Design of Pneumatic Fracturing Experiments for Rare Earth Elements Recovery by Support of X-ray Micro Computed Tomography Imaging

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1. Outline & Motivation
2. Sample Material
3. Experimental Setup
4. First Results
5. Conclusion & Outlook

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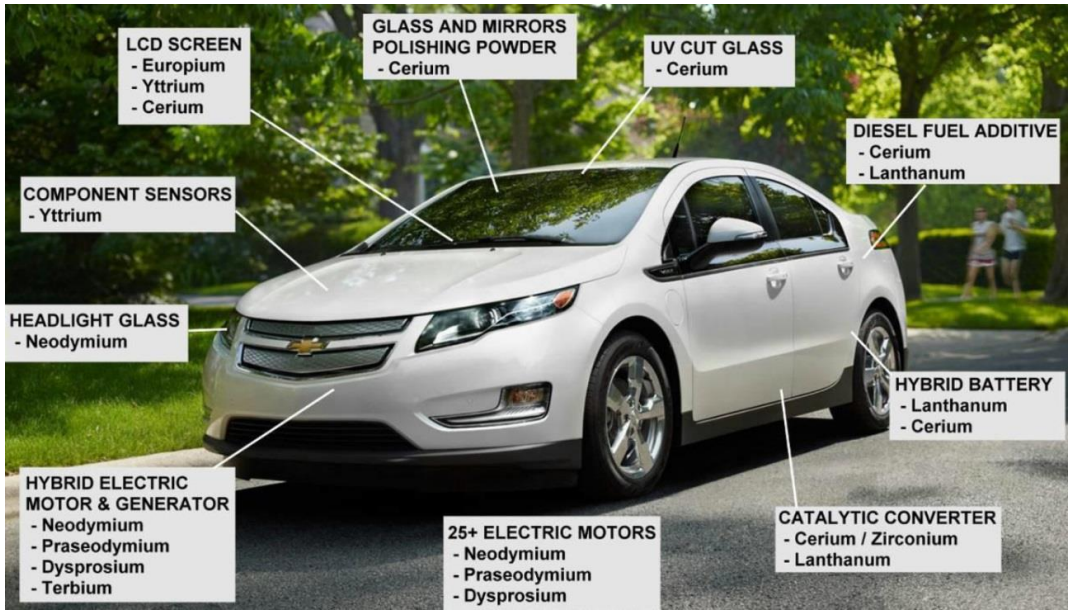
Rare Earth Elements (REE)

What?

Why?

21	39	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
Sc	Y	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Scandium	Yttrium	Lanthanum	Cerium	Praseodymium	Neodymium	Promethium	Samarium	Europium	Gadolinium	Terbium	Dysprosium	Holmium	Erbium	Thulium	Ytterbium	Lutetium



Source: Tantalus AG

REE are essential components of critical technologies (e.g. energy, mobility, communication)

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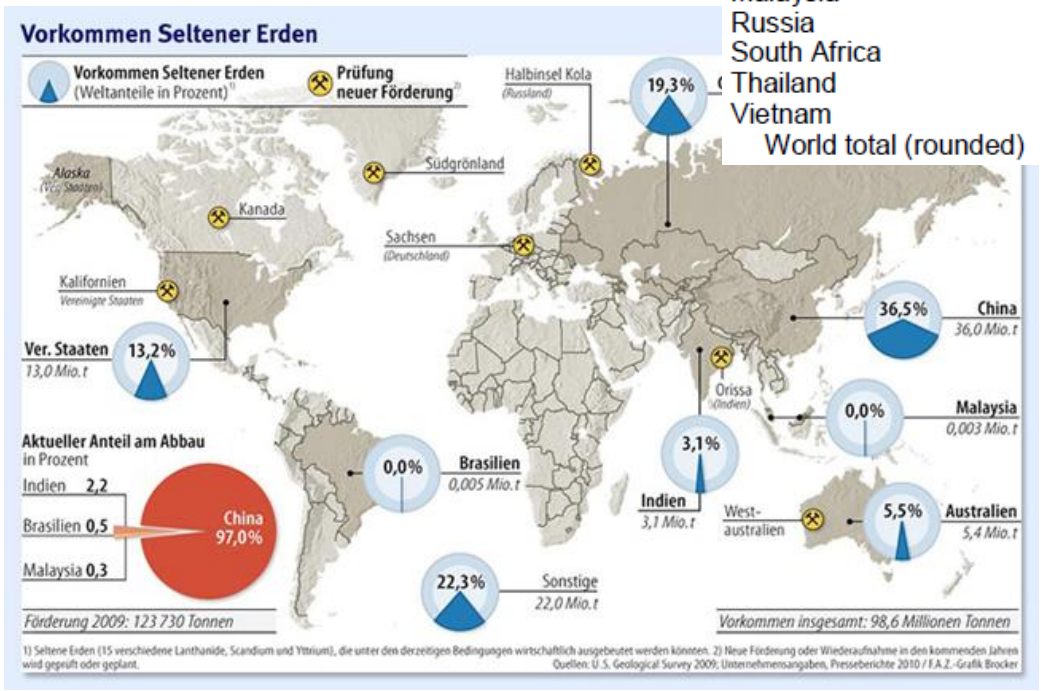
Rare Earth Elements (REE)

Where?

