This research is funded by the European Union
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NOVEL GEOTHERMAL DRILLING FOR DEVELOPING HEAT EXCHANGERS: THE DEEPU PROJECT

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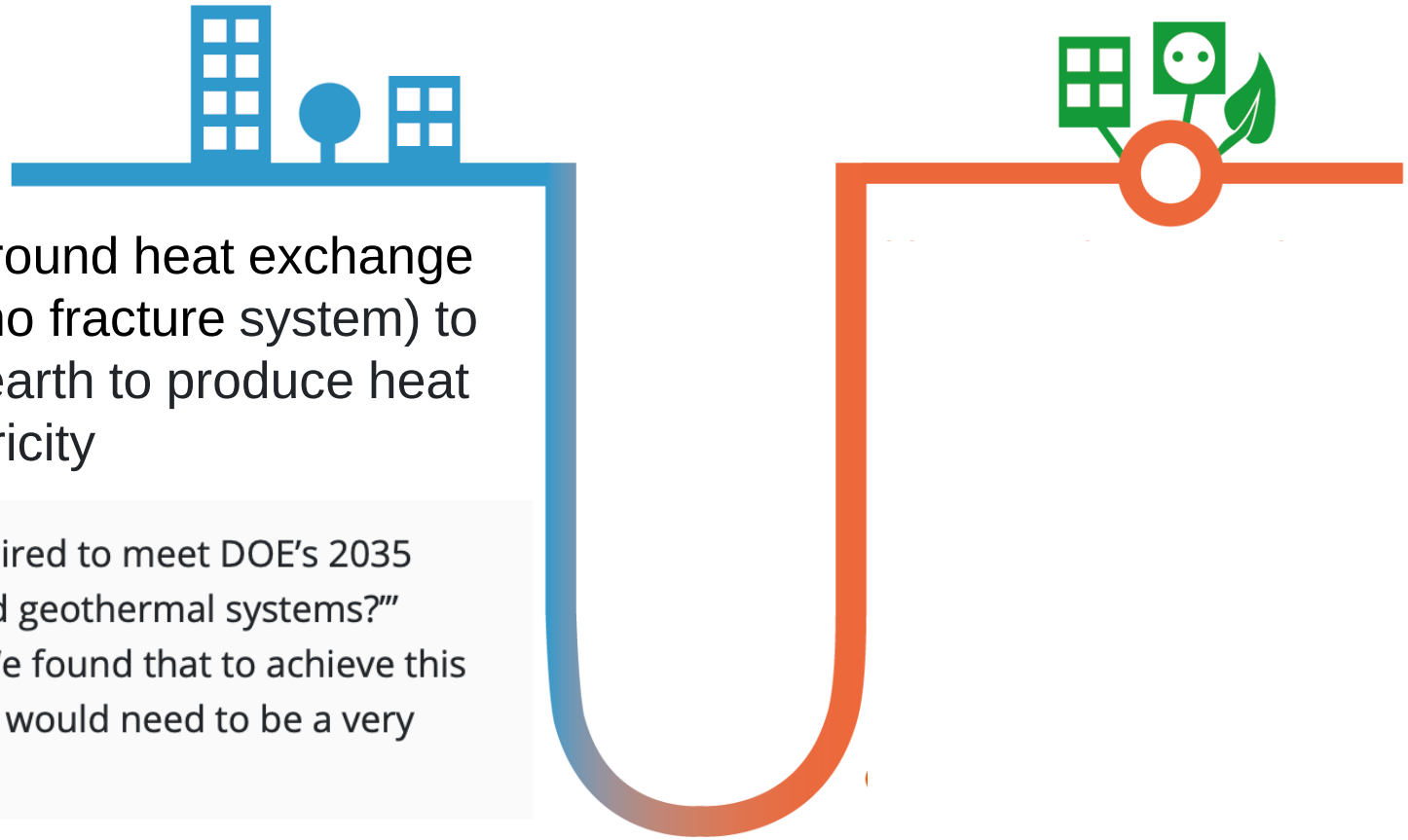
Why DeepU



The **challenge**:
complete engineering of the underground heat exchange (no water production and injection, no fracture system) to extract enough heat from the deep earth to produce heat for direct use or for generating electricity

"We asked the question, 'what is the drilling cost required to meet DOE's 2035 target for the levelized cost of electricity for enhanced geothermal systems?'" Vasyliv said. "This target is $45 per megawatt-hour. We found that to achieve this goal using closed-loop systems in hot, dry rock, there would need to be a very aggressive reduction in the cost of drilling."

From Sandia&NREL study, 2023
https://newsreleases.sandia.gov/geothermal_modeling/

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The DeepU Project Goals and main info

- Innovation & improvement of **laser drilling technology**
- Extracting energy from **deep (>4 km)** U-shaped or other closed-loops
- **Reducing the costs** of well drilling
- Making accessible **geothermal energy anywhere**

Key project figures

7
Partner organizations

4
Involved countries

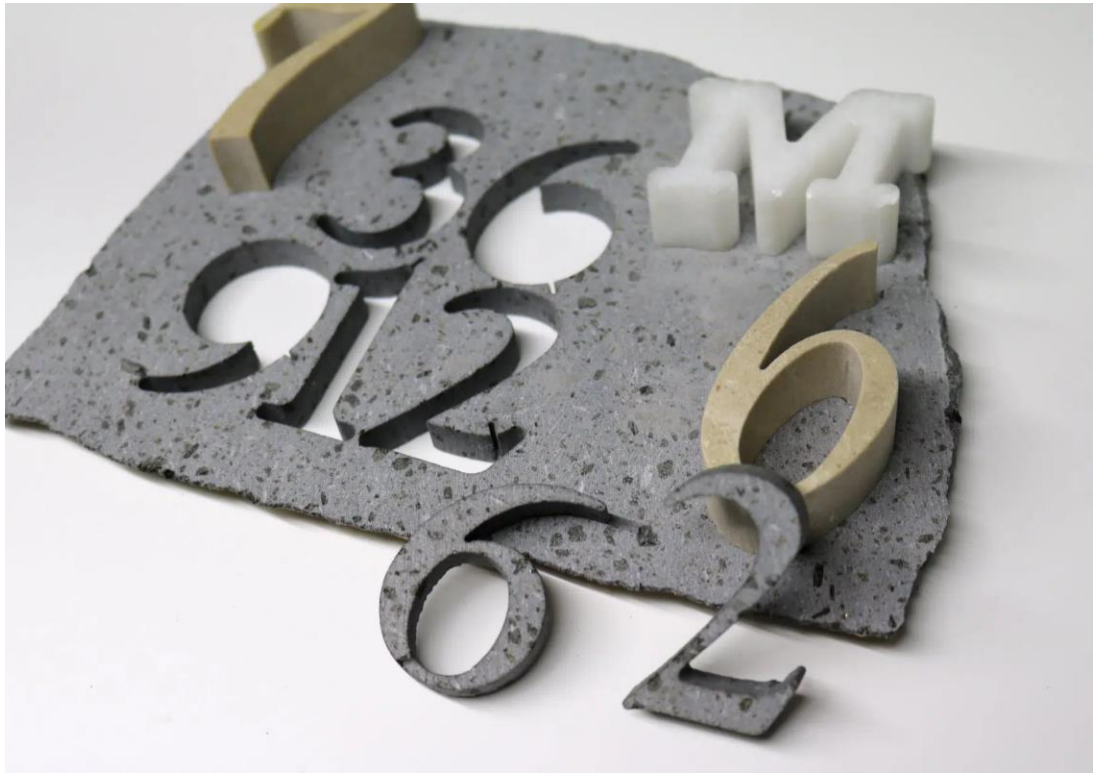
36
Months duration
starting on March 1, 2022

