

Advancements in the development of novel laser drilling technology for geothermal energy exploitation (DeepU)



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DI PADOVA

Pawel Slupski, Cerwenka G., Chorowski M., Di Sipio E., Galgaro A., Mallin K.,
Manzella A., Pasquali R., Romanowski A., Sassi R., Steinmeier O. & Pockele L.

pawelmichal.slupski@unipd.it



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

Why to drill with a laser?

Non contact drilling techniques

- flame
- plasma
- microwave
- **laser**

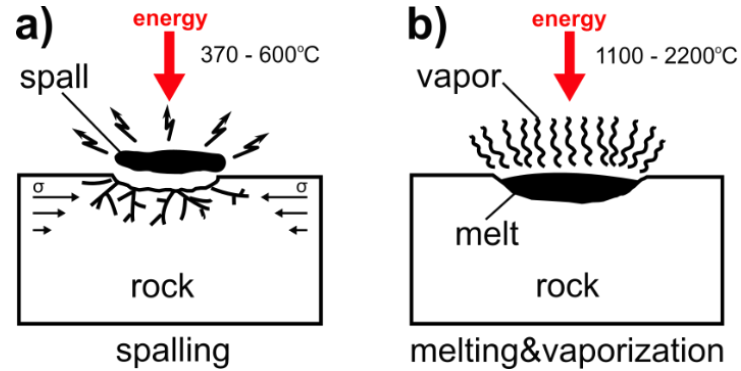
Advantages of laser technology

- commercial availability
- modularity
- high power
- no losses on transmission

DeepU Laser

- Ytterbium fiber laser
- Power range 0.17 – 30 kW
- Wavelength 1070 ± 10 nm
- Continuous beam

Penetration mechanisms



Laser-rock interactions

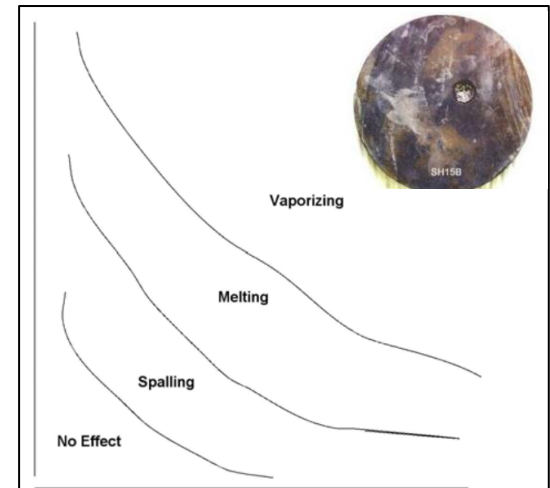


Figure 9. Schematic of relationship between lasing parameters and affect on rocks. Isobarameter lines separate zones.

Gahan B. C. et al., 2002

Feasibility studies



Field test of a Combined Thermo-Mechanical Drilling technology. Mode I: Thermal spallation drilling

Edoardo Rossi ^{a,b,*}, Shahin Jamali ^{c,d}, Martin O. Saar ^{a,b,e}, Philipp Rudolf von Rohr ^b

^a ETH Zürich, Geothermal Energy and Geofluids group, Sonneggstr. 5, 8092 Zürich, Switzerland

2020

Study on the rock-breaking characteristics of high-energy pulsed plasma jet for granite

Yancong Han, Chao Zheng, Yonghong Liu ^{*}, Yufei Xu, Peng Liu, Yejun Zhu, Xinlei Wu

^{*} China University of Petroleum East China, Qingdao, Shandong, 266580, PR China

Mechanism and Feasibility Evaluation of Laser-Assisted Rock-Breaking in Drilling Fluid Environment

Xuemin Zhou^{1,2,3} · Mingzhong Gao^{1,2,3,4} · Junjun Liu^{1,2,3,4} · Lei Yang⁴ · Haichun Hao^{1,2,3} · Bengao Yang⁴ · Zhiqiang He⁴ · Xuan Wang^{1,2,3}