In Ion Adsorption Clays (IAC): Lateritic sediments formed through the weathering of granitic source rocks under warm and humid conditions



World Mine Production and Reserves:

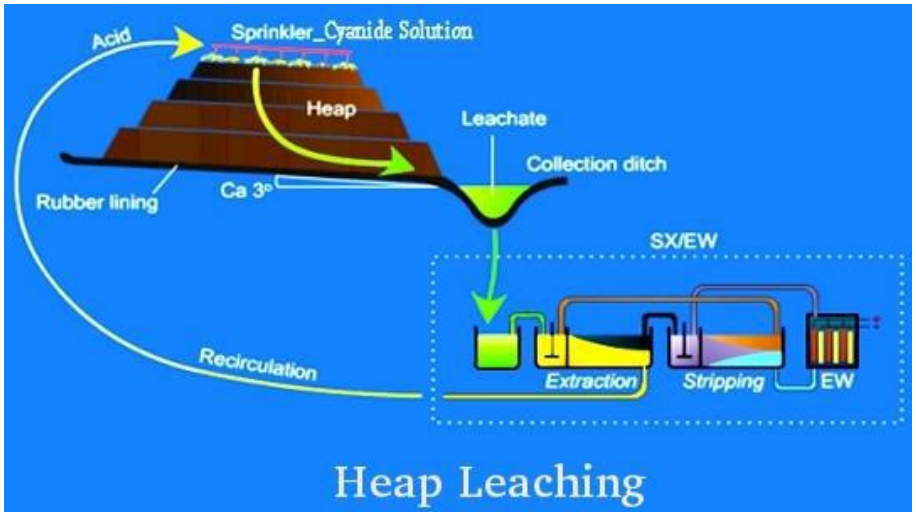
	Mine production[e] 2016	Mine production[e] 2017	Reserves[7]
United States	—	—	1,400,000
Australia	15,000	20,000	[8]3,400,000
Brazil	2,200	2,000	22,000,000
Canada	—	—	830,000
China	[9]105,000	[9]105,000	44,000,000
Greenland	—	—	1,500,000
India	1,500	1,500	6,900,000
Malawi	—	—	140,000
Malaysia	300	300	30,000
Russia	2,800	3,000	[10]18,000,000
South Africa	—	—	860,000
Thailand	1,600	1,600	NA
Vietnam	220	100	22,000,000
World total (rounded)	129,000	130,000	120,000,000

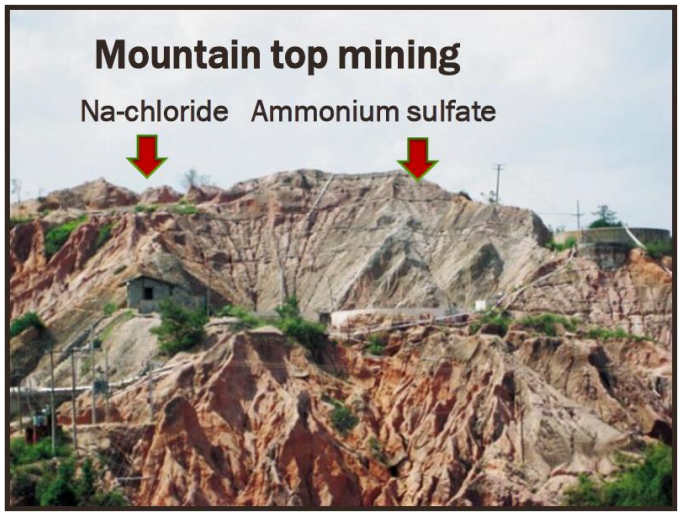
U.S. Geological Survey, Mineral Commodity Summaries, January 2018

Production versus Reserves

Rare Earth Elements (REE)

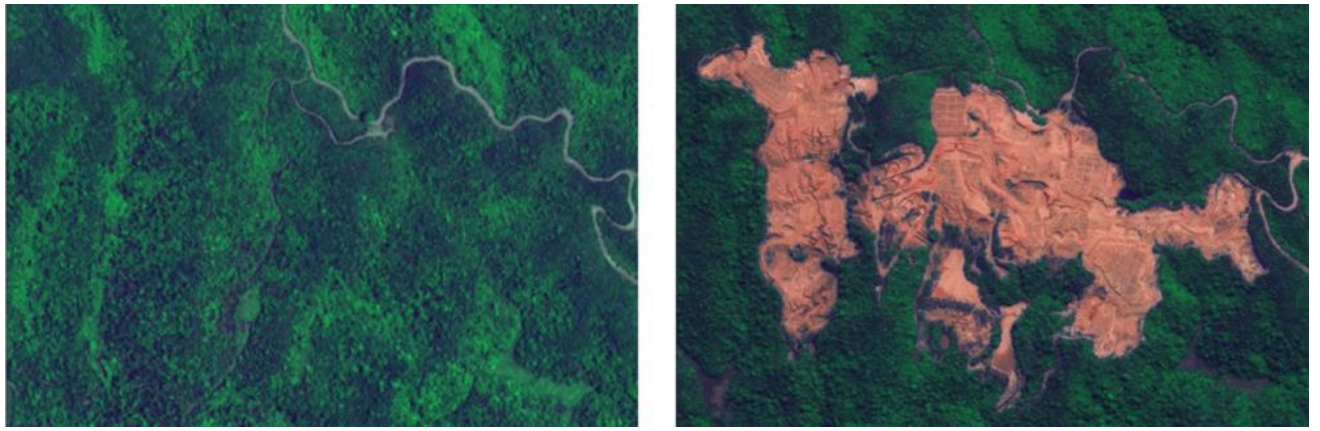
How?