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

Project duration: 36 months (+8)
Hop-on extension: July 2023

Laser cutting and drilling



- Not a novelty. Proven technology for cutting hard rocks
- Laser drilling researched for at least two decades in the geothermal sector
- Stand-alone solution or in combination with mechanical drilling
- Never really convincing for open-loop geothermal systems, for which fractures are precious
- What about closed-loop, deep geothermal heat exchanger (**DGHE**), at depths where traditional drilling technologies face many problems due to demands on equipment, life-span of drill string components (most notably drill bits) resulting in higher levels of Non-Productive Time (NPT), and increased completion costs?

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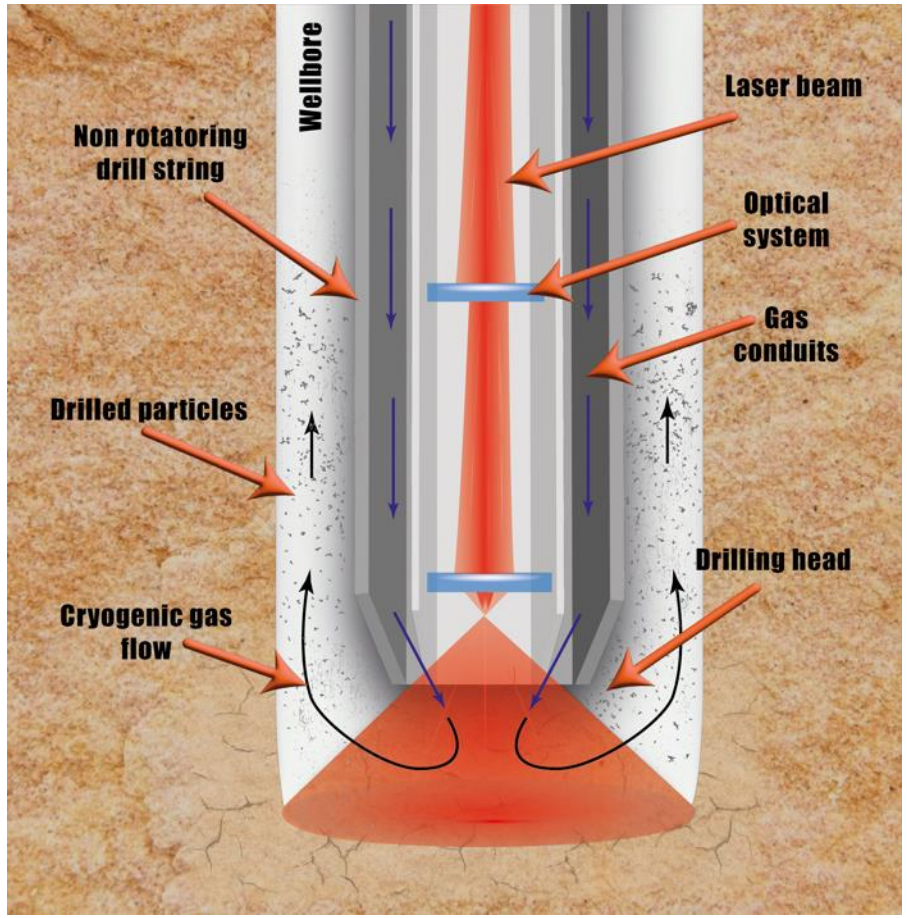
INNOVATIVE DRILLING TECHNOLOGY

A **laser** propulsion drilling method is combined with **cryogenic gaseous flushing** for cooling the laser drill head, borehole walls and bring the cuttings to the surface

Improved ROP
Reduced drilling time and cost

In case a glazed layer is formed on the borehole walls, the borehole is physically isolated from the surrounding formations without requiring further casing activities.

Reduced time and casing cost for setting up the DGHE



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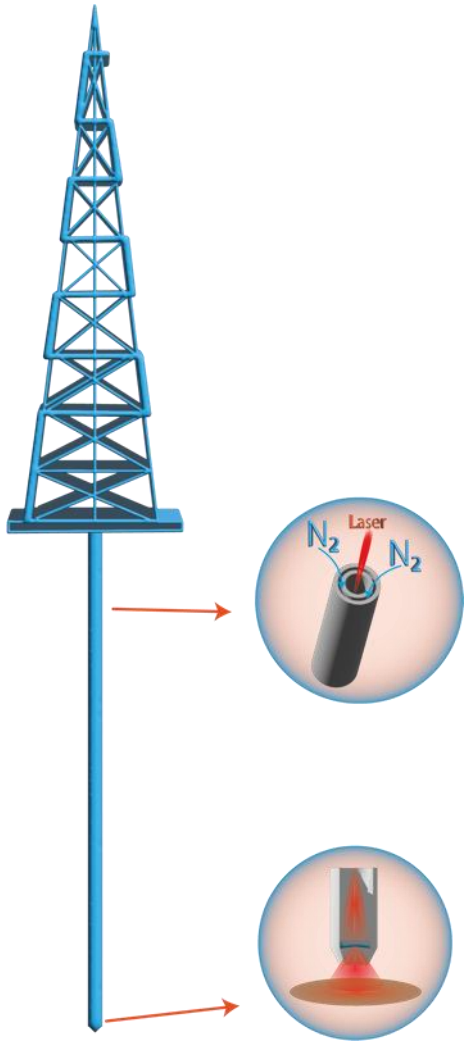
The DeepU Team

7 international teams work on different aspects of DeepU Project, such as:

- Laser driven drill bit
- Gas flushing system and drill string design
- **Scaled model** of U-tube heat exchanger
- Petrophysical characterization of drilling process
- Standards and regulatory integration
- Exploitation planning and IPR management
- Communication
- Management



