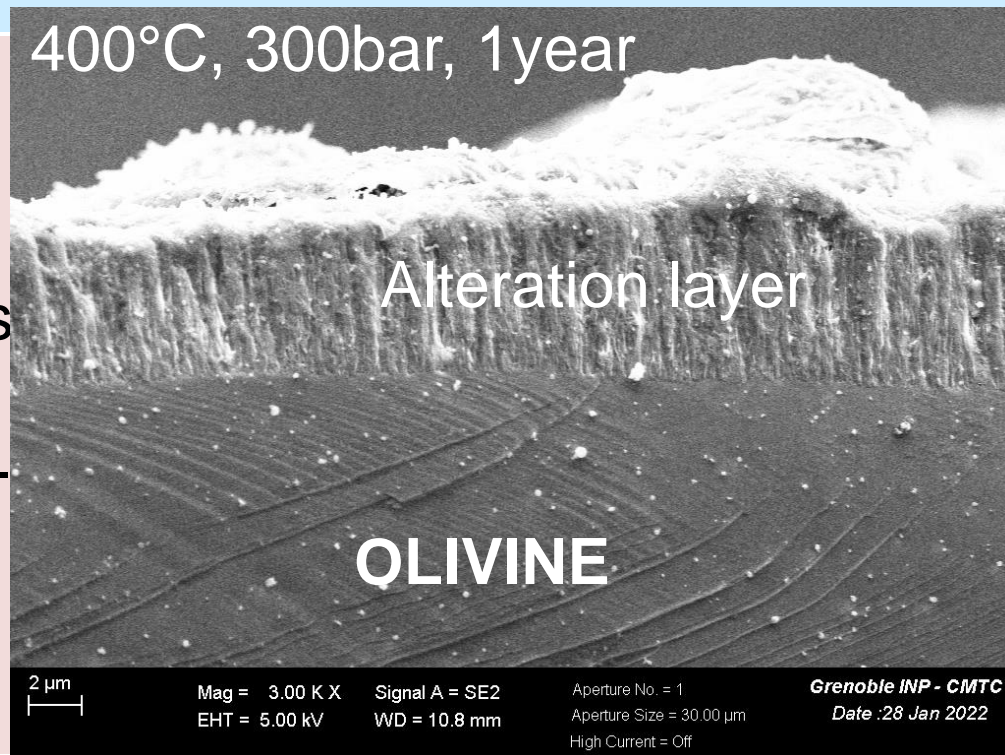


# Nucleation, Growth and transformation of minerals under mild and hydrothermal conditions

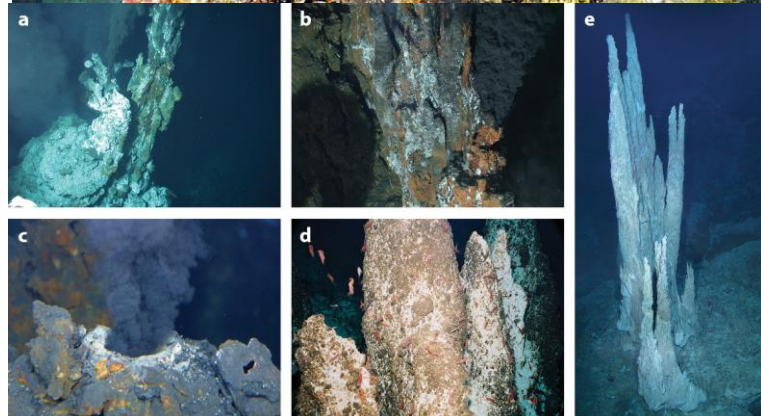
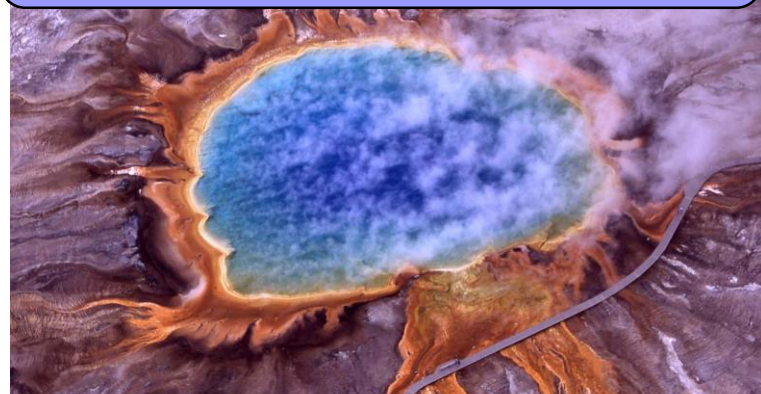
## German Montes Hernandez

PhD and Chemical Engineering

- Implications and some relevant research results in the last 5 years
- Current studies and for the next 5-10 years



Some examples of natural hydrothermal systems



Up to 400°C,  
500 bar



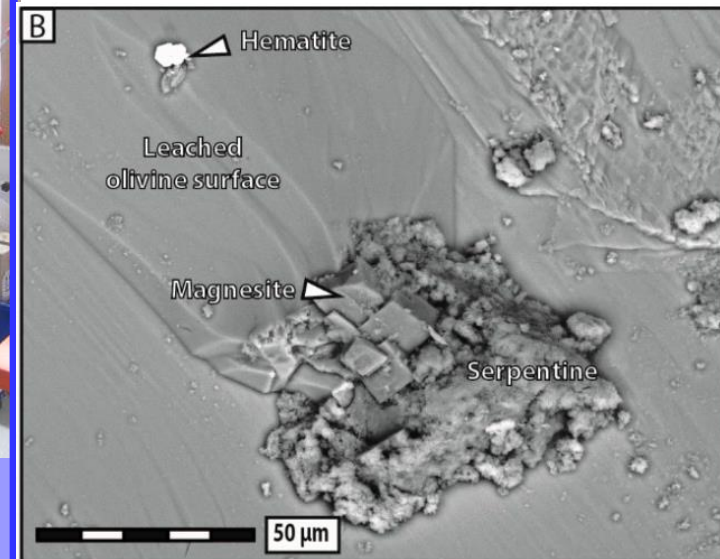
Minerals formation  
under mild and  
hydrothermal conditions