2024

2025

Laser drilling experiments

Experimental setups

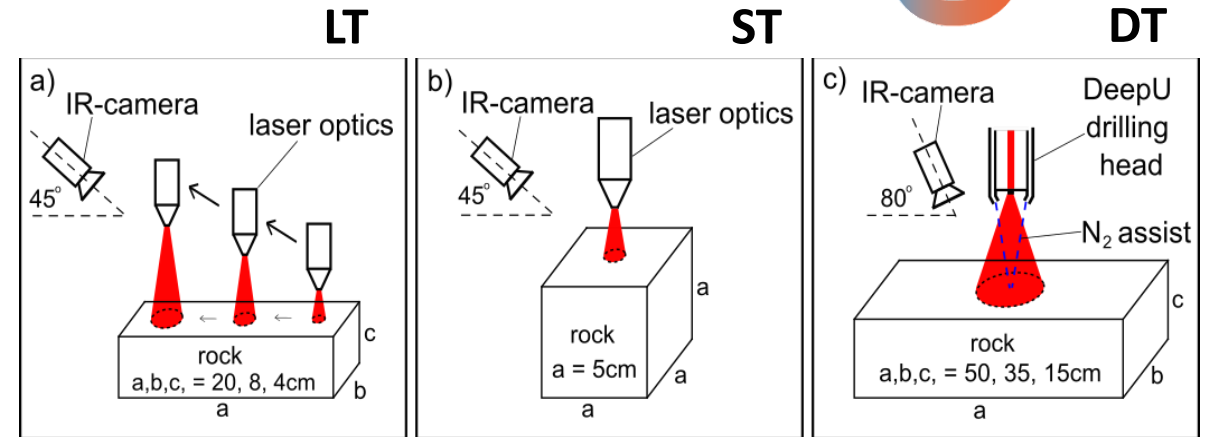
- Linear track tests (LT)
- Single spot tests (ST)
- DeepU drill-head tests (DT)

Selected lithologies

- primary lithologies; **granite, sandstone, limestone**
- secondary lithologies; gneiss, basalt, slate, migmatite

