This research is funded by the European Union
(EIC, Pathfinder Programme, G.A. 101046937)

Deep U-tube heat exchanger breakthrough: combining laser and cryogenic gas for geothermal energy exploitation – **a perspective of laser-rock interactions**

Università degli Studi di Padova

Pawel Slupski, Enrico Zampieri, Eloisa Di Sipio, Adele Manzella, Riccardo Pasquali, Luc Pockéle, Arno Romanowski, Raffaele Sassi, Olaf Steinmeier, and Antonio Galgaro

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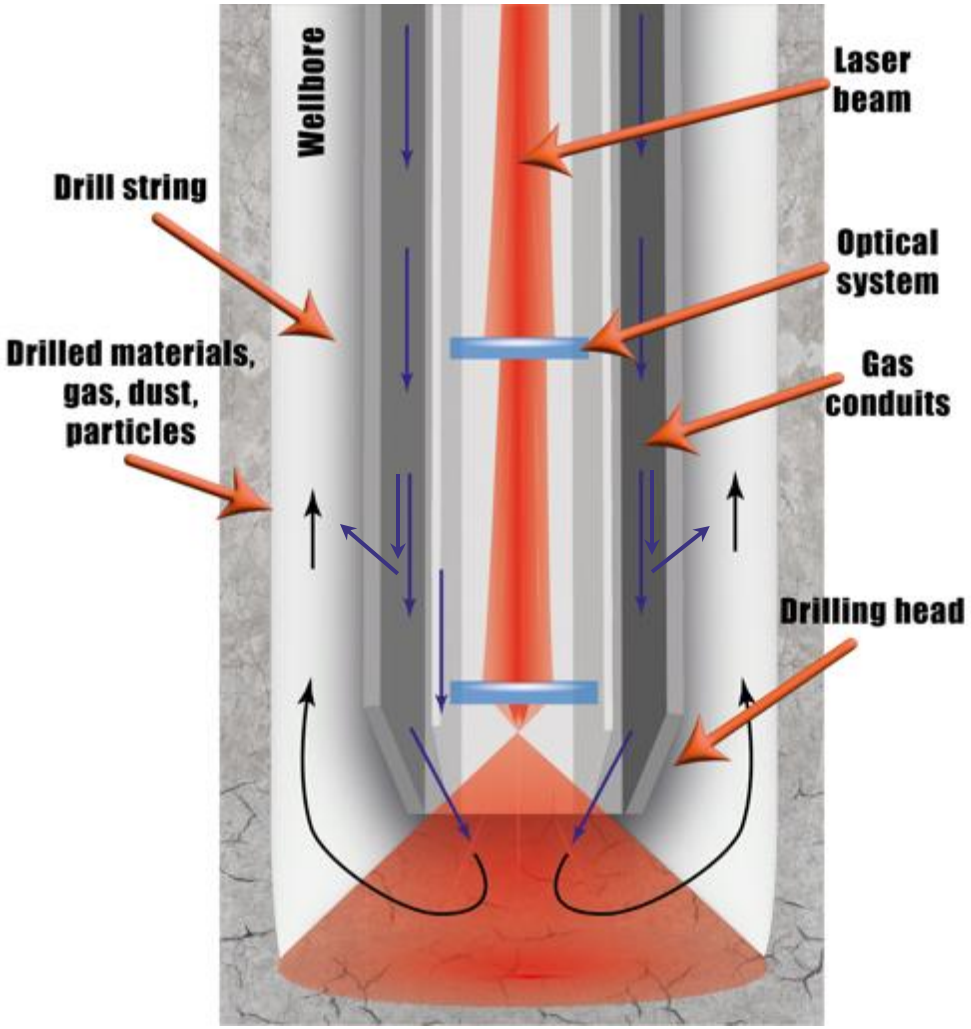
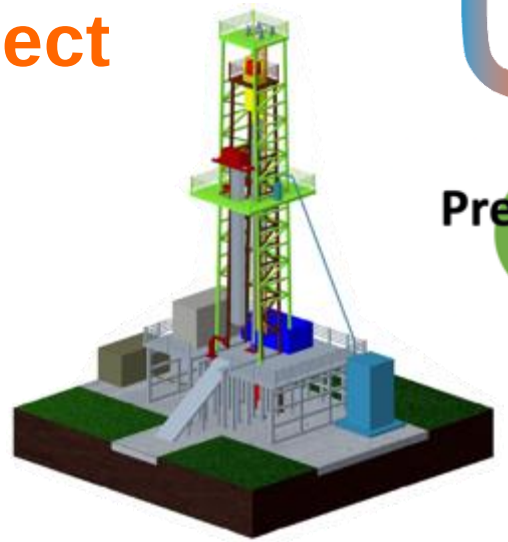
Laser-drilling concept and workflow in the project

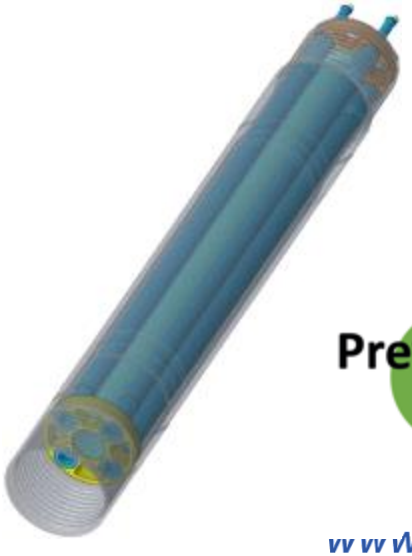


Realized designs:

- Drilling tower
- Drilling string
- Drilling head

Laser-drilling experiments were performed on granite, sandstone and limestone





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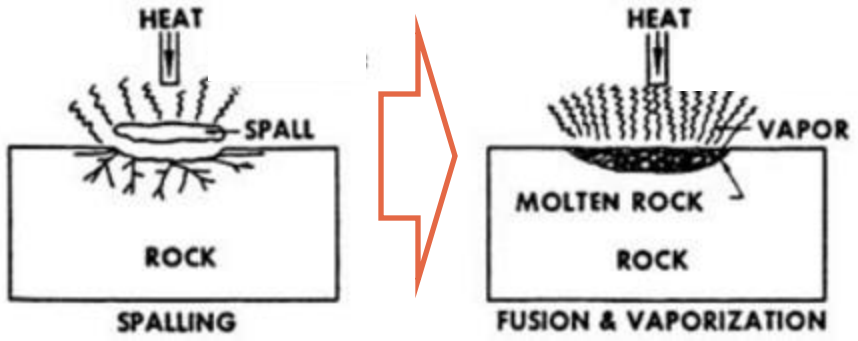
Laser-rock interactions

