Case Study: Tauhara New Zealand

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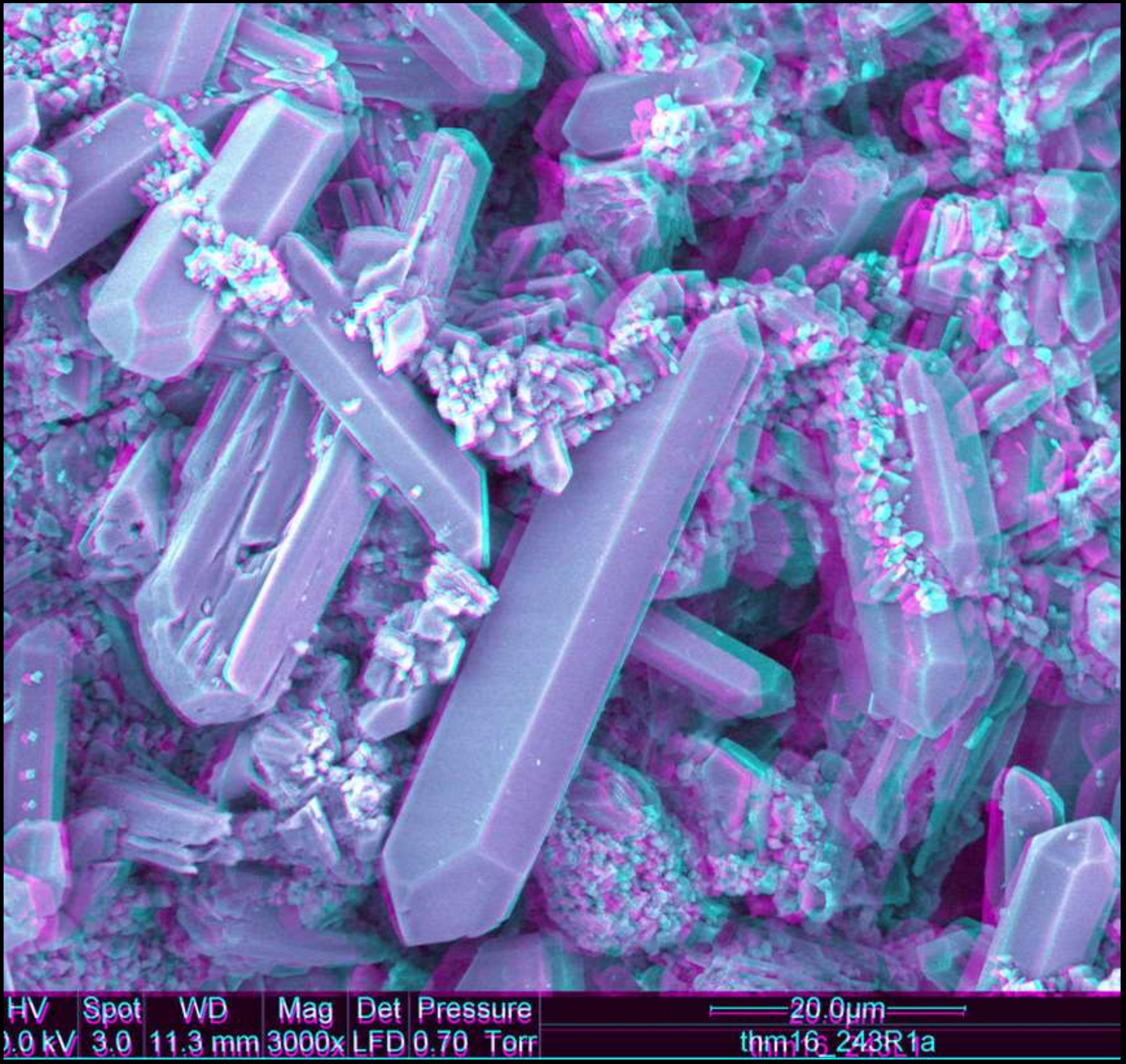
Santiago de Chile, 26-29 May 2014

GEOTHERMAL INSTITUTE

THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Te Whare Wānanga o Tāmaki Makaurau

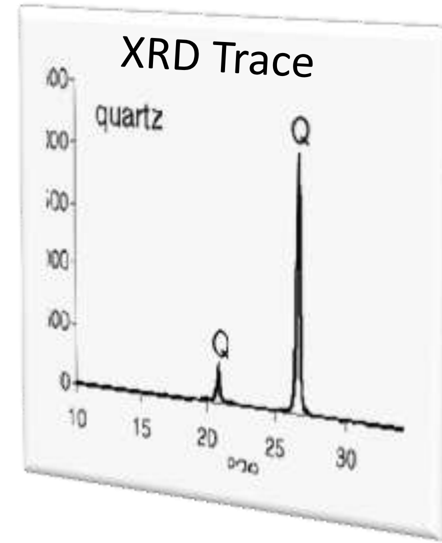
Tauhara Subsidence Case Study



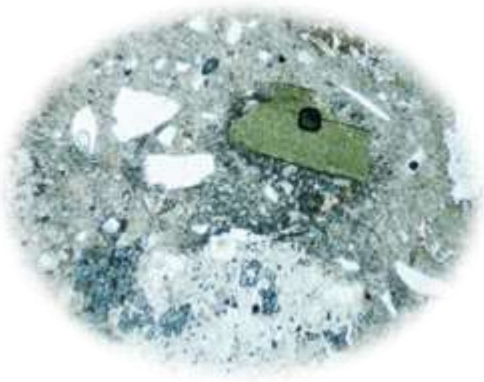
Bridget Y. Lynne
Mick Pender
Trystan Glynn-Morris

Analytical techniques traditionally used for rock analysis

XRD – identifies mineralogy



Petrography



Primary vs secondary minerals

Alteration mineralogy

Fluid/rock interaction

XRF/microprobe - composition

All techniques contribute to our understanding of subsurface processes

TALK AIMS:

1. **To show how the addition of SEM enhances our understanding of subsurface processes and fluid-rock interactions**

2. COMPARE

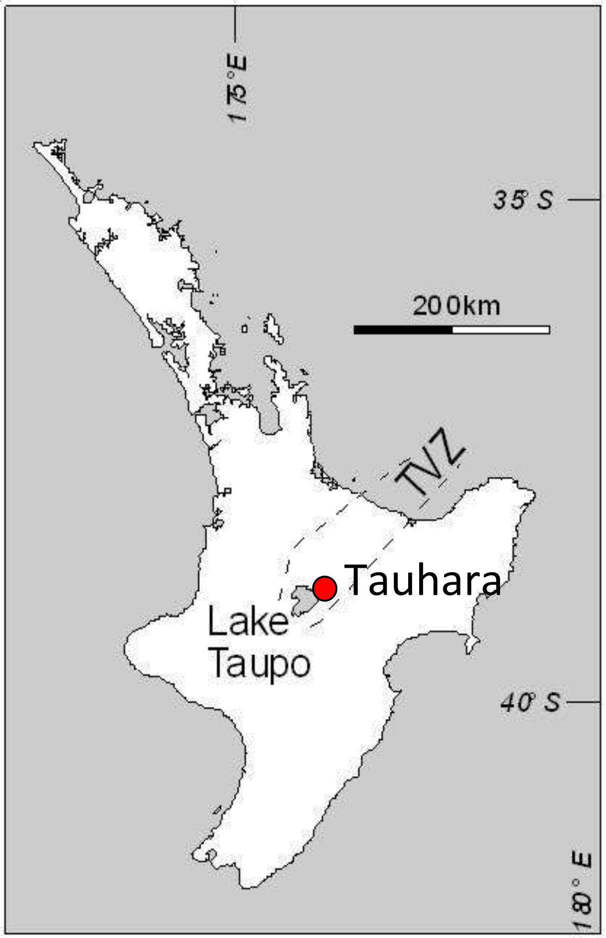
2D imaging (petrography) ← → **3D imaging (SEM)**

3. Combine SEM with compressibility testing

Information on rock strength
+ subsurface processes

Subsidence in geothermal areas
(Case Study)