Up to 300°C, 300 bar  
with Raman

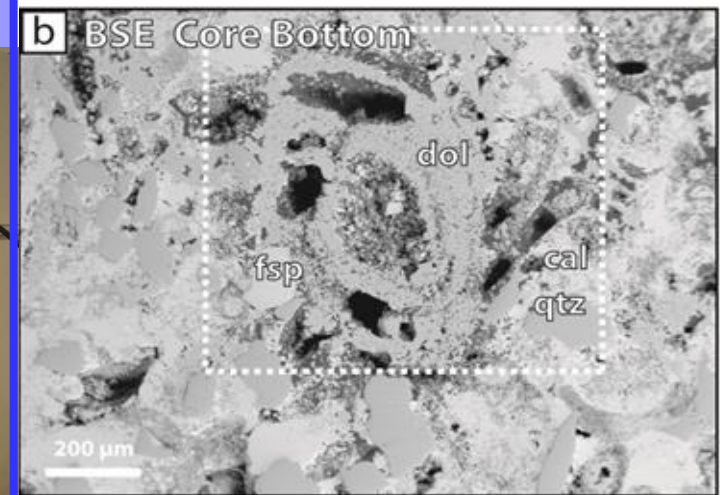


Some reactivity minerals  
under hydrothermal conditions

Concurrent serpentinization and  
carbonation of olivine



Dolomitization of limestone cm-  
cores

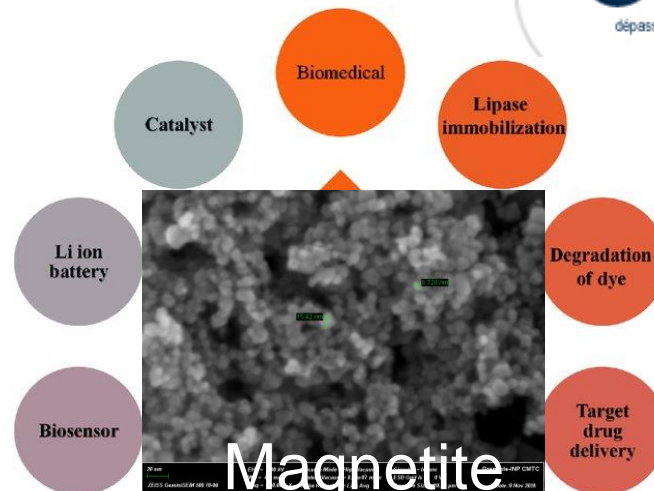


## Nanotechnology in Medicine

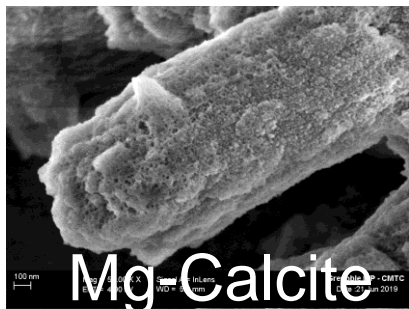


Paint, Paper, etc. industry

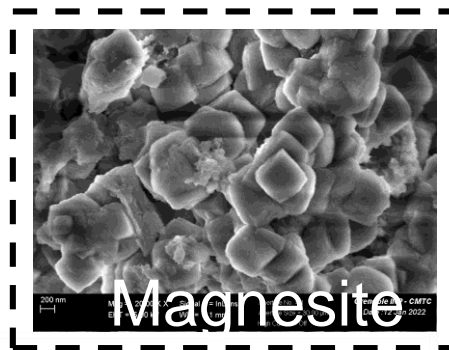
Nano Calcite



Magnetite



Mg-calcite



Magnesite

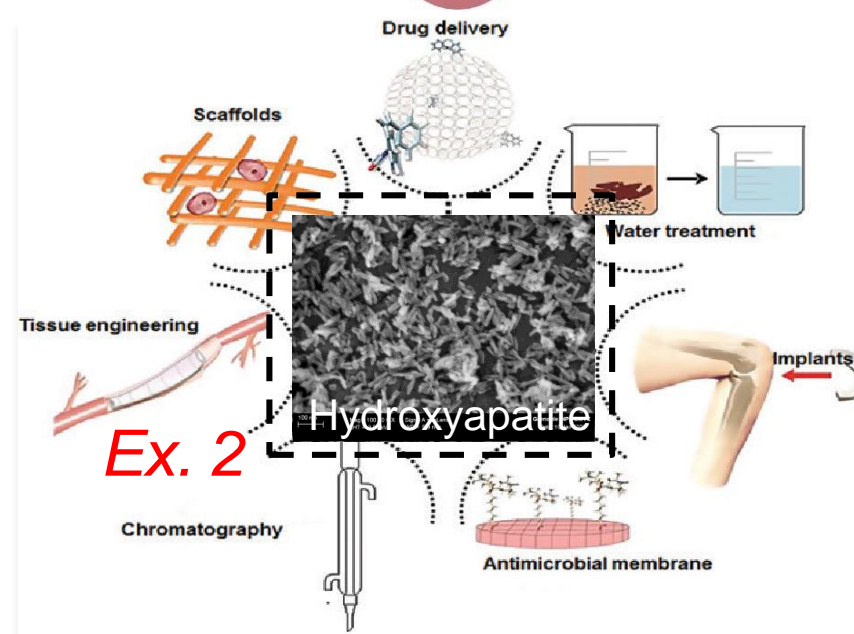
Ex. 1

## FUNMIN European Project

Fast-tracked optimisation of cost-effective mineralised-CO<sub>2</sub> materials under mild, non-hazardous, non-toxic conditions

Mechanism of Mg-dehydration	MgCO <sub>3</sub> nucleation pathway	Magnesite growth processes	CO <sub>2</sub> mineral under mild conditions
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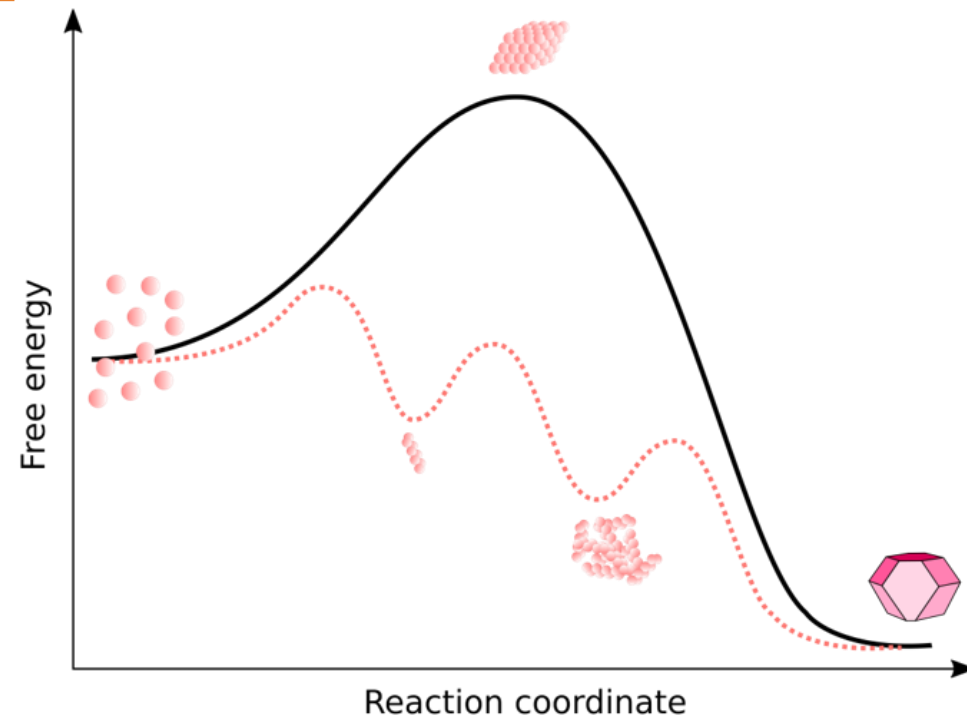
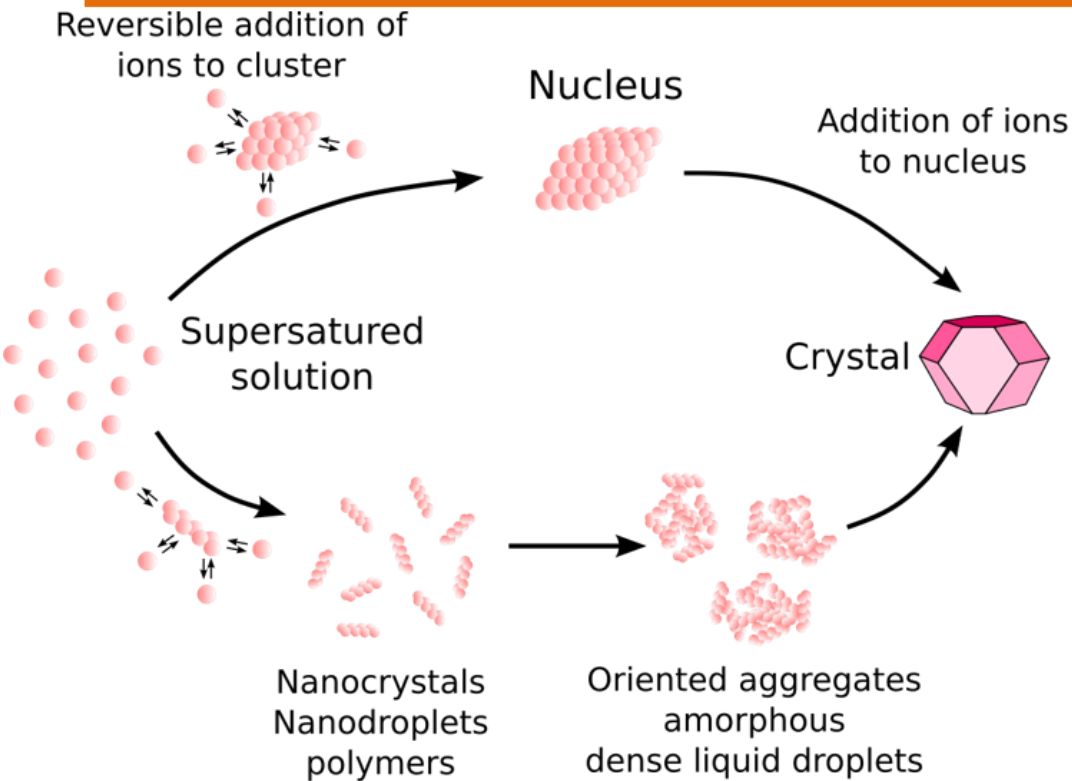
THE OBJECTIVES



Ex. 2

To get a clear picture of the nucleation pathway we need time-resolved *in situ* data