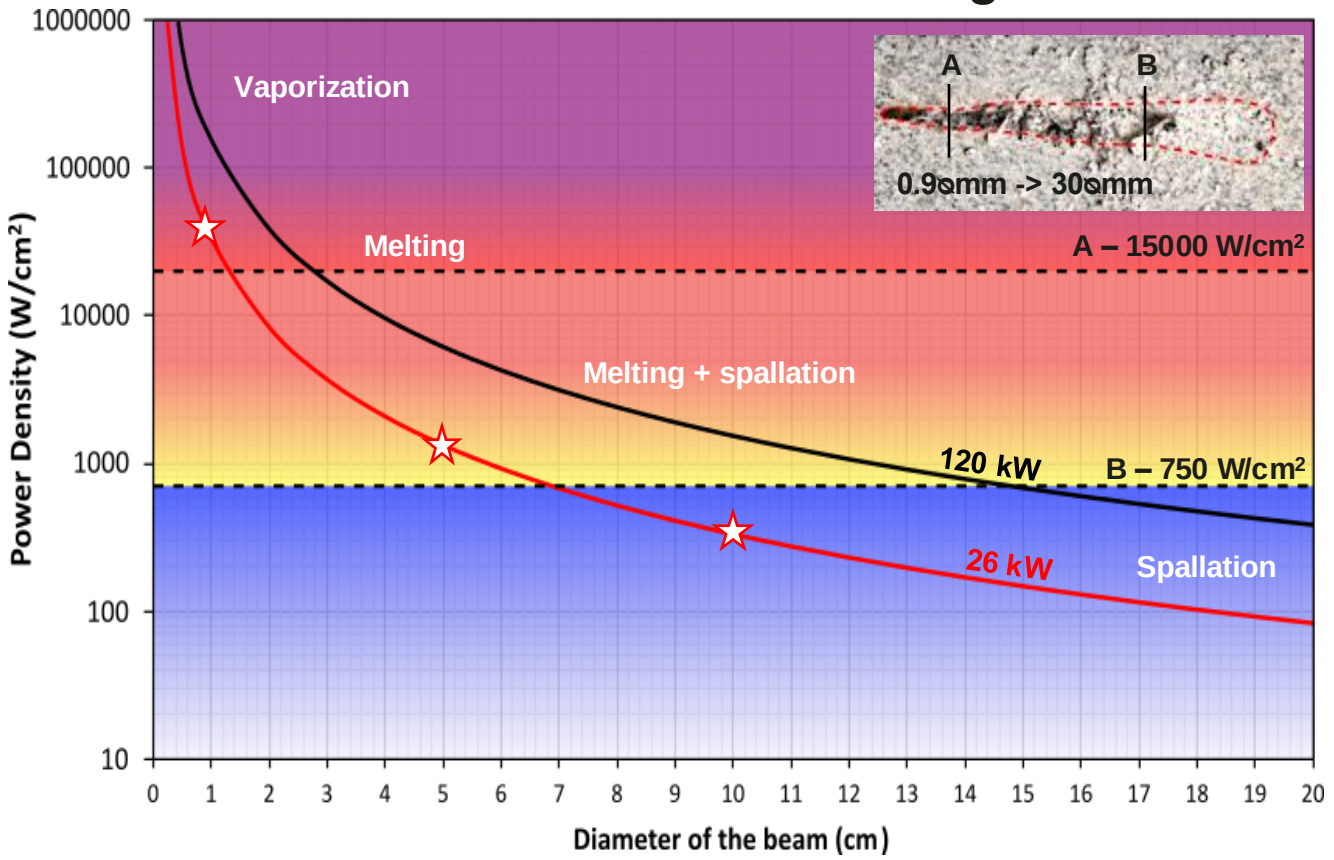
Classification of non contact excavation methods after Mauer 1980



Parameters controlling drilling regime:

- Thermal and physical properties of rock
- Chemical composition of rock
- Irradiation time (s)
- **Power density (W/cm²)**

Laser-rock interactions for granite



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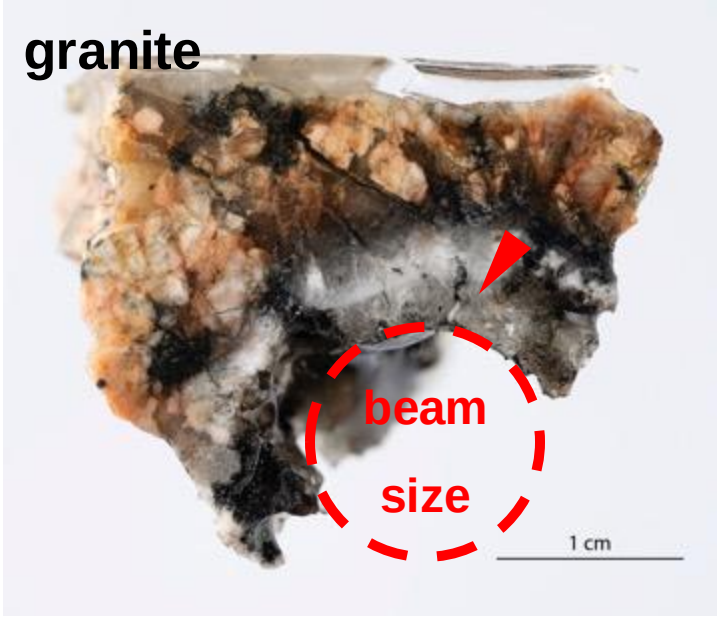
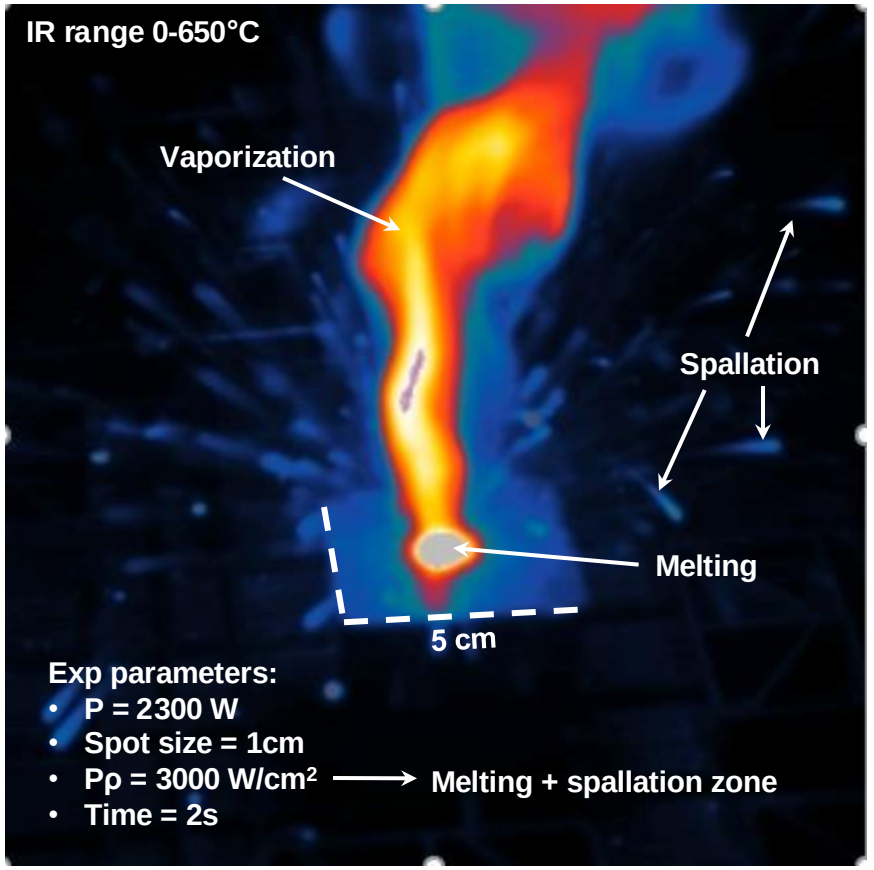
Melting-evaporation laser drilling



