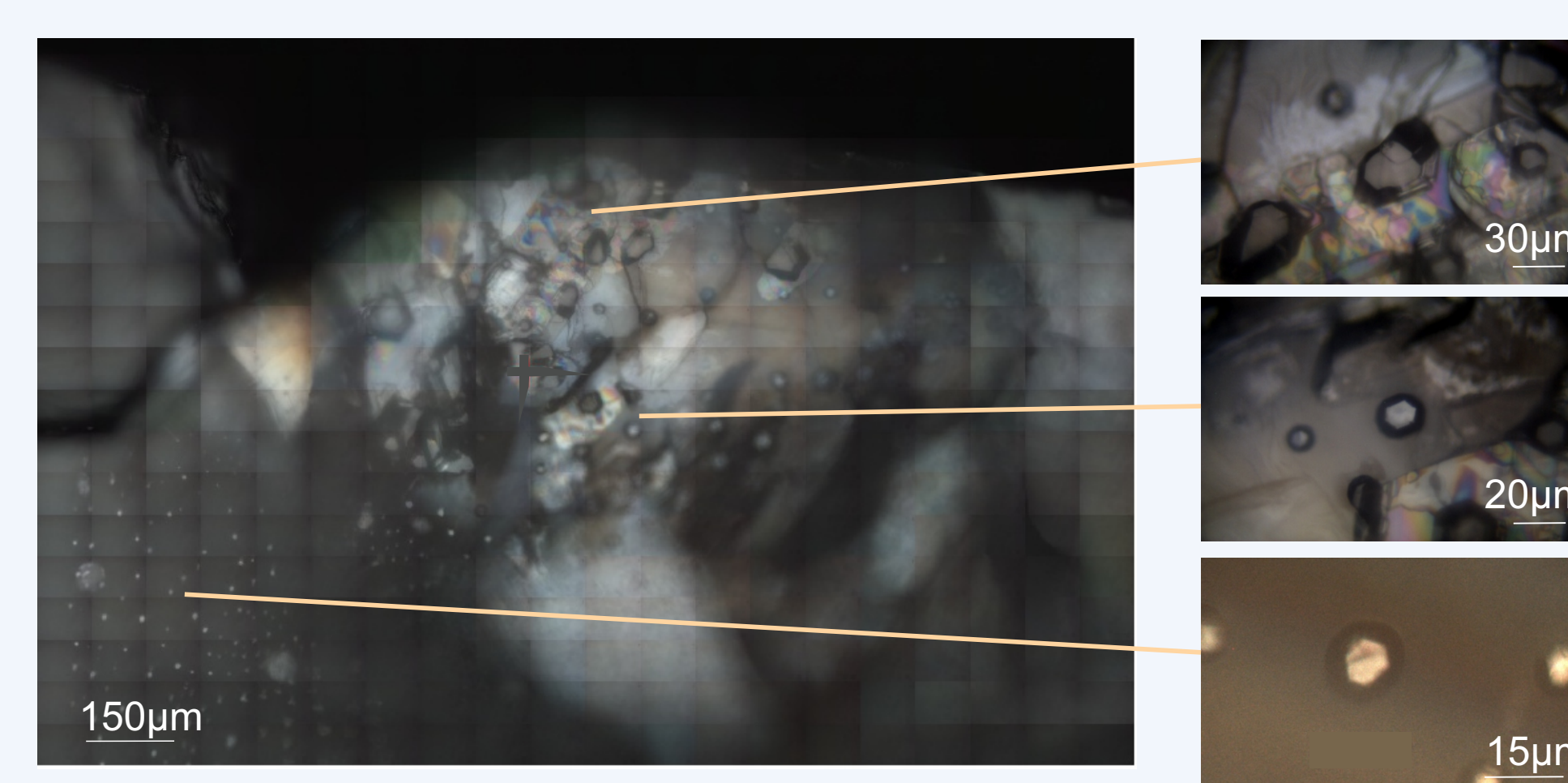


Contemporaneous to the diamond growth or at least trapped during the growth



+ Inclusions of CaSiO₃-walsstromite

Inclusions II

