4D imaging of fracturing of organic-rich shales during heating

Maya Kobchenko[1]

H. Panahi[1], F. Renard[1,2], J. Scheibert[1], D. Dysthe[1], A. Malthe-Sørenssen[1], A. Mazzini[1], B. Jamtveit[1] and P. Meakin[1,3]

Petromaks, NRC

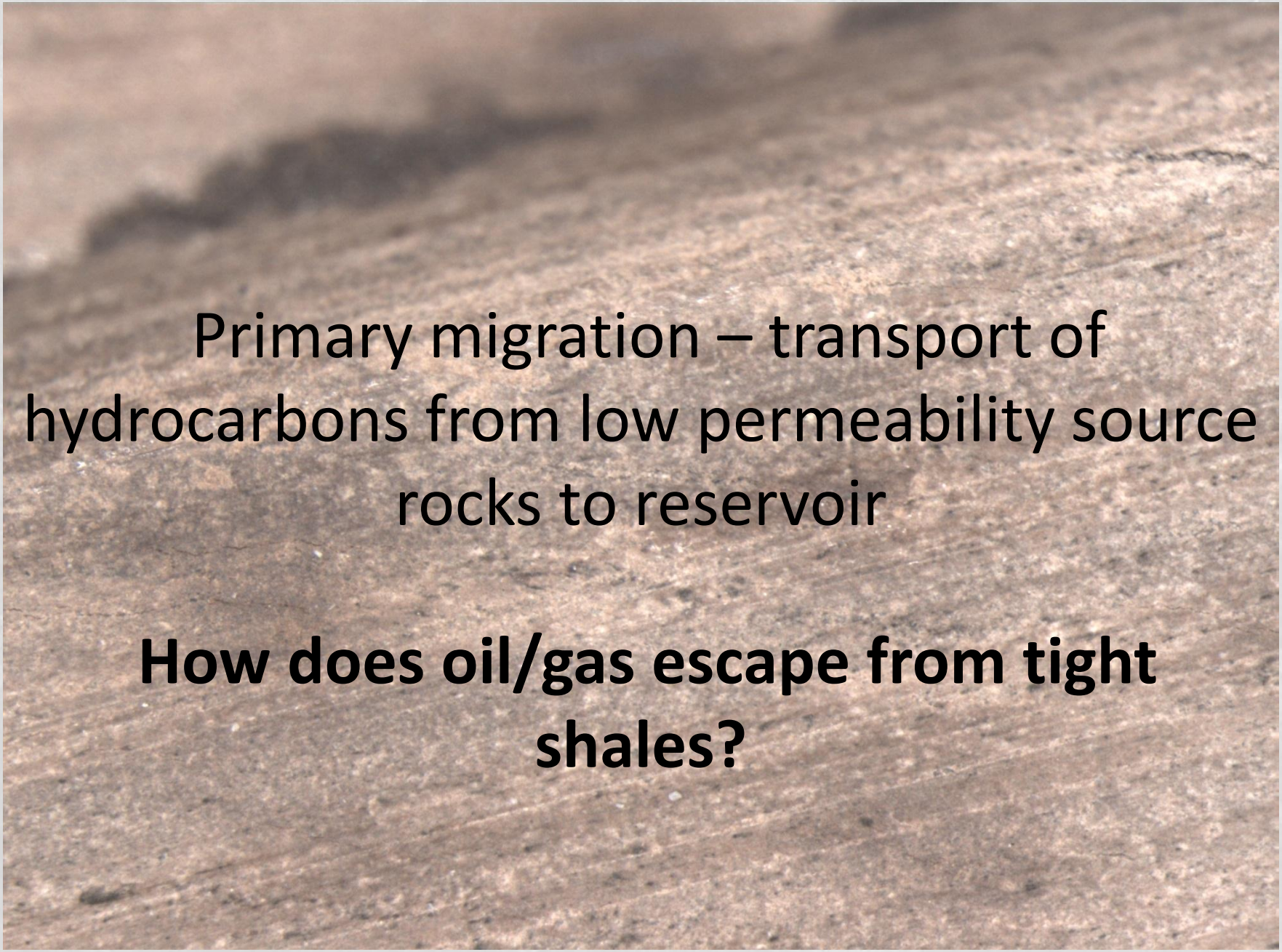
[1] PGP, University of Oslo, Norway
[2] UJF and CNRS, Grenoble, France
[3] INL, Idaho Falls, USA

maya.kobchenko@fys.uio.no

Norwegian Centre of Excellence

PGP PHYSICS OF GEOLOGICAL PROCESSES

UNIVERSITY OF OSLO


Primary migration – transport of hydrocarbons from low permeability source rocks to reservoir
How does oil/gas escape from tight shales?

