



# HYDROTHERMAL FORMATION OF COPPER SULFIDES IN THE R CHONDRITES

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Tom  
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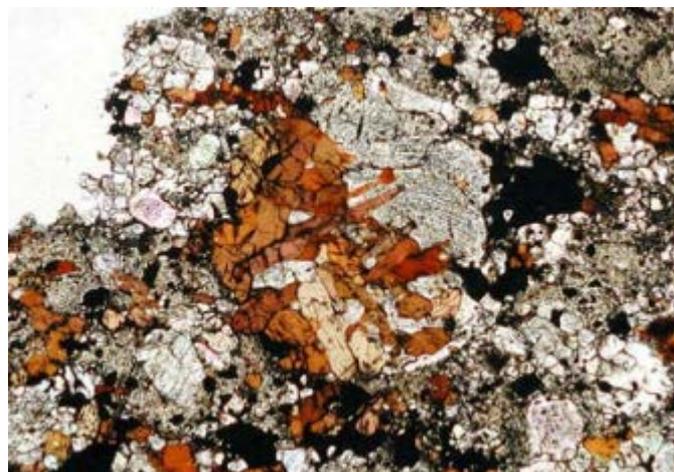


Katrina  
Jackson



# R Chondrites

- Highly oxidized, highly sulfidized, high  $\Delta^{17}\text{O}$
- *Weisberg et al., 1991, Righter and Neff, 2007, McCanta et al., 2008, Jackson and Lauretta, 2010, Miller et al., in prep*
- Hydrothermal alteration on parent body
- *McCanta et al., 2008, Mikouchi et al., 2007, Treiman and McCanta, 2010, Ruzicka et al., 2013, Gross et al., 2013*