IAC mining in Ganzhou, Jiangxi Province, China (K. Wang, 2012)

significant environmental impact

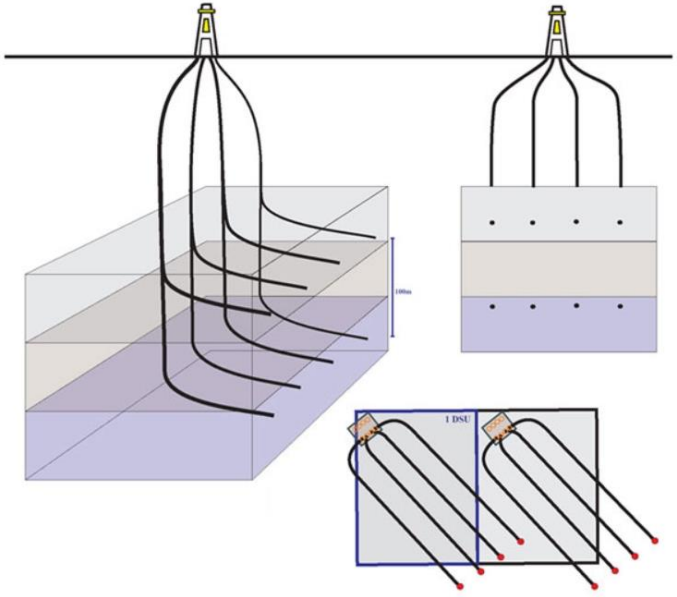


Satellite images of a rare earth mining site in Ganzhou on April 14, 2005, (left) and February 9, 2009 (right) (Guo, 2012)

REE-mining-project in Madagascar

General view of the eastern part of the Tantalus REE-mining-project in Madagascar

How to improve?



Modified after National Energy Board Canada, 2017

1) **Pneumatic fracturing** using inert N2-gas to enhance sediment porosity

2) **In-situ (bio)leaching** to mobilize REE via ion exchange processes from the sediment

3) **REE recovery/separation** above ground using a combination of chemical and biological processes

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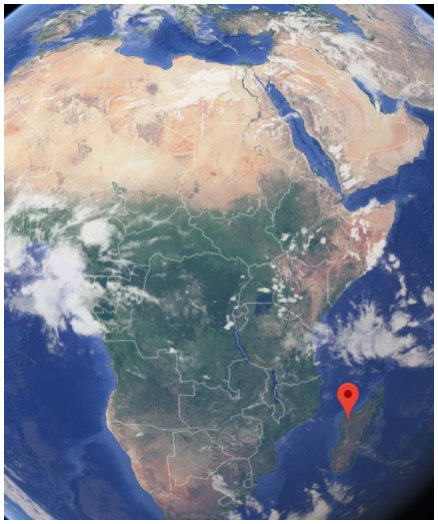
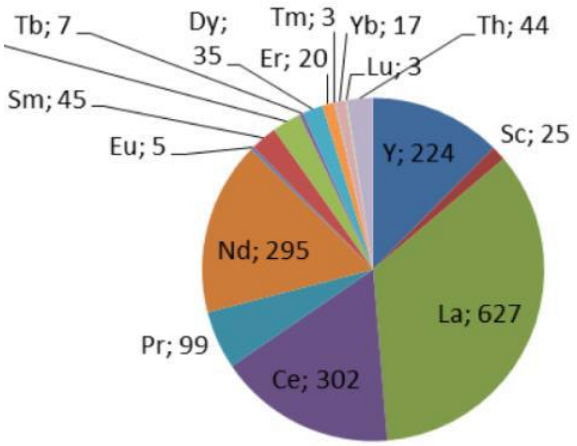
Sample Material

Clay containing ~ 0.18 % REE (Tantalus deposit)

Caldera of the Ambohimirahavavy Igneous Complex, Madagascar





Clay mineralogy: mostly 2-layer clay minerals such as Kaolinite: **non-swelling**

Therefore fractures and fissures should remain open during the leaching phase and the application of proppants may not be necessary.

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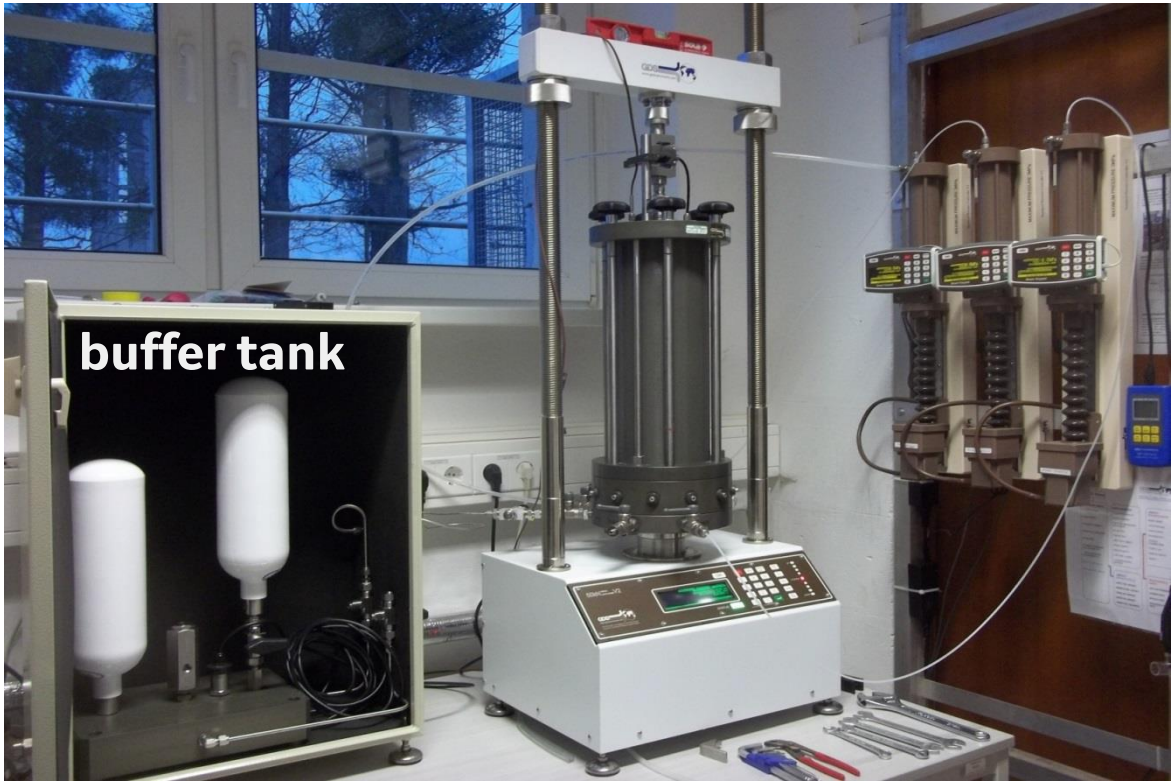
Triaxial Test Device for Pneumatic Fracturing