Case Study known subsidence bowls
Tauhara Geothermal Field



Prior to consent for further geothermal development

Cause of known subsidence bowls must be understood

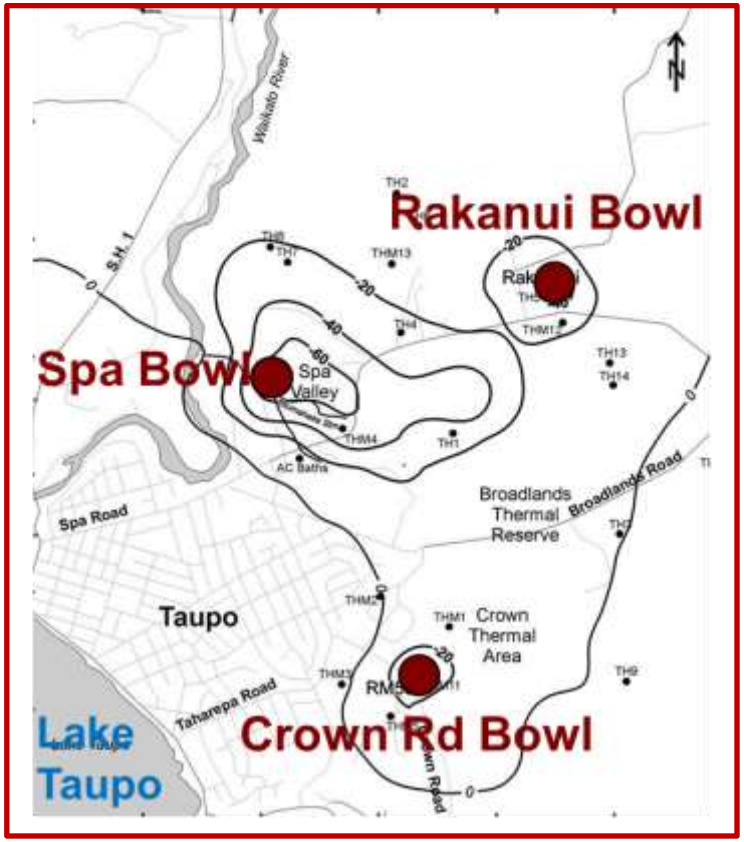
Extensive drilling program

Drilling Aims

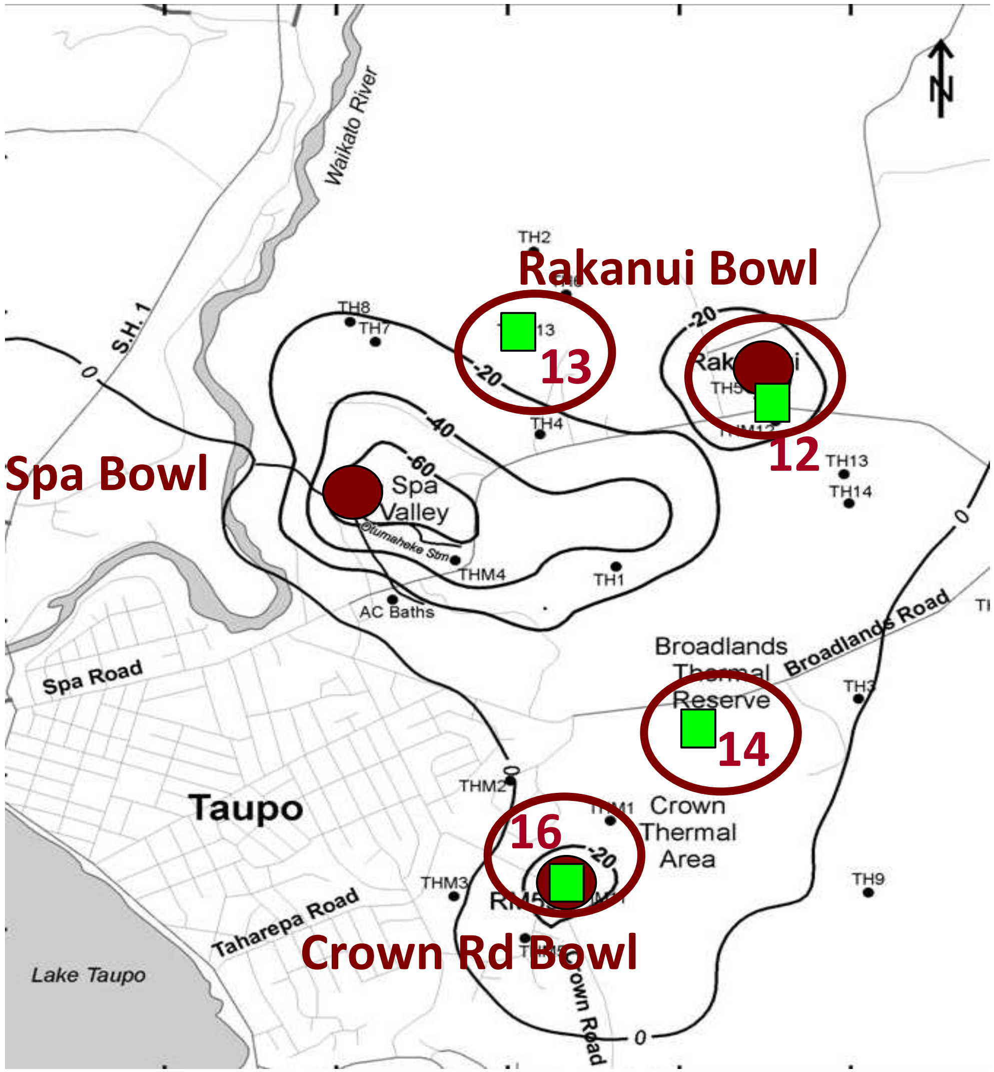
Determine subsurface processes responsible for subsidence

Identify weak horizons and possible future subsidence sites

Establish physical characteristics of subsurface rocks



Continuous core drilling program



Outside

Margin

Inside

Multiple testing approach undertaken

Physical Characteristics

- XRD
- Clay analysis
- Petrography
- Porosity
- Scanning Electron Microscopy (SEM)

Geotechnical Tests

- Pocket penetrometer tests
- Shear Vane tests
- Stiffness tests
- Atterberg Limit tests
- Compressibility tests to evaluate rock strength

For each slide …

Drill hole with stratigraphic column

I = inside subsidence bowl

M = margin

O = outside

Compressibility Value (CV)

High CV = strong rock (1700 MPa)

Low CV = weak rock (30 MPa)

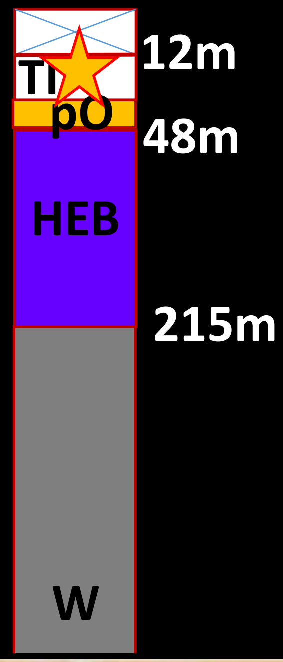
★ **Sample site**

2D vs 3D imaging

Petrography vs SEM

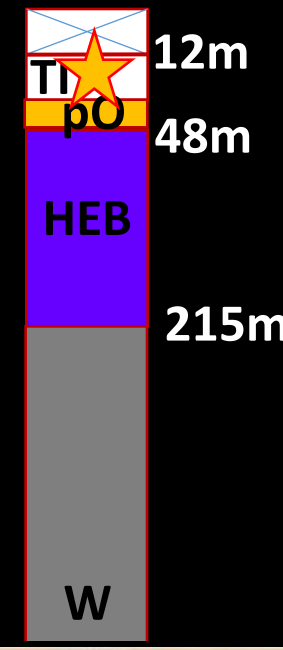
22m

THM16 (I)



30m

THM16 (I)



Taupo Ignimbrite

Pumice-rich

Taupo Ignimbrite Pumice horizon

22 m

CV = 294 MPa

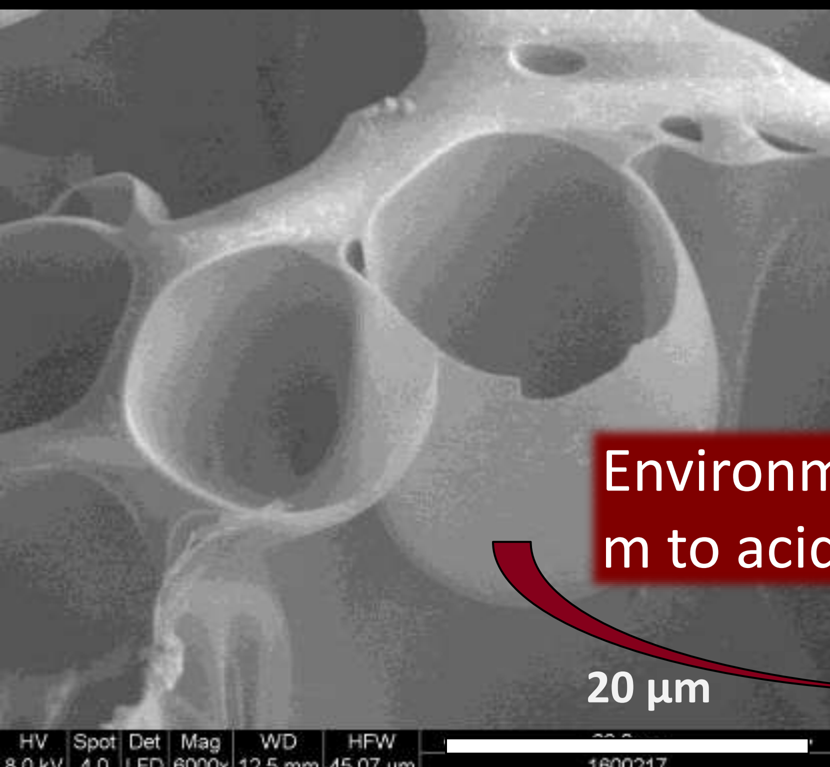
30 m

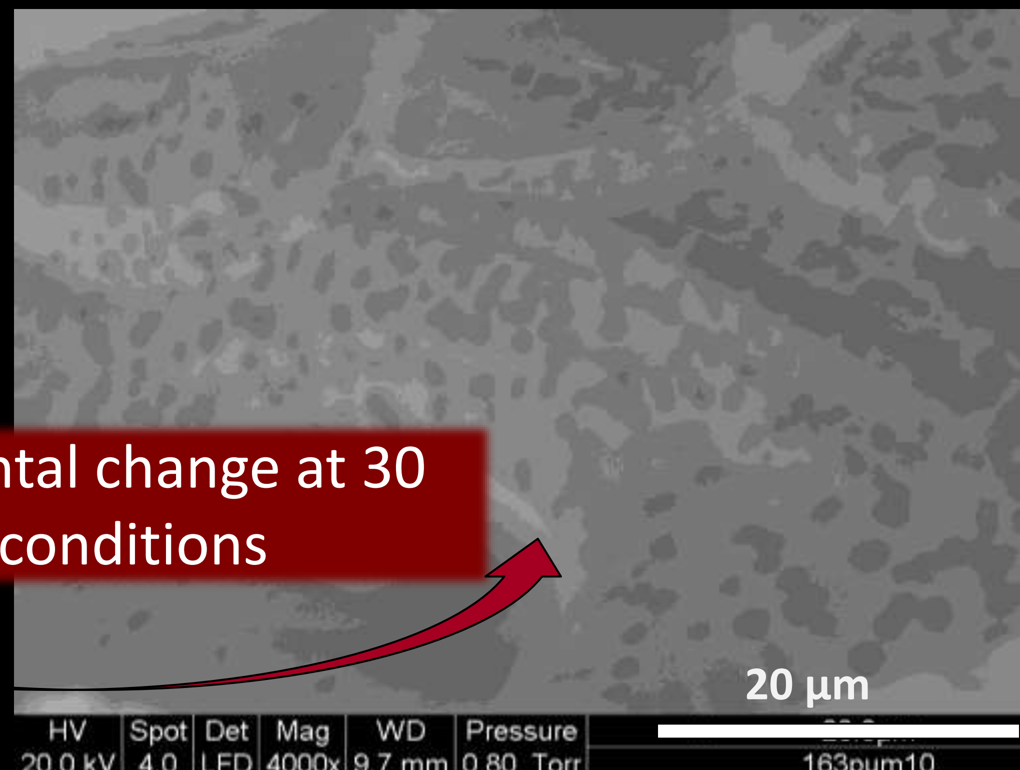
CV = 108 MPa

?? Process ??