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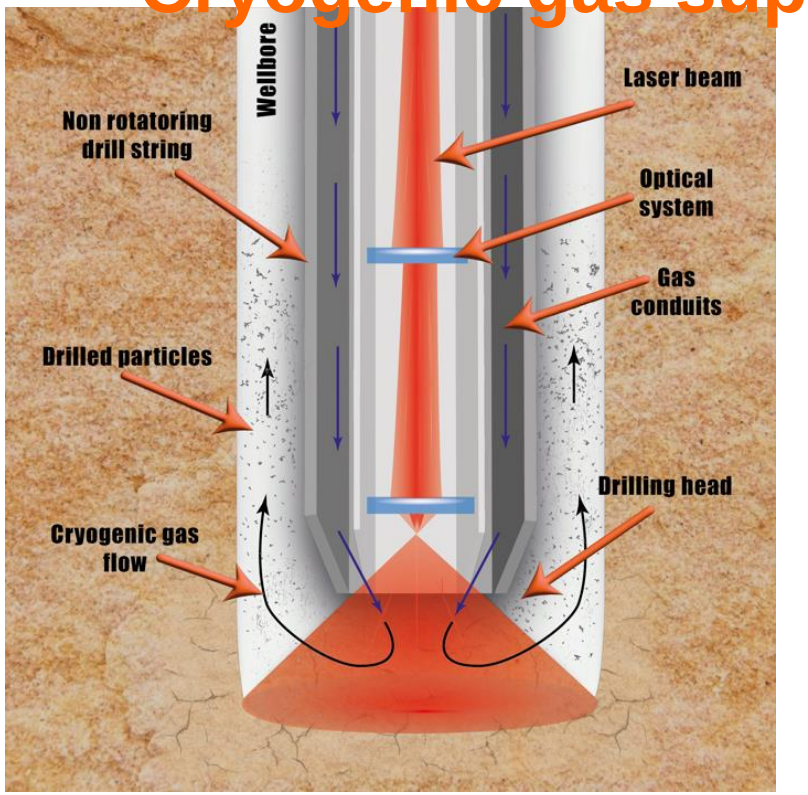
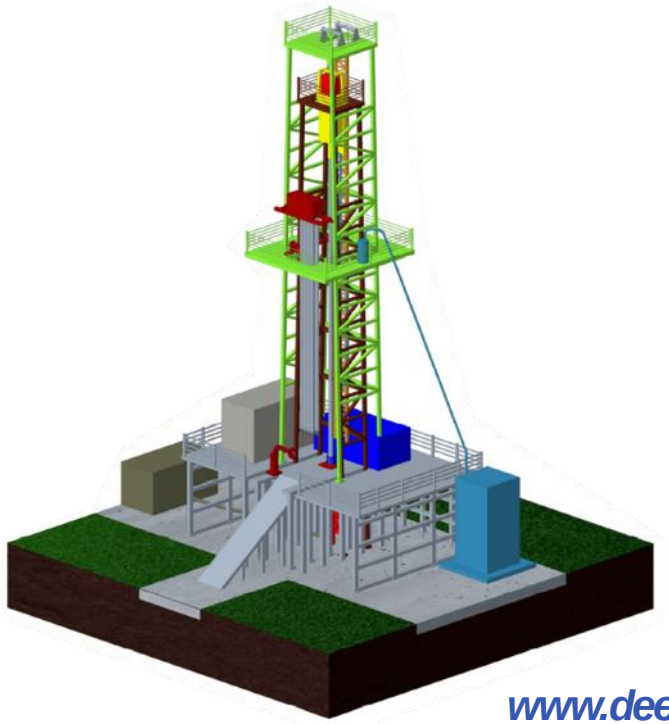
Cryogenic gas supported laser drilling technology



Drilling head with gas flushing nozzles

Drilling Tower adaptions needed



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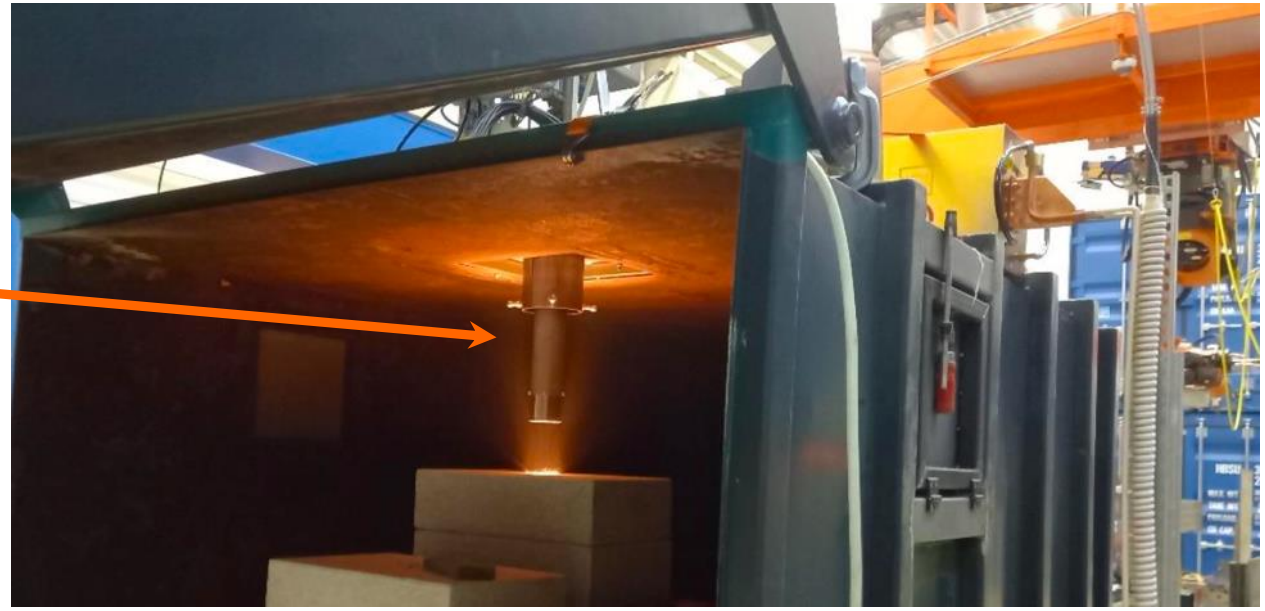
Laser drilling laboratory tests