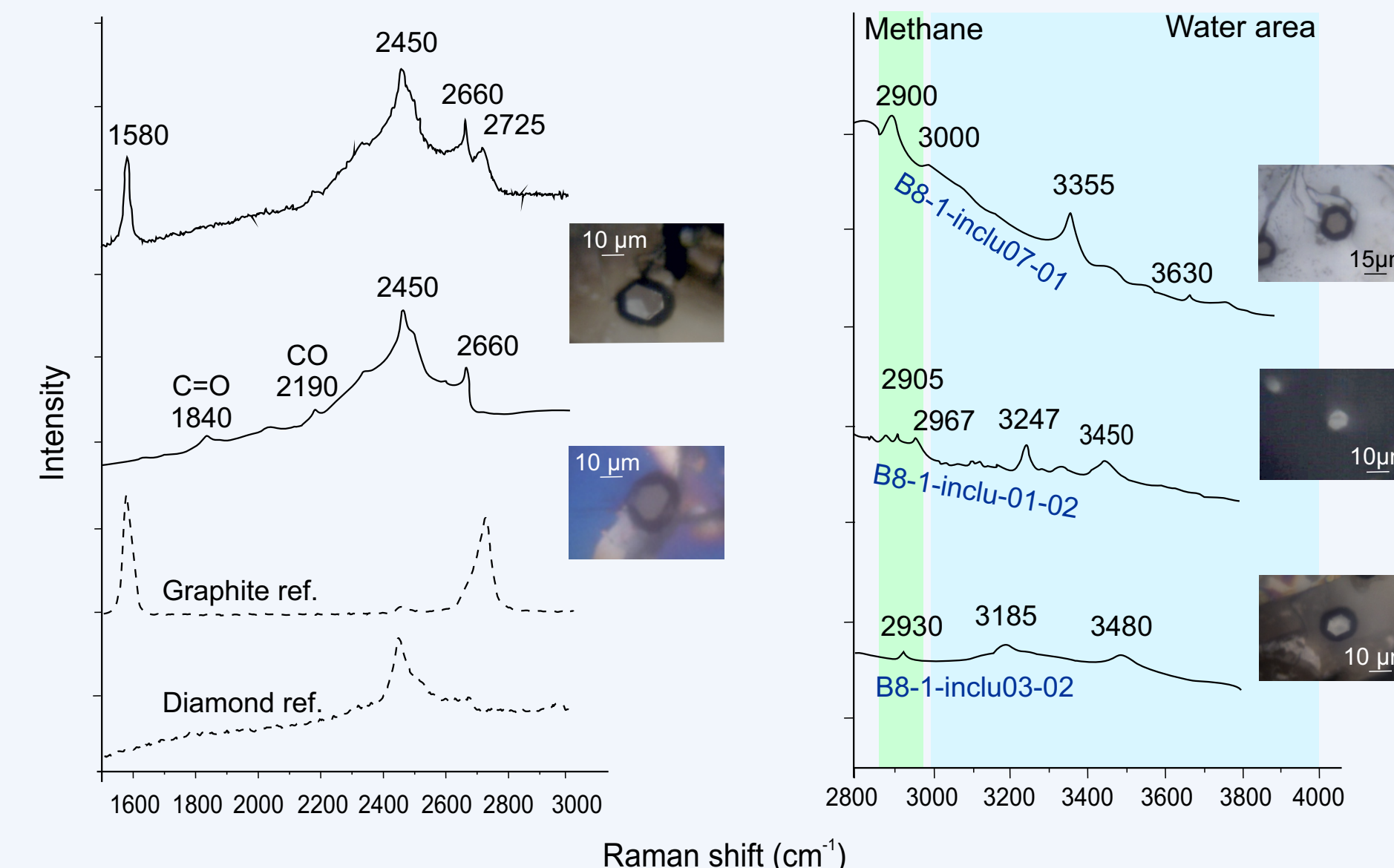


Healed fractures: **Post-growth event**

Two-phase inclusions

Central Hexagonal Mineral

Outer Colorless Halo



+ Ilmenite (FeTiO₃)