Hornblende in  
LAP 04840;  
from Mikouchi  
et al., 2007;  
FOV ~2.5 mm

# Petrologic Types

Type 1

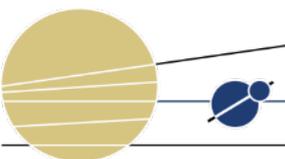
Aqueously altered

Type 3

Unaltered

Type 6

Thermally altered



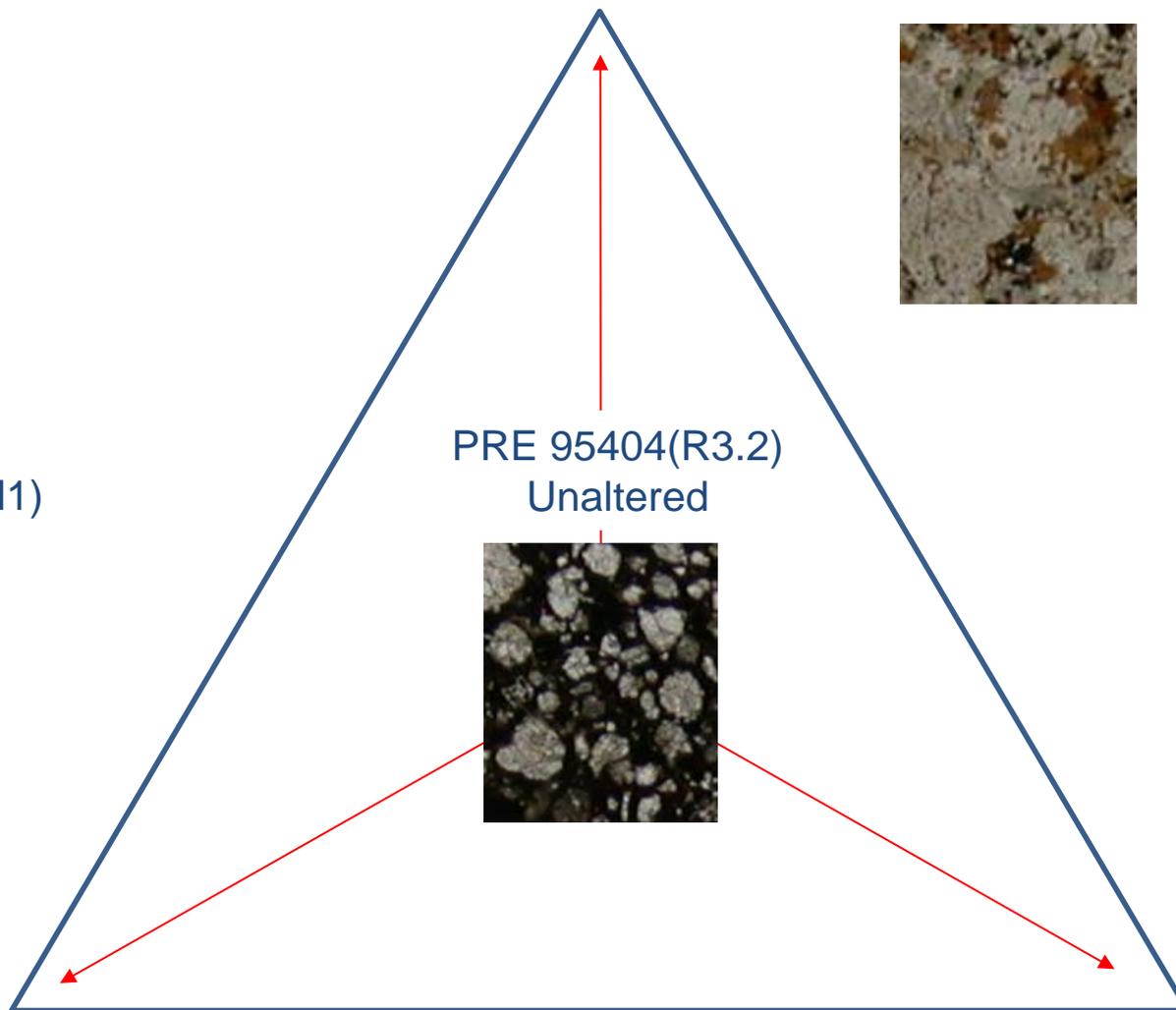
# Petrologic Types

—  
~500  $\mu\text{m}$