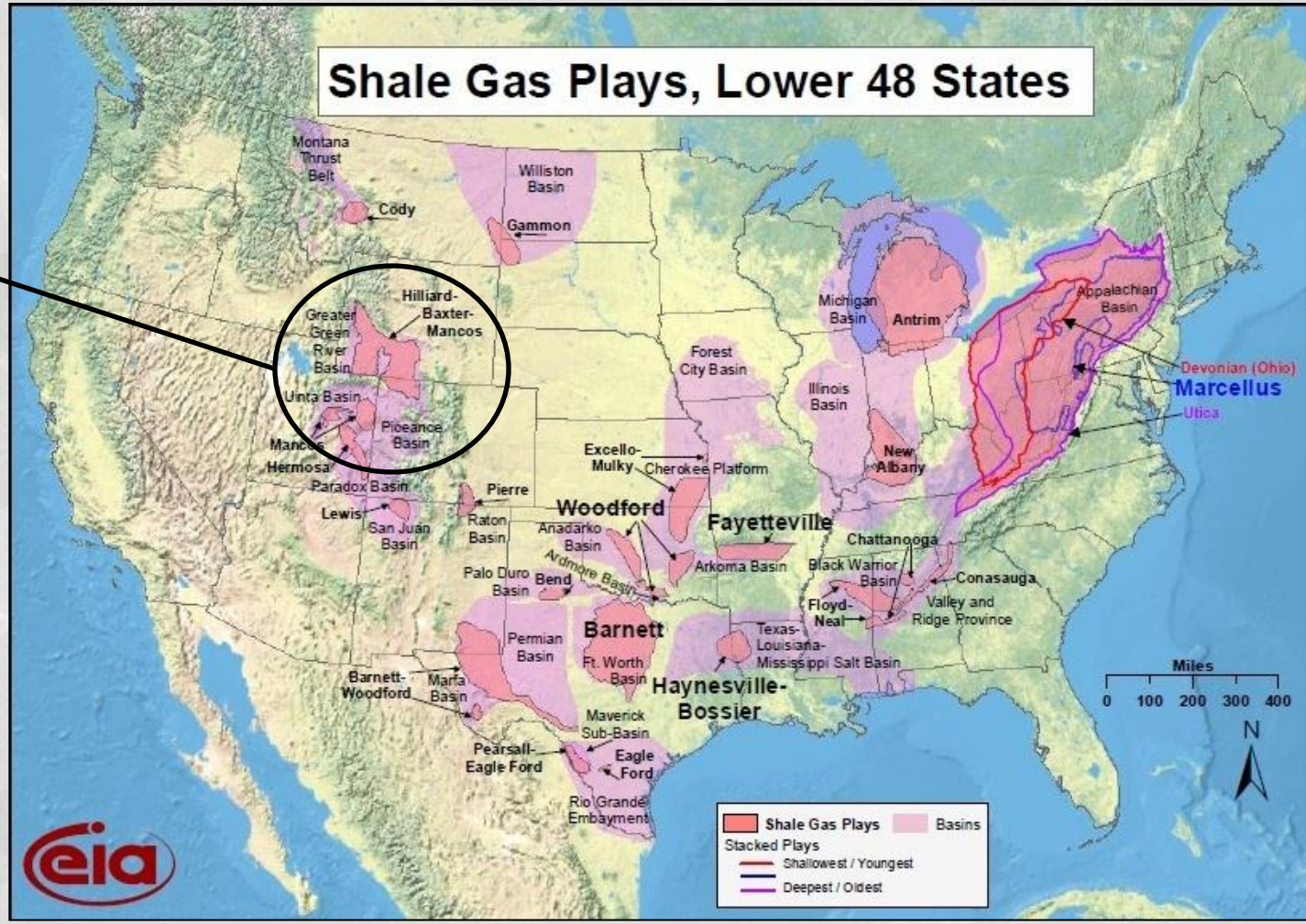
- Real-time 3D tomography of fracturing during heating of shales

