CARBON POLYMORPHS IN UREILITES : A FINE-SCALE RAMAN AND SYNCHROTRON MAPPING

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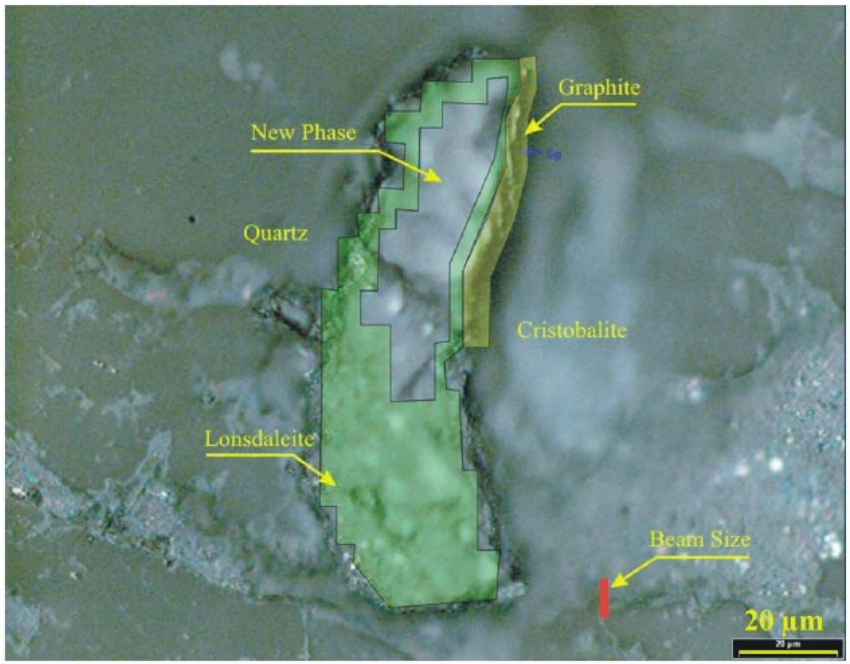
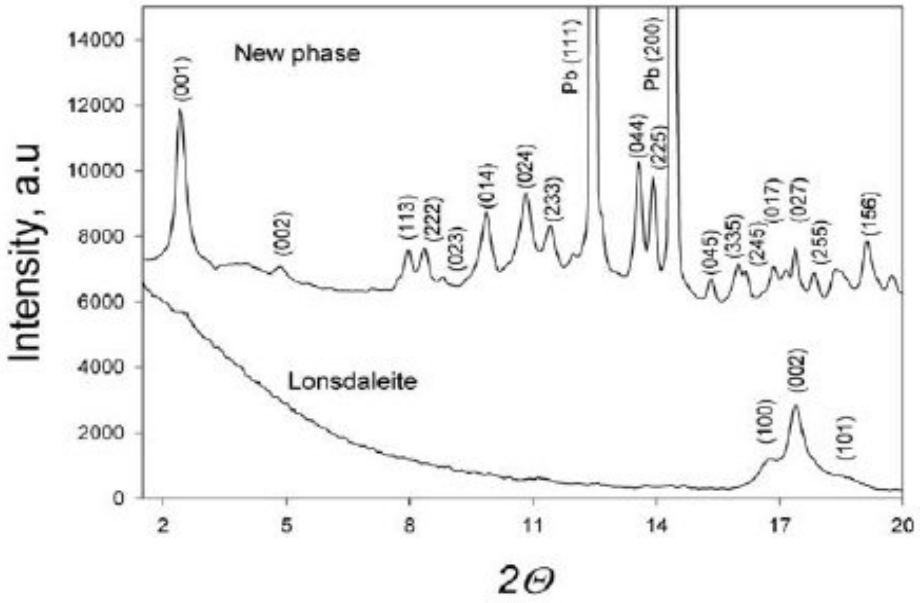
Introduction

- Natural phases of carbon : diamond (3C), graphite, lonsdaleite (6H), chaoite and fullerenes
- In 2003, El Goresy et al. found a new HP phase in the Popigai impact crater





El Goresy et al., CR Geoscience, 2003

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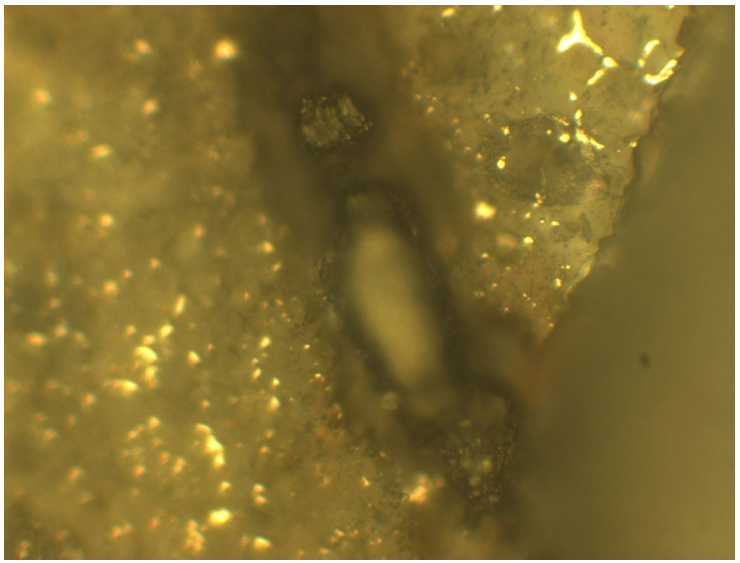
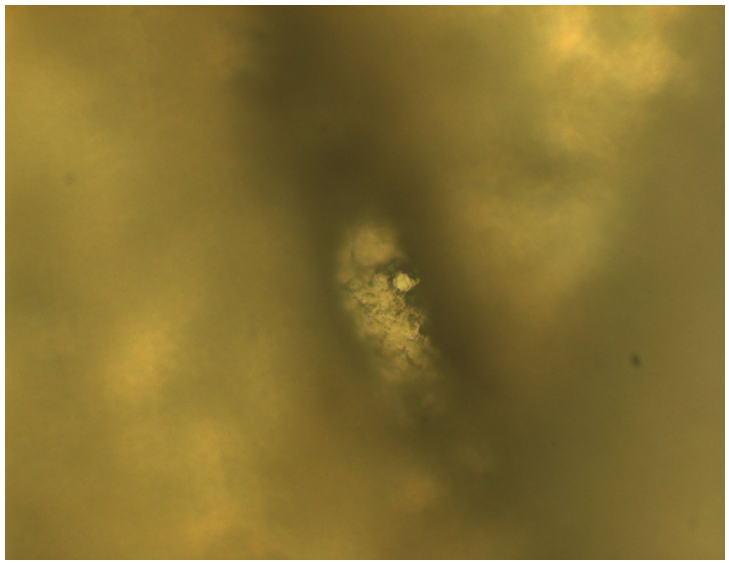
Introduction