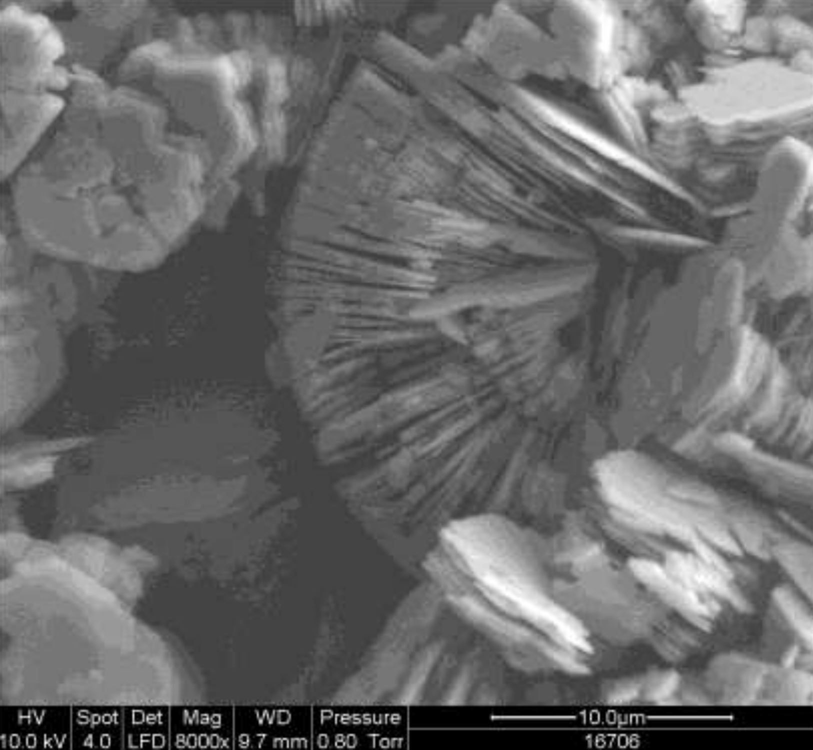
Unaltered

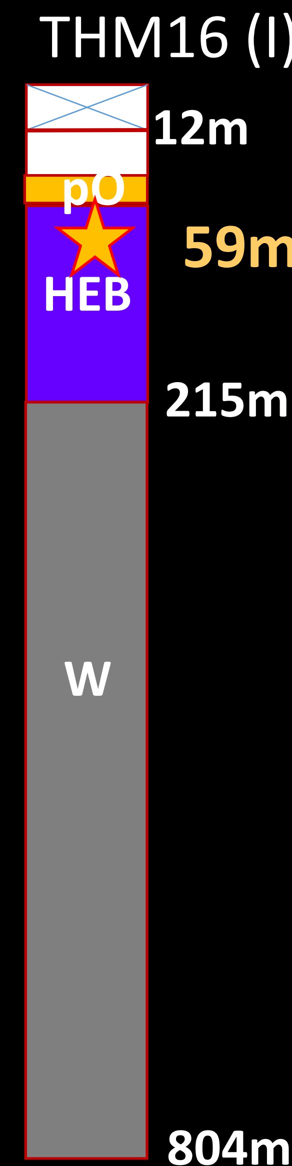
Dissolution





Environmental change at 30 m to acidic conditions





59m

CV = 36 MPa (very weak)

Kaolinite

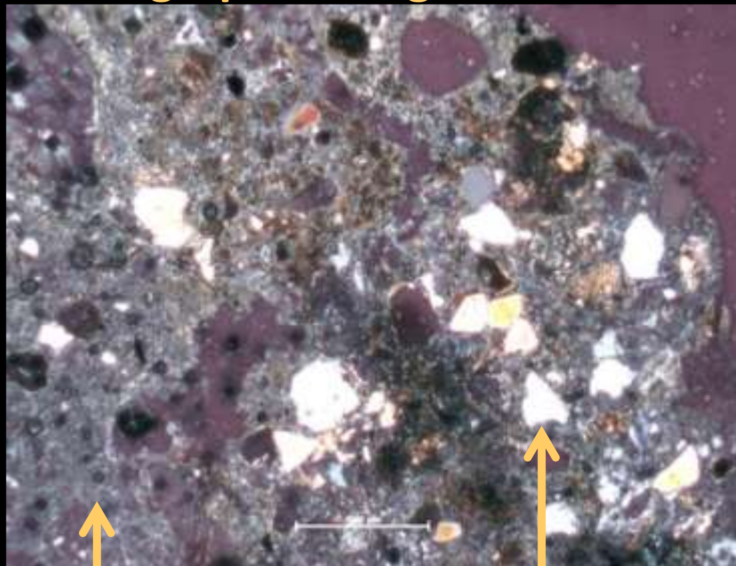
pH ~3

T <120 °C

Acidic conditions

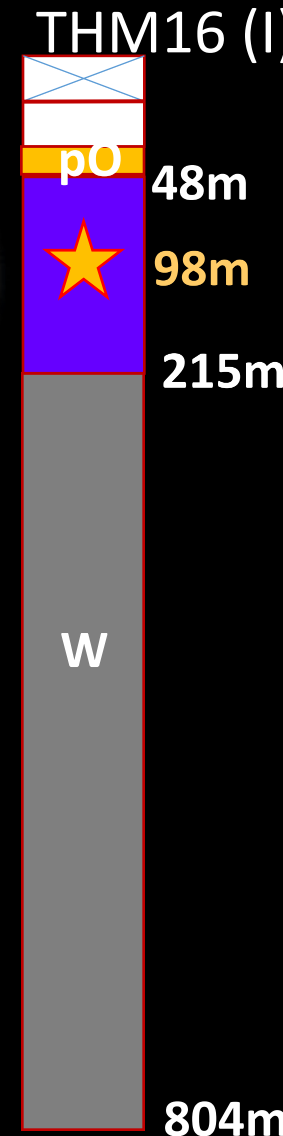
THM 16   59 m   Kaolinite platelets   36 MPa