- Thermogravimetry and gas chromatography

- Petrography of thin sections before and after heating

Green River Shale, USA

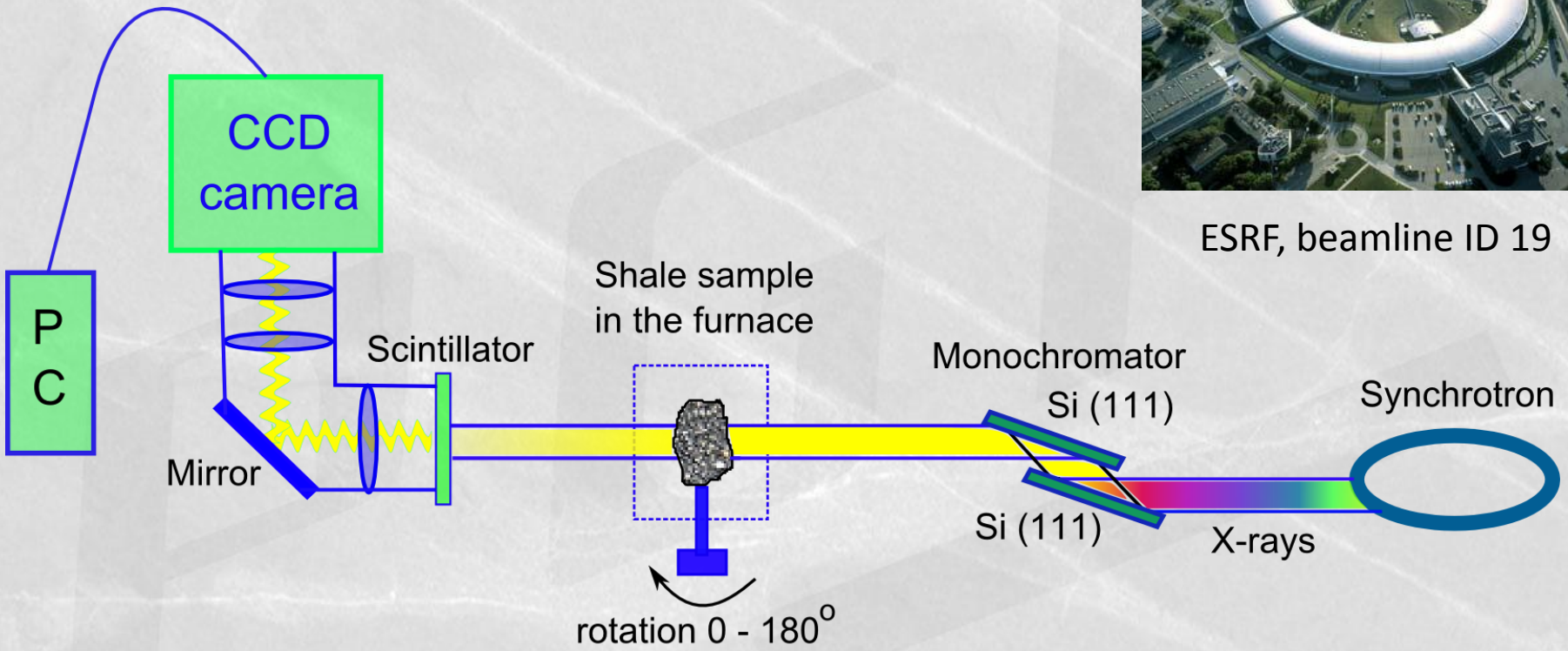
Immature black shales
TOC ≈ 10%



http://www.eia.doe.gov/oil_gas/rpd/shale_gas.pdf