- Ureilites : meteorites with 3% carbon mainly diamond and graphite
  - Compressed Graphite (Nakamuta and Aoki; 2000)
  - Secondary Graphite by Diamond-Graphite Back Transformation (Nakamura et al.; 2000)
- Possible Origin of Diamond and Lonsdaleite
  - CVD at Low-Pressure in the Solar Nebula (Fukunaga et al.; 1987,Matsuda et al.; 1991; 1995).
  - Natural Shock-Wave Propagation of Parental Graphite in the Parent Body (Lipschutz; 1964)

Samples

- Preparation : thin section of meteorite polished by diamond paste
- Preliminary Investigation by Optical microscopy Raman and SEM





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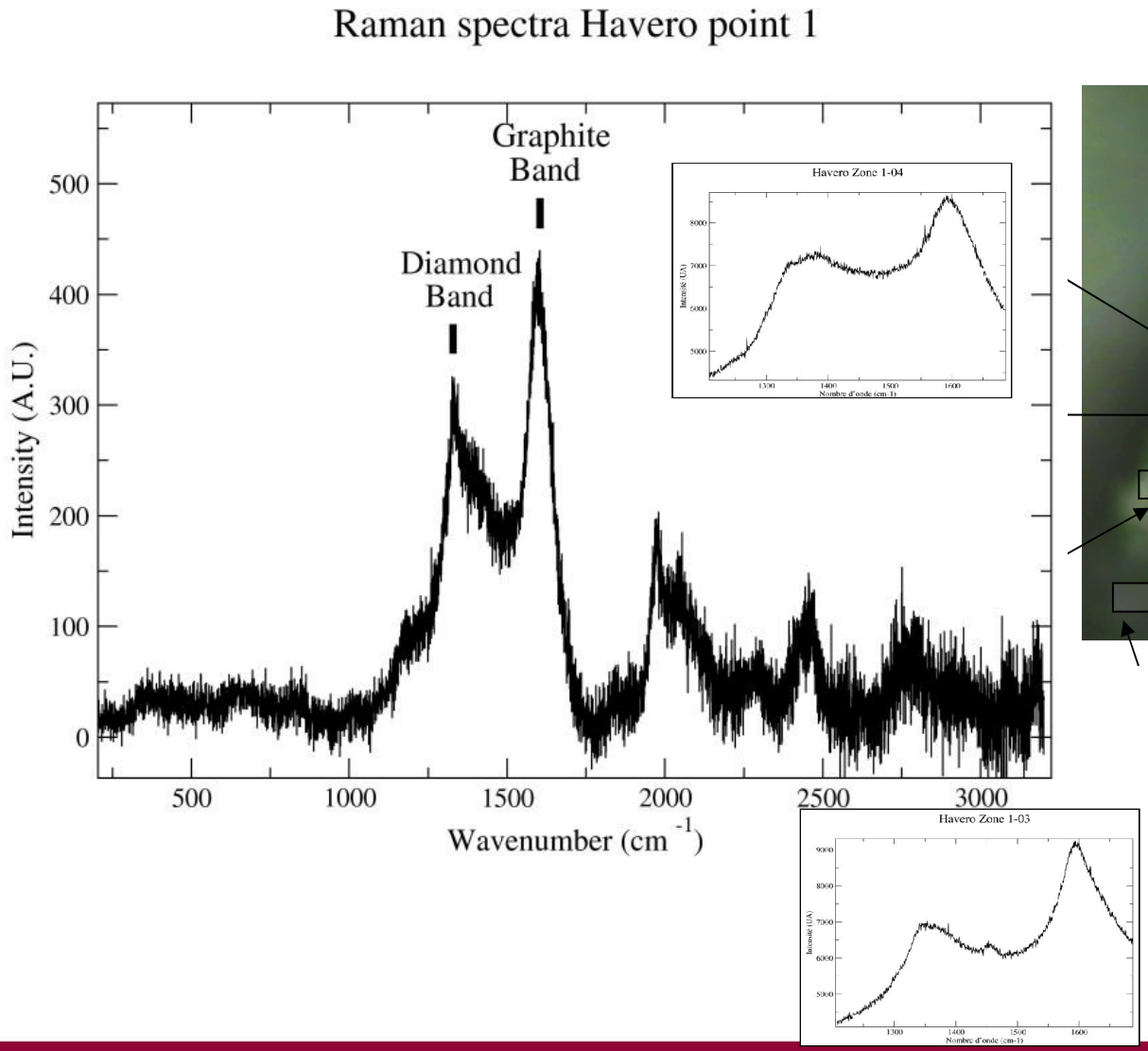
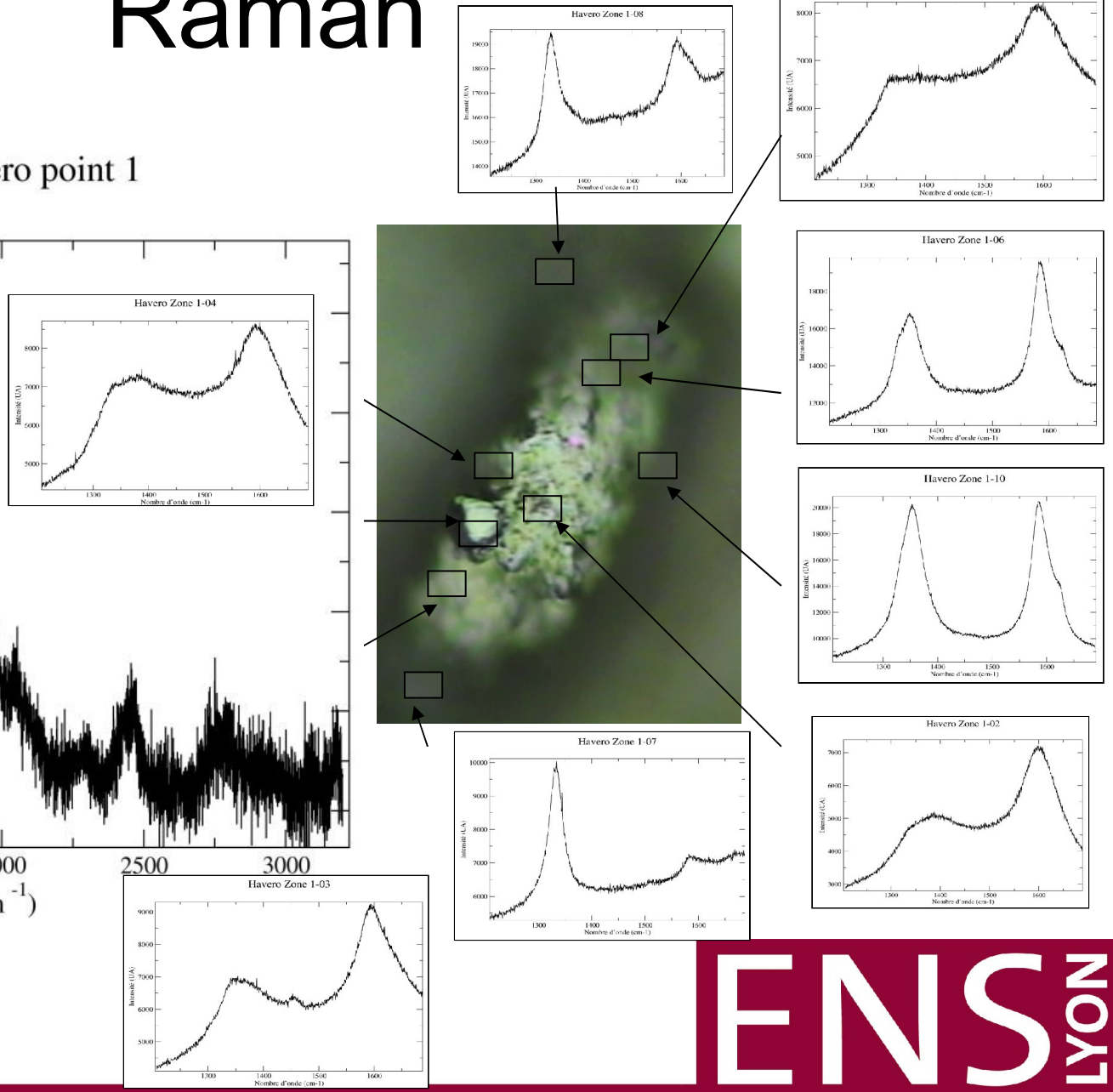
Raman