Petrographic image



Crystals

Clay matrix



Hydrothermal Eruption Breccia

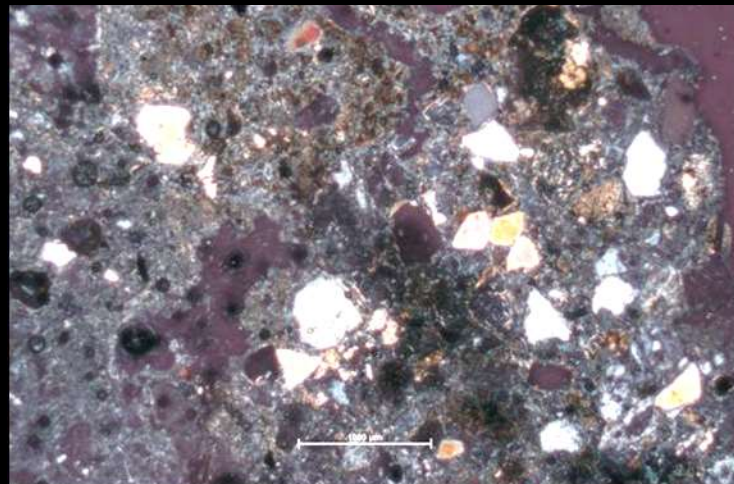
98m

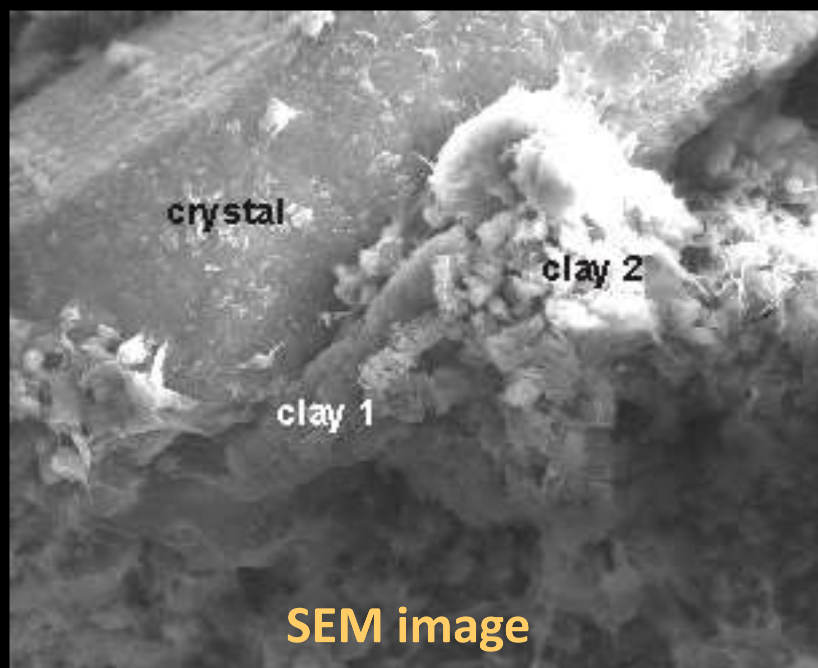
CV = 65 MPa

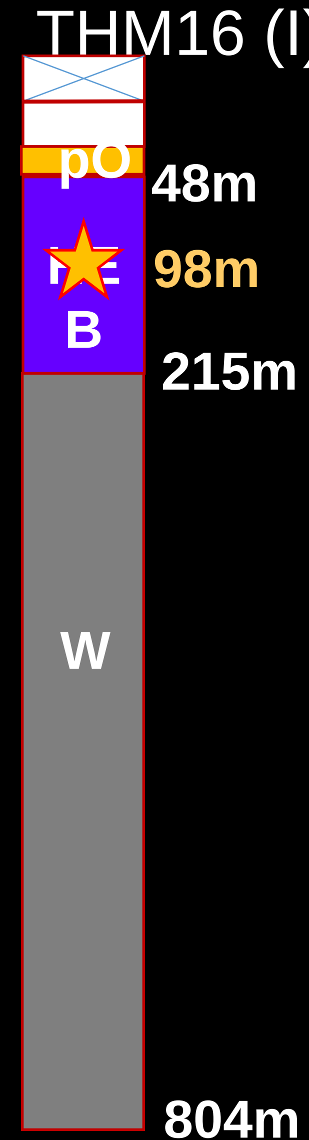
98m

CV = 65 MPa

Petrographic image

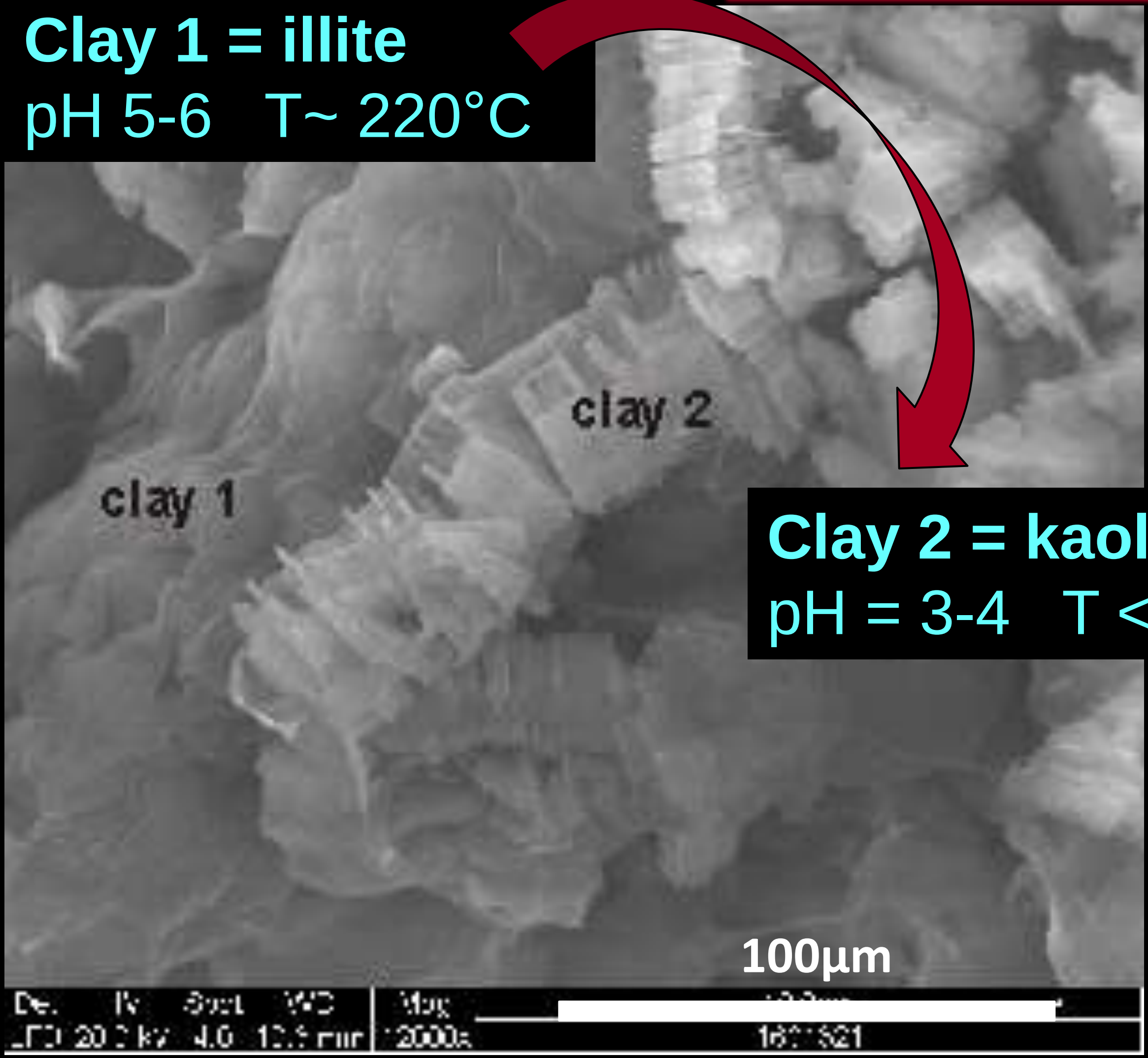






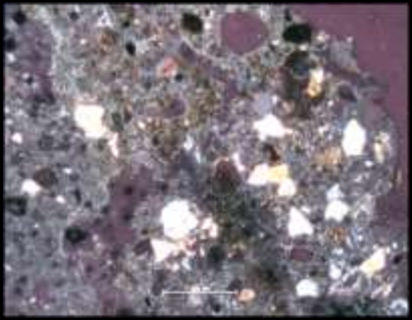
Environmental change
pH decrease

Clay 1 = illite
pH 5-6   T~ 220°C



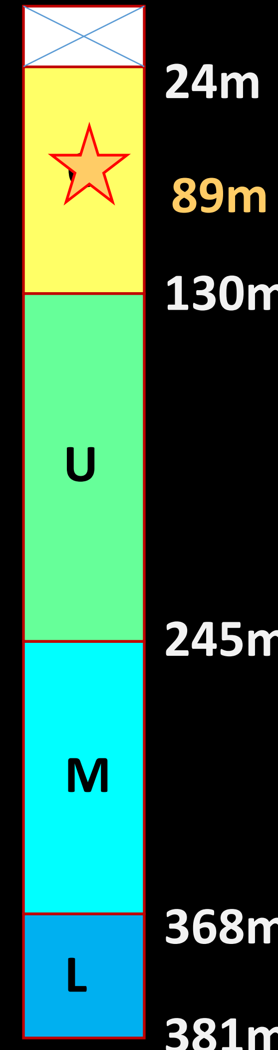
Clay 2 = kaolinite
pH = 3-4   T <120°C

98m
CV = 65 MPa
THM 16 (I)

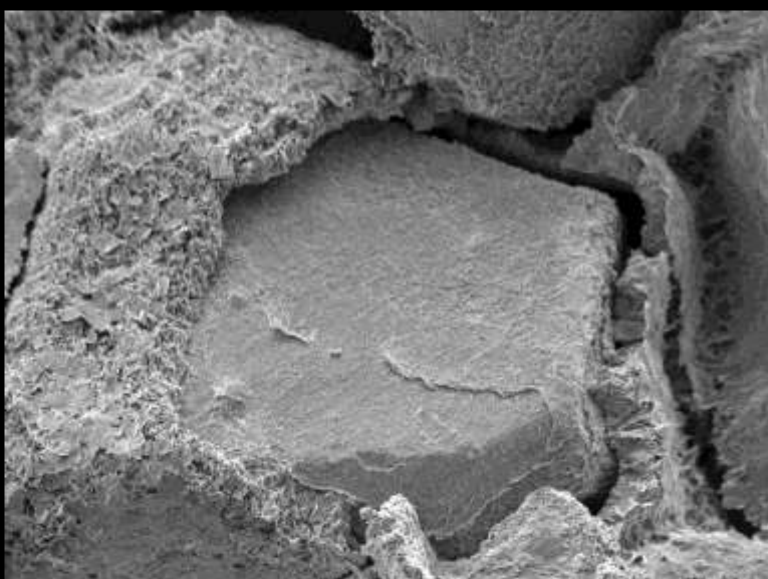


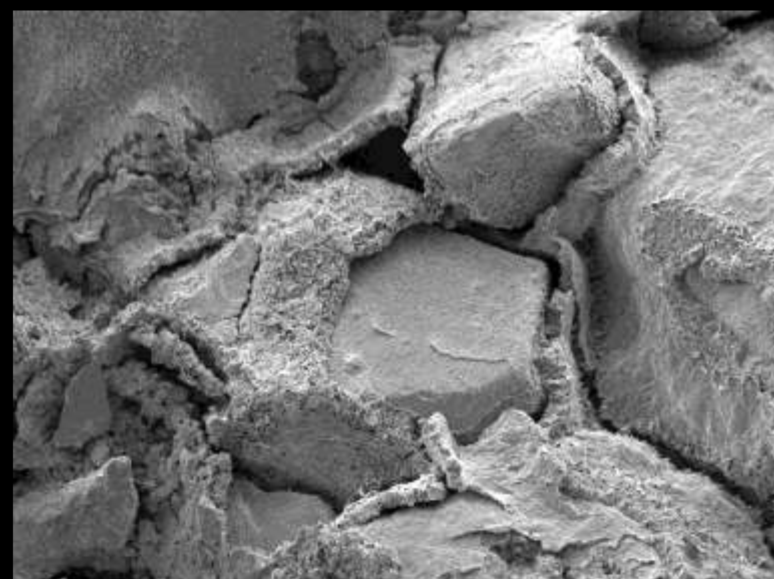
89m
CV = 490 MPa
Oranui Fmn

THM13 (O)

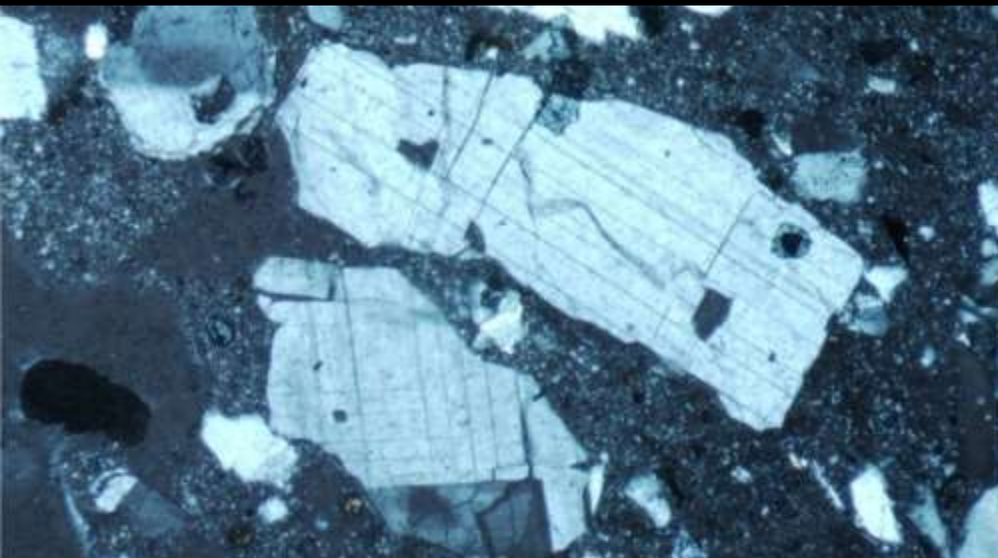


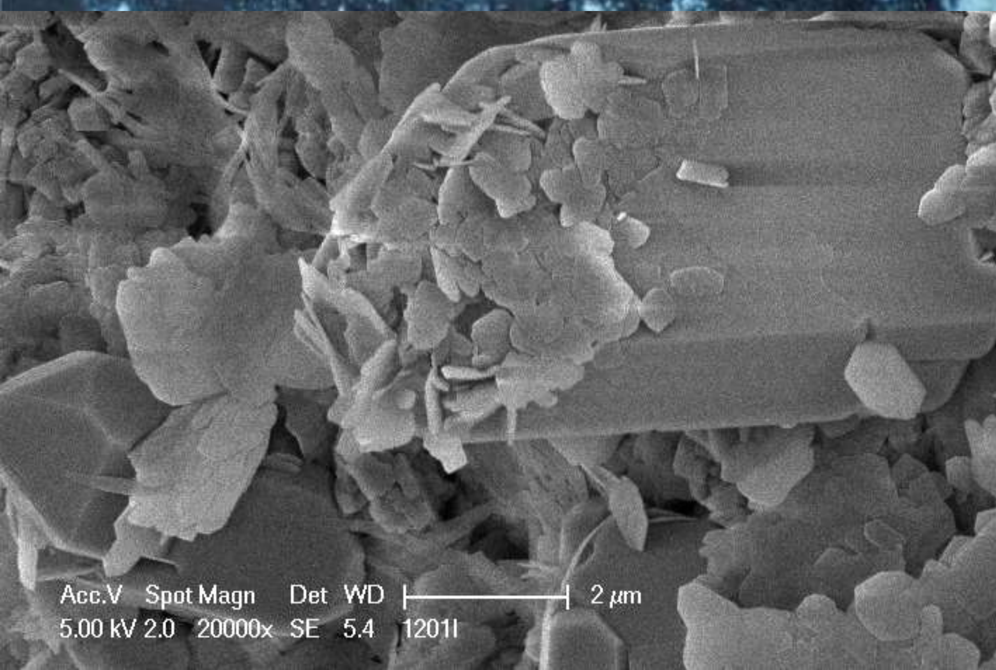
Chlorite coating fragments



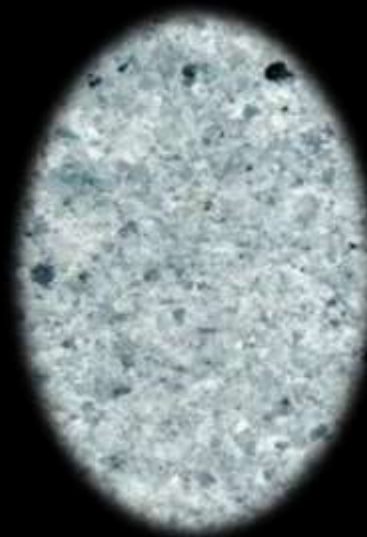


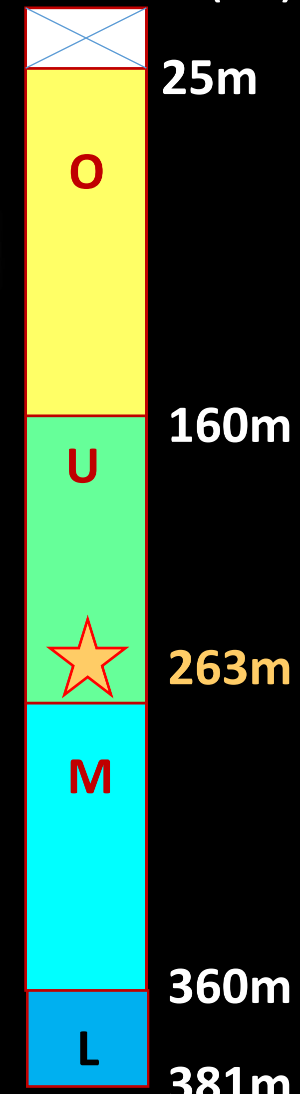
Fractured crystals
Etched edges





THM12 (M)