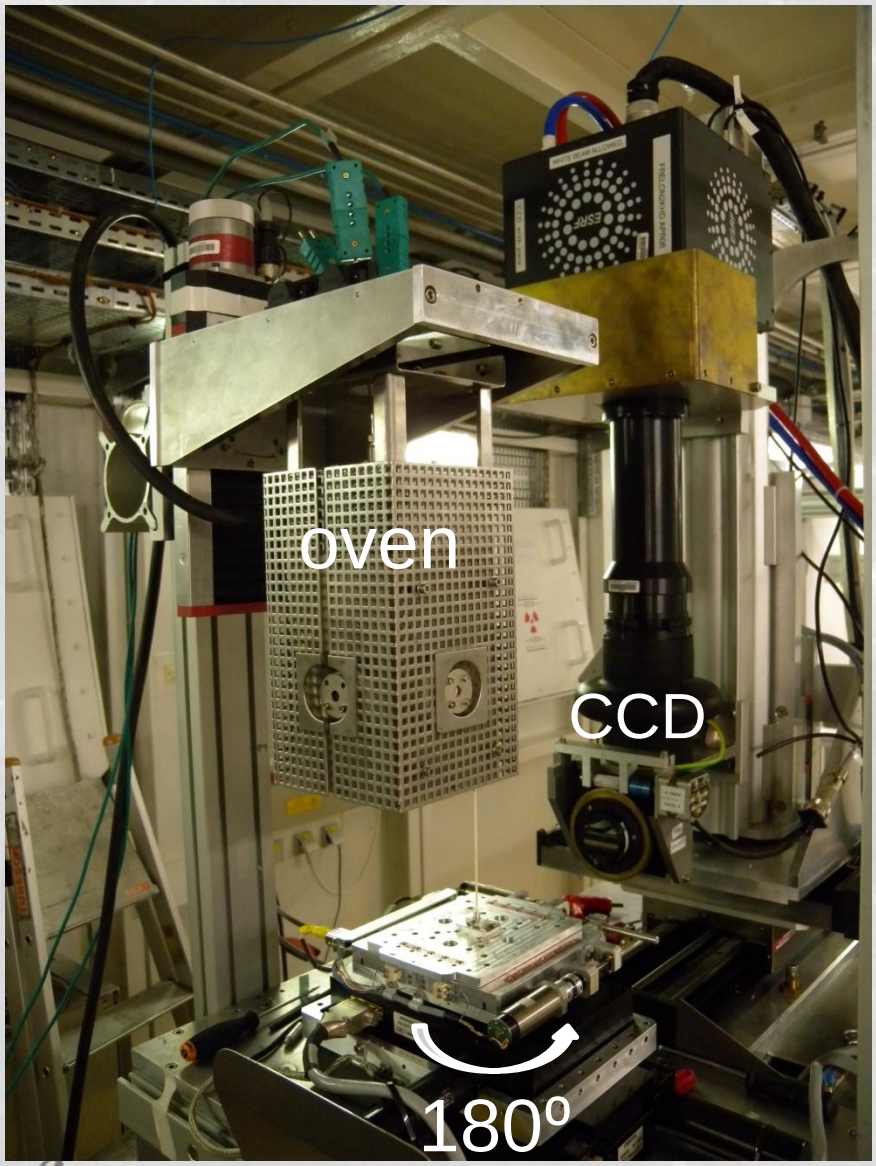
X-ray micro-tomography

ESRF, beamline ID 19

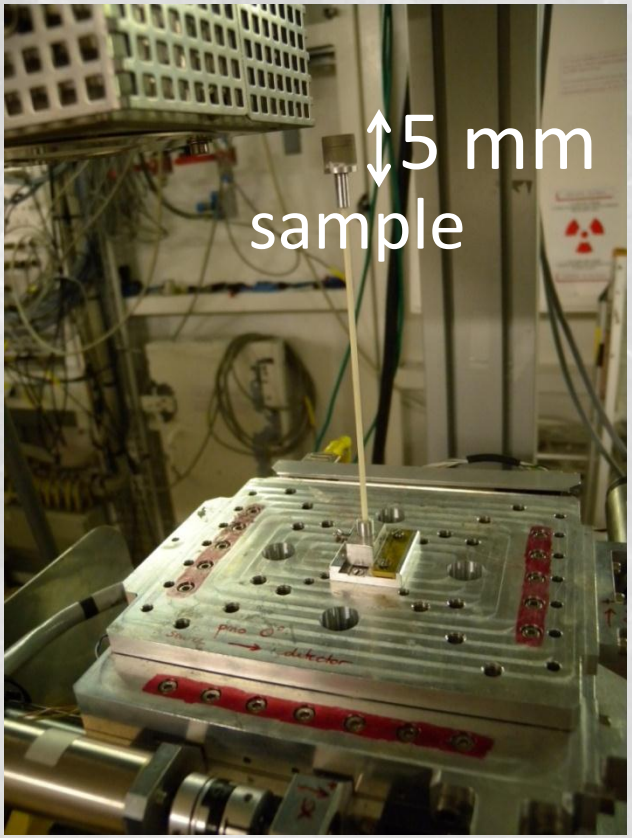


- Image – density map
- 1500 projections reconstructed into 3D image
- 15 minutes/3D image