Methods

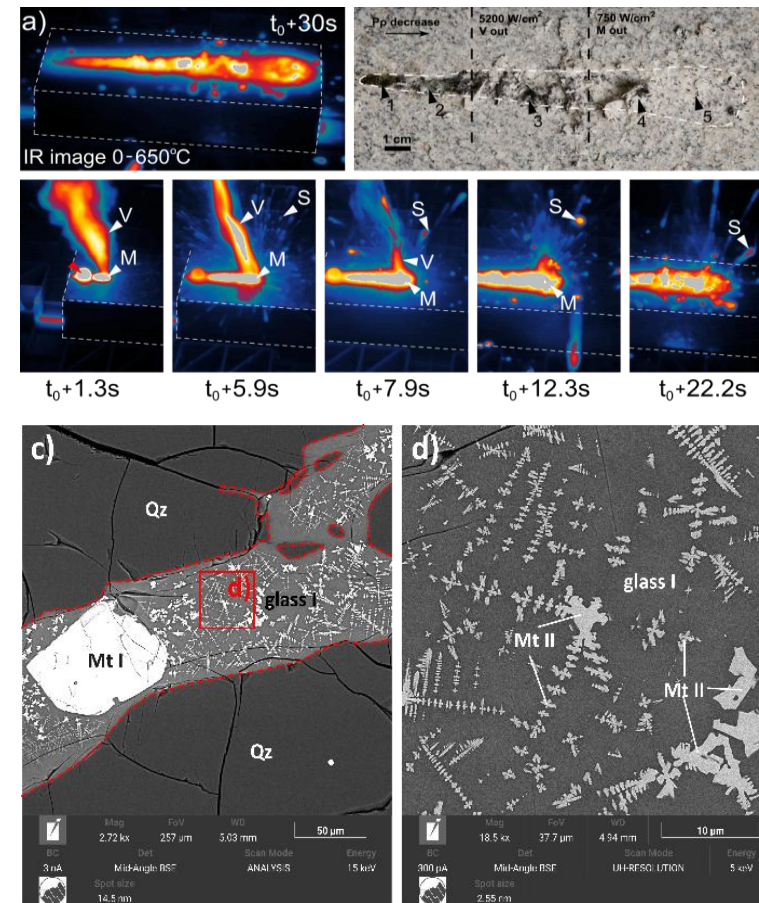
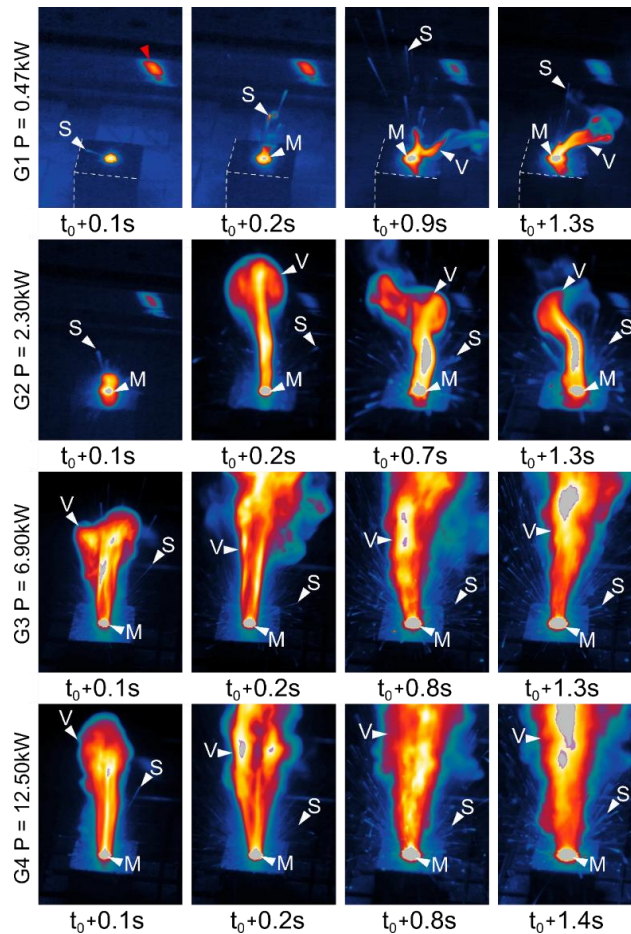
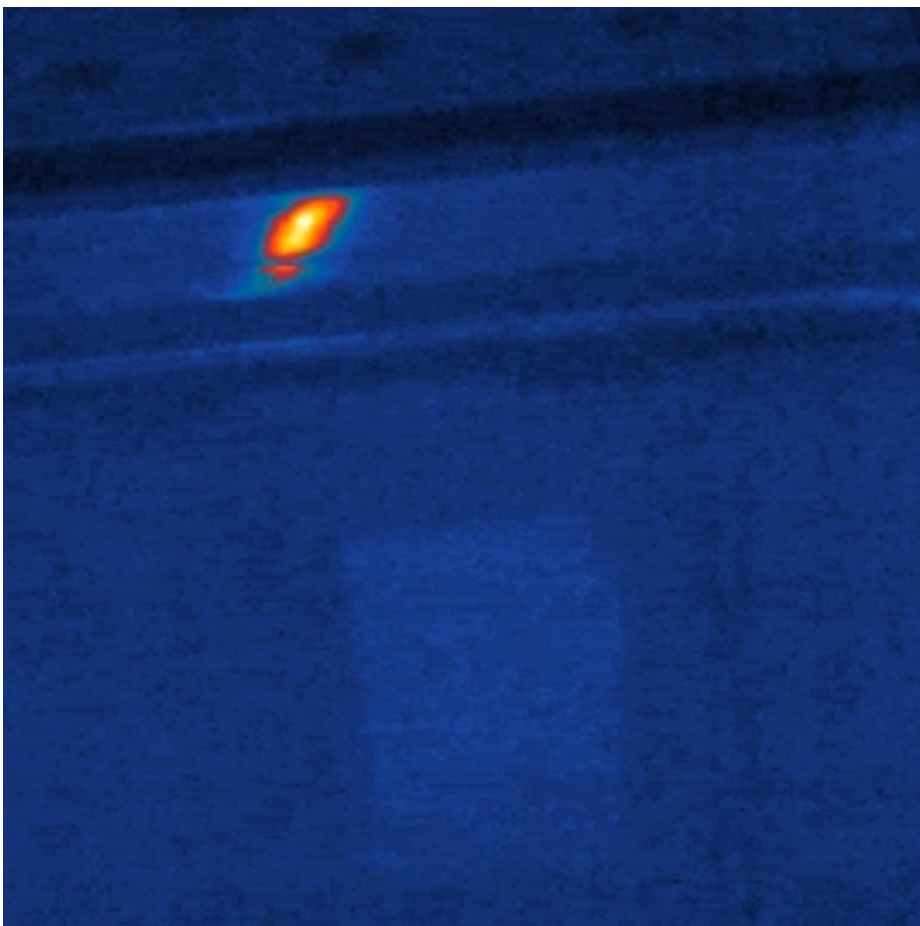
- **IR-imaging (FLIR GF77a)**
- photogrammetry
- optical and electron microscopy
- XRD, XRF