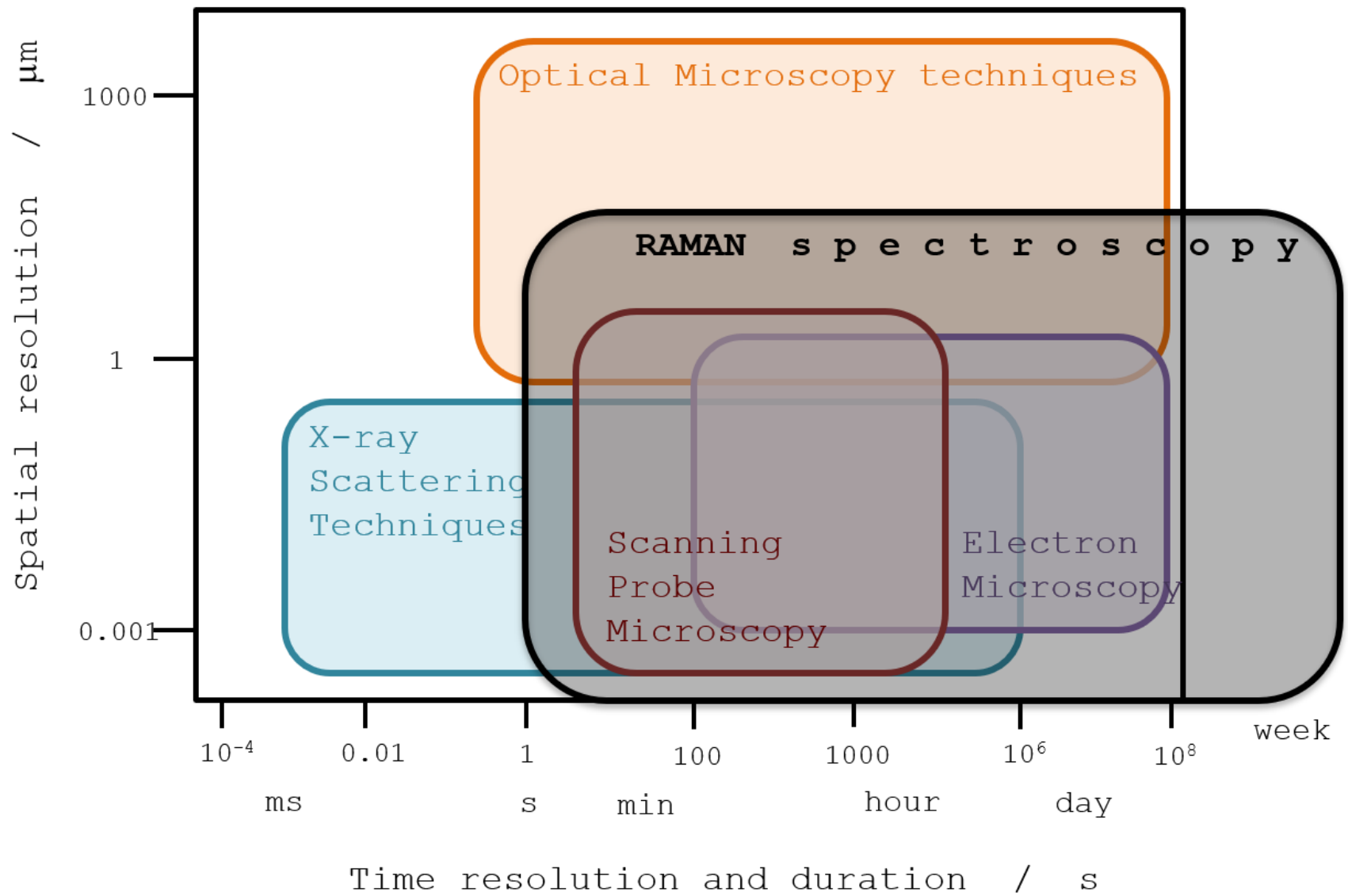
## Classical Nucleation



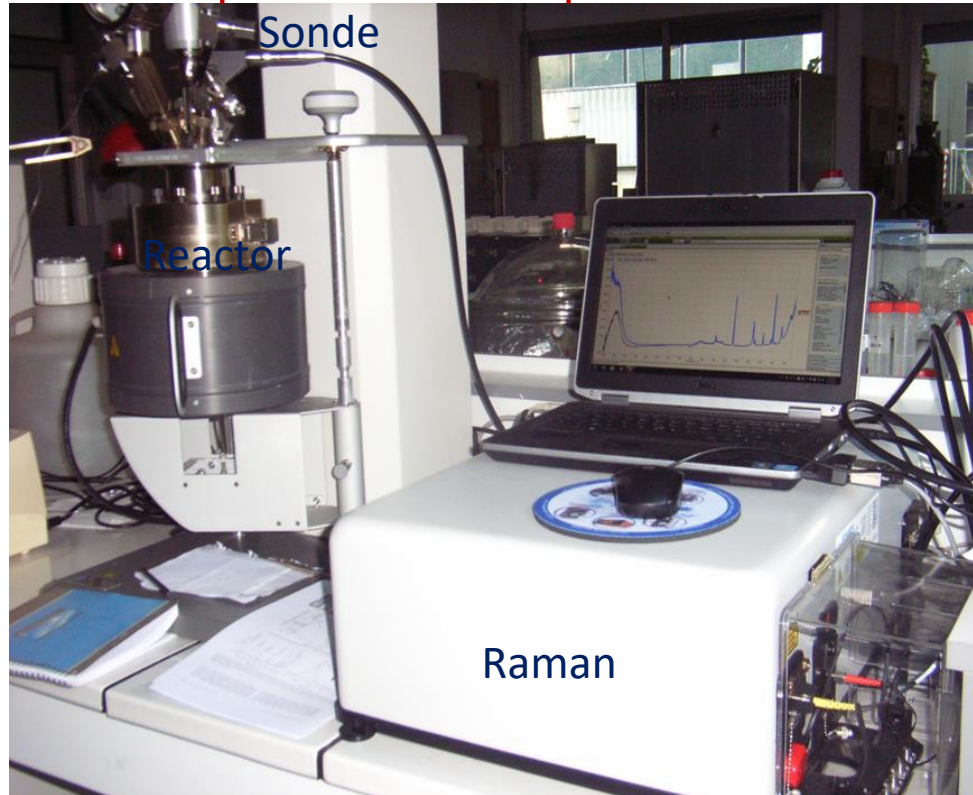
## Non-classical Nucleation

Two-step nucleation, pre-nucleation clusters, oriented attachment, ...

## Different in situ techniques

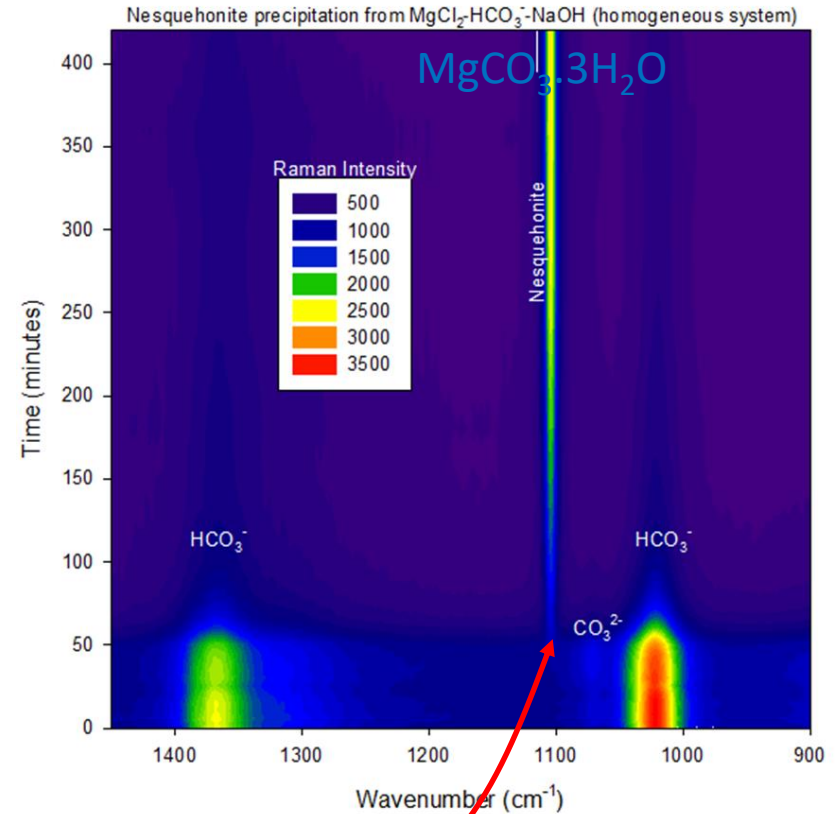


## Experimental Setup at ISTERRE



T: -10-300°C  
P: 1-300bar

## Nesquehonite formation: 25°C, 1bar



Nucleation Time !