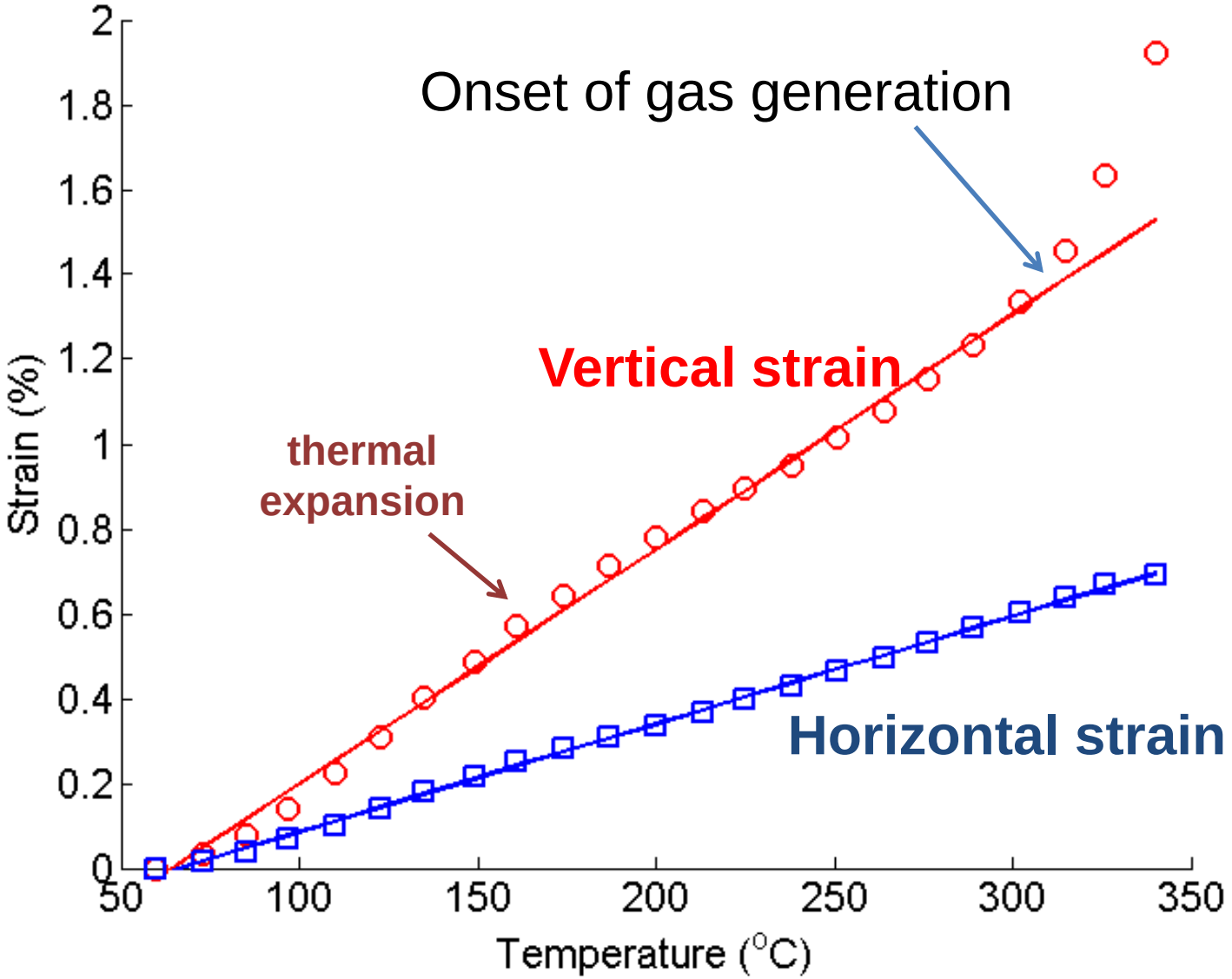
Sample setup



- Heating rate 1ºC/min
- In air, atmospheric pressure
- Without confinement

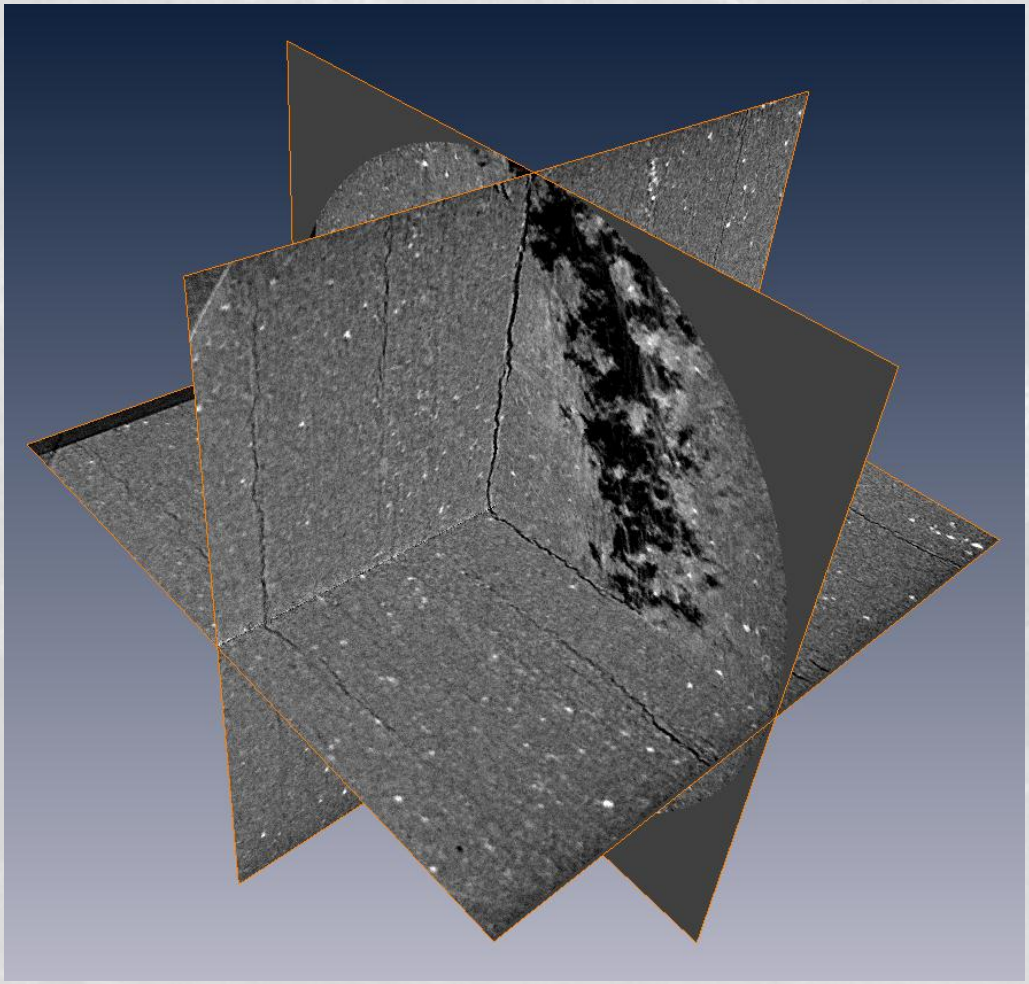


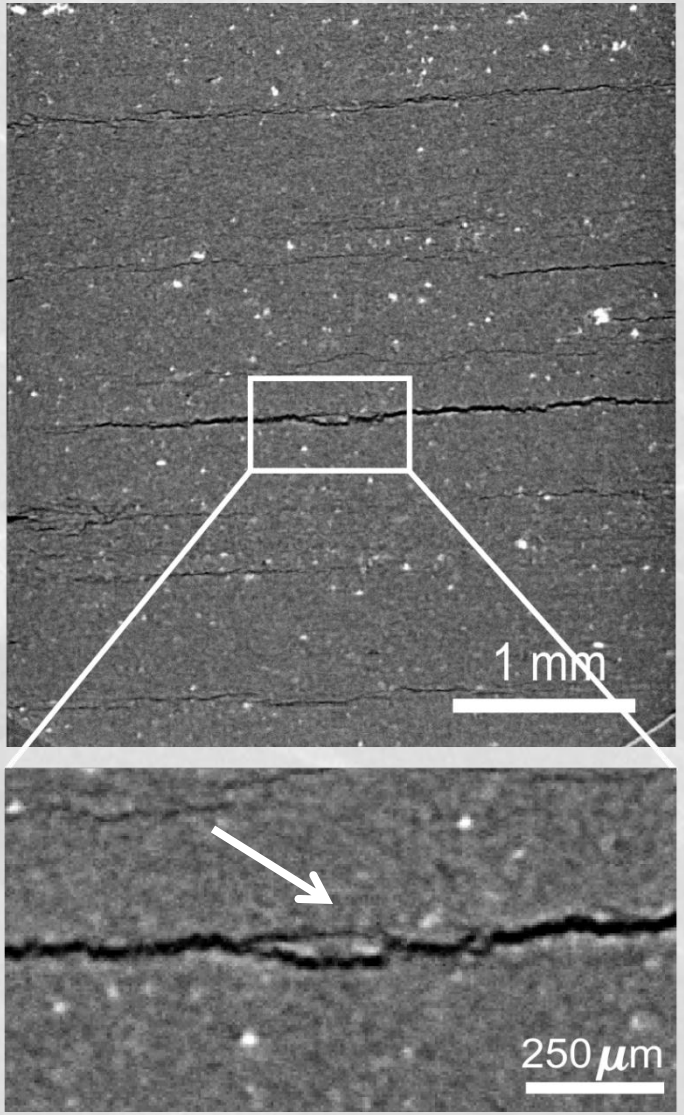