cylinder shape test sample

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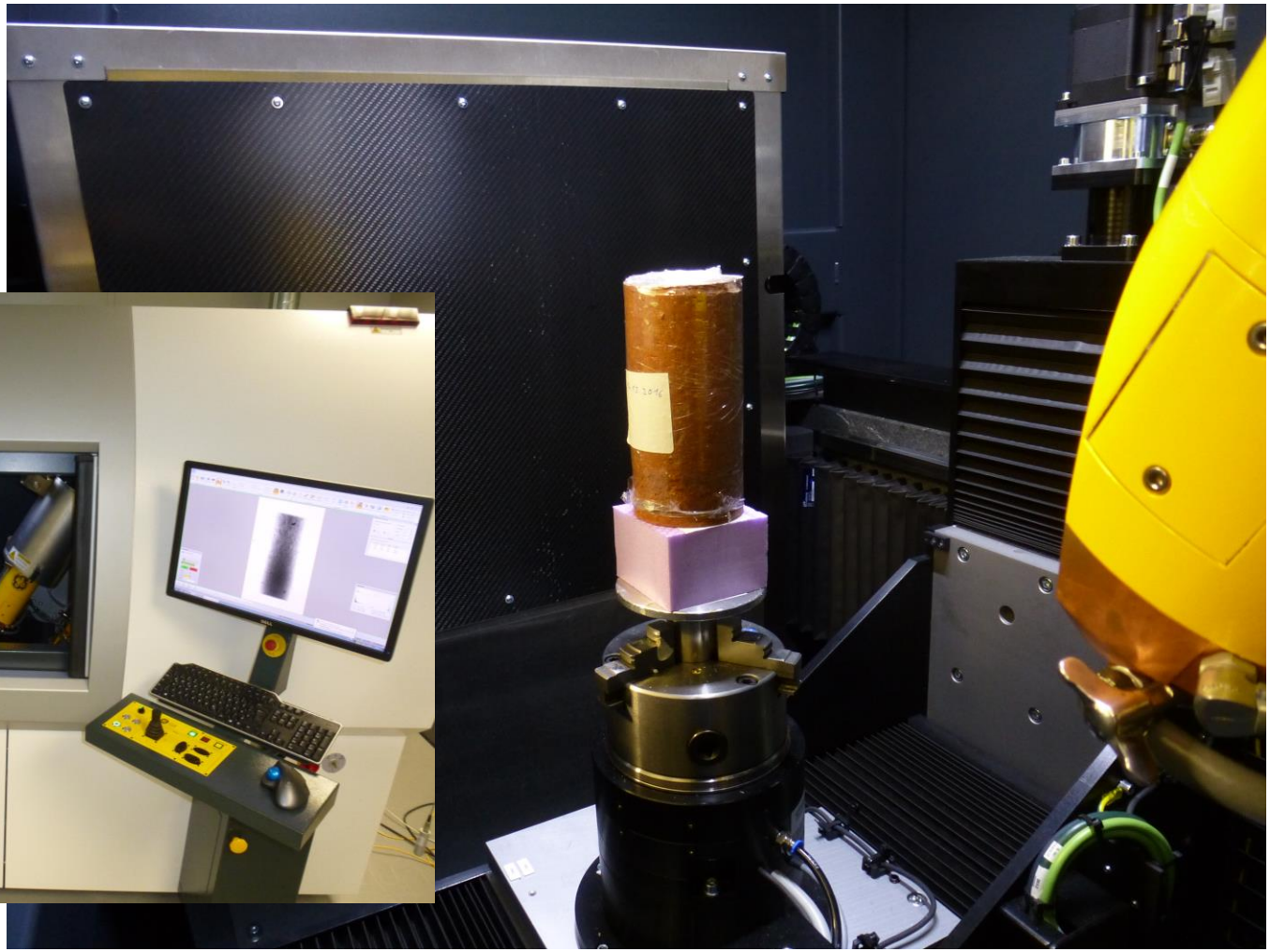
X-ray Micro Computed Tomography (CT)