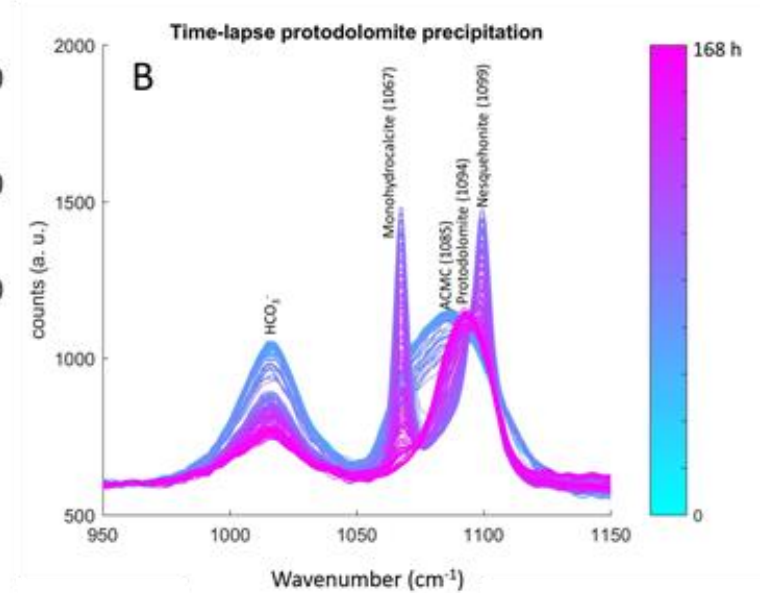
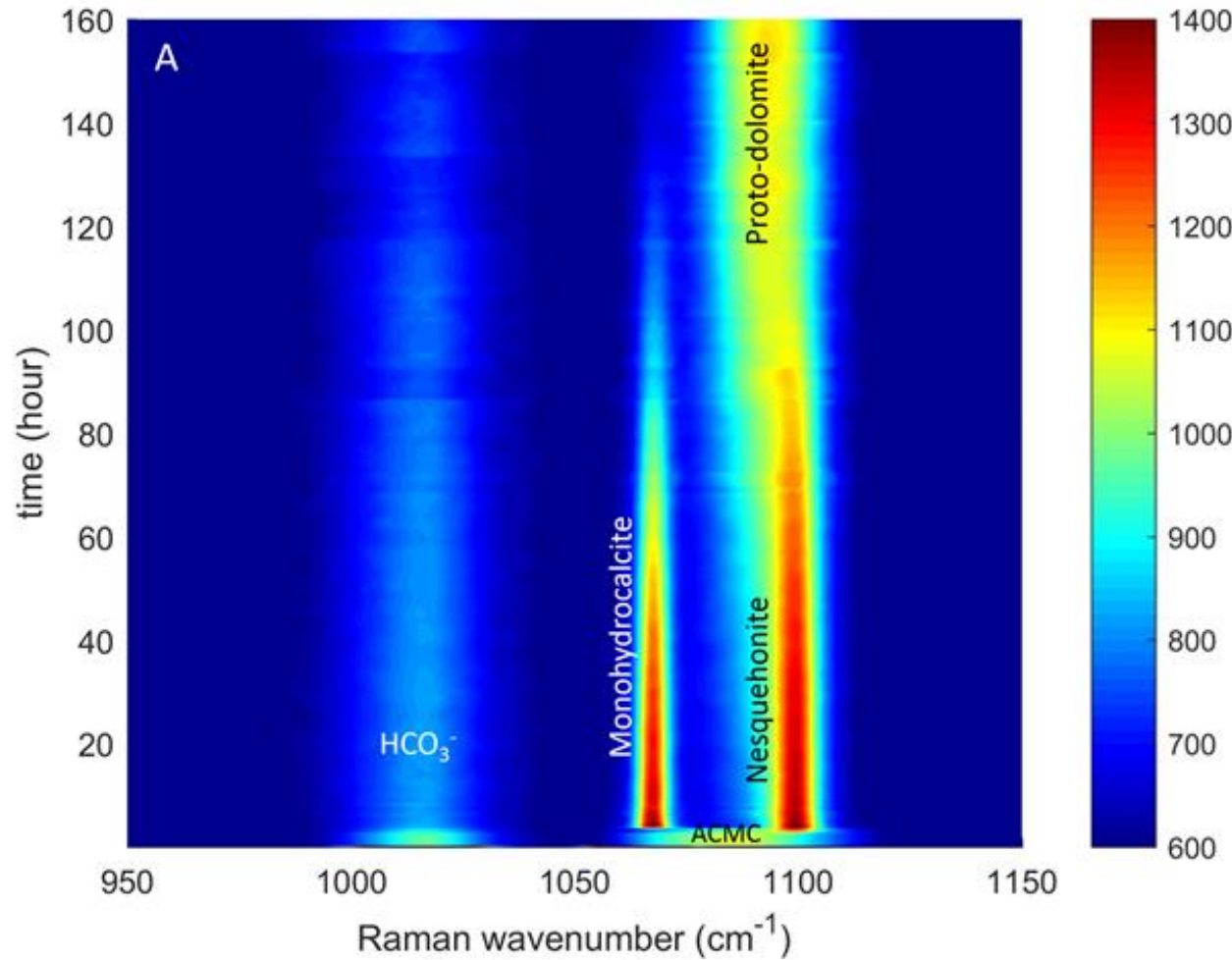
Classical  
crystallization  
pathway

Montes-Hernandez and Renard, 2016

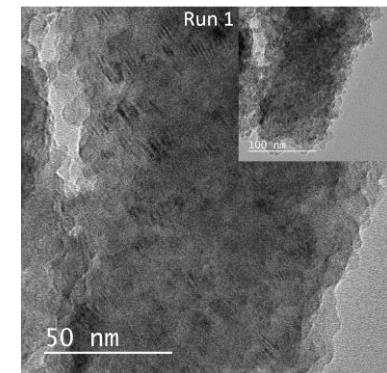
see also press communication, <http://www.insu.cnrs.fr/en/node/6188>

# Proto-dolomite formation at room T

Ca+Mg sources  
 $\text{HCO}_3^-/\text{CO}_3^{2-}=0.5$   
 $\text{pH}=\text{pKa}_2=10.22$



**TEM Images**



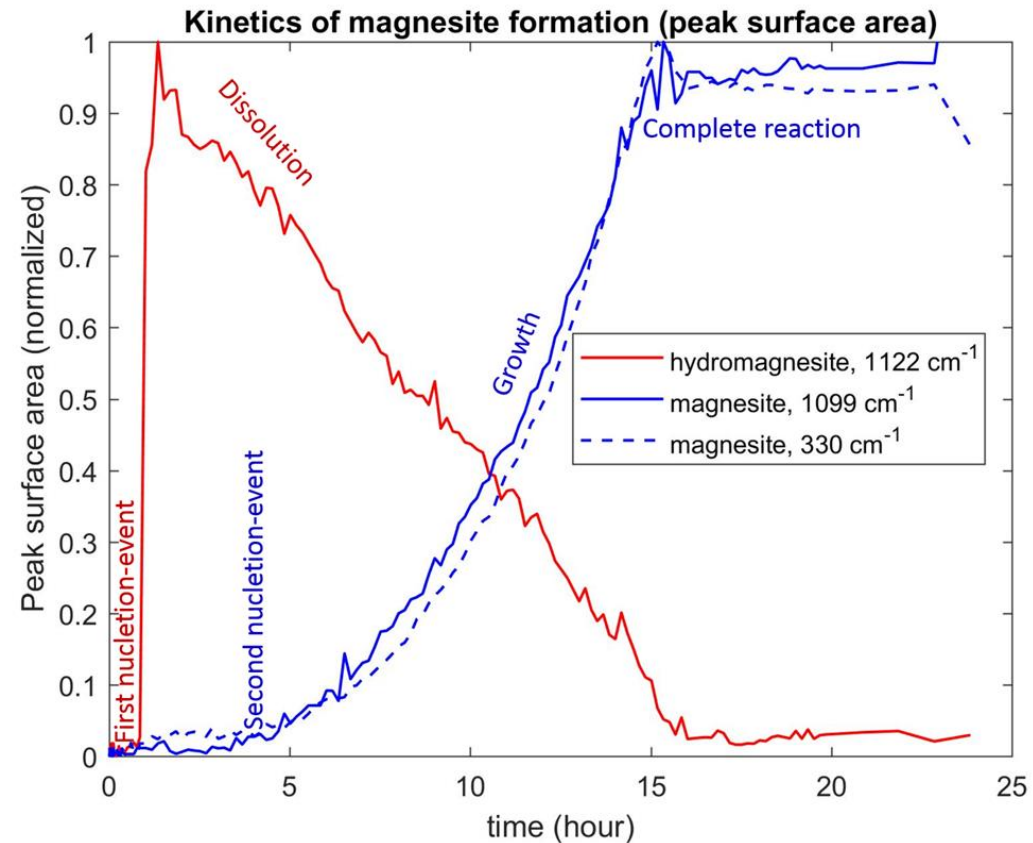
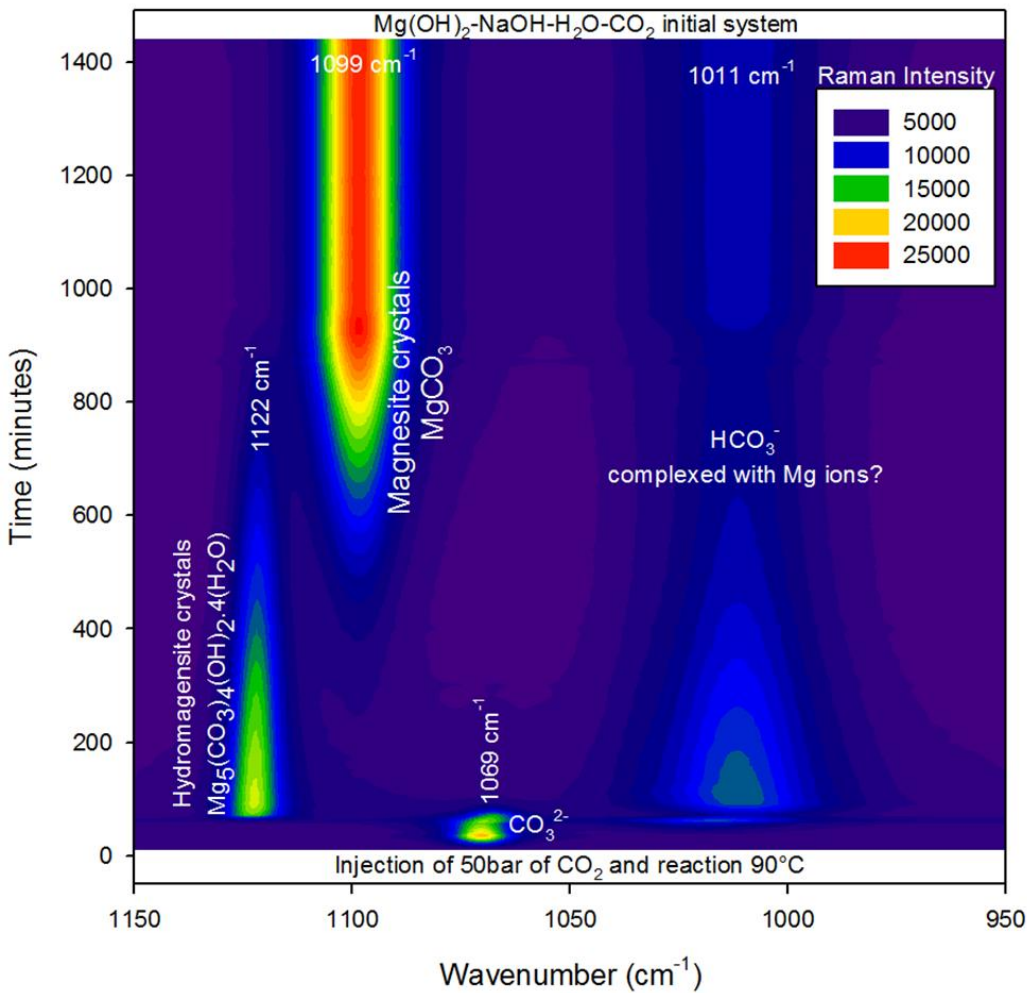
Montes-Hernandez et al., 2020