- Small diameter of borehole (<1cm)
- **Vitrified walls**
- Low efficiency of drilling
- High temperature **(>1500°C)**
- Penetration by evaporation

IR imaging of irradiated granite



Frame 1.32s

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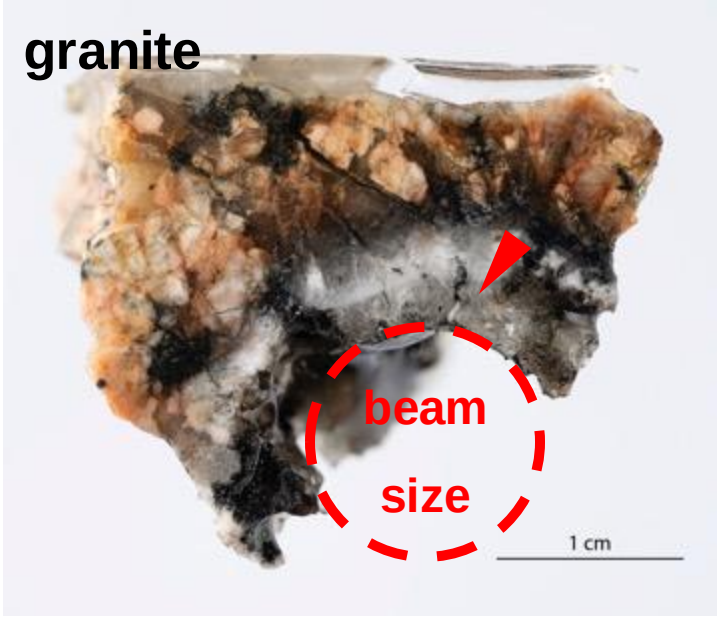

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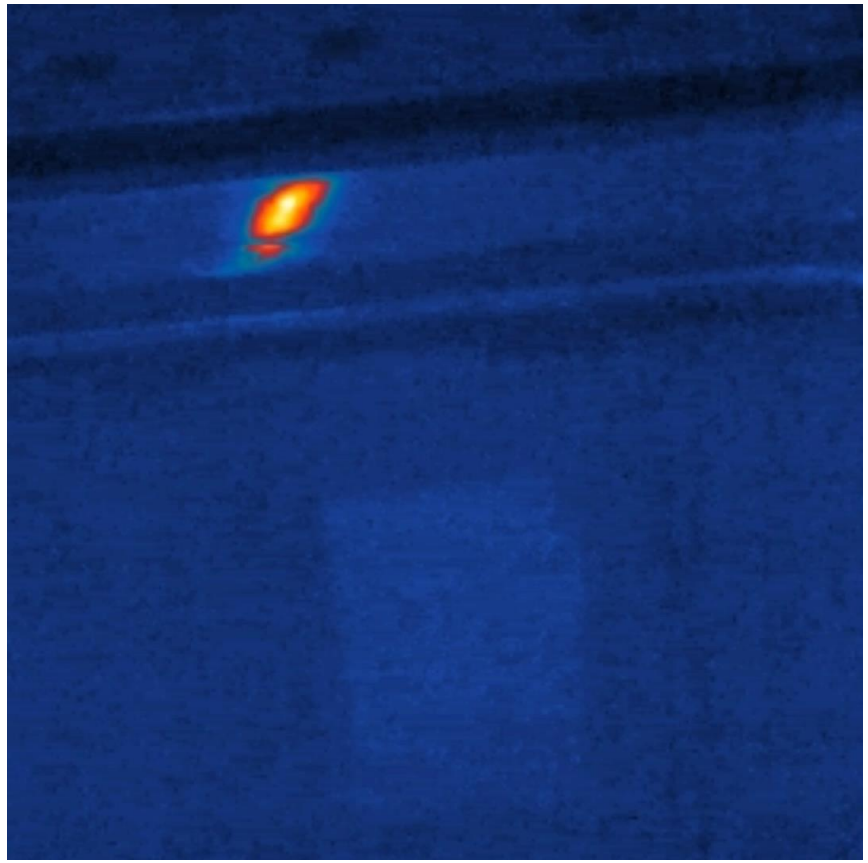

Slow motion 2s

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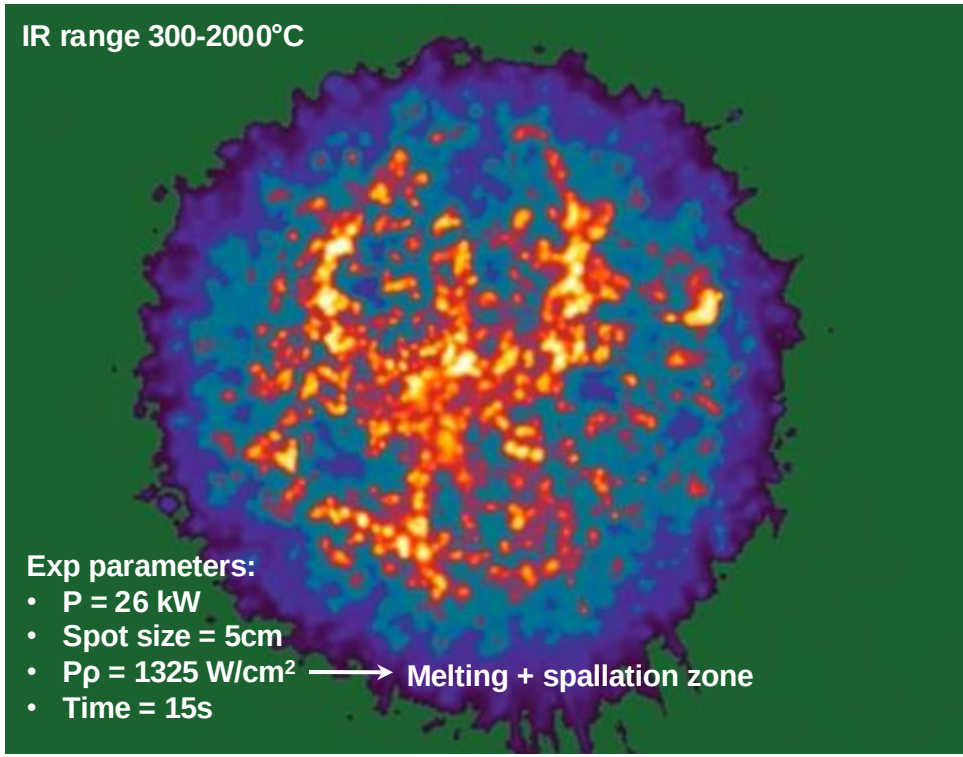
Thermal spallation drilling with N_2 assist