Correlation analysis



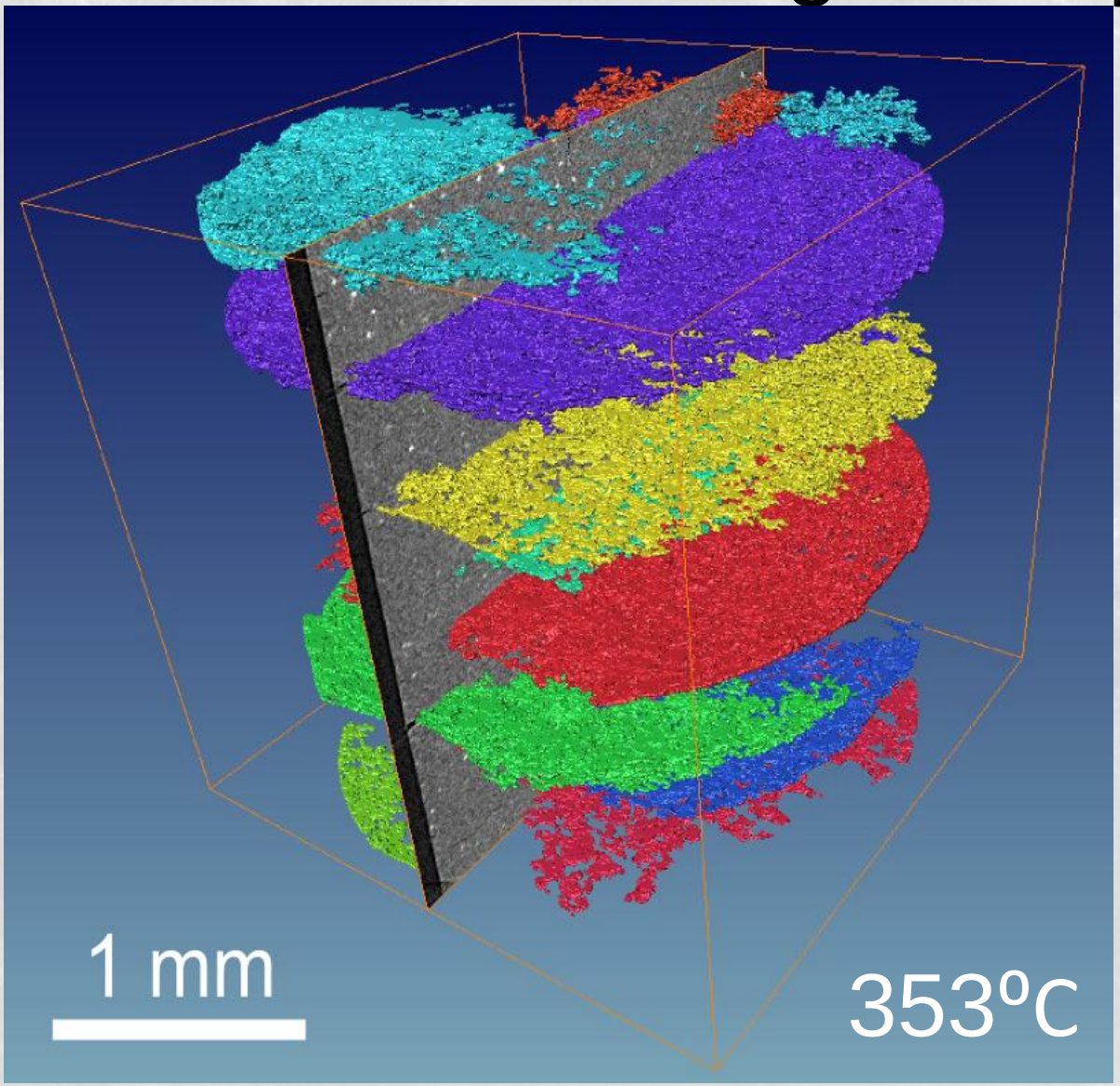
Fracturing at 353ºC

Cracks opening: 15-20 µm



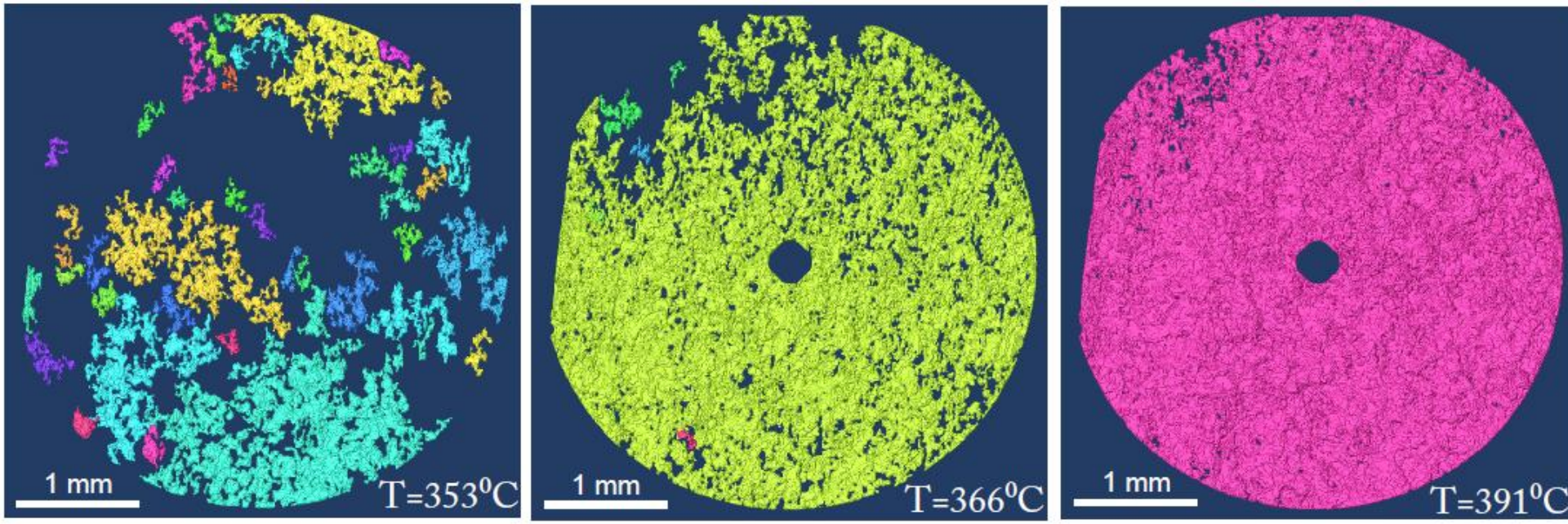


3D image analysis



- Cracks are parallel to the lamination
- Rough surface