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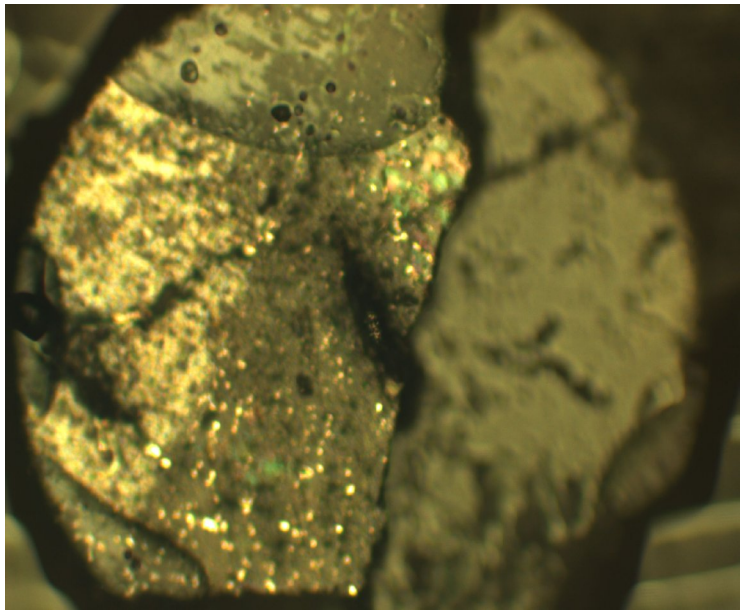
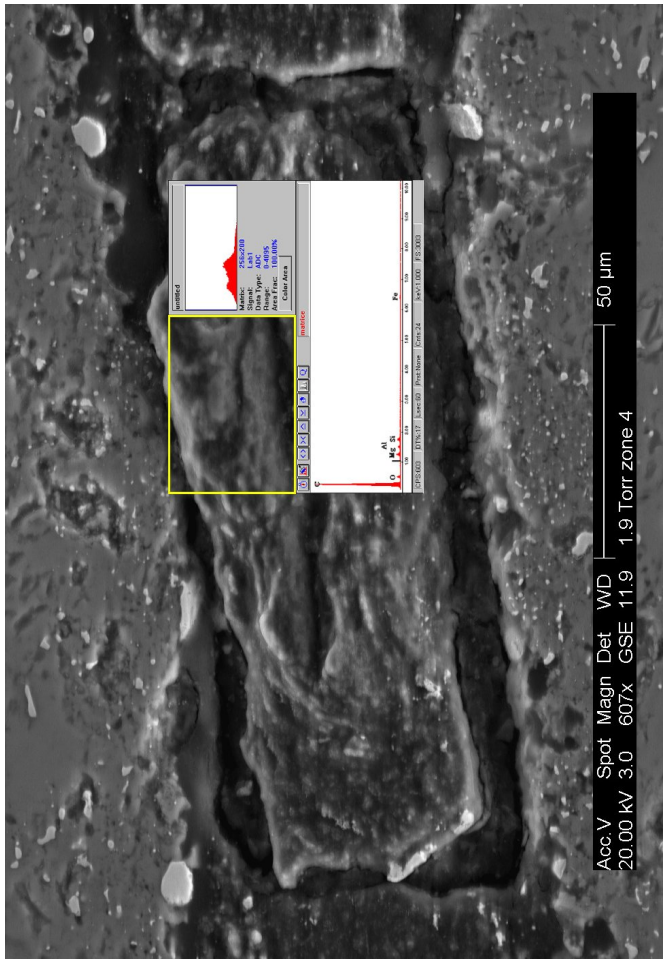
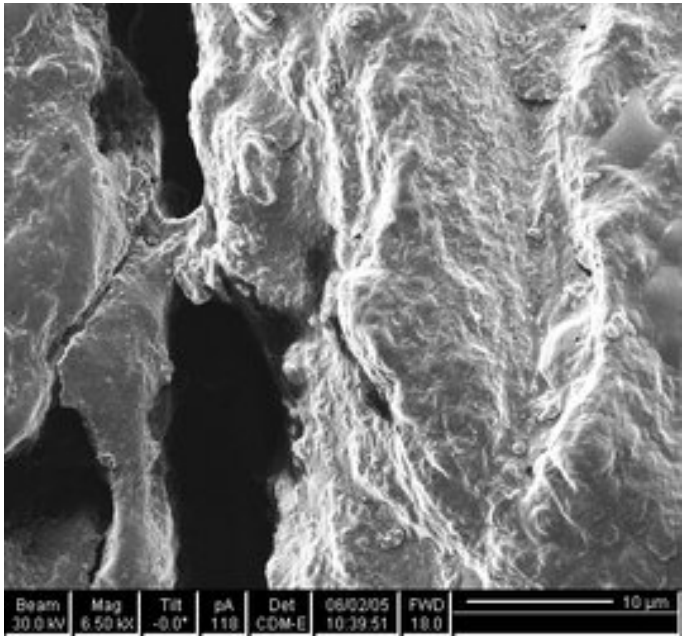
Extraction