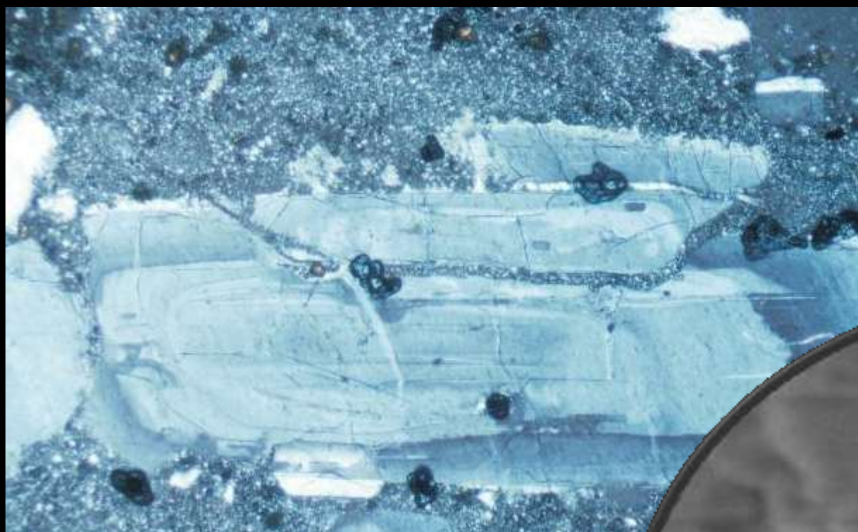


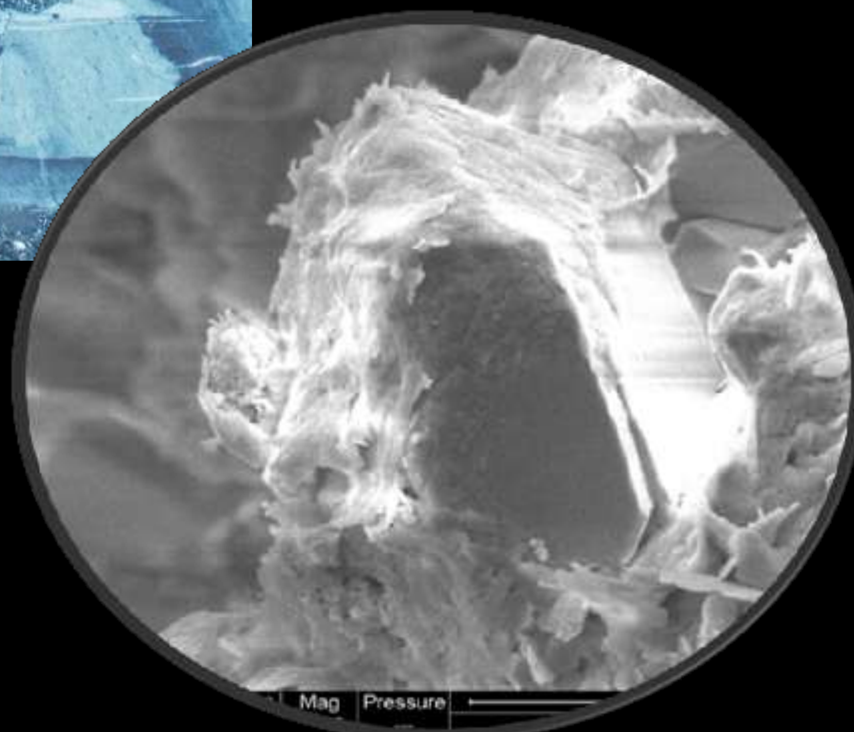
263m
CV = 84 MPa
Chlorite + illite + feldspars