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

Results: laser-rock interactions

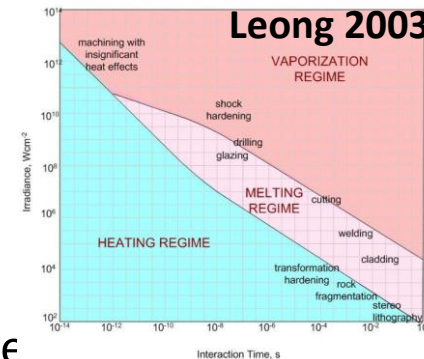




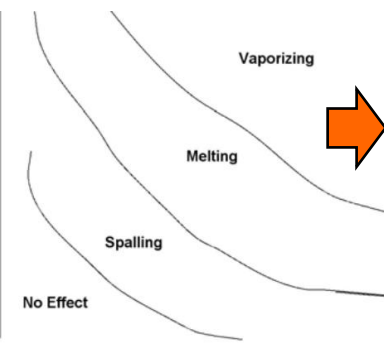
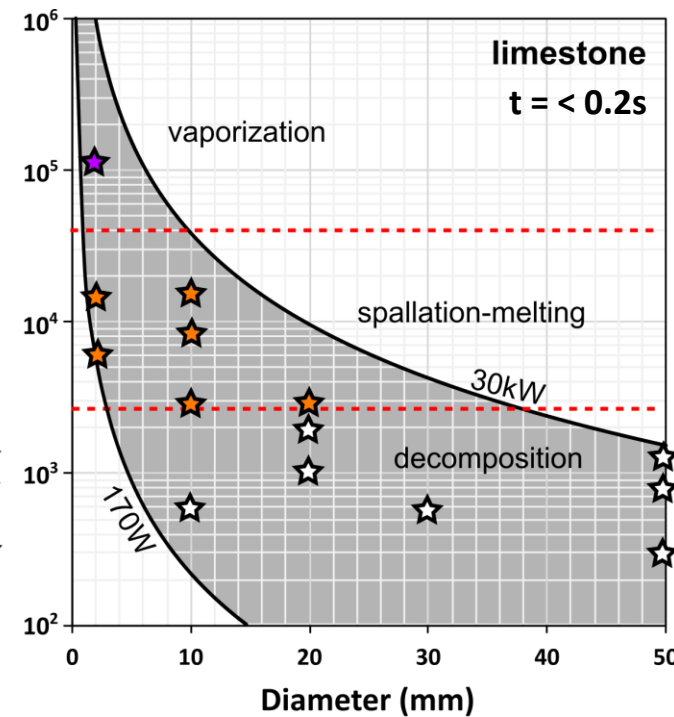
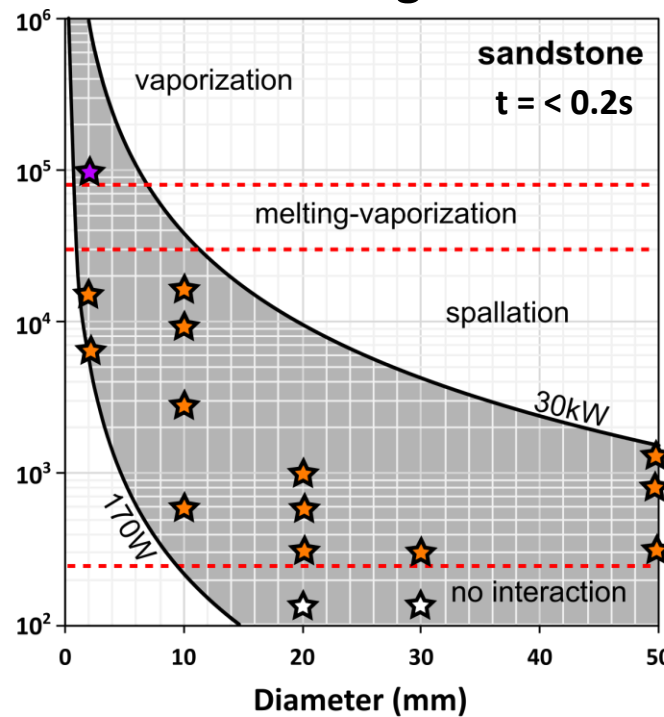
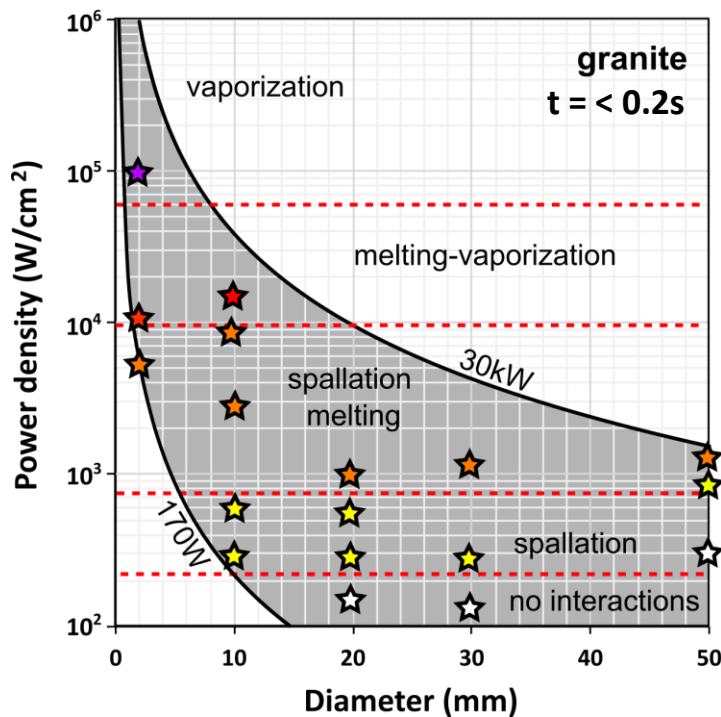
Deep U-tube heat exchanger breakthrough: combining laser and cryogenic gas for geothermal energy exploitation