- On two different areas, two extractions mode : coring or FIB







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Synchrotron Experimental Conditions on ID22 (μFID)

- Experiments in ESRF, Grenoble, France
- X-Ray wavelength: 0.7293 Å (17keV)
- X-ray beam diameter: < 1.5 μm vertical and 5 μm horizontal (K-B focusing)
- Sample geometry: 45° from incident X-ray beam; Energy dispersive detector at 90°
- Simultaneous imaging by X-Ray Diffraction and X-Ray Fluorescence mapping
- Point by Point (5 μm step) Scanning and Detection.
- Beam dwell time per spot for both XRD

and XRF 5sec

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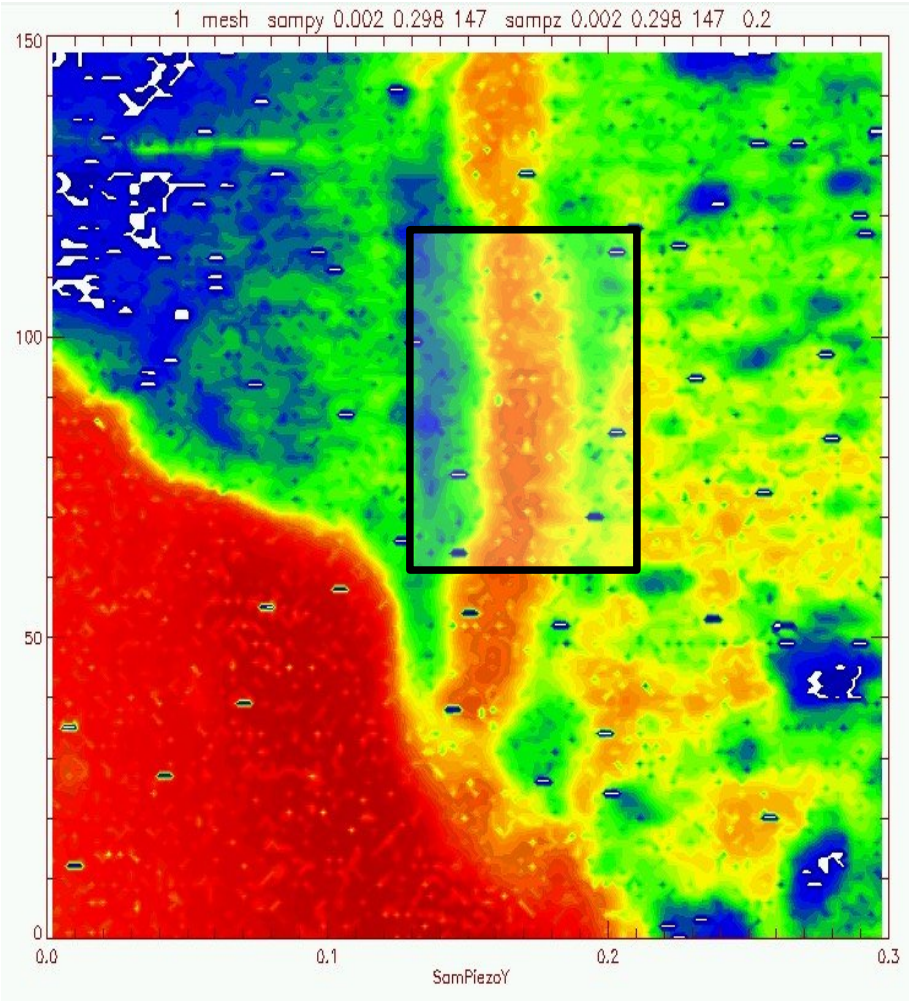
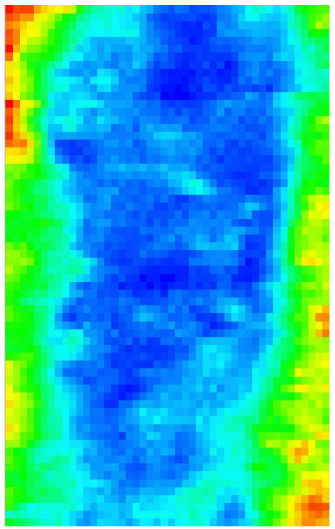
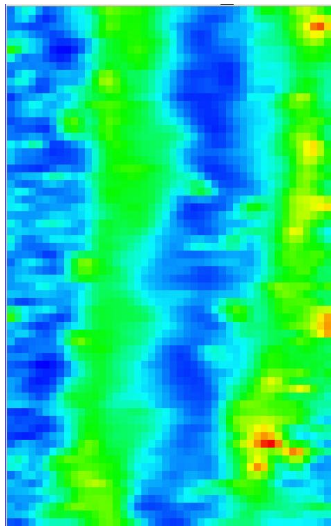
ID 22 XRF Mapping Results on cored sample