Rock slabs

150mm x 300 mm x 500 mm



Laser drilling laboratory tests

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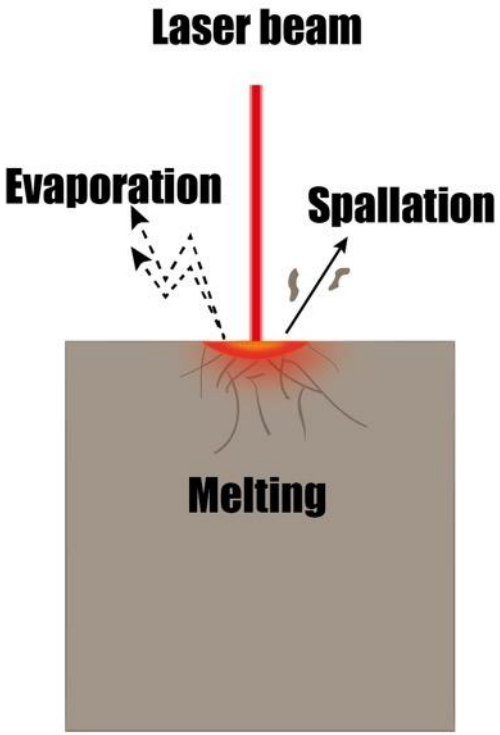
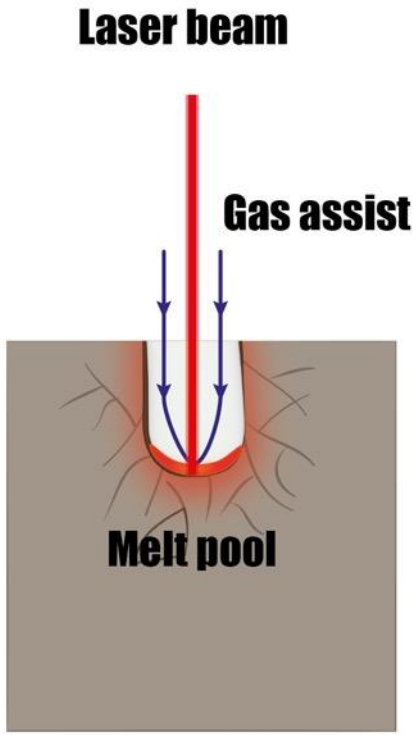
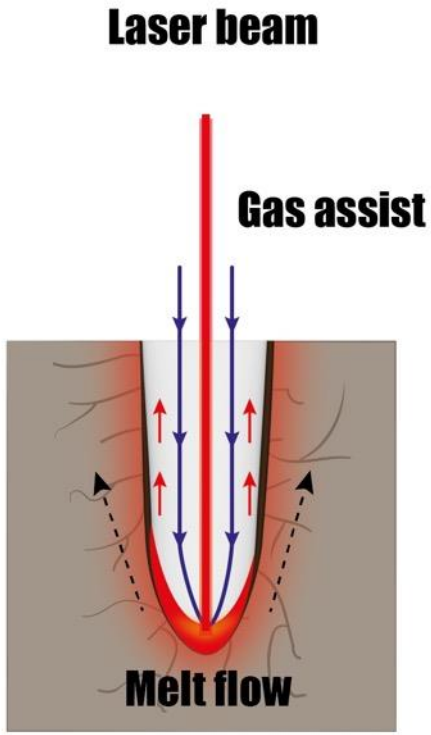
Laser-rock interactions

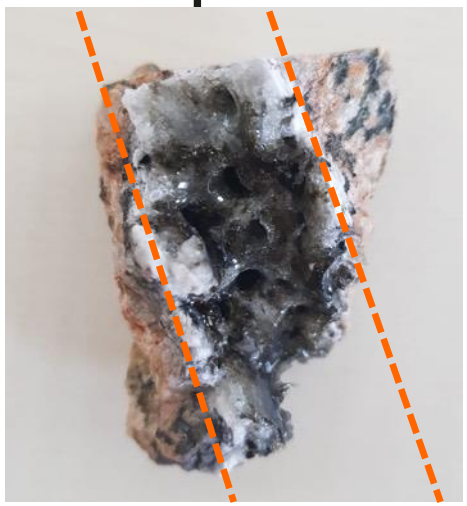


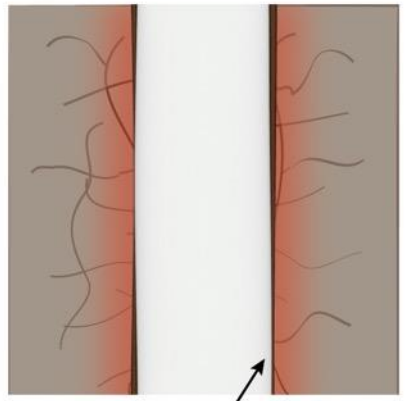




Based on Li et al. 2015

RFE Exp

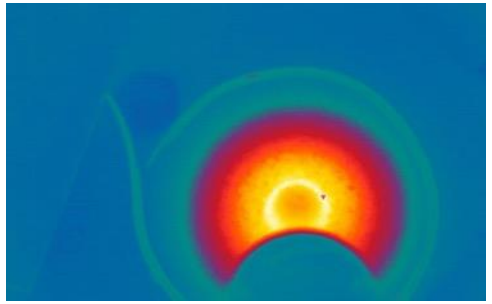


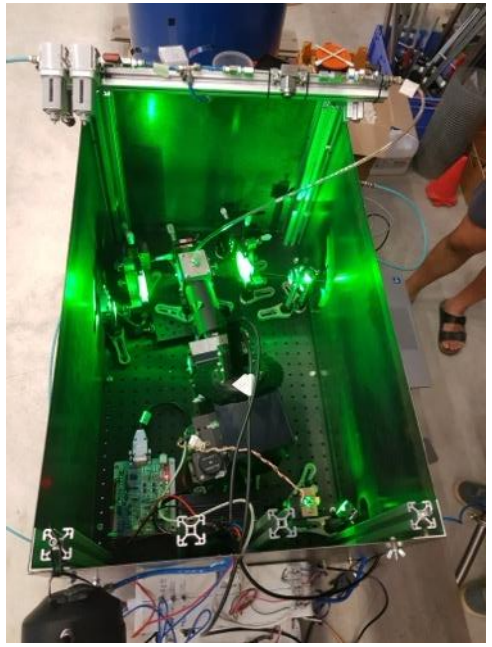


Experimental setup

- Fixed position of robotic arm (working distance)
- Drill with and without assistance of room temperature N_2 flux
- Testing drilling heads
- Laser power: 6-30 kW
- Beam diameter: 5-20 cm
- Selected lithologies: granite, sandstone, limestone

- Video documentation
- IR video documentation (thermocamera)
- Gas spectrometry





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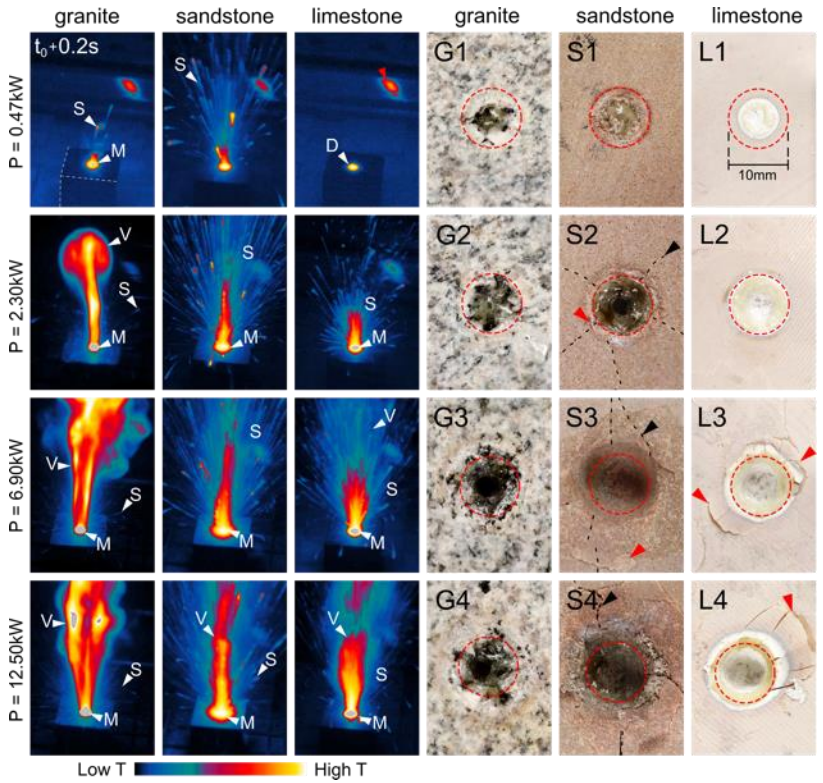
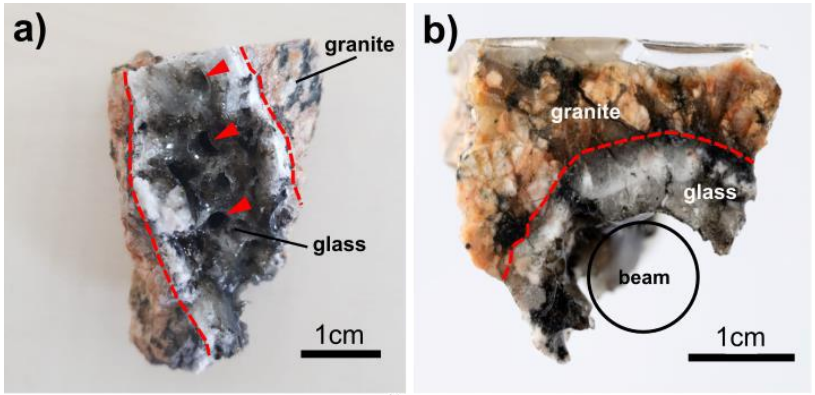
Deep U-tube heat exchanger breakthrough: combining laser and cryogenic gas for geothermal energy exploitation