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

Discussion

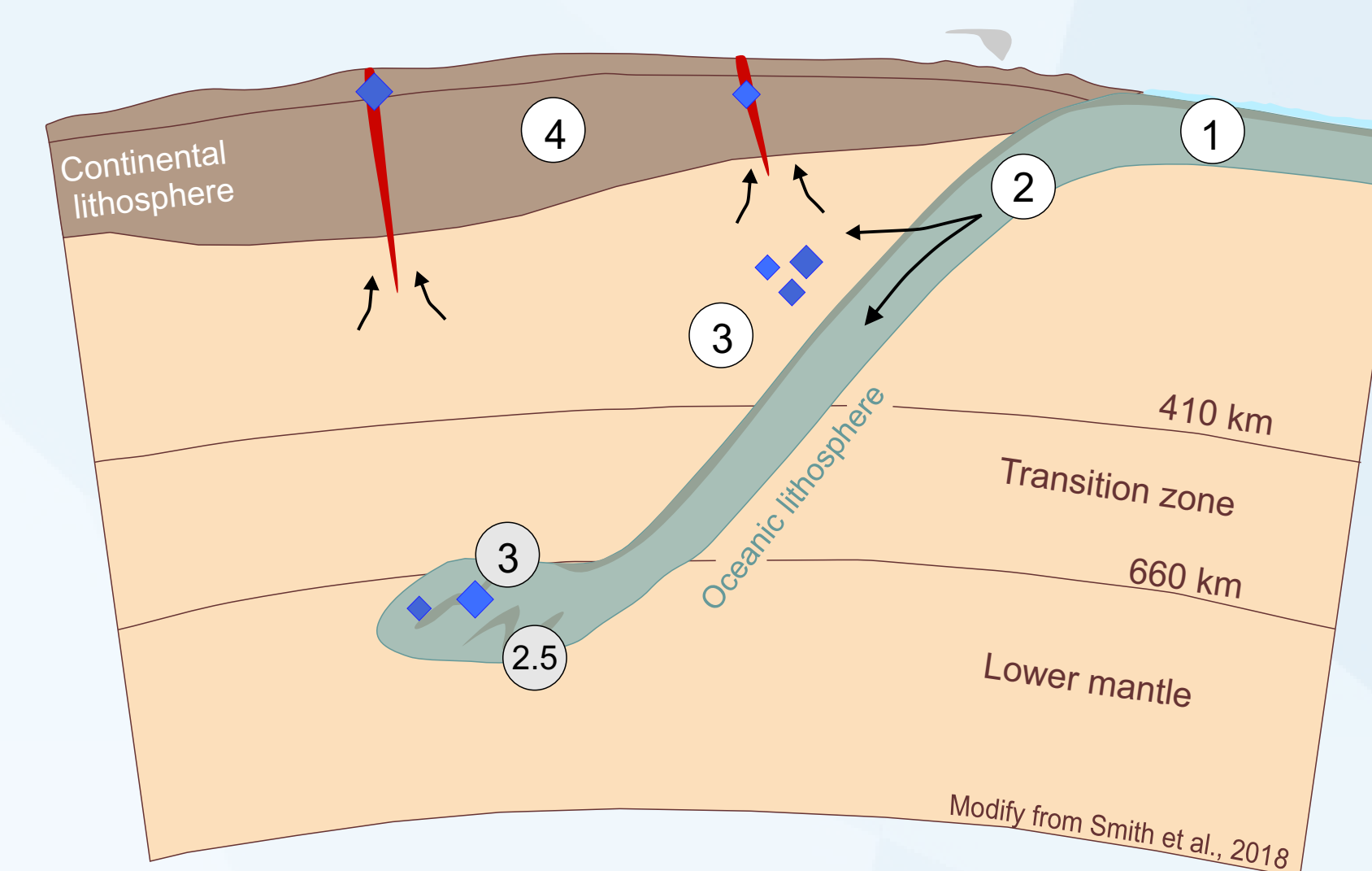
Forming fluid: Primary and secondary inclusions may be the witness of a **H₂O-C_{graphite} parent fluid**

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

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

Boron: inherited from sea water through the subduction zone : H₂O + C_{organic} + boron, available in the lithosphere after **slab dehydration**: **Data suggest a deep recycling of marine fluids that may be 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-H₂O-rich fluids.



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

2: Water and boron release during slab dehydration or serpentinite to DHMS and 2.5 DHMS breakdown and release boron [2]

3: Growth of B-bearing diamond

4: bring to surface through kimberlite eruption

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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).