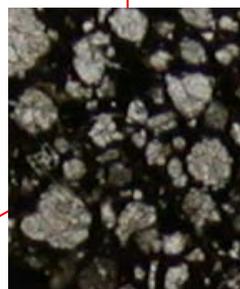
ALH 83100 (CM1)  
*Image: NASA*



Aqueously  
Altered



PRE 95404(R3.2)  
Unaltered



LAP 04840 (R5)  
Hydrothermally  
Altered



NWA 7514 (R6)  
Thermally  
Altered

# EMPA Survey

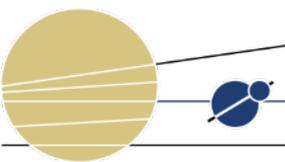
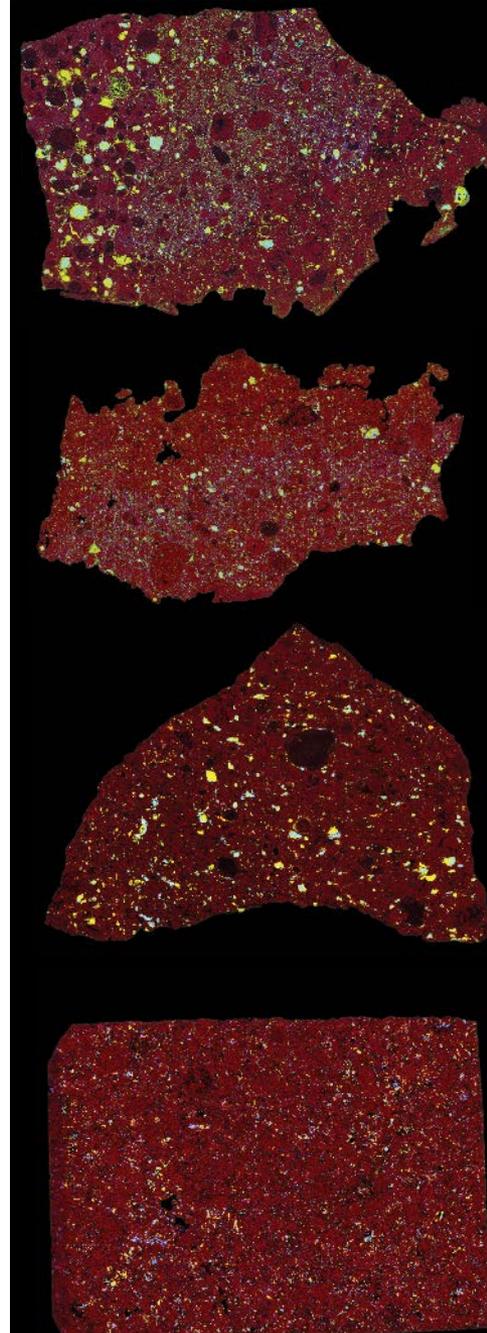
FeS/Ni  
RGB