- Irregular outlines

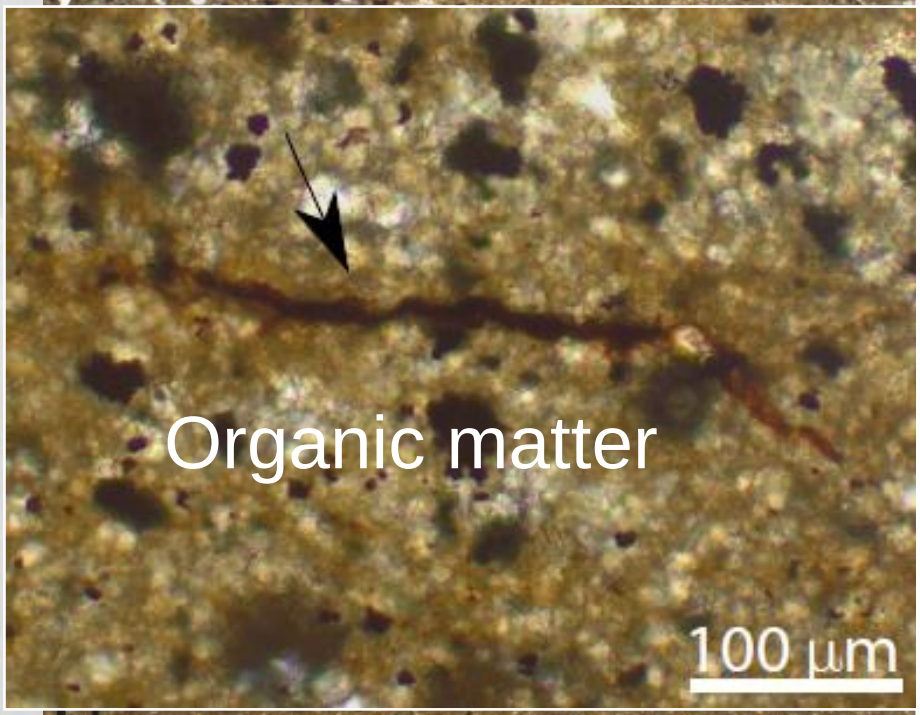
Fracture evolution in time

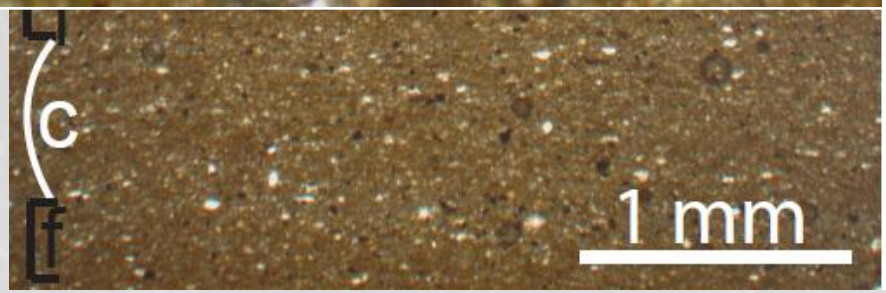


- Nucleation of small cracks
- Growth of separate cracks
- Coalescence into one big crack