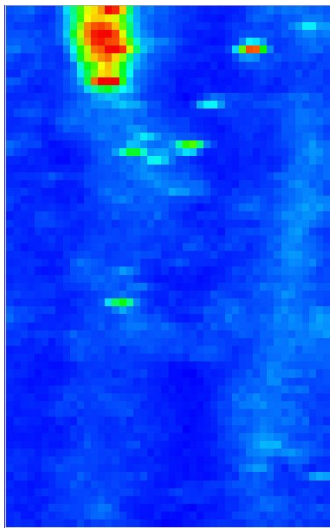
Transmission map



Mn map



Fe map



Ca map

Less dense area depleted in Fe, Mn, Ca and also other elements

→ carbon phase

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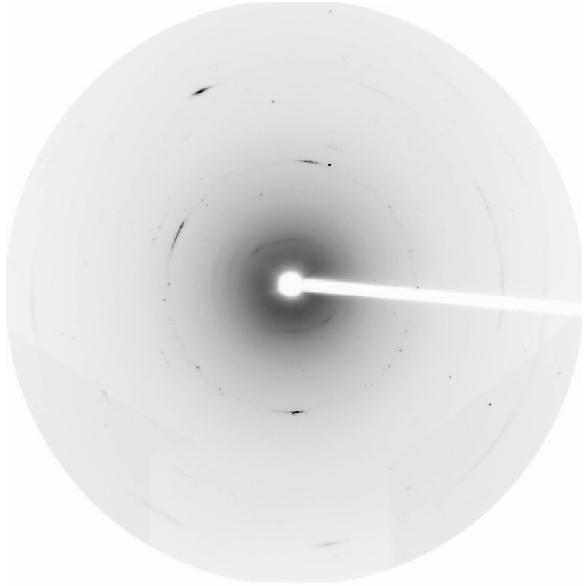
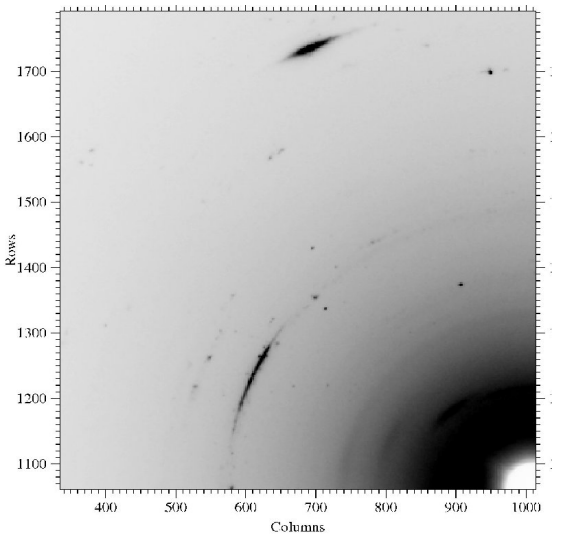
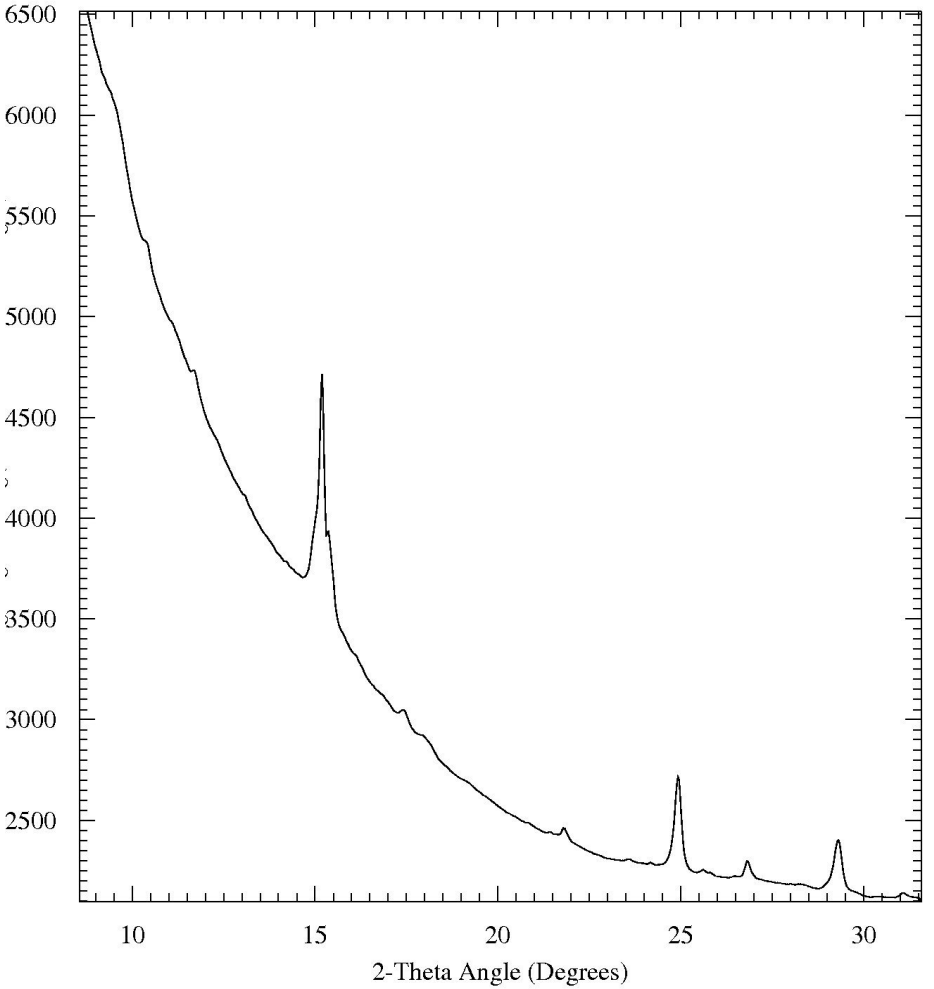
ID 22 XRD results on FIB cut