Non-Classical crystallization pathway

# Magnesite formation

## 90°C, 50bar of initial CO<sub>2</sub> pressure

*Ex. 1*



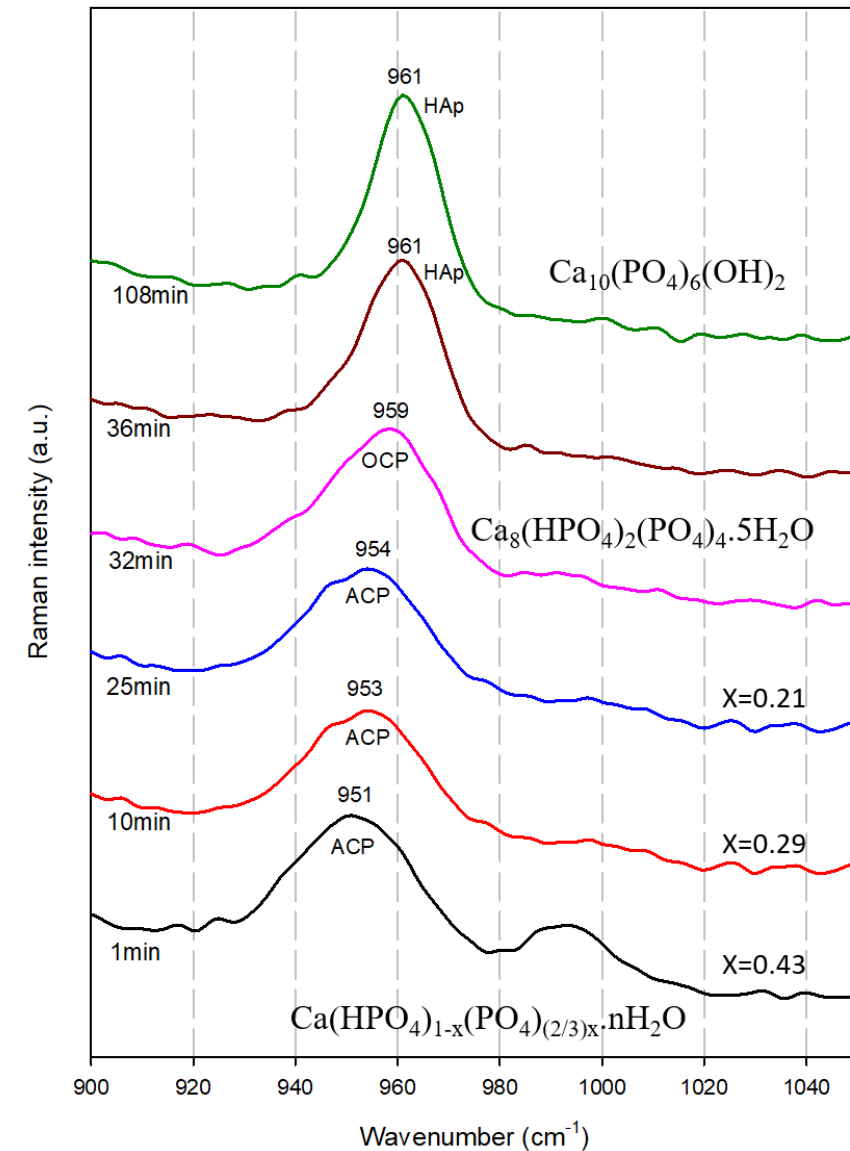
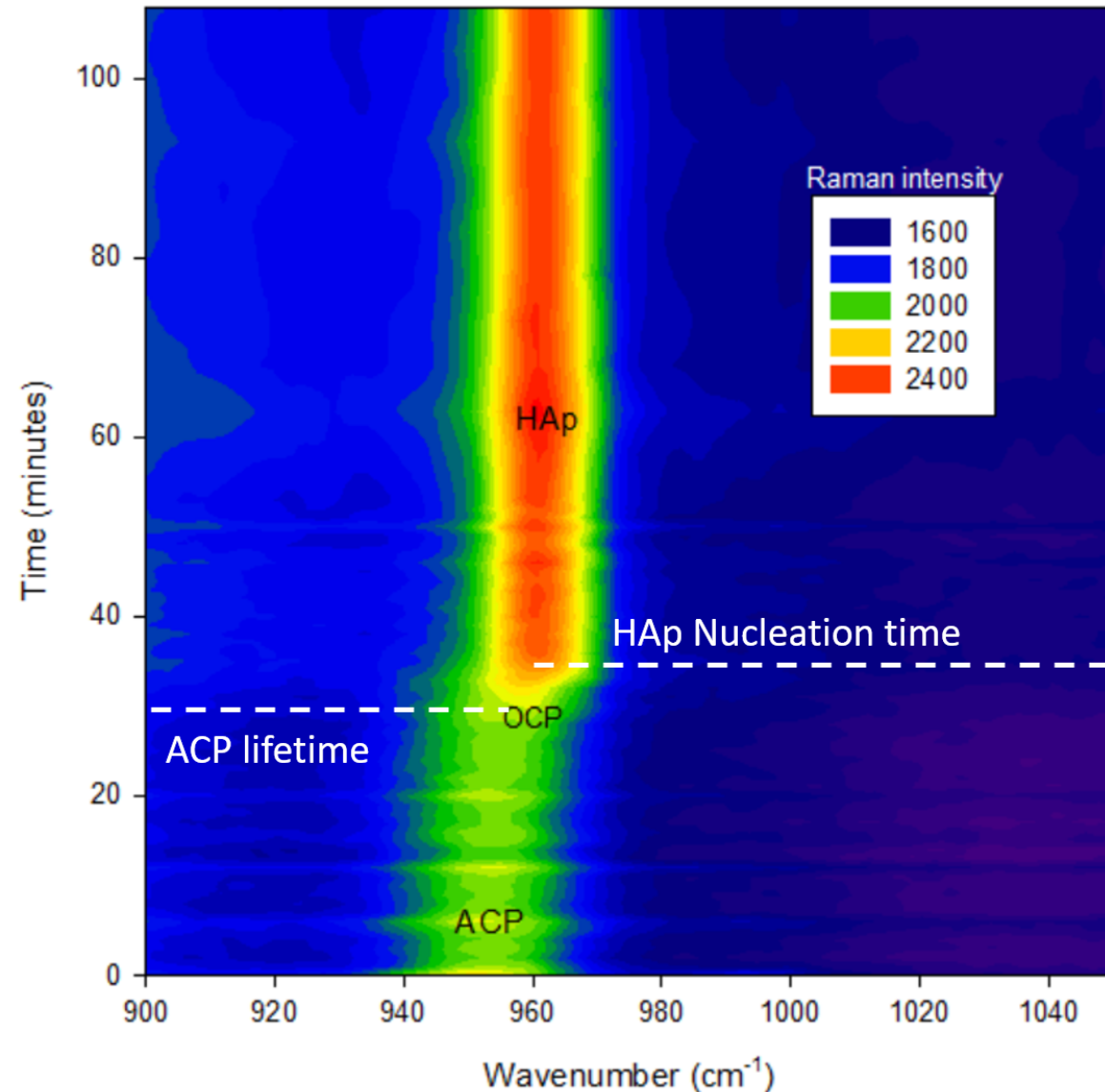
Montes-Hernandez et al., 2020