GE phoenix v|tome|x m 300



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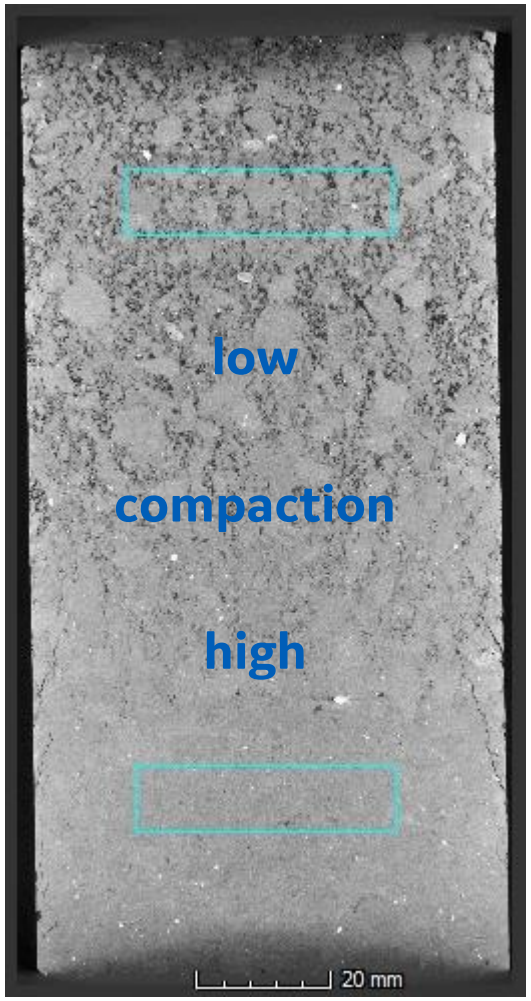
Consolidated Clay Cylinder