- Small thickness of the phases
- Phase is diluted

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Synchrotron Experimental Conditions on ID09 (HP)

- Experiments in ESRF, Grenoble, France
- X-Ray wavelength: 0.4132Å (30keV), X-ray beam diameter: 10µ.
- Slit-collimated beam
- Sample geometry: normal incidence X-ray beam and XRF 20sec/pts

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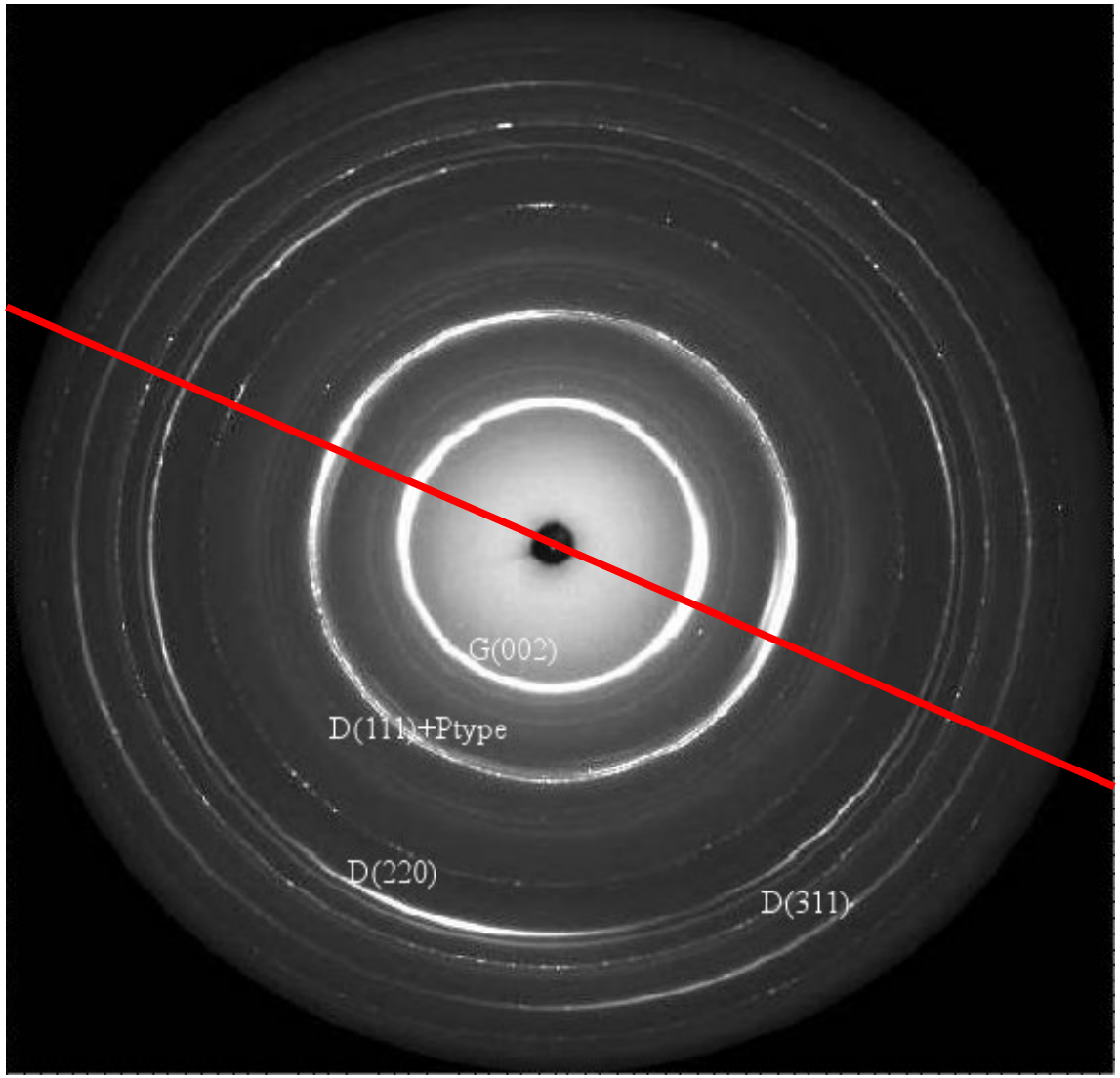
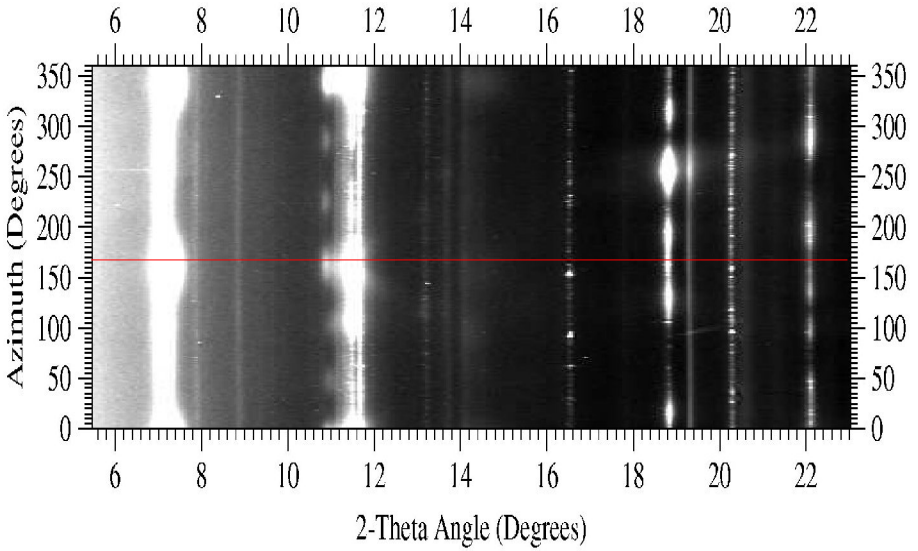
ID09 results