Results: laser-rock interactions

- **spallation, melting and vaporization** often occur together but to various intensity
- occurrence of each process depends on **power density**, irradiation time and rock type
- Power density based **process diagrams** were constructed for granite, sandstone and limestone



Process diagrams



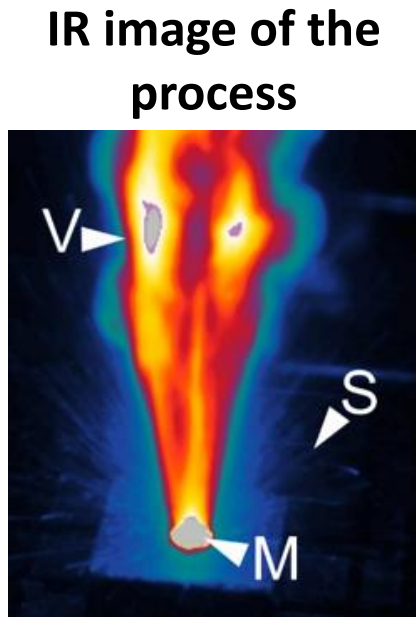
Gahan B. C. et al., 2002



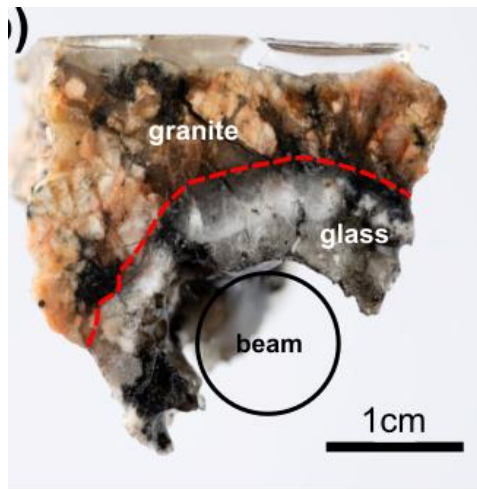
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Summary