PRE 95404 (R3.2 clast):  
*Ubiquitous **Cu-rich lamellae** in pentlandite*  
*Cu-rich lamellae in some pyrrhotite*

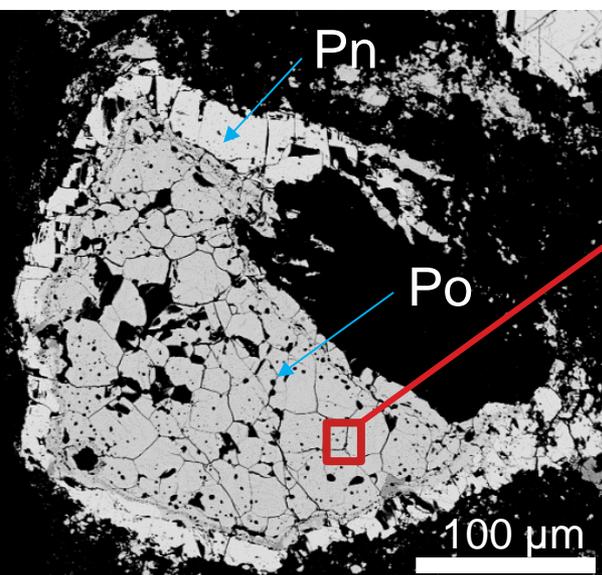
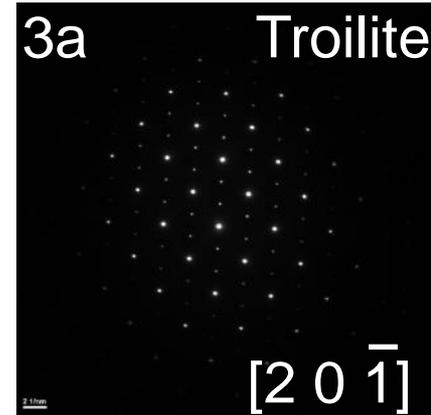
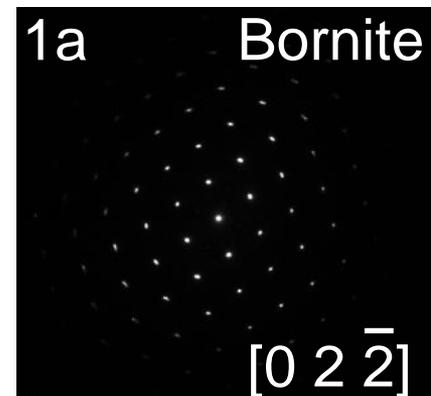
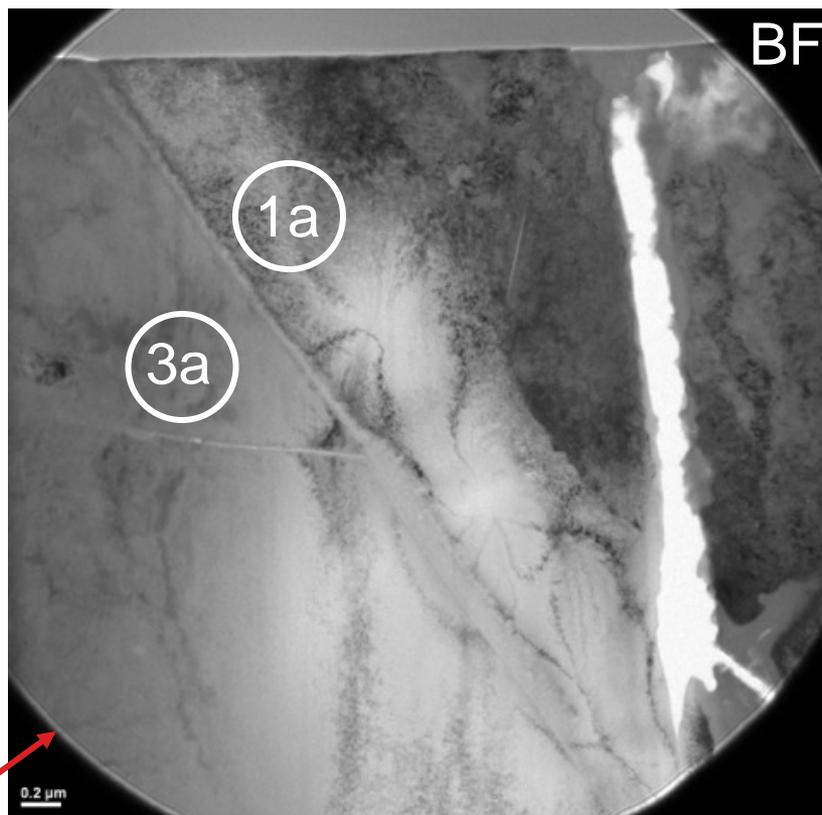
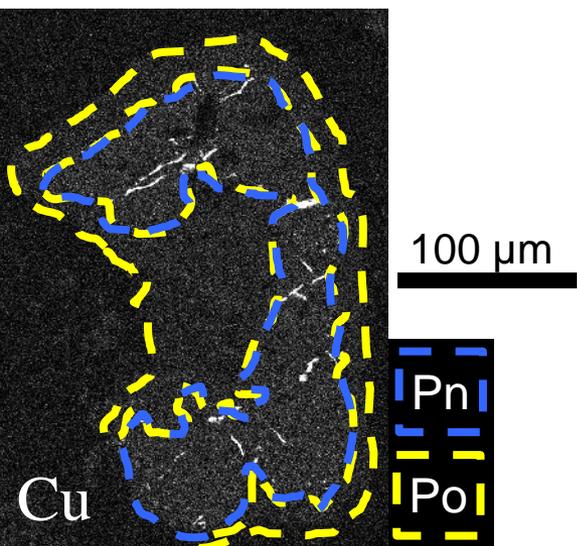
PRE 95411 (R3):  
*12 grains with **chalcopyrite** chemistry*  
*Distributed throughout thin section*