Spallation temperature:

- Granite 600 - 700°C
- Sandstone 350 - 450°C
- Limestone >2000°C, no spallation
- H_2O saturated sandstone 250 - 350°C
- H_2O saturated limestone 200 - 300°C

- Large diameter of borehole (>5cm)
- **Purging system necessary (N_2 flux)**
- High efficiency of drilling
- Low temperature **(<700°C)**
- Penetration by spallation



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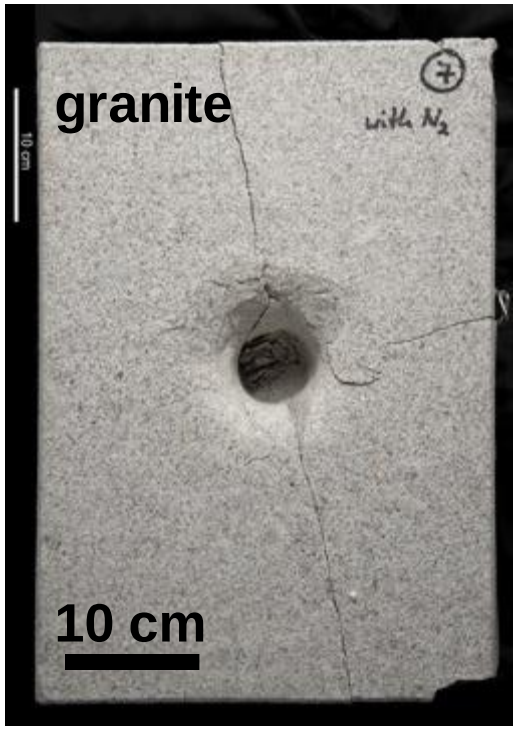
Thermal spallation drilling – DeepU setup



Supported spallation on H_2O saturated rocks

Photogrammetry

Lithology	ROP (m/h)	Specific Energy (kJ/cm³)
granite	4,1	6,35
sandstone	5,9	2,54
limestone	2,0	**8181,82**
saturated limestone	3,9	8,20

melting

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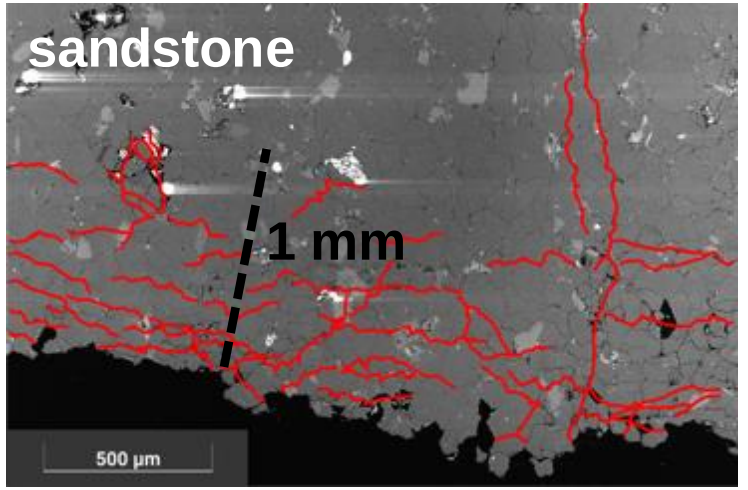
Laser-drilled rocks

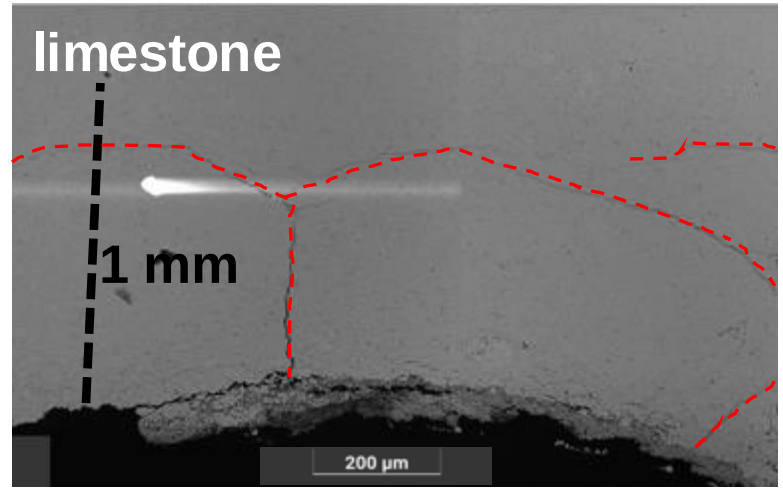
Thermally spalled rocks are affected up to 1 mm in depth