Non-Classical crystallization pathway



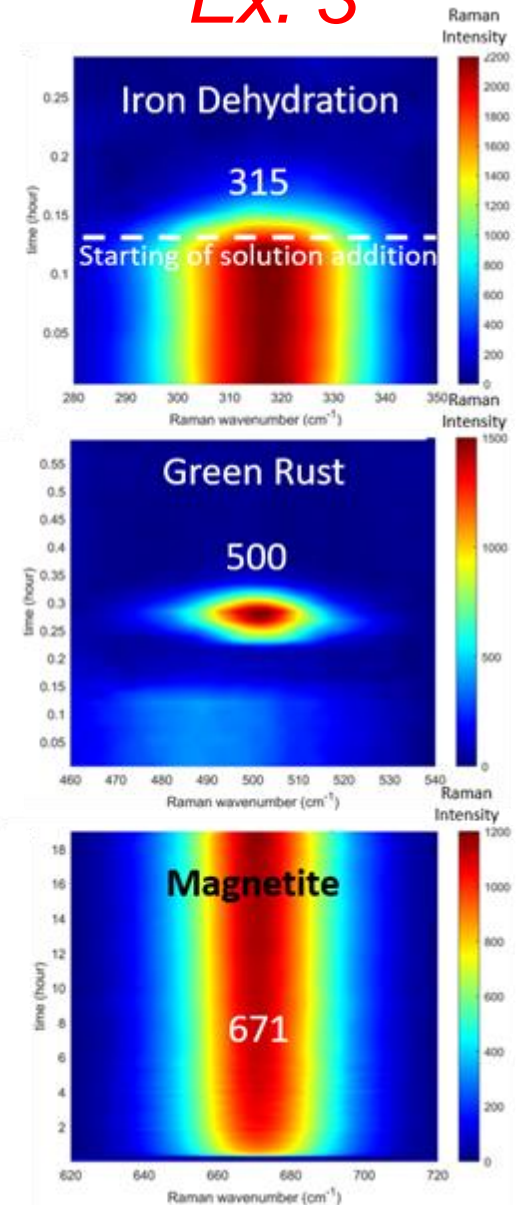
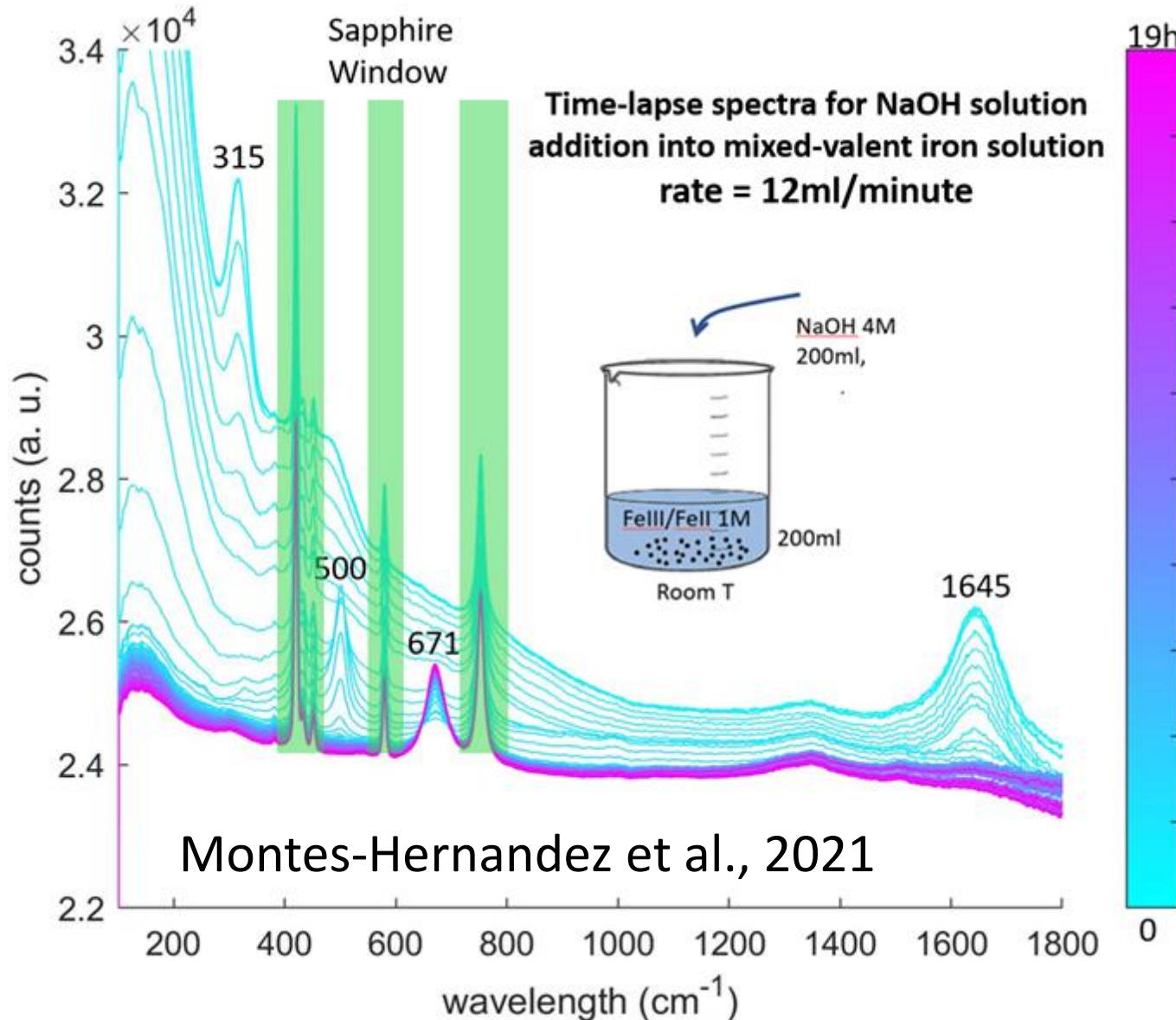
# Hydroxyapatite formation from CaCl<sub>2</sub> as Ca source