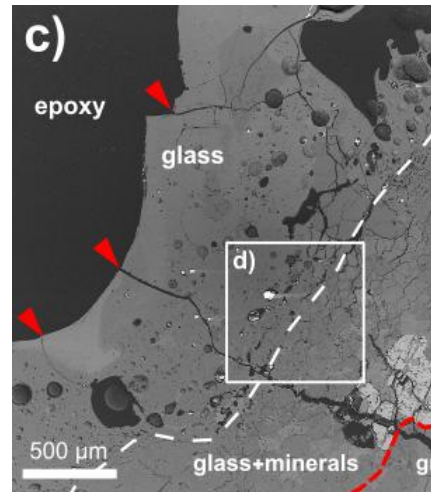
Melting-
vaporization
laser drilling



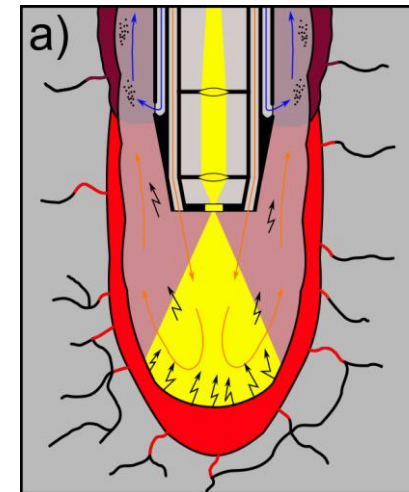
Crater morphology



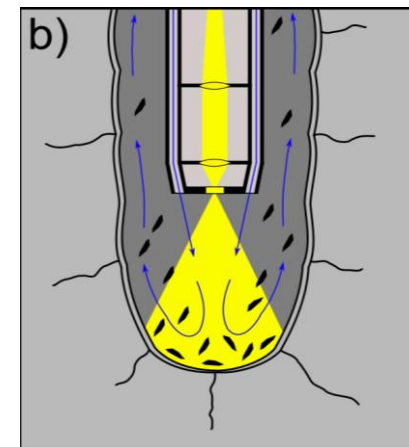
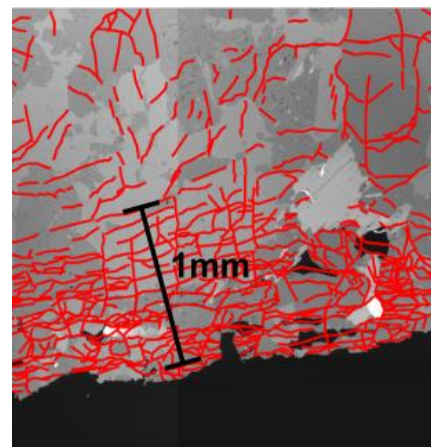
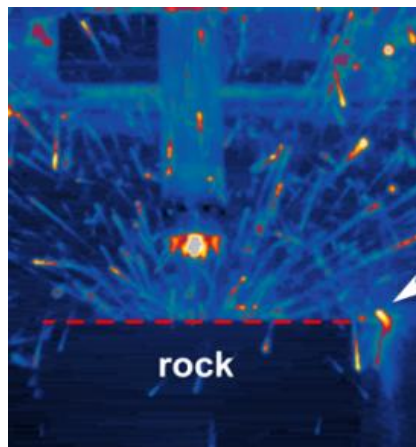
Crater walls BSE images



Drilling method



Thermal spallation
laser drilling





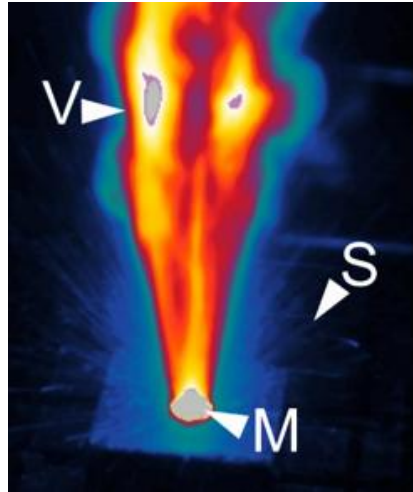
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Summary