Results of the lab tests

- Description of petro-physico-mechanical phenomena; **spallation, melting, evaporation**
- **Formation of glass layer** (1-5 mm)
- **Successful drills** of selected lithologies
- ROP up to **26 m/h**



IR images and pictures of crater from drill head tests



Thermally spalled borehole

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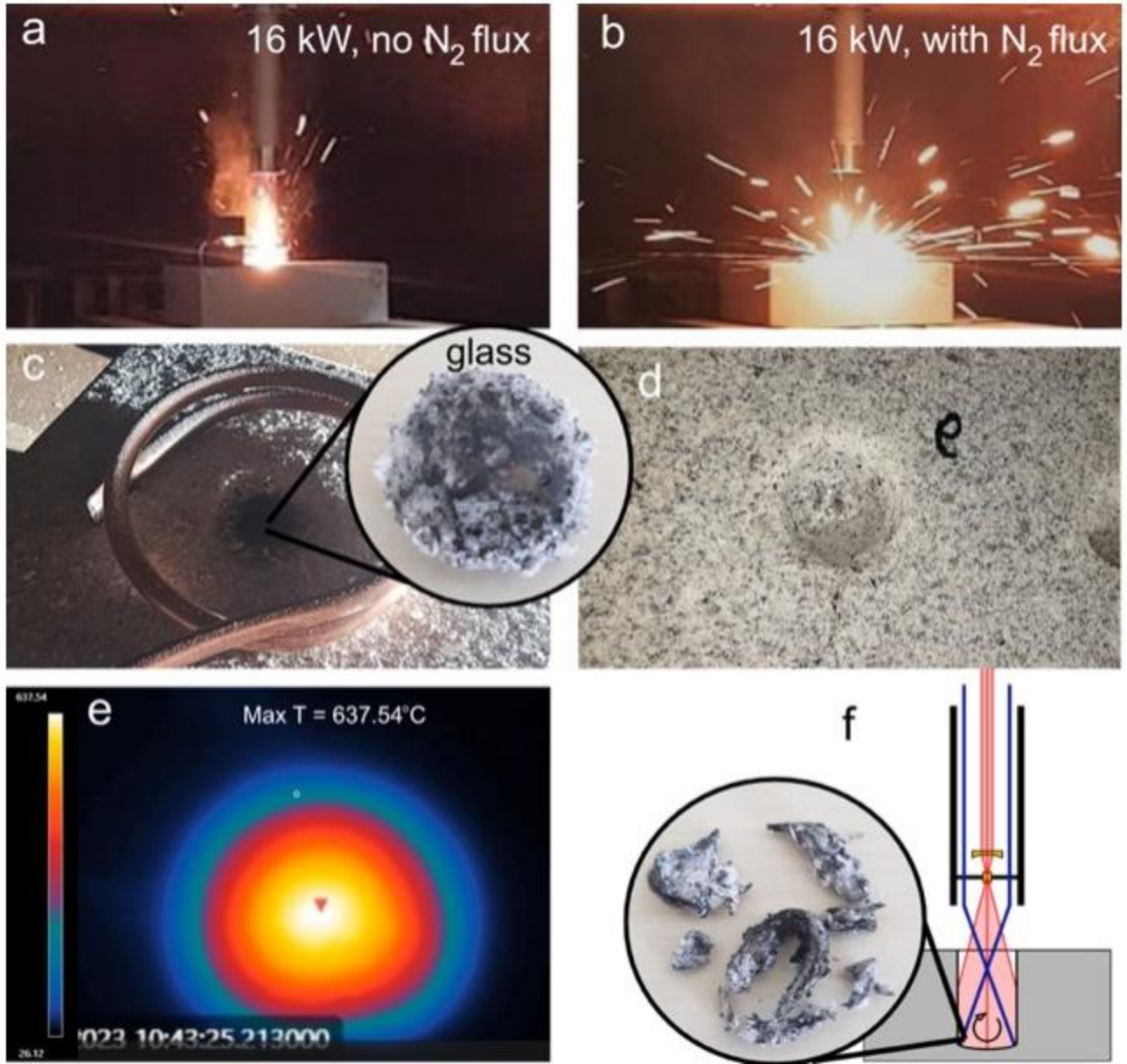
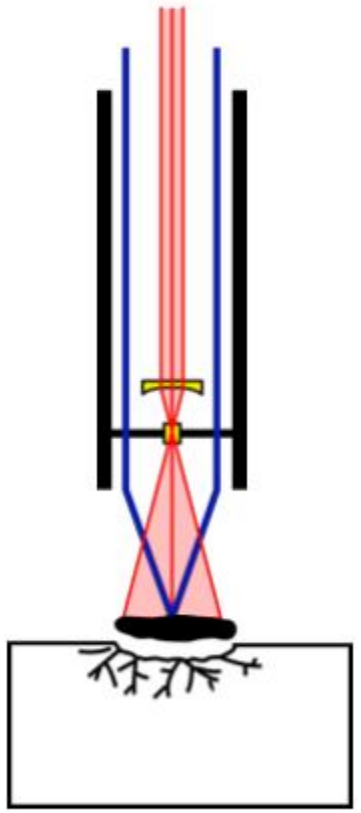
Granite

- The power has little effect on efficiency of the drilling
- N_2 flux has crucial effect on the drilling
- Spallation dominated drilling occurs at low temperature