Ex. 2



# Indirect nucleation of Magnetite: NaOH solution adding into Fe solution

Ex. 3

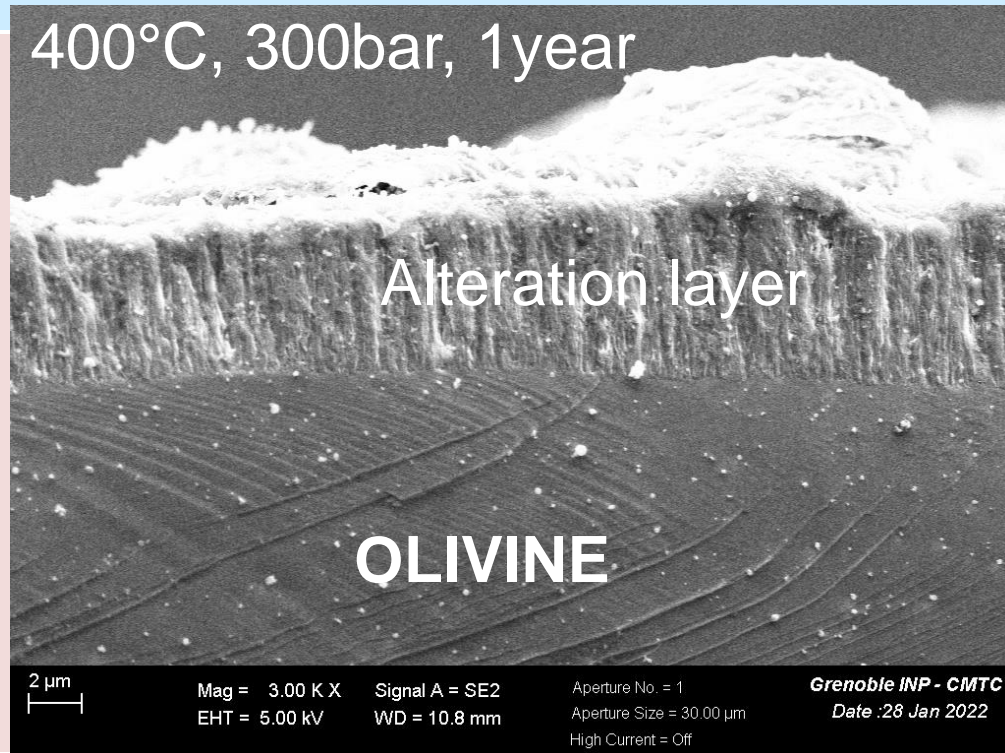


# Nucleation, Growth and transformation of minerals under mild and hydrothermal conditions

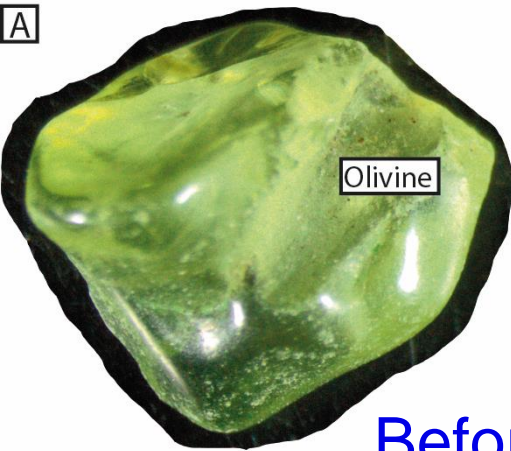
## German Montes Hernandez

PhD and Chemical Engineering

Current studies and  
for the next 5-10 years

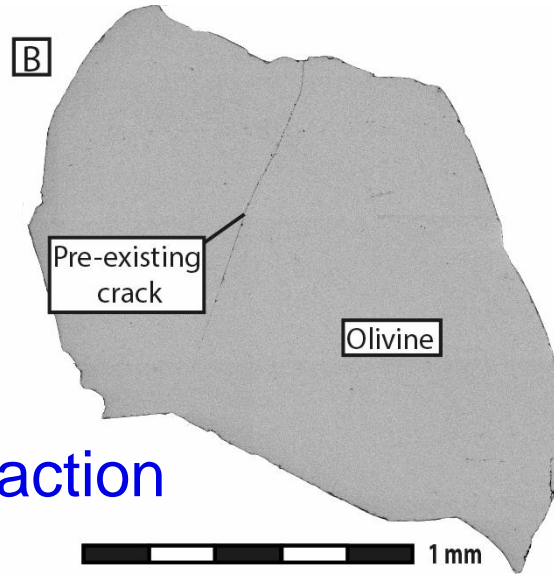


## Hydrothermal alteration

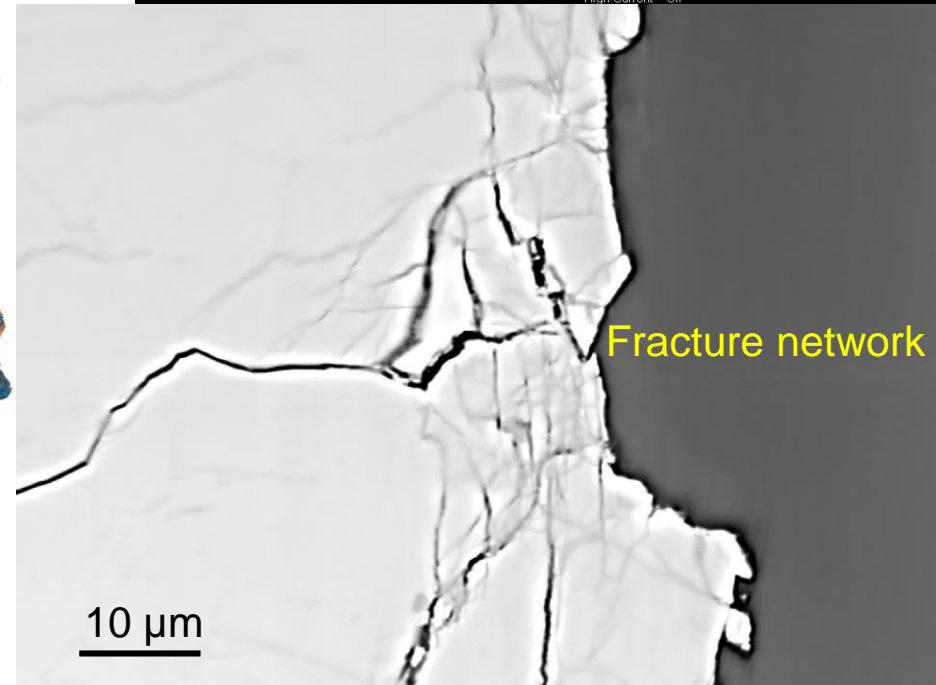
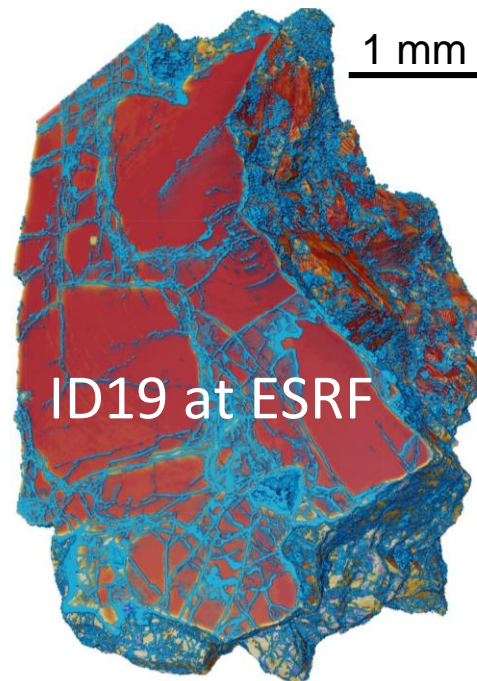
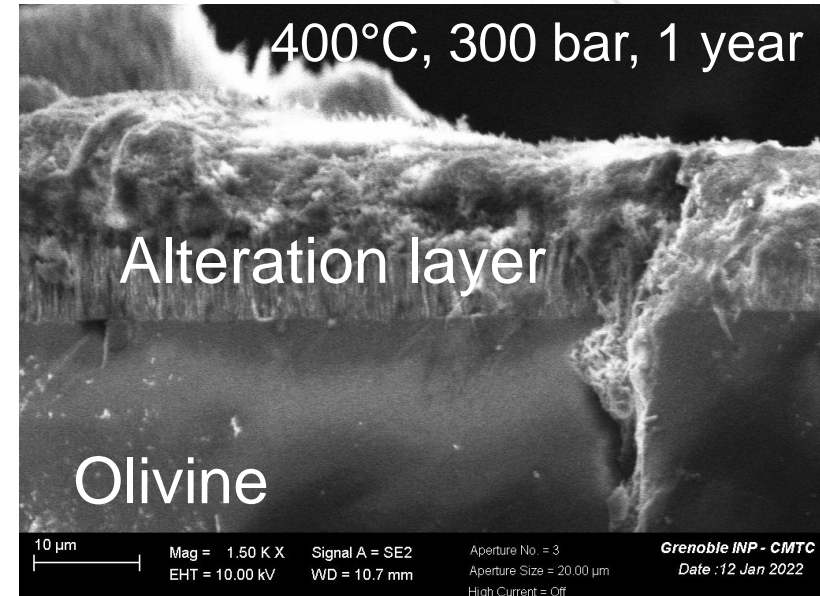


Before reaction

5 mm

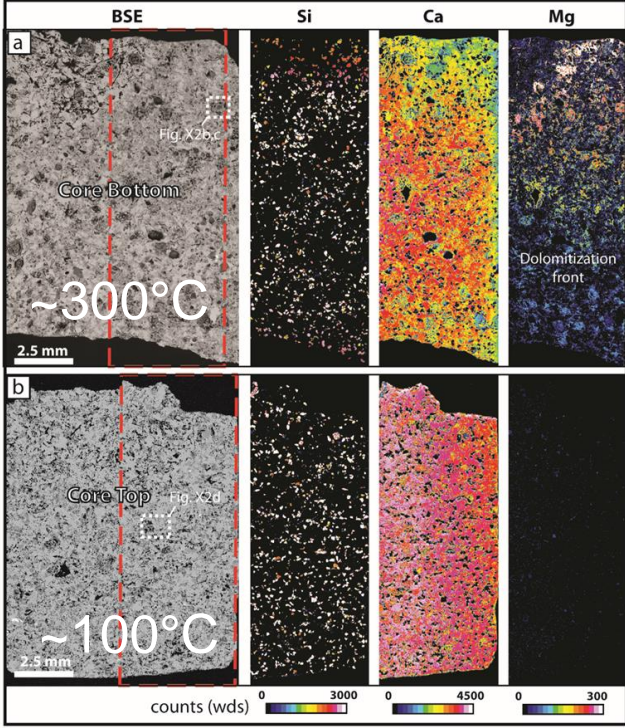
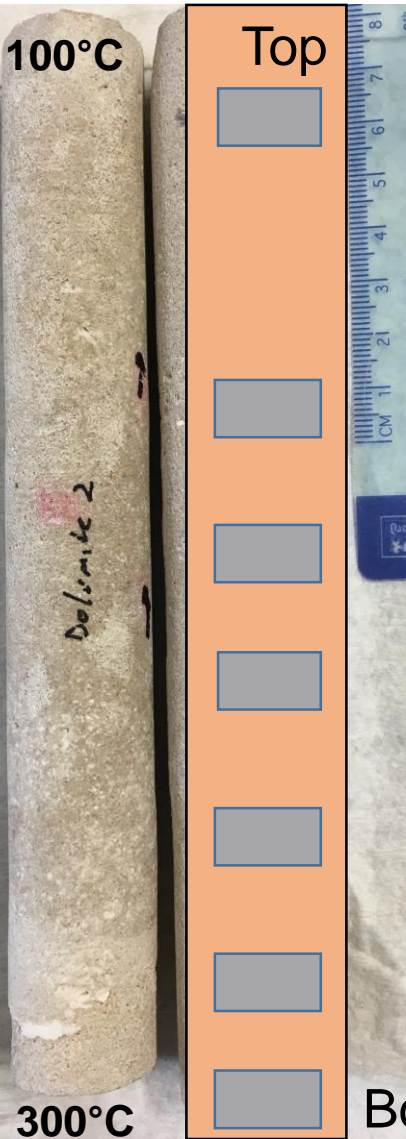


1 mm

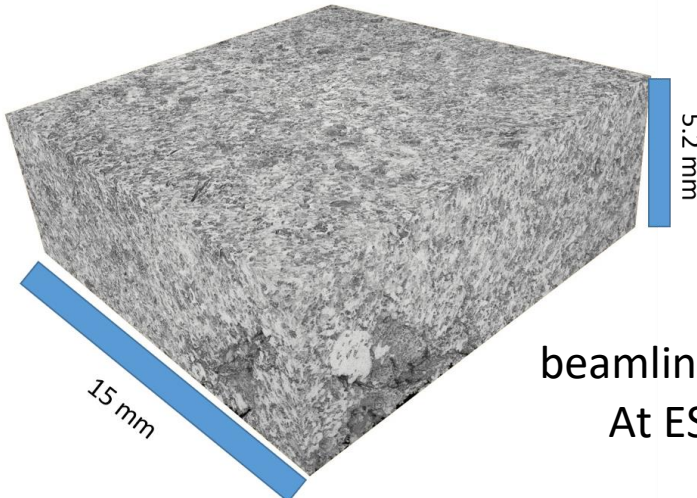




# Experimental Limestone Dolomitization Under Non-isothermal Conditions in cm-cores



BSE imaging and element mapping in Cameca SX 100 electron-microprobe at Géosciences Montpellier