CT results (cross section and 3D view) with porosity analysis

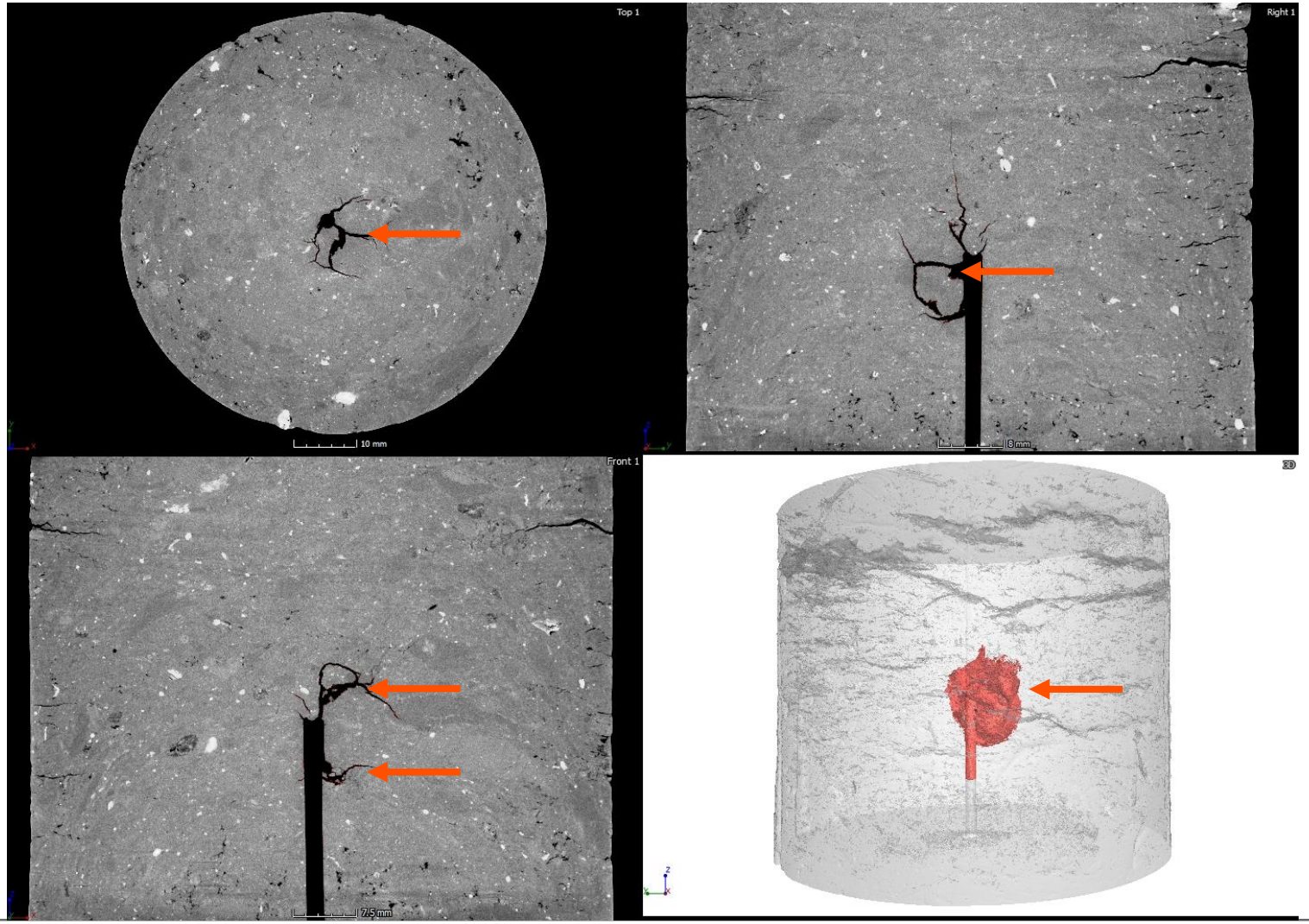


porosity ~ 9.7 %

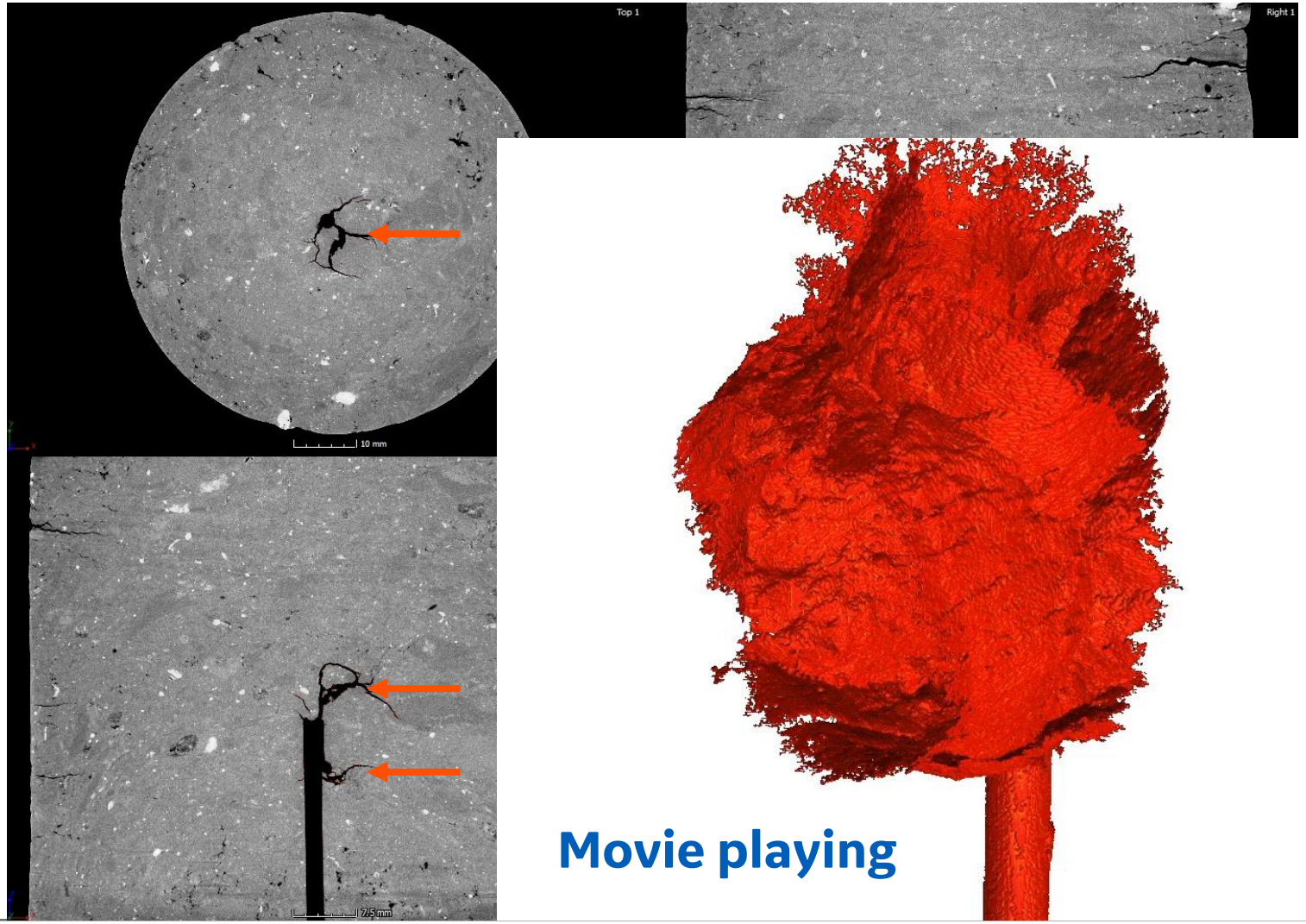
porosity ~ 0.6 %