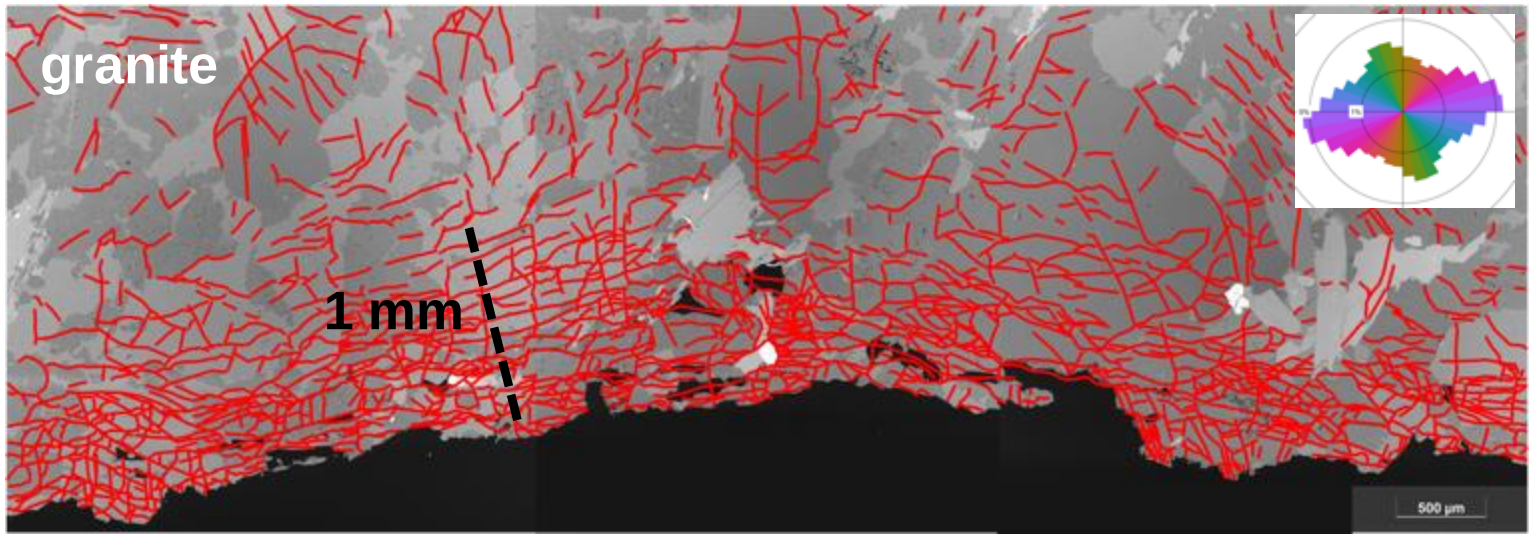
Young's modulus based on fracture density for granite:

34 GPa → 9 GPa

BSE images of boreholes







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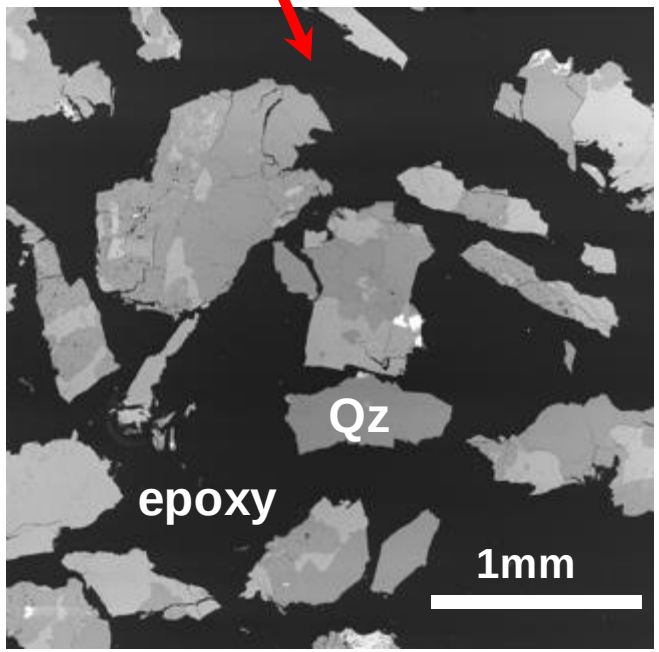
Transport of drilled material

⌀ 0.2-2mm
sphericity <0.6
rock removal rate 32g/s



Mass flow rate is sufficient to provide pneumatic transport of particles!

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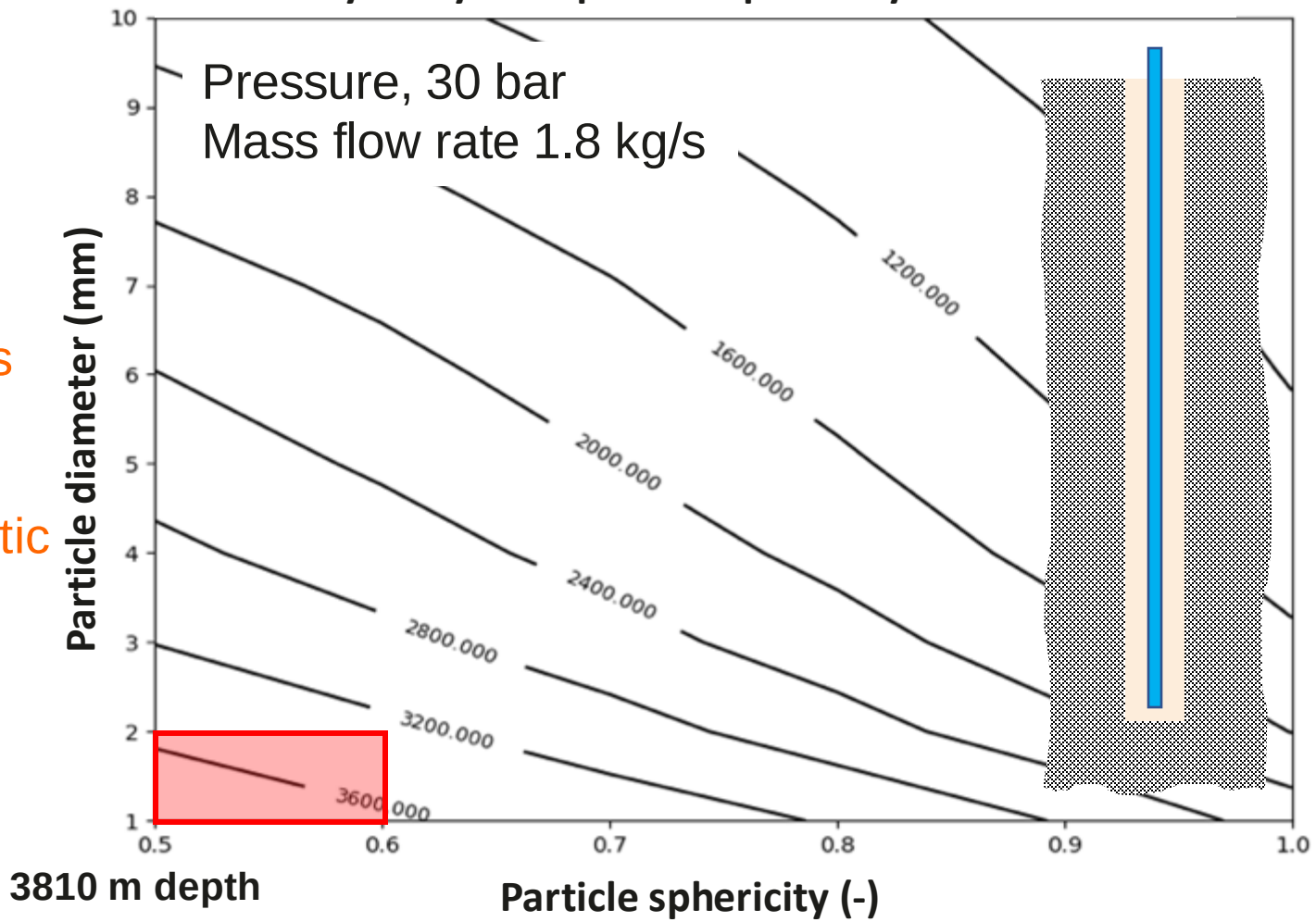
Sensitivity analysis to particle sphericity and diameter