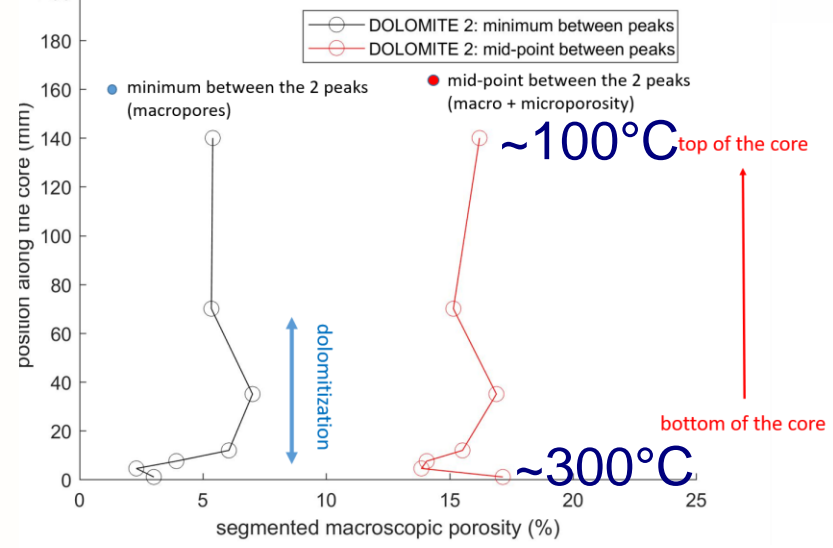


3D view of a subvolume 2150x2150x800 voxels

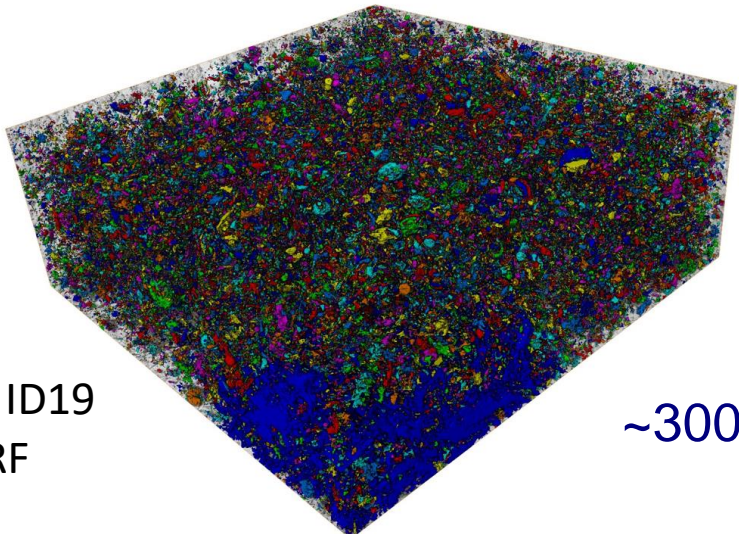
beamline ID19  
At ESRF

Sample DOLOMITE2

## Evolution of porosity along the core

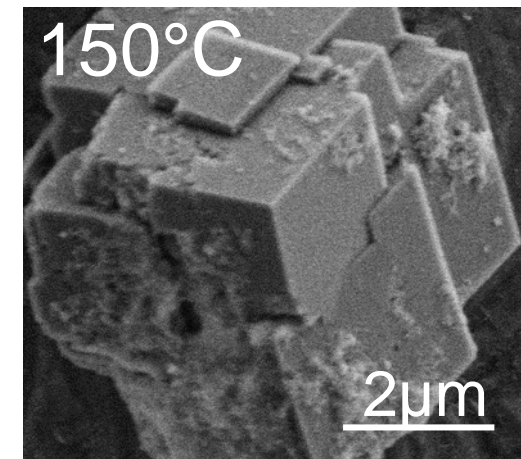
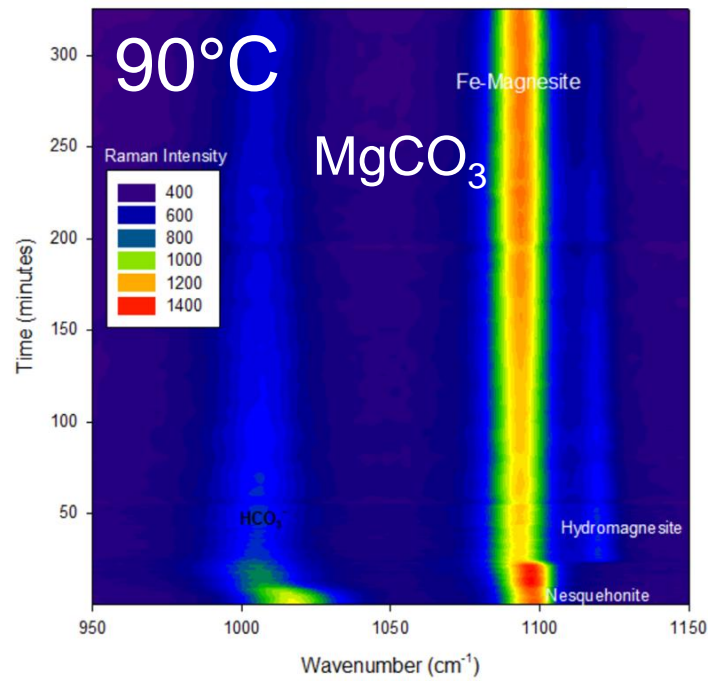
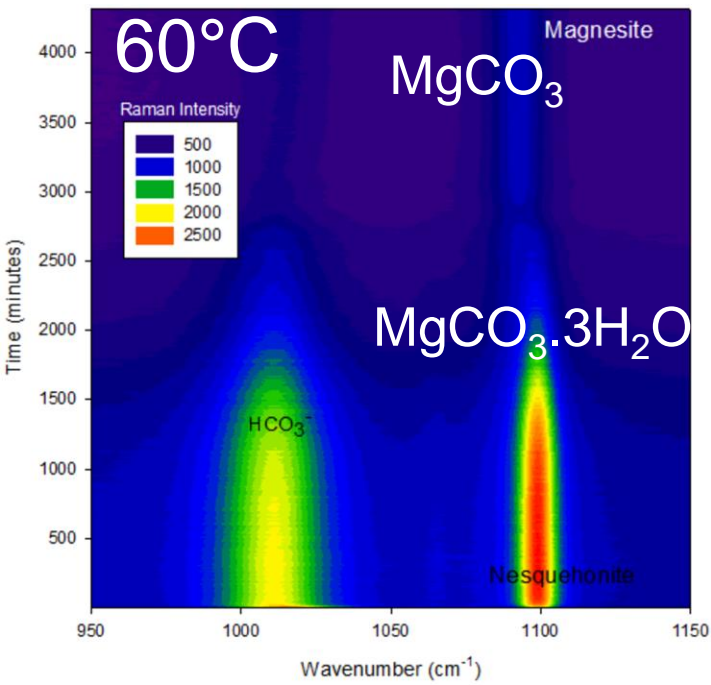
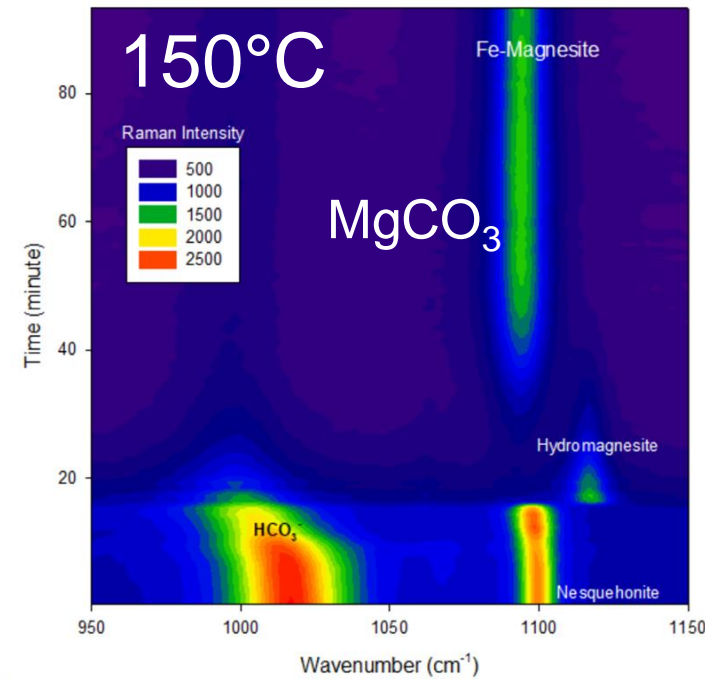
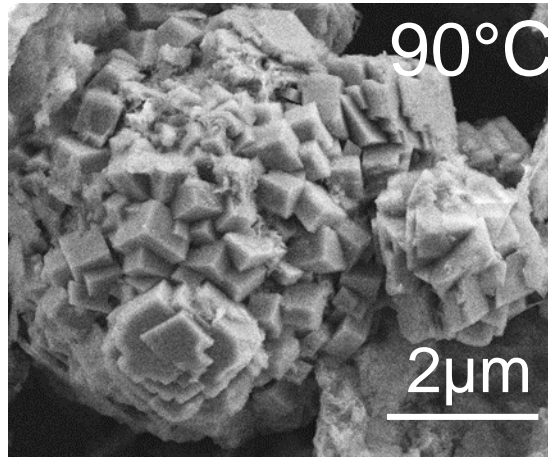
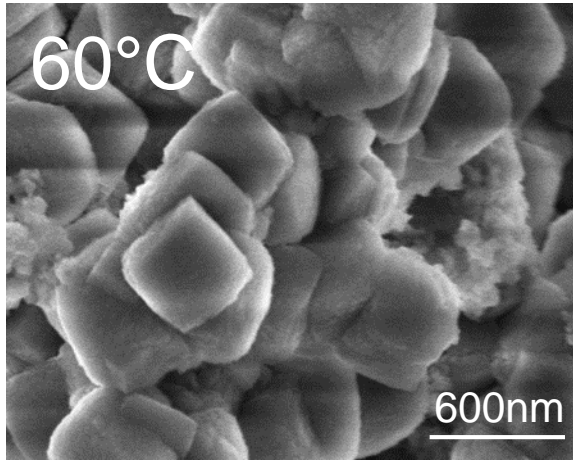


Segmentation of the macroporosity



● minimum between the 2 peaks (macroporosity)

# Fe-Magnesite production via indirect carbonation of peridotite



# Nucleation, Growth and transformation of minerals under mild and hydrothermal conditions

Varios other projects with existing collaborations and varios other activities related to my reserch...