Strong preferred orientation of diamond and graphite with a topotaxial relationship between (002) of graphite and (111) of diamond

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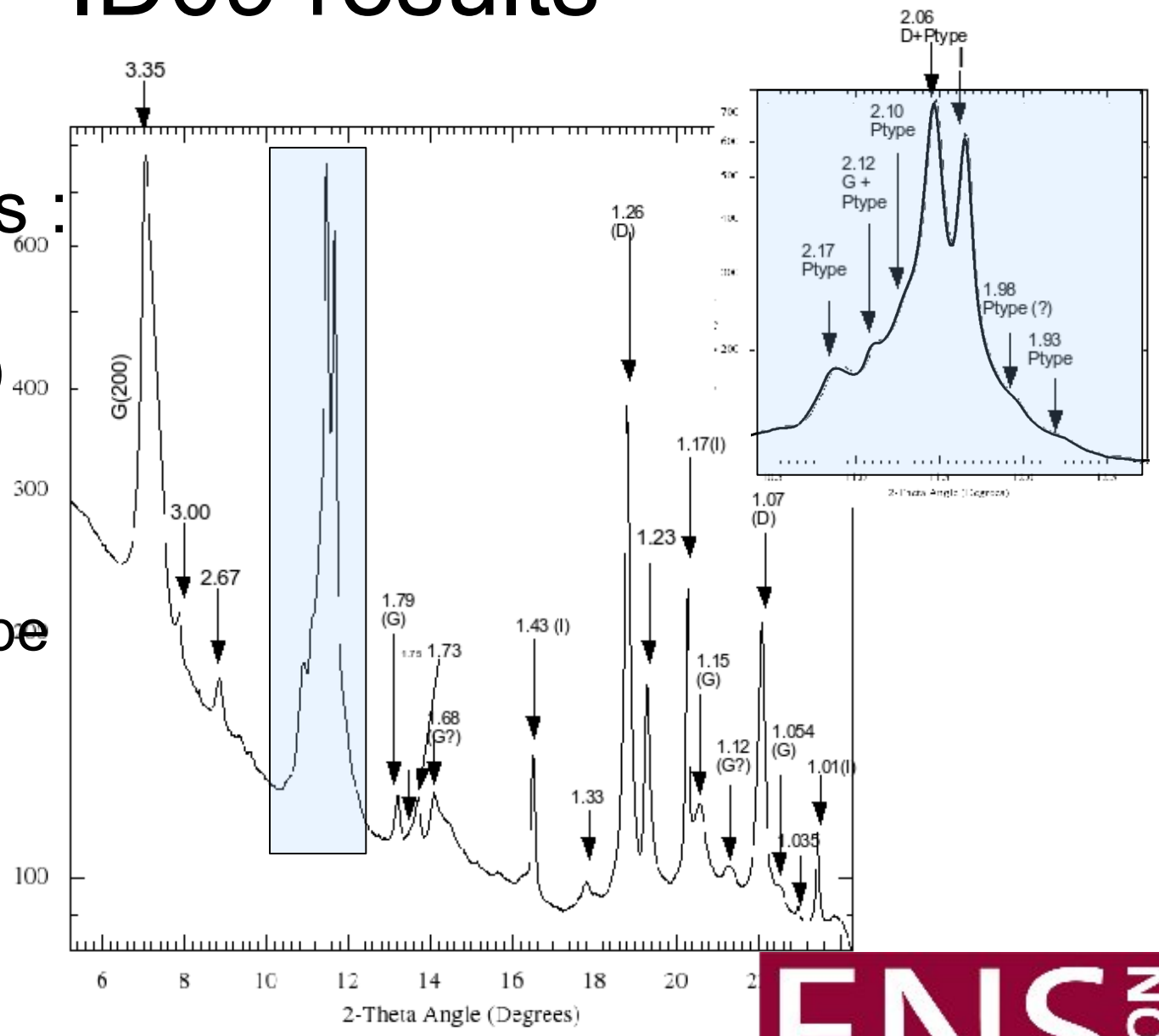
ID09 results

- Putative species :
  - graphite (uncompressed)
  - diamond (3C)
  - Iron (bcc)
  - Diamond polytype