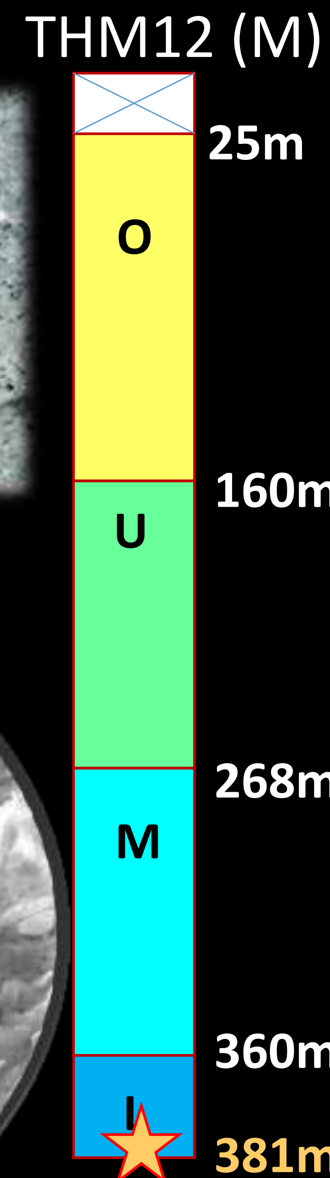
381 m

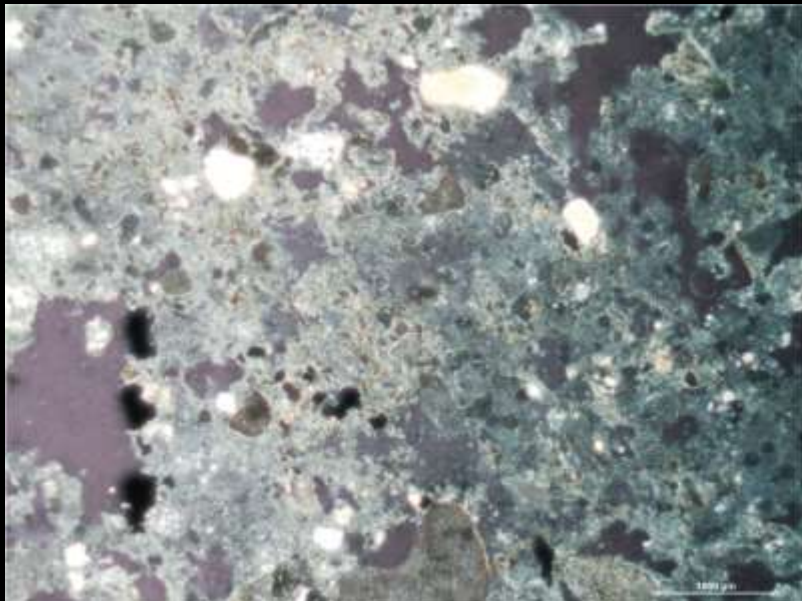
CV = 522 MPa

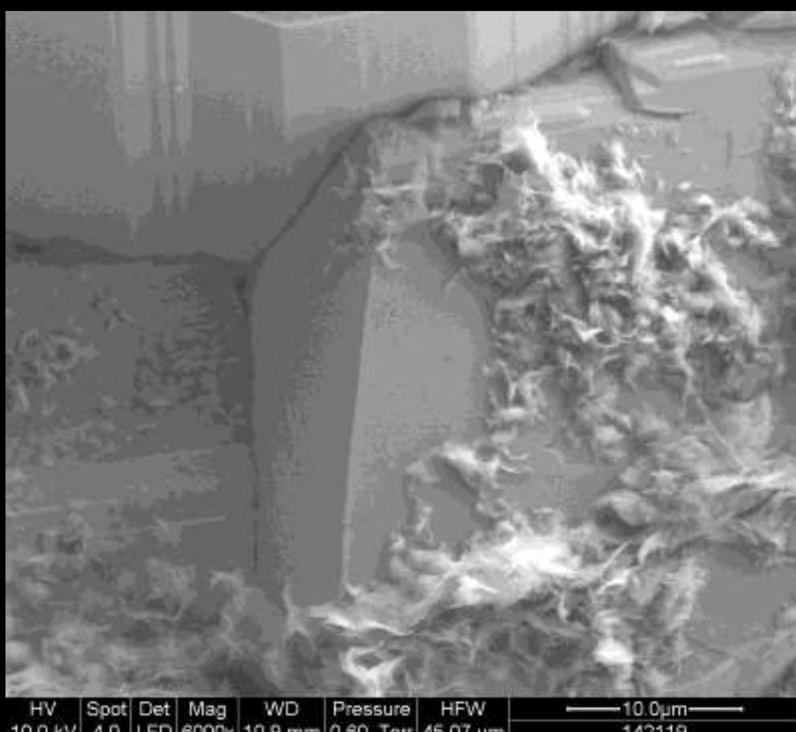
Chlorite/illite

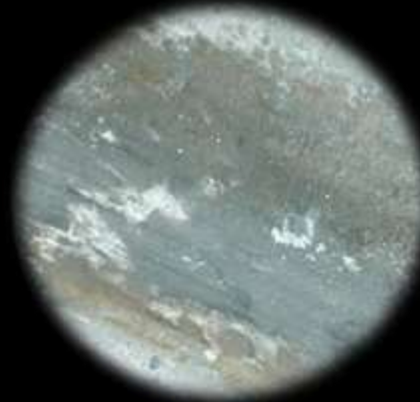




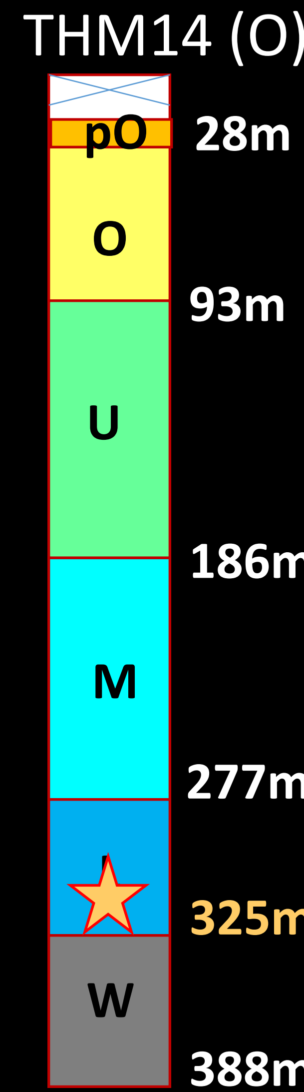


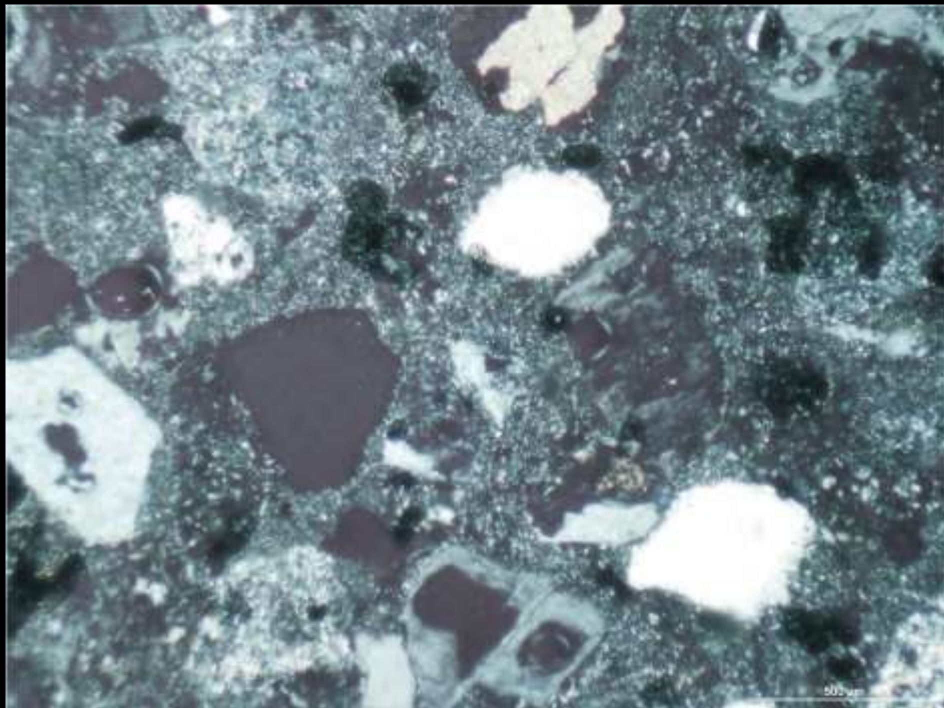


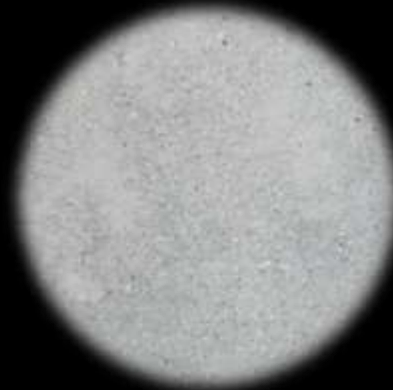




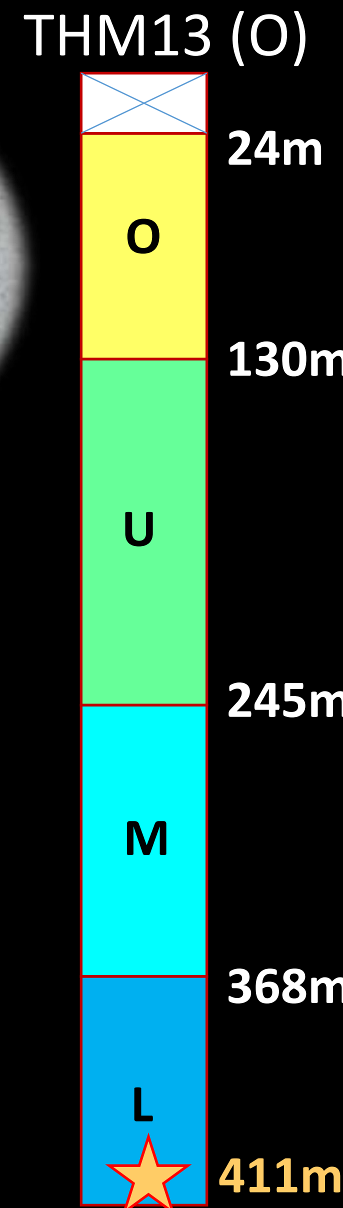
325m
CV = 390 MPa
Illite + crystals







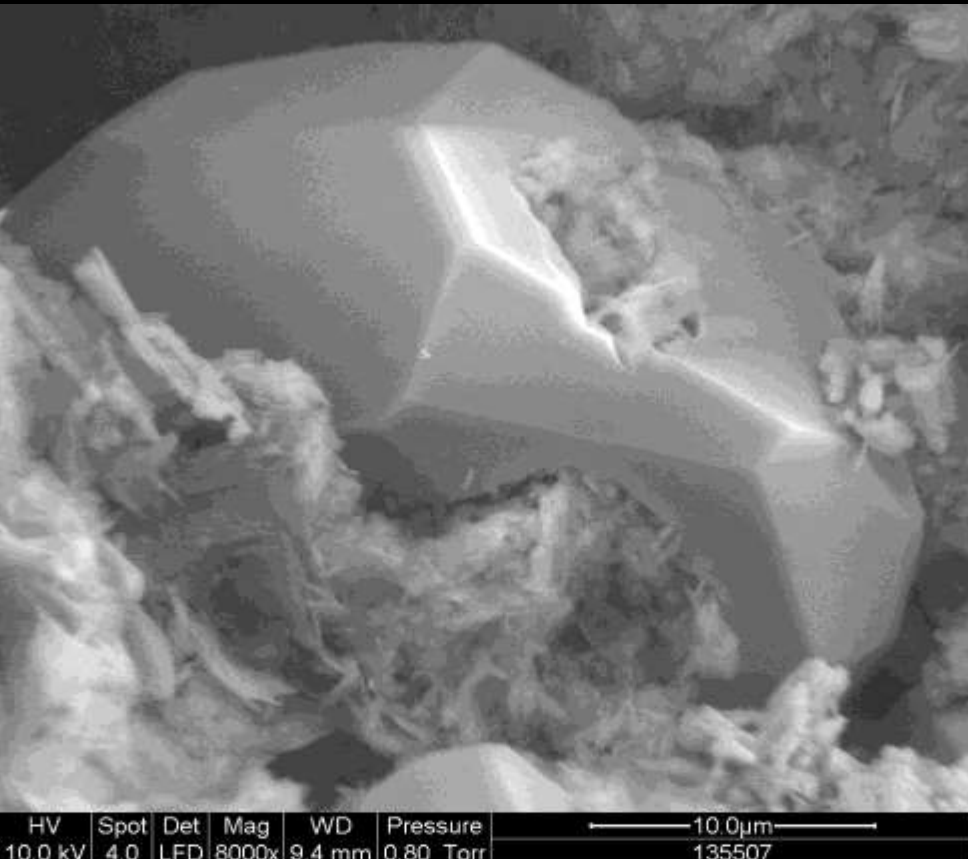
Crystals – etched edges in a clay groundmass (illite)