First Fracturing Test: 6 Pulses 3s, Pressure 450 kPa

local fracture system



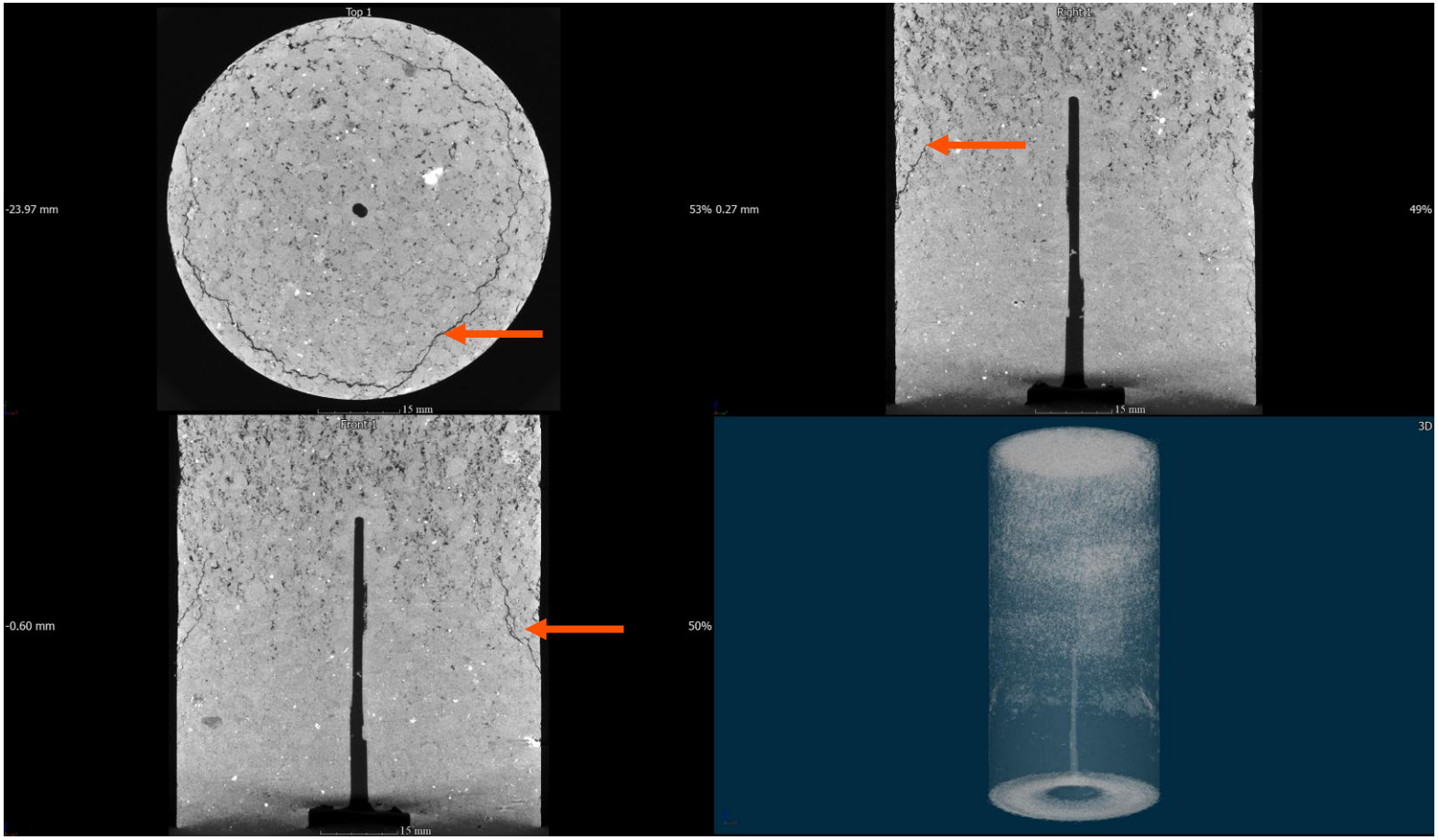
First Fracturing Test: 6 Pulses 3s, Pressure 450 kPa