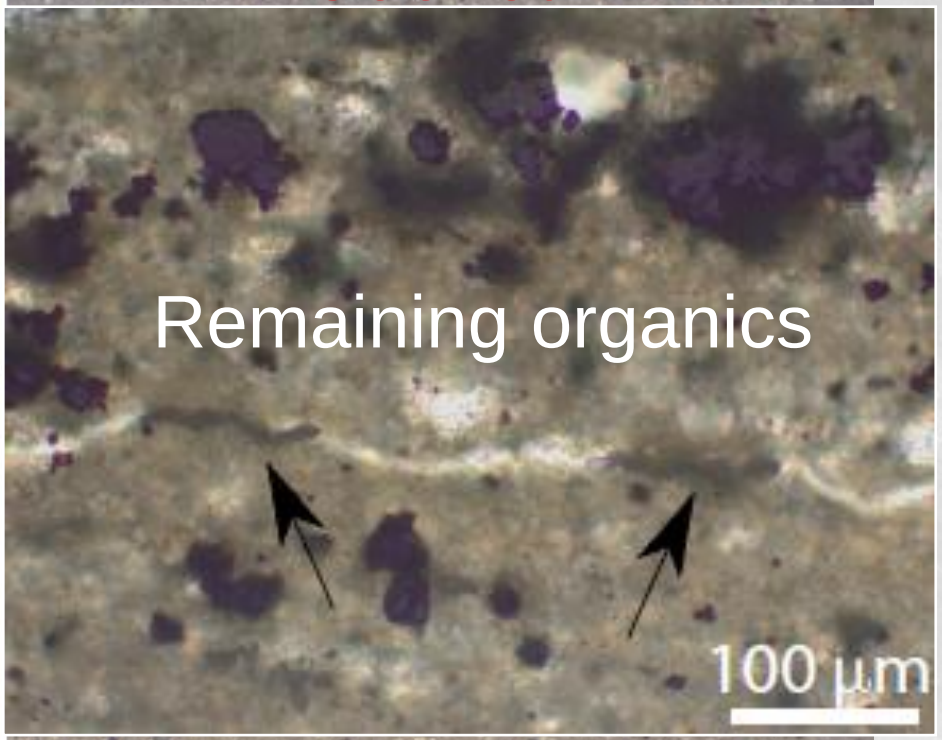
Thin sections – Optical imaging

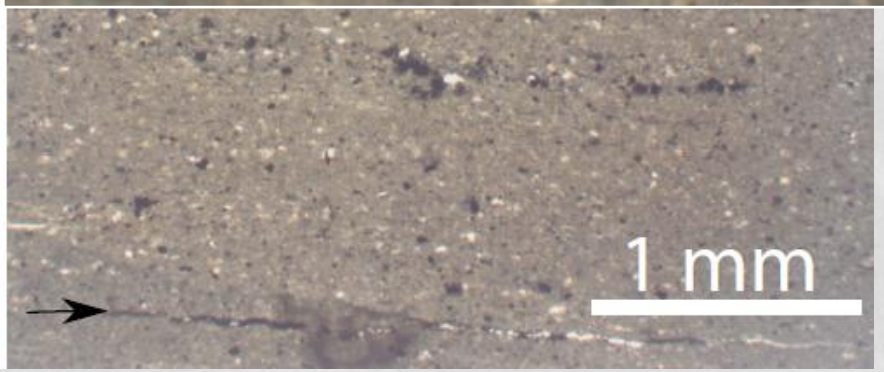
Uncooked

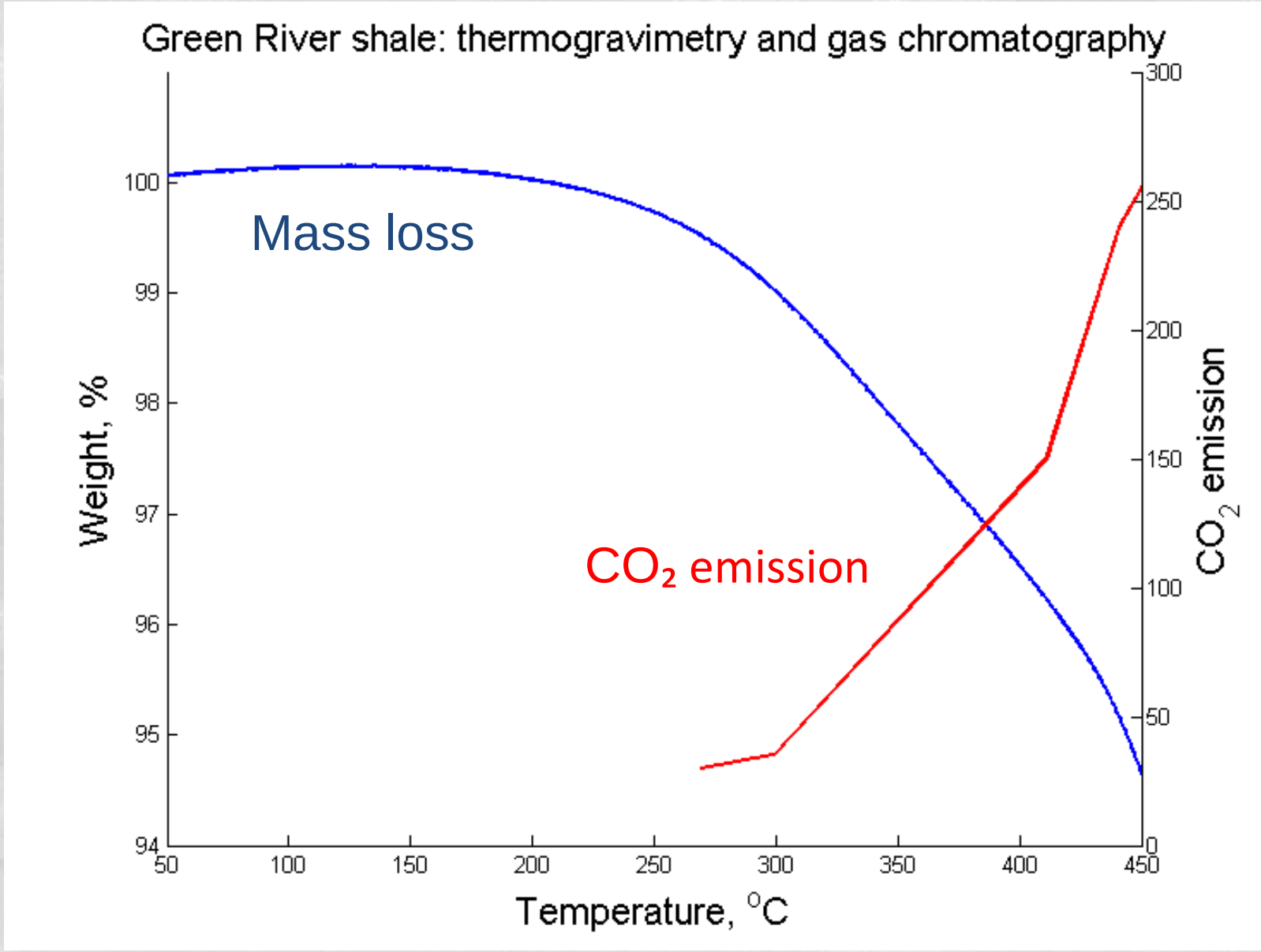




Cooked






Green River shale: thermogravimetry and gas chromatography
Mass loss
CO_2 emission
Weight, %
CO_2 emission
Temperature, °C
100
99
98
97
96
95
94
300
250
200
150
100
50
0
50
100
150
200
250
300
350
400
450

Summary:

- Organics starts to decompose around 350°C, causing volume increase and pressure build up leading to fracturing.

- Cracks nucleate, grow and coalesce until a percolation network spans the sample