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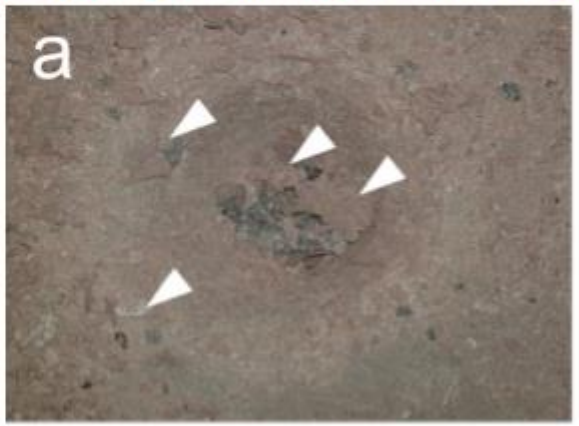
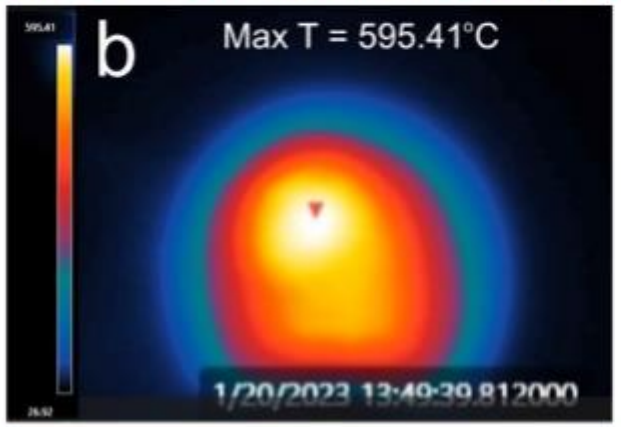
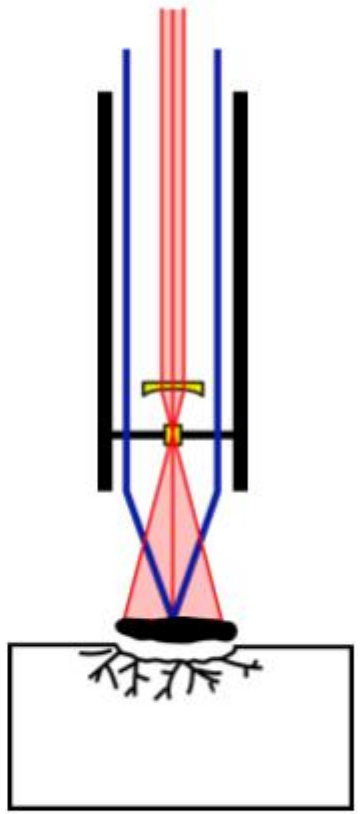
Sandstone

- The power has little effect on efficiency of the drilling
- N_2 flux has crucial effect on the drilling
- Spallation dominated drilling is much more efficient that in granite
- In wet sample size of spalled flakes decreased

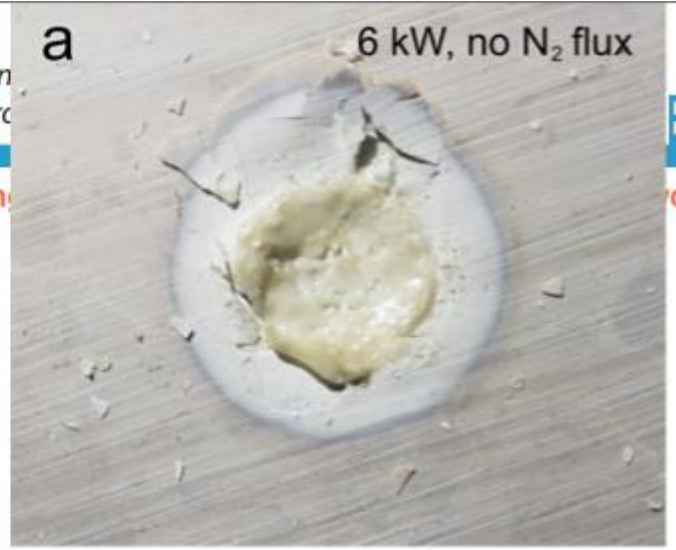


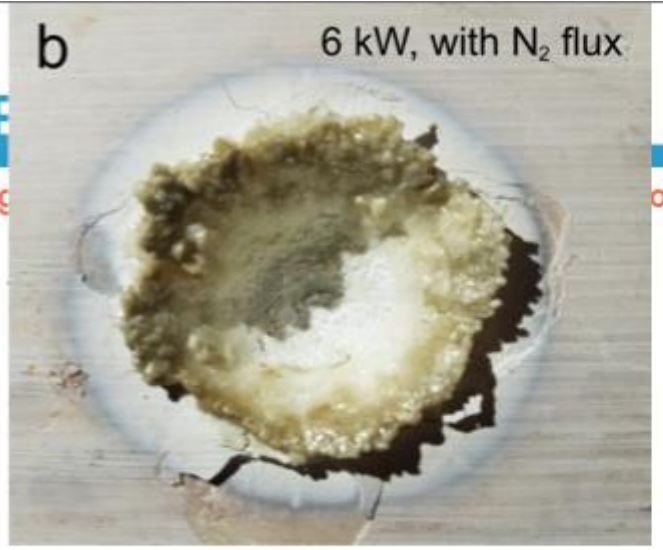


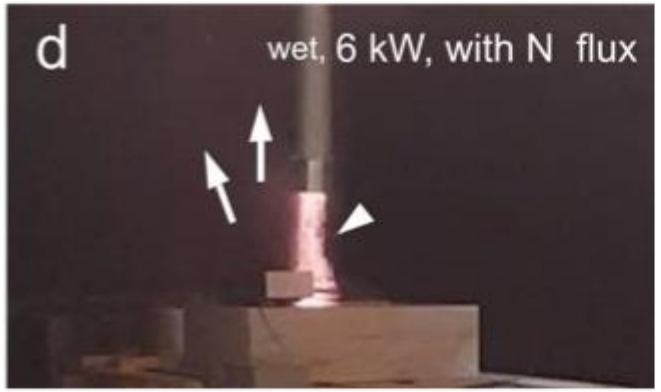


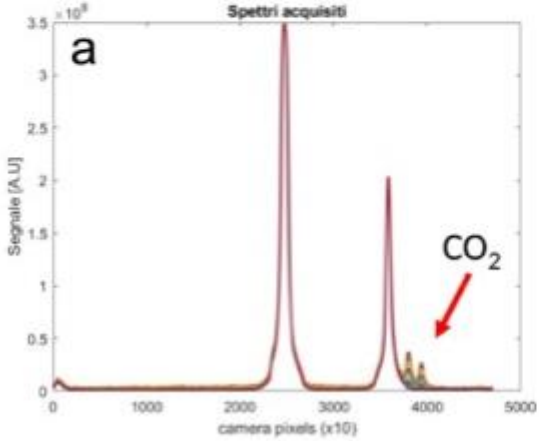
Limestone

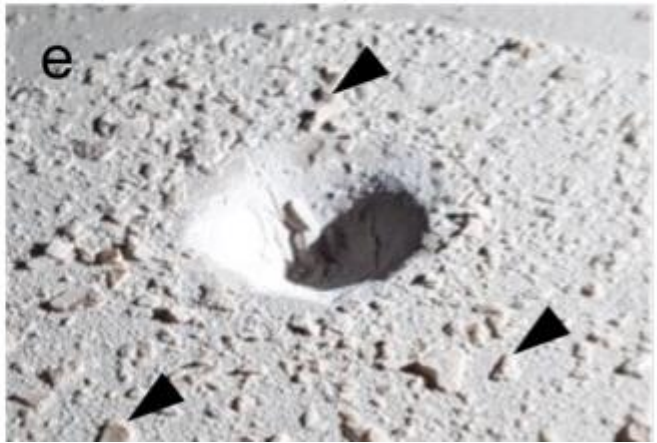
- **Spallation can be induced** by introducing H_2O into the natural porosity of the rock