local fracture system

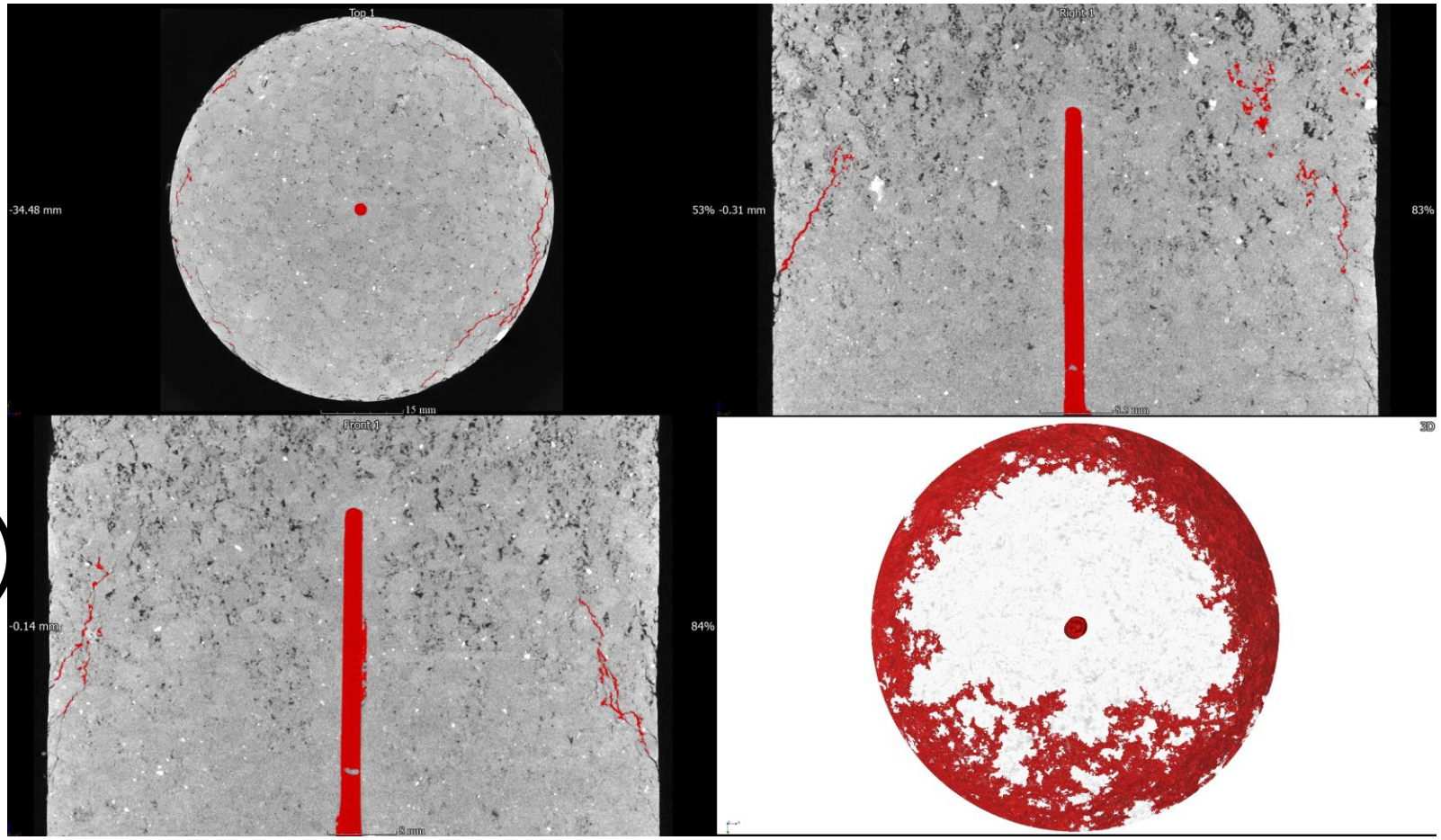
Movie playing

2nd Fracturing Test: 1 Pulse 3s, Pressure 800 kPa



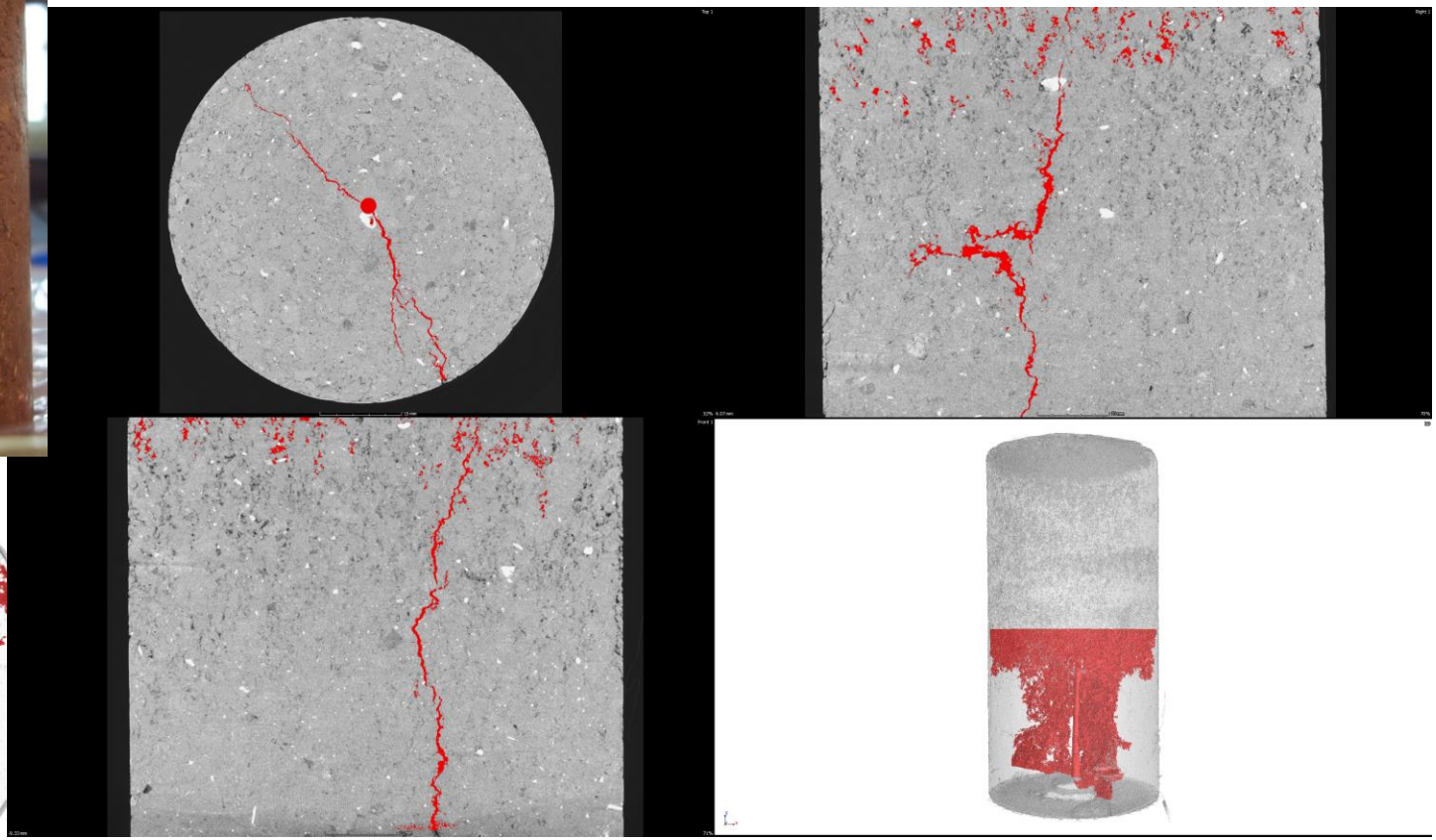
CT results (cross section and 3D view) with highlighted cracks.

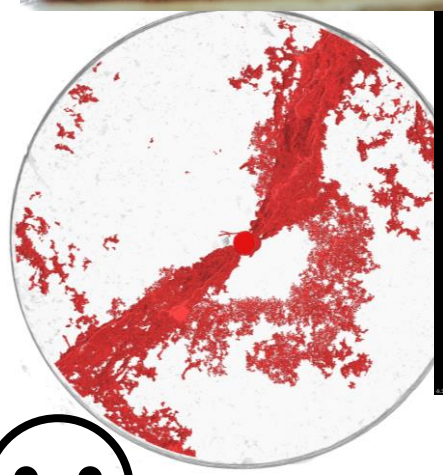
2nd Fracturing Test: 1 Pulse 3s, Pressure 800 kPa



Segmented cracks, no connection to injection source.

3rd Fracturing Test: 2 Pulse 1+3s, Pressure 2000 kPa





Segmented cracks along injection channel.

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Conclusion & Outlook

- Injection of nitrogen gas proved to be a suitable method to induce cracks for this type of material under reservoir conditions.
- X-ray micro CT is an excellent method to control sample conditions and monitor the results of the fracturing tests.
- The CT results helped controlling the experimental setup and optimizing the pulse rate, length and pressure.
- Based on these results, an optimized process ready for in-situ pilot testing is currently being developed.

Contact and further information:

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