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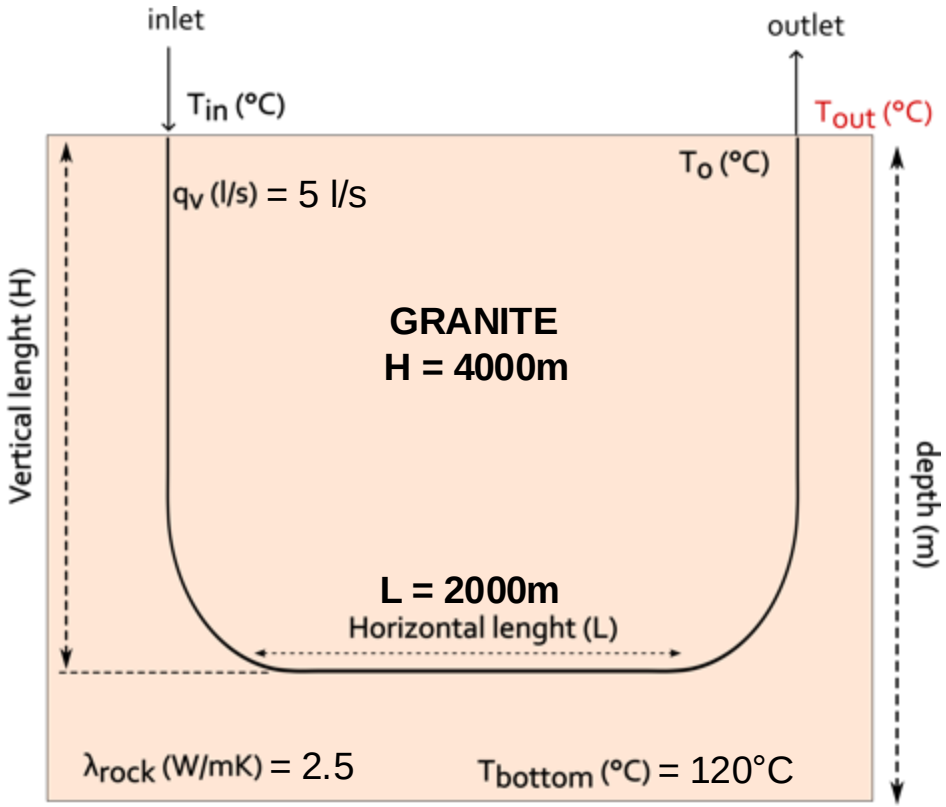
Geothermal modeling

3D geometry and mesh for numerical simulation – Comsol Multiphisics 6.2



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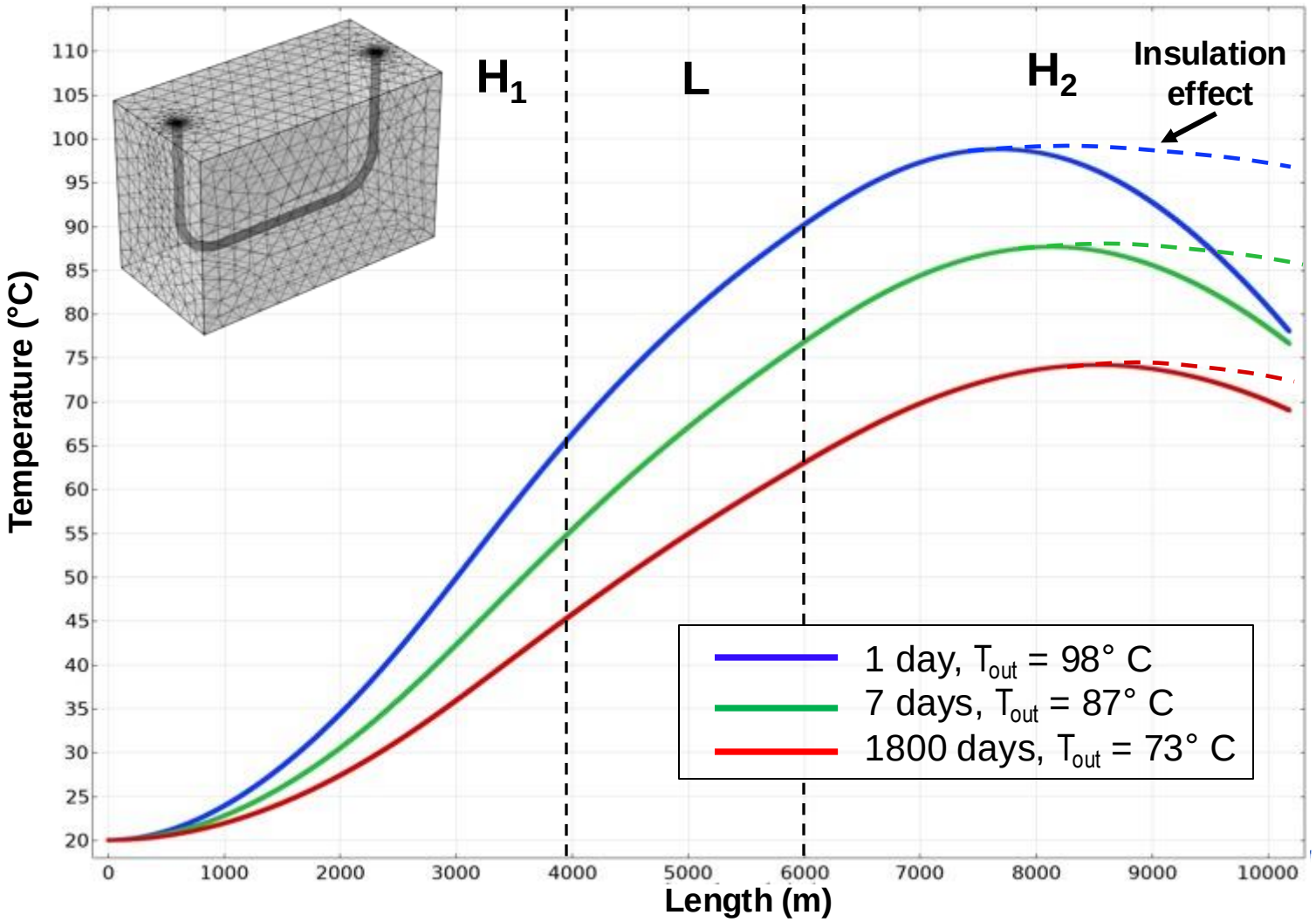
Temperature in U-shaped heat exchanger



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Conclusions

- Melting-evaporation laser drilling is possible but inefficient
- Thermal spallation laser drilling is possible and efficient for wide range of lithologies
- Thermal spallation affects only the surface of the rock, < 1mm
- Vitrified walls of borehole formed in melting process are fractured and permeable
- Pneumatic transport of spalled material can be archived to the depth ~4km
- U-shaped heat exchanger can provide sufficient heat for electricity production, however insulation must be applied.