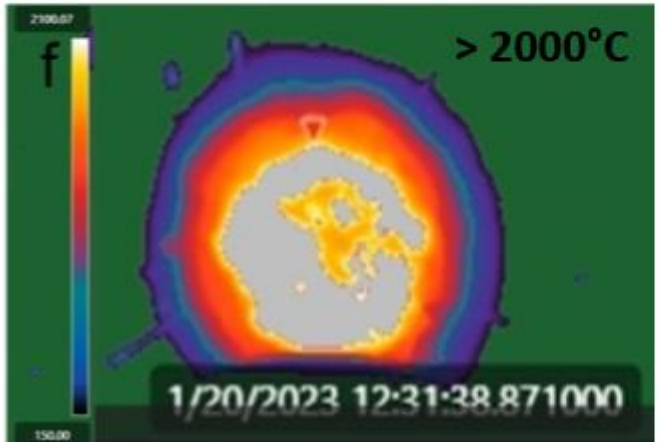


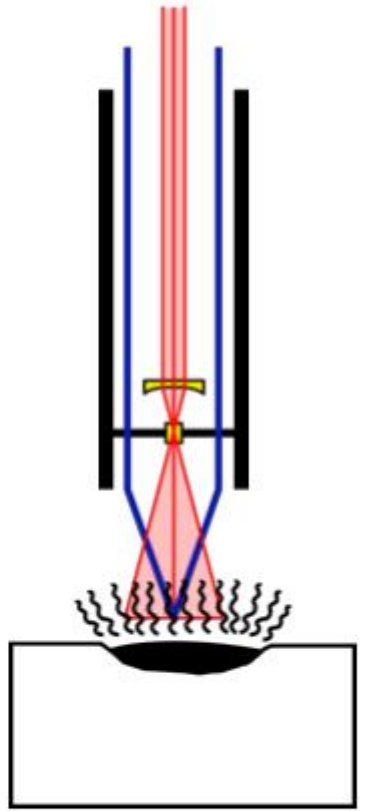












www.deepu.eu

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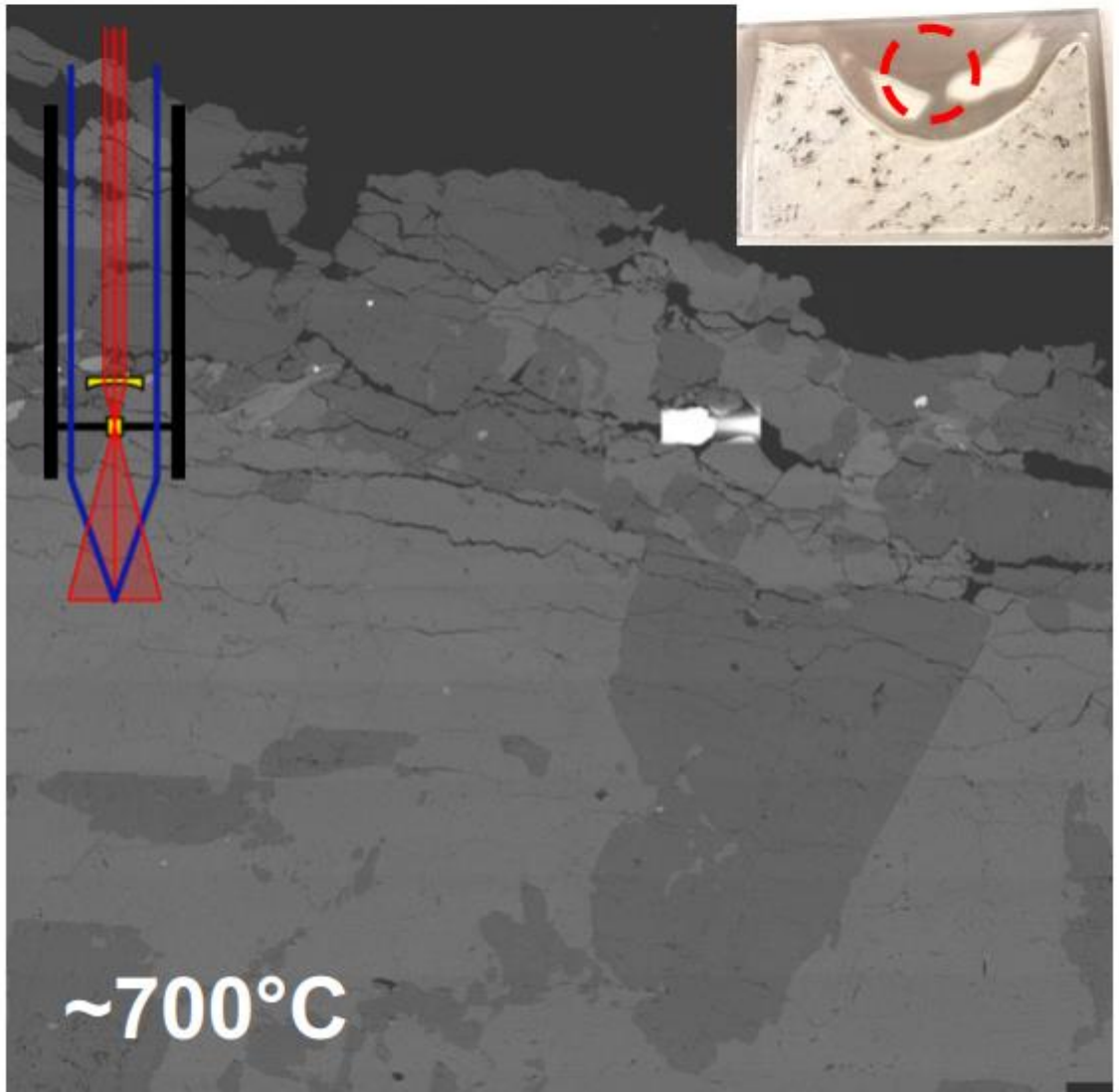
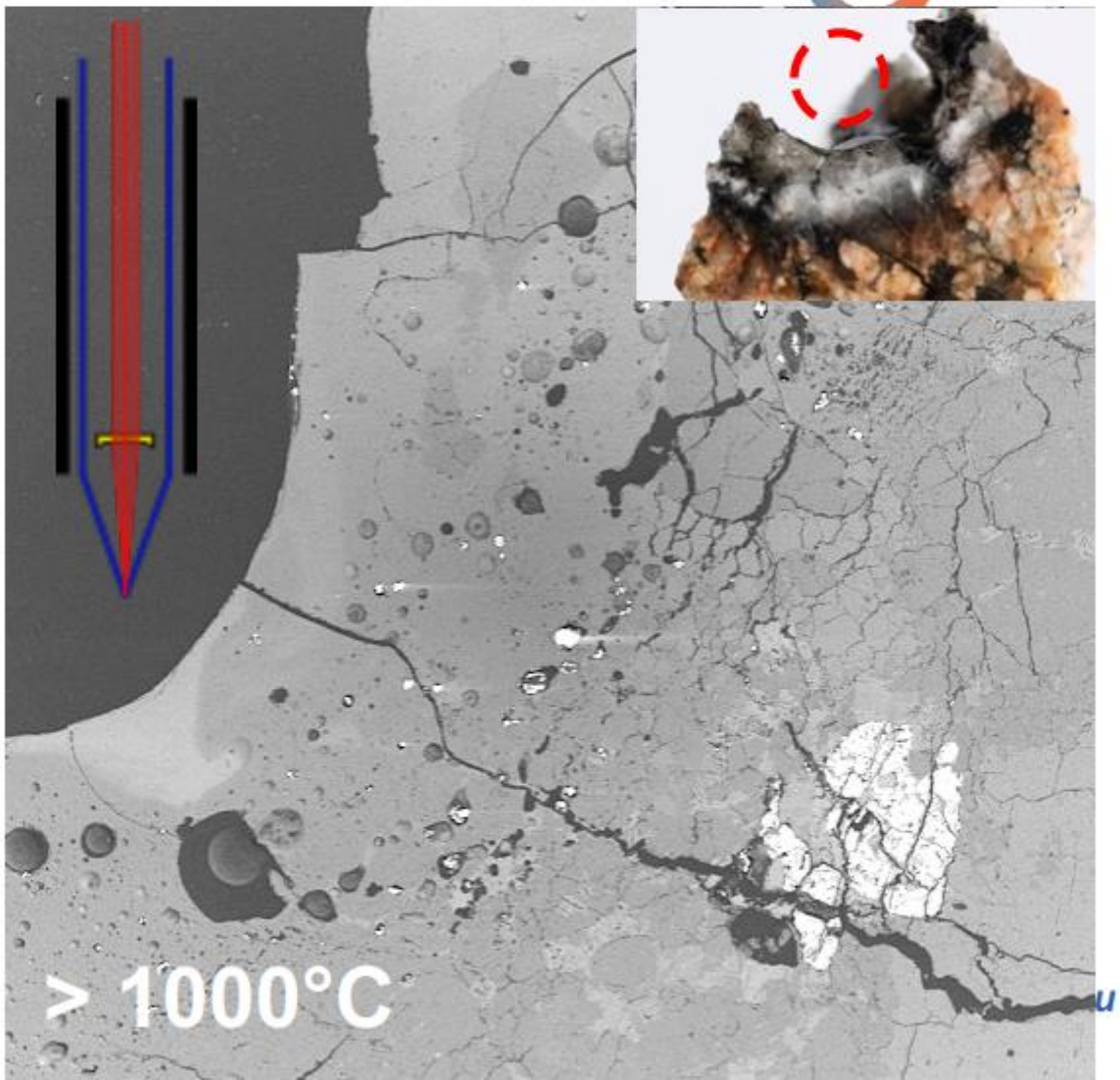
Deep U-tube heat exchanger breakthrough: combining laser and cryogenic gas for geothermal energy exploitation