PCA 91002 (R3.8 to R5):  
***Chalcopyrite** in three assemblages*  
***"Cubanite"** in one assemblage*  
*Cu-bearing phases in less equilibrated lithologies*

NWA 7514 (R6):  
***Chalcopyrite** in six assemblages*

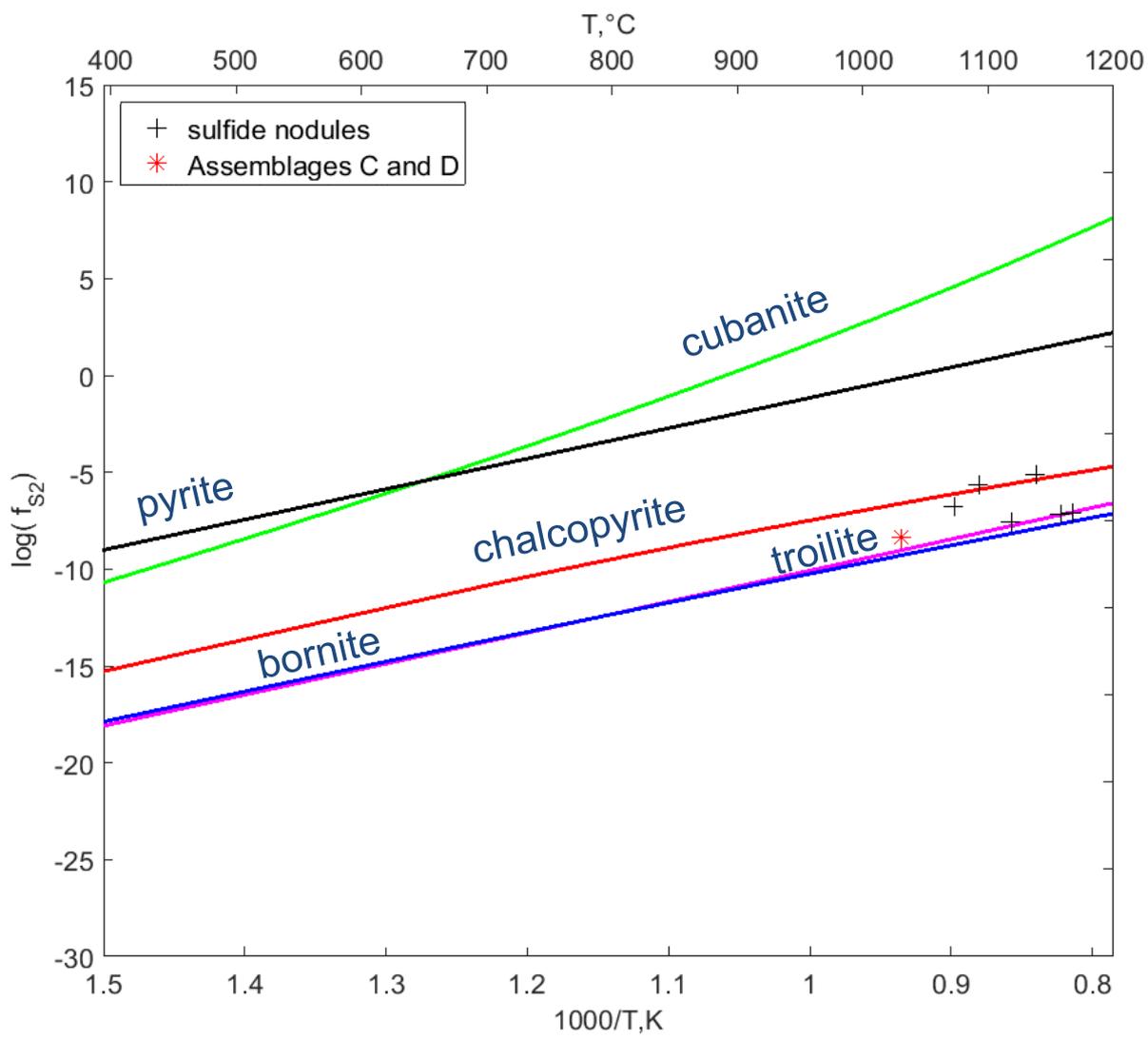


# PRE 95404 (R3.2): Bornite

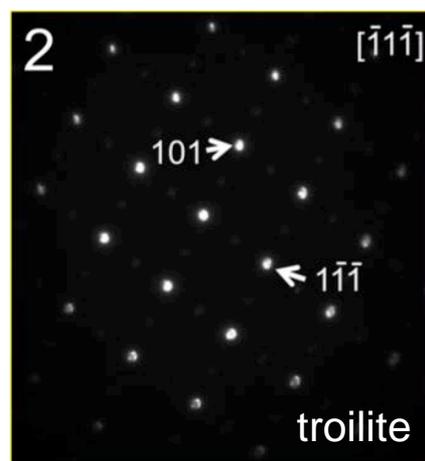