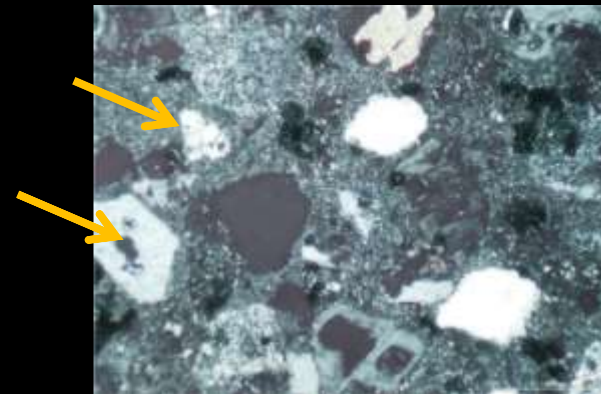


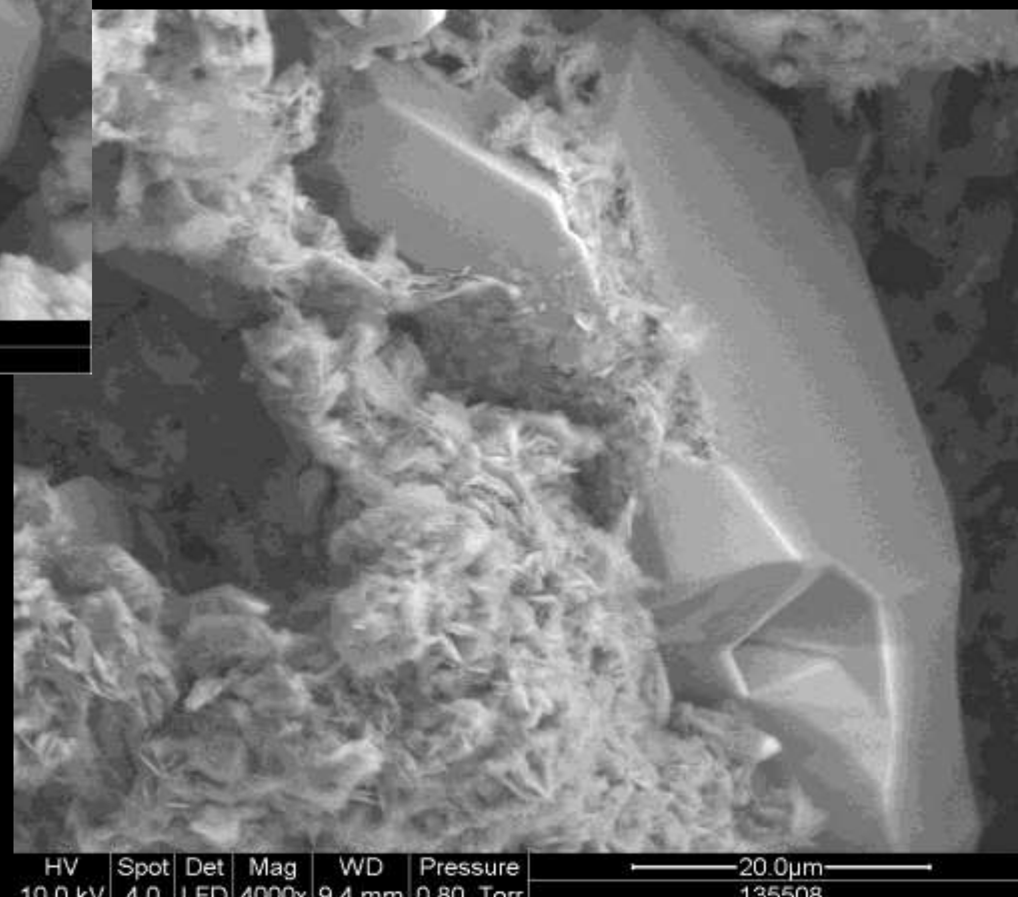
411m

CV = 1730 MPa

Illite/feldspar





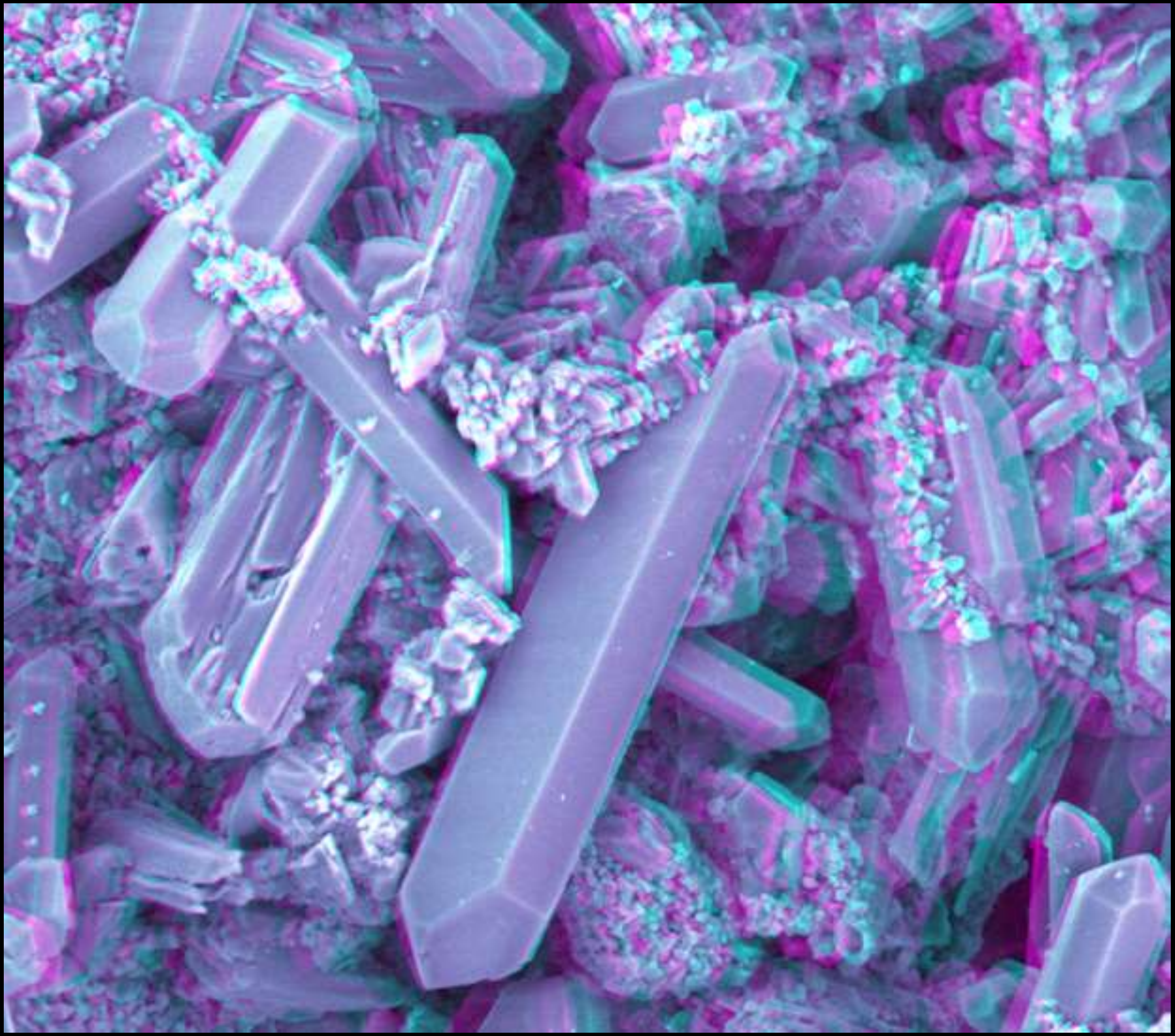


411m

CV = 1730 MPa

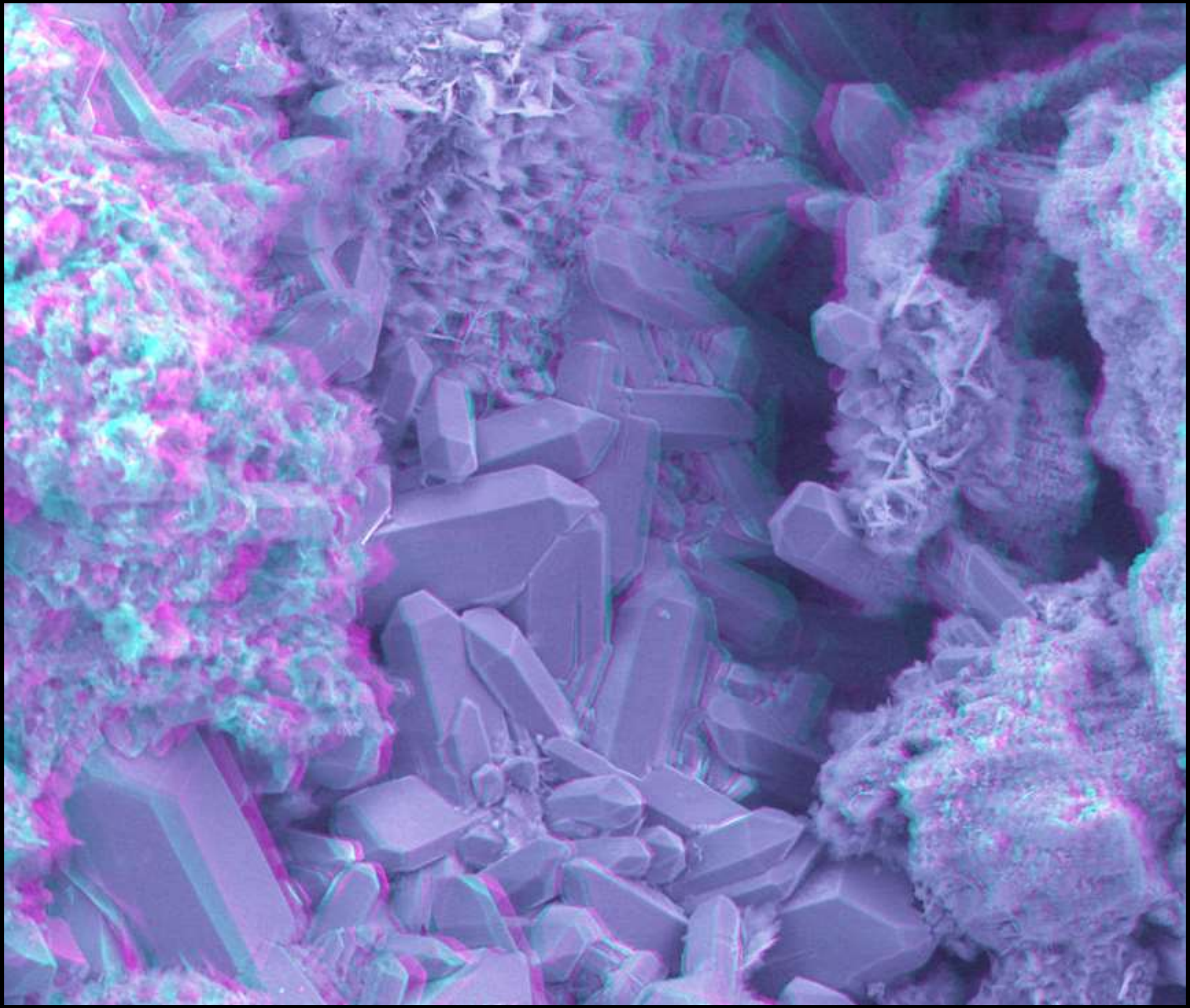
Illite/feldspar

THM 13 411 m CV = 1730 MPa



20 µm

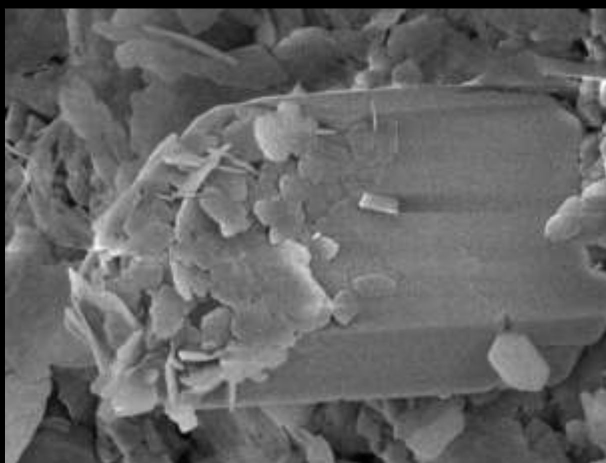
THM 13 411 m CV = 1730 MPa



50 µm

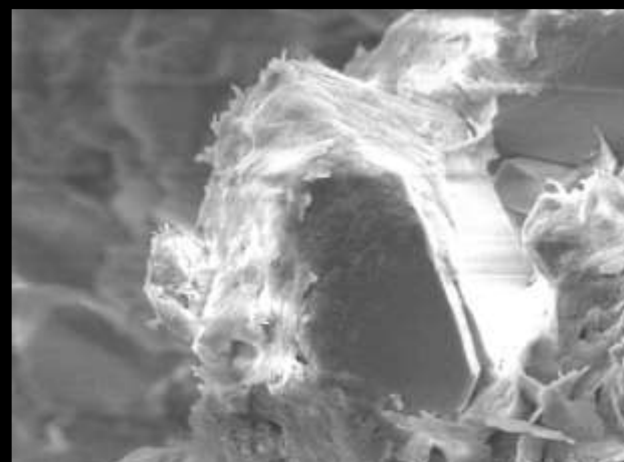
Crystal structural integrity contributes to rock strength

2 µm



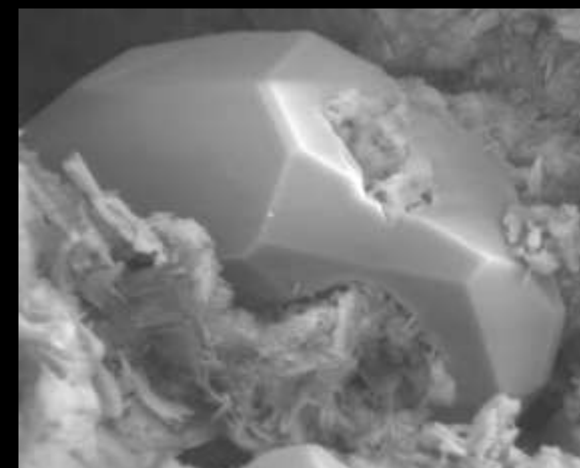
263 m
CV = 84 MPa
THM 12

5 µm



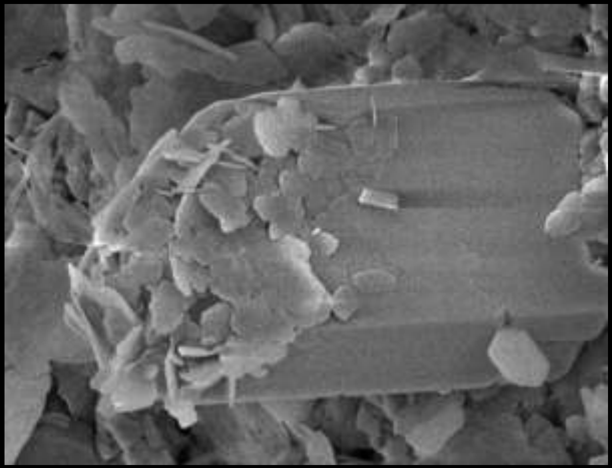
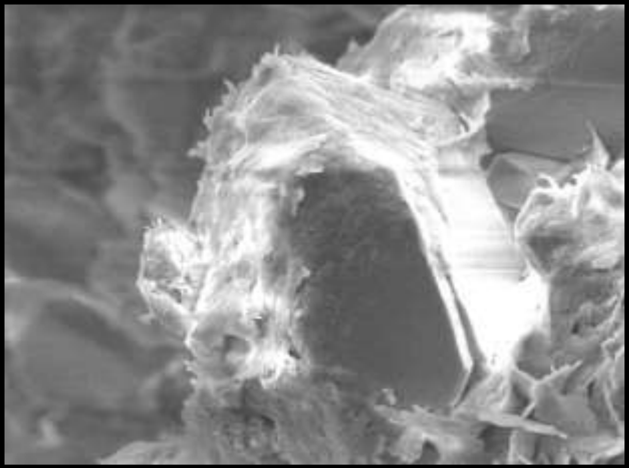
280 m
CV = 522 MPa
THM 12