Spallation vs Melting as a drilling process





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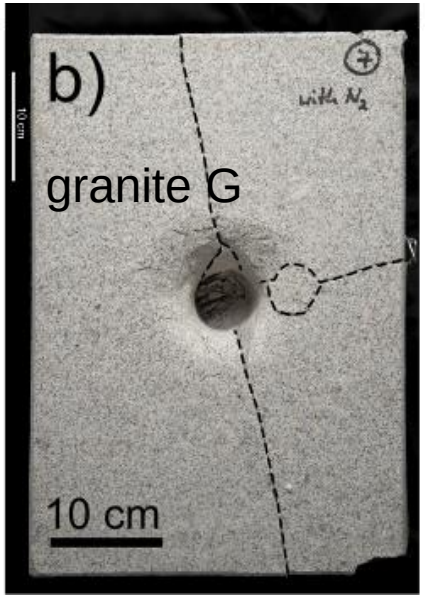
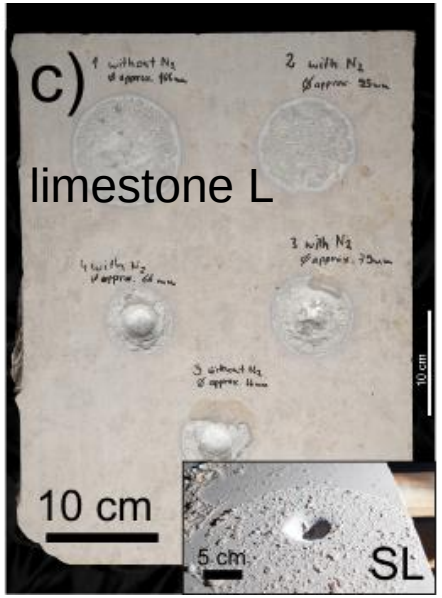
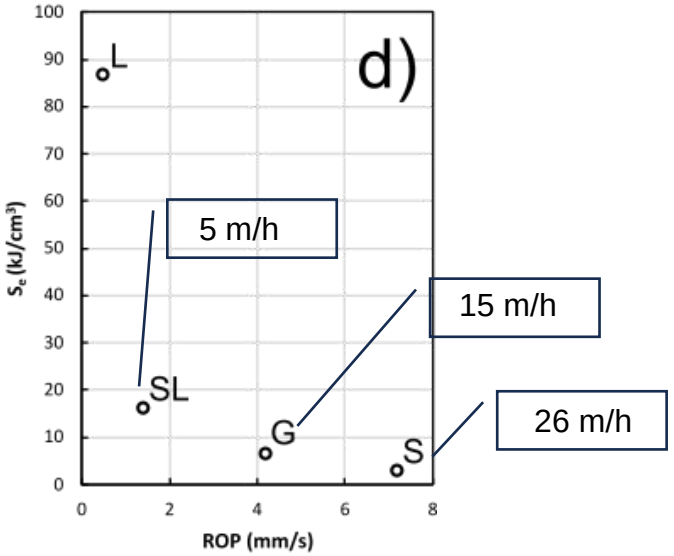
Efficiency of laser drilling

- Optimal in quartz-rich rocks (α ↔ β phase transition). The > the quartz content, the > intensity of spallation and < spallation temperature (**ST**. In sandstone is 400 °C)
- Limestone is the most difficult to drill with laser (ST=2100 °C) unless it is soaked in water (ST= 180 °C in saturated rock)







saturated limestone SL

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Conclusions

- Description of petro-thermo-mechanical phenomena; **spallation, melting, evaporation**
- **Formation of the glass** at the bottom of the borehole
- No vitrification of walls!
- **Successful drills** of selected lithologies
- Diameter of the boreholes up to **18 cm**
- ROP up to **20 m/h**
- **Drilling with laser is possible!**

Available on the project website

- DeepU concept and goals in detail
- 2 Newsletters
- All public reports (more advanced reports will be available soon)
- Posters, presentations, proceedings
- Press releases
- The results of the first webinar organized by the project and related to the numerical simulation of DGHE