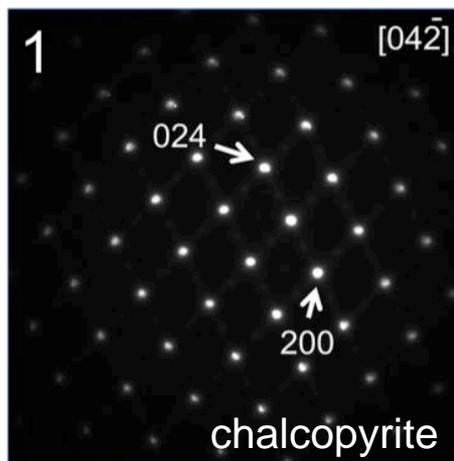
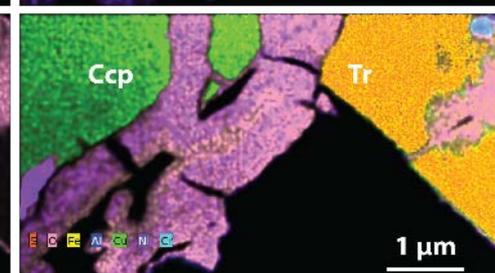
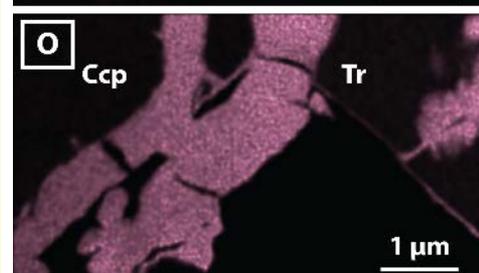
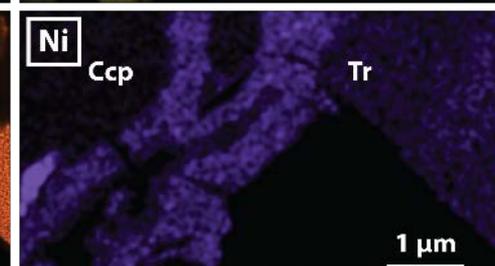
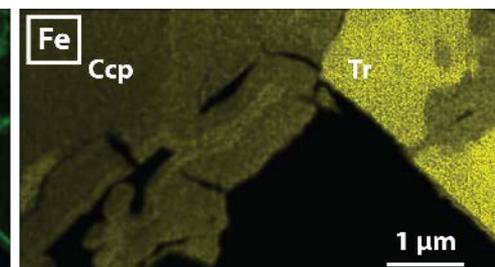
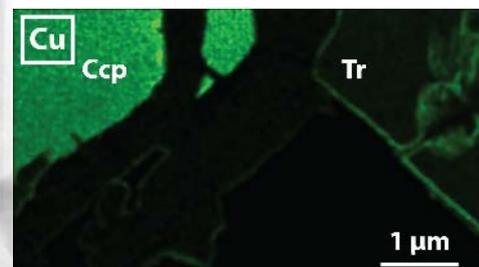
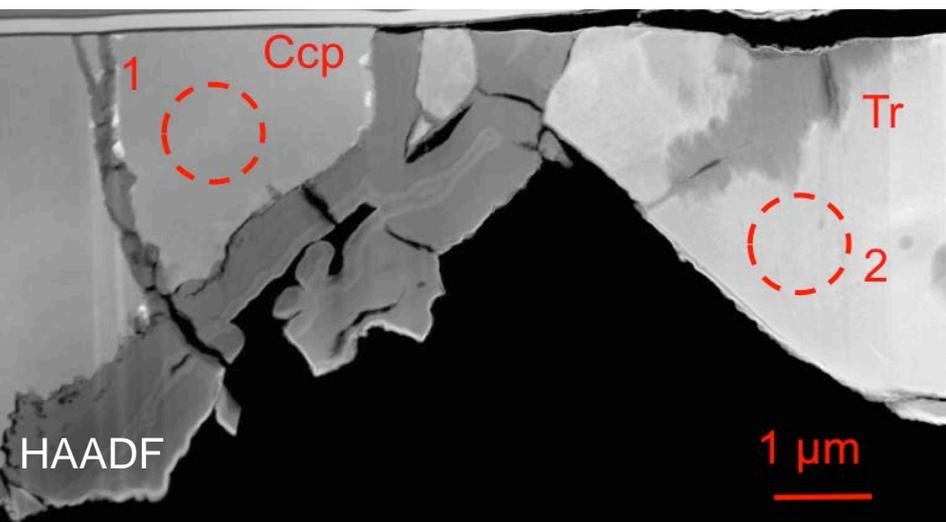