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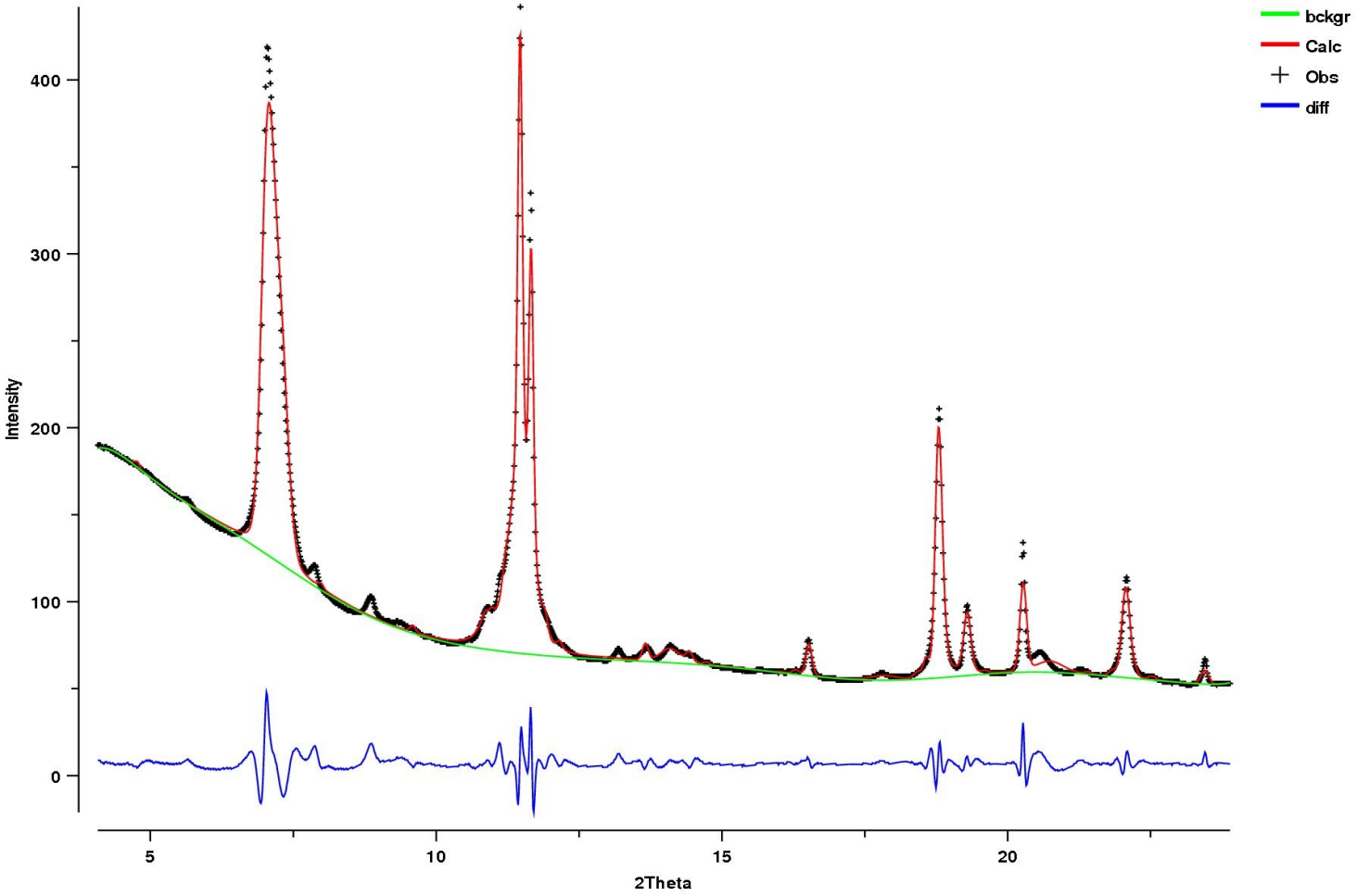
Le Bail refinement of ID09 spectrum



- Refinement is compatible with :
  - 3C Diamond
  - 21R Diamond
  - Uncompressed graphite

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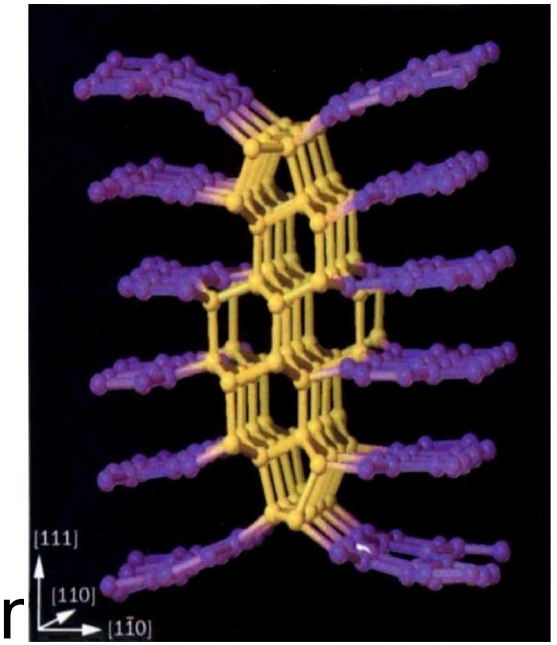
ID09 results

- This topotaxial relationship has been predicted theorically (De Vita et al., *Nature*, 1996) to explain the formation of graphite islands inside CVD diamonds at 2000K



➡ graphite is derived from diamond

➡ it needs high temperature (~2000K)

- either formation very close to the sun by CVD (very unlikely)
- or shock at high temperature

➡ Graphite is uncompressed : validation of our hypothesis

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Conclusions and outlook

- First observation of 21R natural diamond polytype
- Strong arguments in favor of shock origin of diamonds in ureilites

- Confirm shock origin by D/H isotope ratio (nanoSIMS)
- Active search for other natural polymorphs and diamond polytypes in ureilites

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