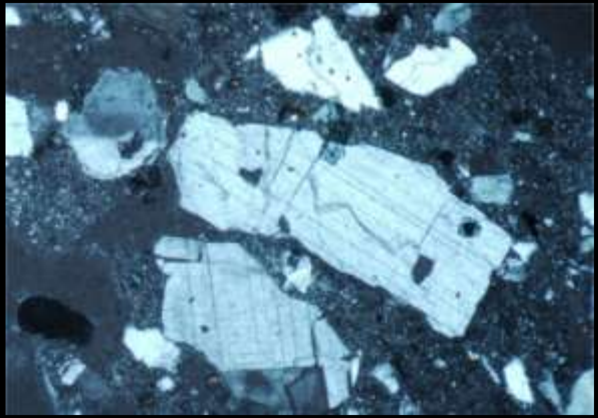
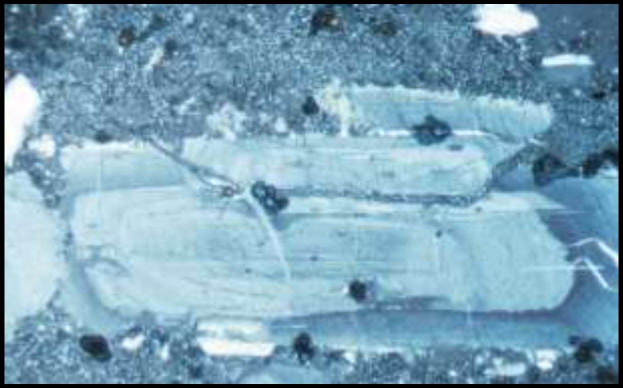
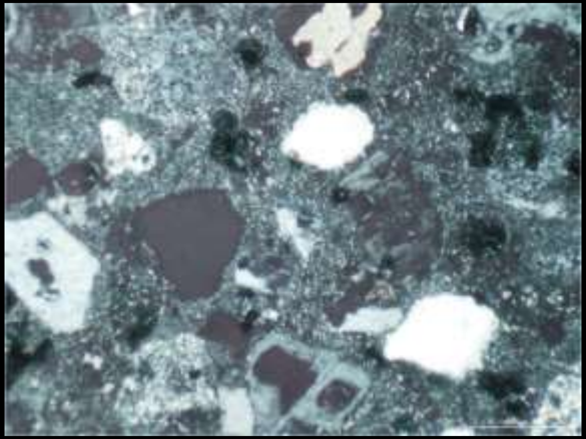
10 µm

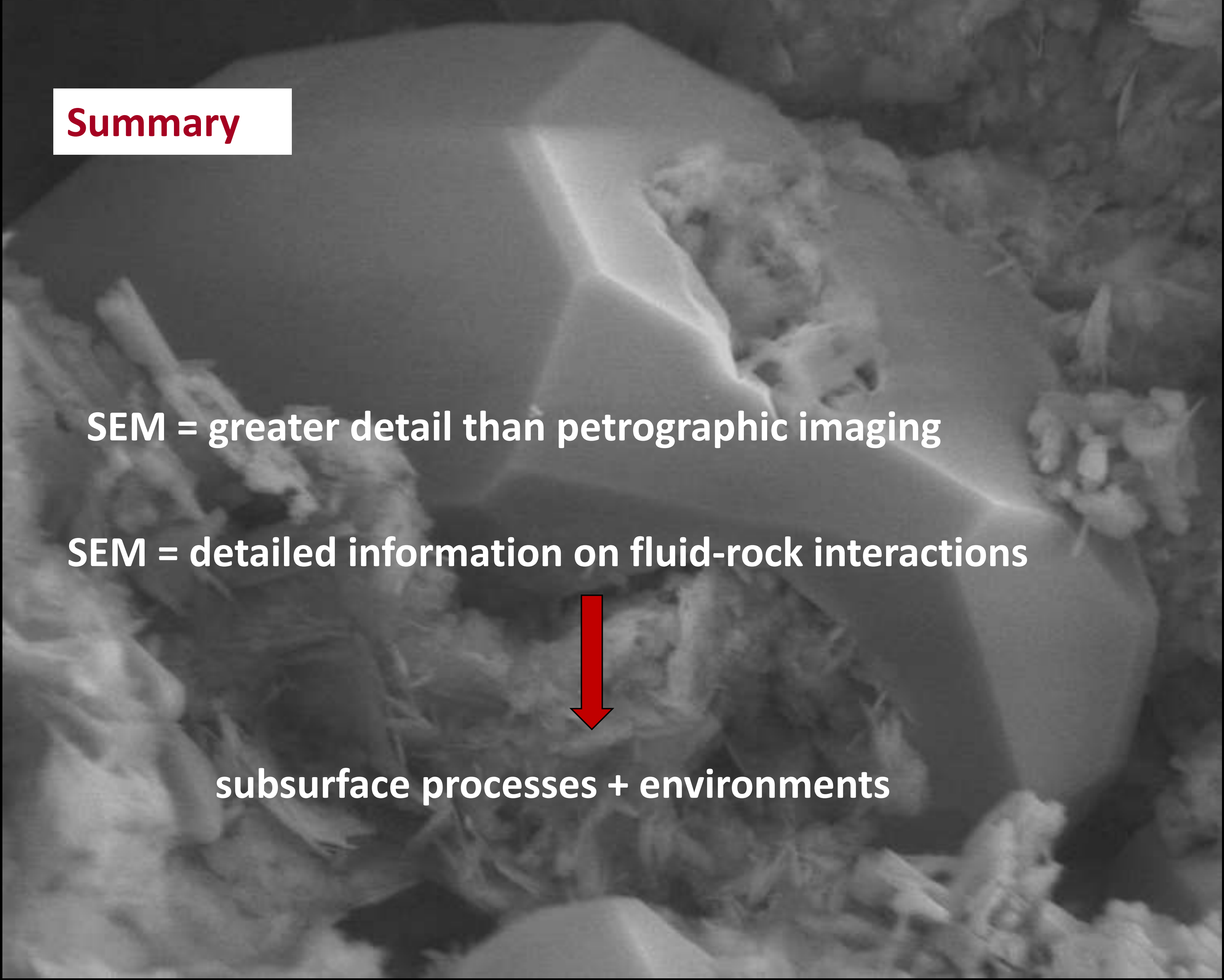


411 m
CV = 1730 MPa
THM 13

Compare SEM to Petrographic Microscopy



Summary

SEM = greater detail than petrographic imaging

SEM = detailed information on fluid-rock interactions

↓

subsurface processes + environments

Summary

Compressibility testing → rock strength

Combination of SEM + compressibility testing

↓

Useful method in establishing:

(1) rock strength

(2) subsurface processes responsible for altering the rock which affects its strength

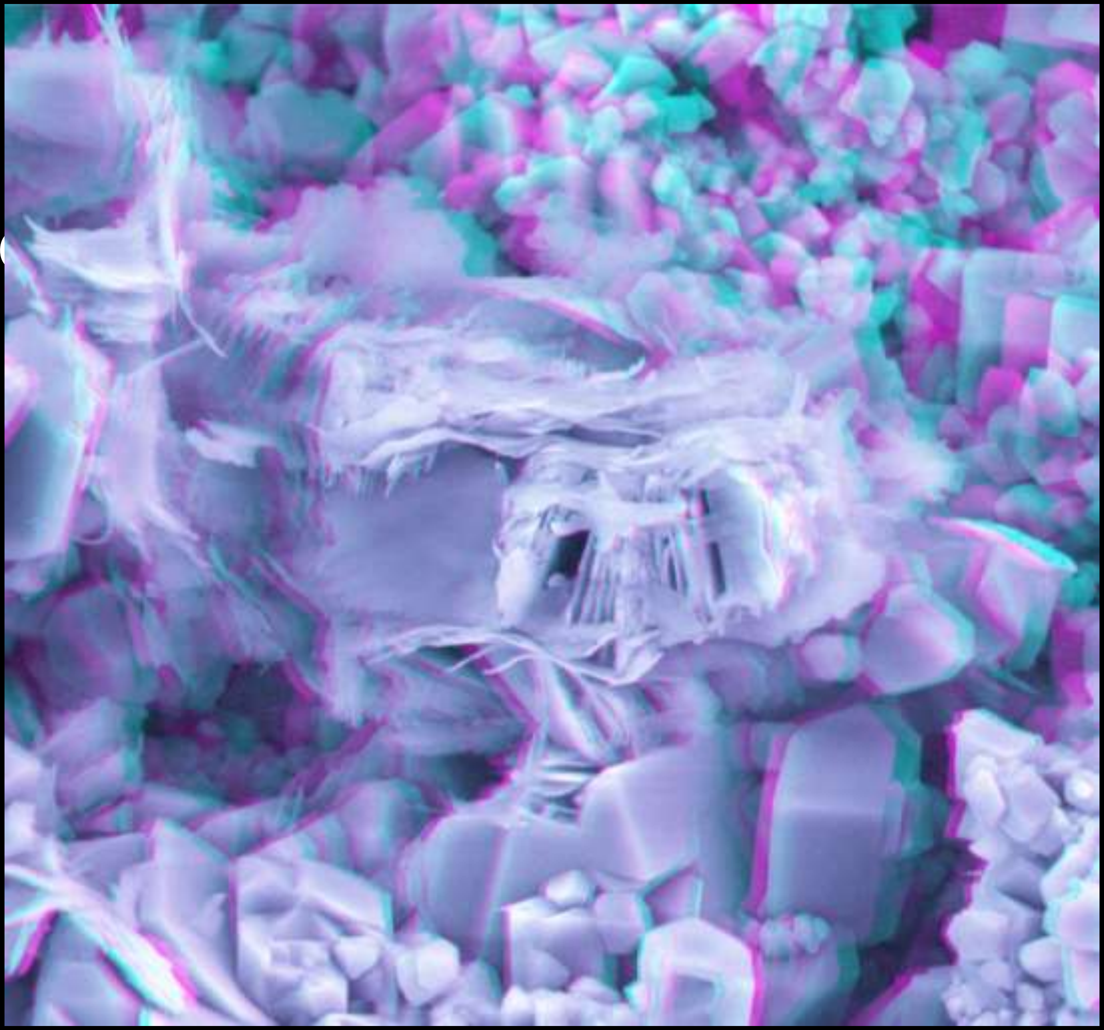
Subsidence (SEM + Constrained Modulus Values)

Subsidence studies can be applied to

- pre-exploitation phases
  - Evaluate potential risk of subsidence following fluid extraction
- Environmental Impact Studies
  - Identification of pre-exploitation rock characteristics e.g. natural vs induced subsidence
- producing fields
  - Identify lithologies susceptible to subsidence in existing fields

Useful study to identify subsurface processes showing why some lithologic units subside and others do not

Acknowledgements



Contact Energy   Catherine Hobbis   FEI