Pn = pentlandite  
Po = pyrrhotite

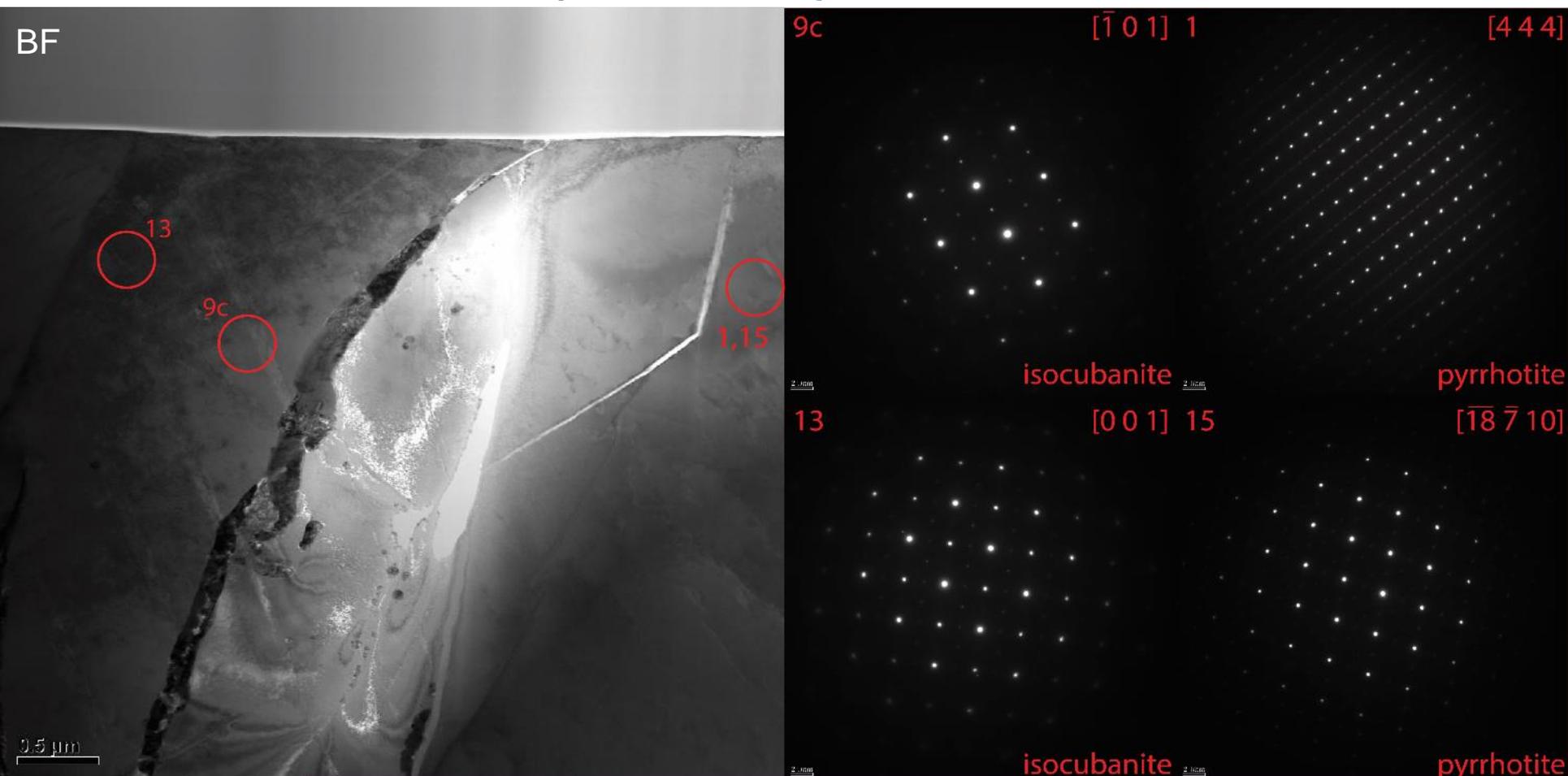
# Pre-Accretionary Bornite



# PRE 95411 (R3): Chalcopyrite



# PCA 91002 (R3.8-5): Isocubanite



# Temperature Constraints

Assemblage Source	Phase	Temperature Constraint
PCA 91002	Isocubanite	Formation > 210 °C
PCA 91002	Pyrrhotite with superstructure	Equilibration ≤ 308 °C
PCA 91002	Isocubanite + pyrrhotite	Equilibration between 200 and 300 °C, <b>hydrothermal</b>
PRE 95411	Chalcopyrite + pyrrhotite <b>Vein structure</b>	Equilibration to ≤ 200 °C
PRE 95411	Troilite	Formation ≤ 140 °C

Isocubanite  $\xrightarrow{< 210\text{ °C}}$  Chalcopyrite + Pyrrhotite

# Formation of copper sulfides

Hydrothermal alteration in low petrologic types!

Formation > 210 °C; equilibration to ≤140 °C