Thank You for Your Attention!

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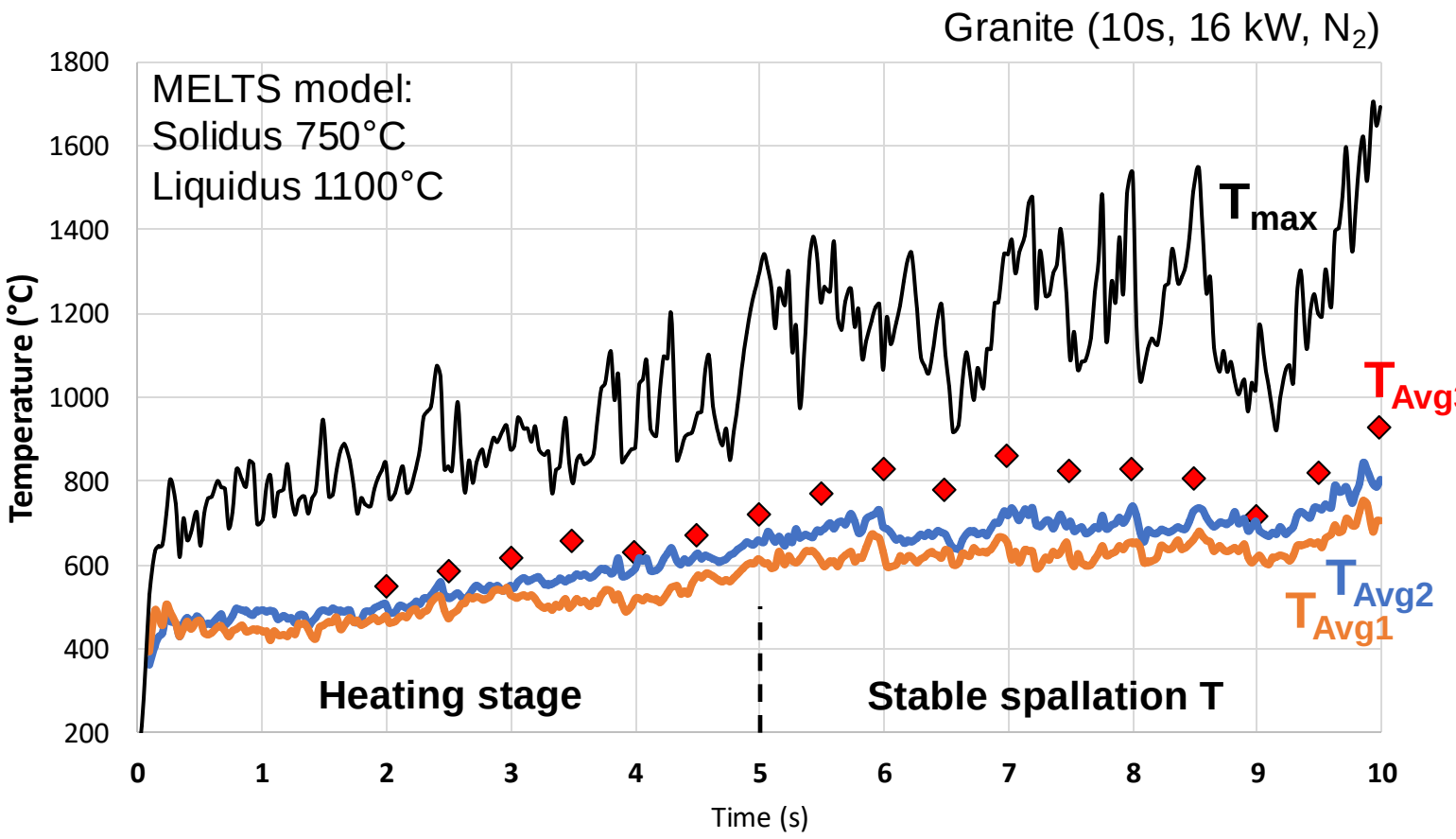
Thermography



- Distribution of temperature is heterogenous
- Maximum T represents local temperature
- Average T of spallation 600-700°C
- T of spallation depends on spalled material

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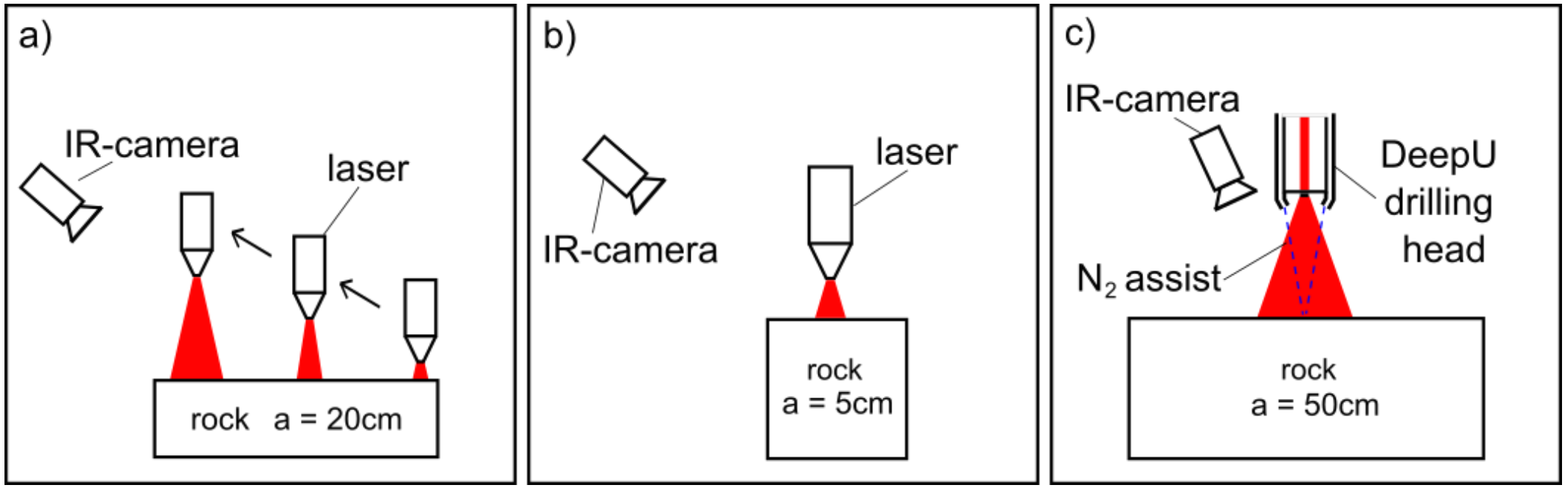
Experimental setups



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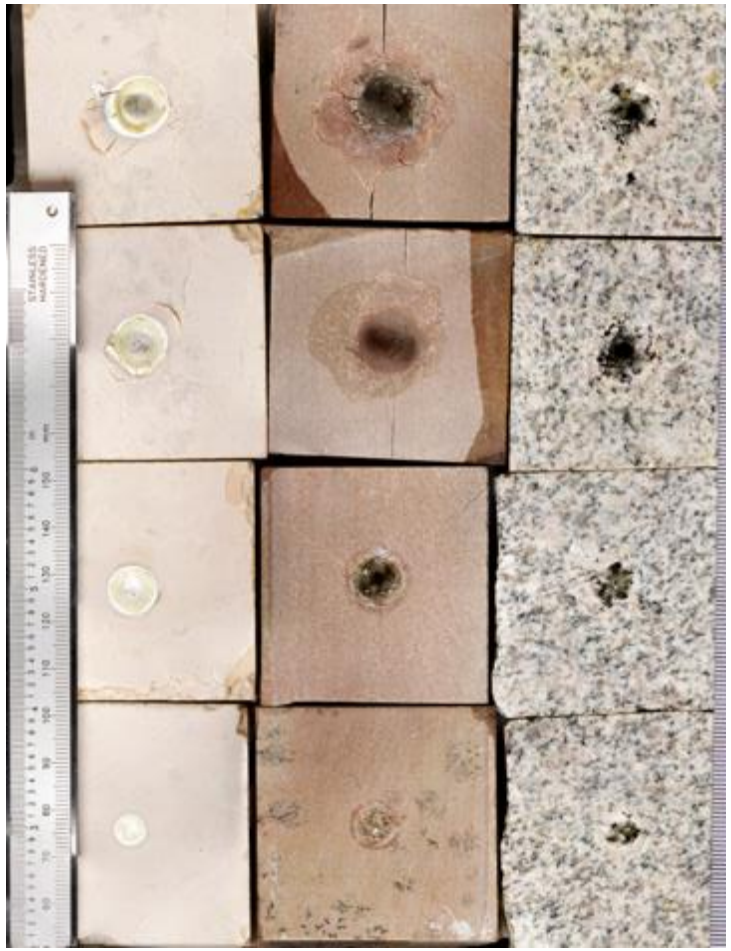
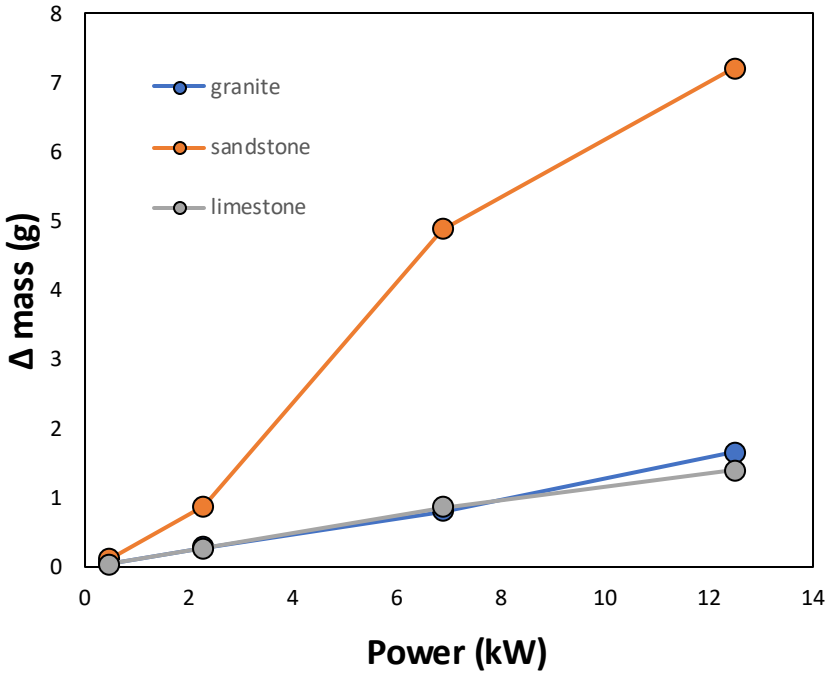
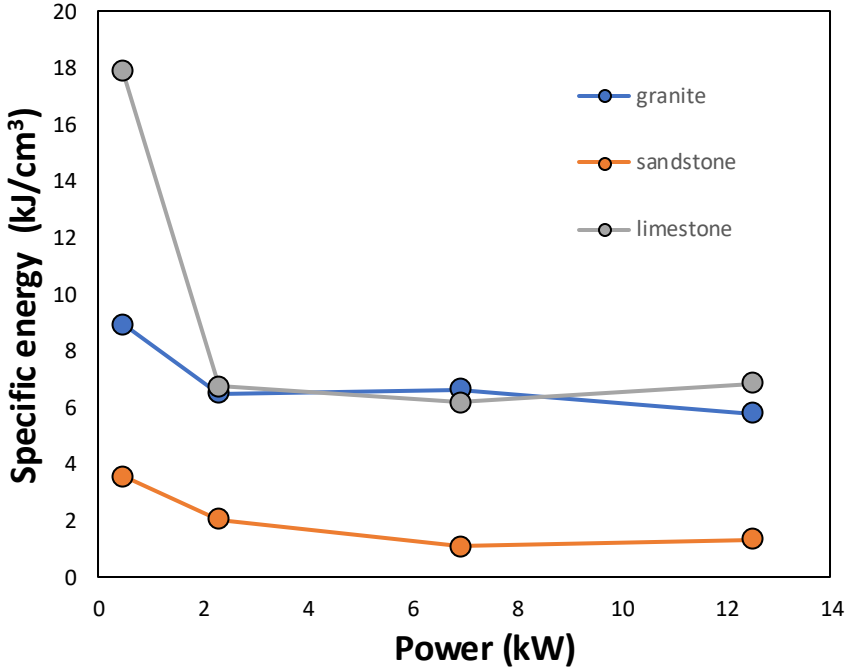
Discrete laser tests



Fixed parameters

- Irradiation time 2s
- Beam diameter 10mm





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DeepU Project

Goals

- Developing new **laser drilling technology**
- Extracting energy from **deep (>4 km)** U-shaped closed-loop
- **Reducing the costs** of well drilling
- Making accessible **geothermal energy anywhere**

Key project figures

7
Partner organizations

4
Involved countries

36
Months duration
starting on March 1, 2022

Key project actions

- Drilling technology design and development
- Validation at the lab scale
- Compliance with legal and environmental aspects
- Closed-loop scenario definition
- Cost-effectiveness assessment