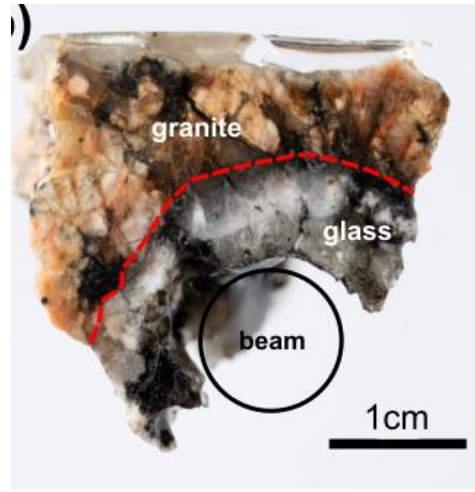
Melting-vaporization laser drilling



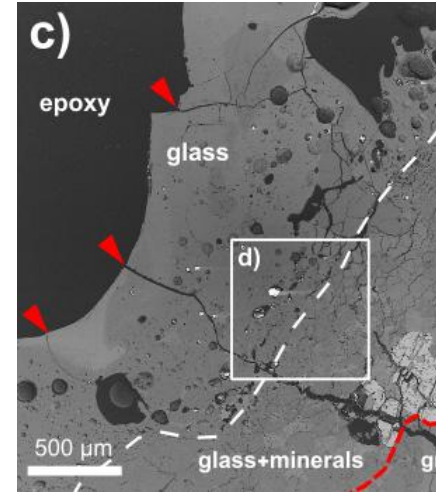
IR image of the process



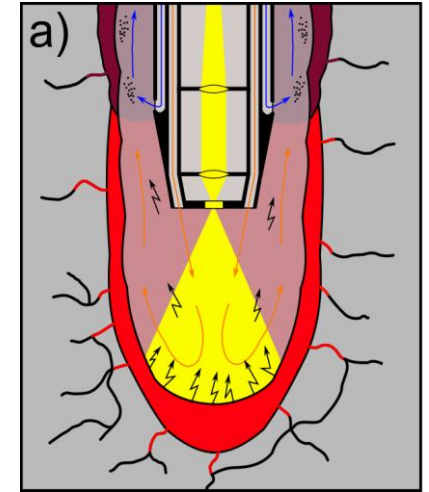
Crater morphology



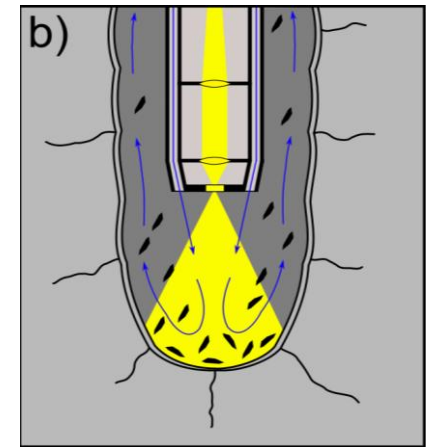
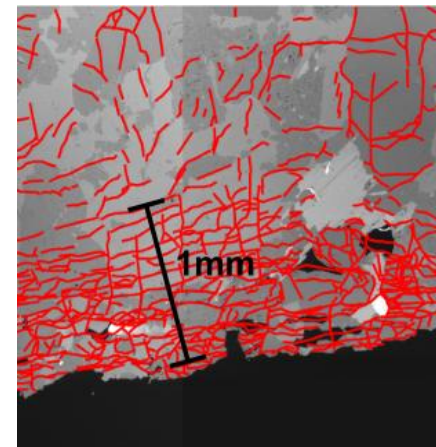
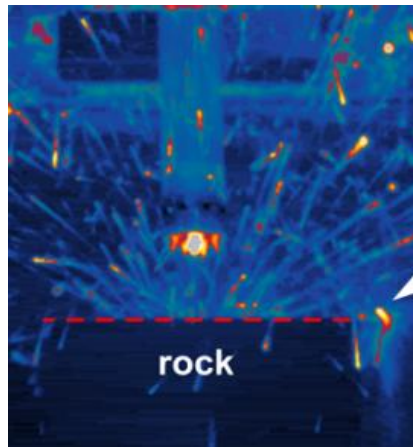
Crater walls BSE images



Drilling method



Thermal spallation laser drilling



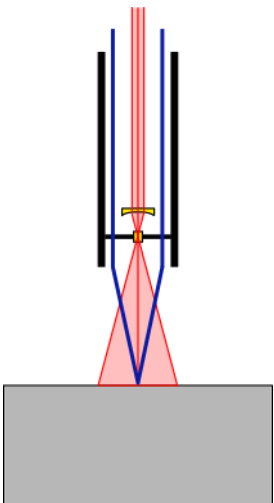


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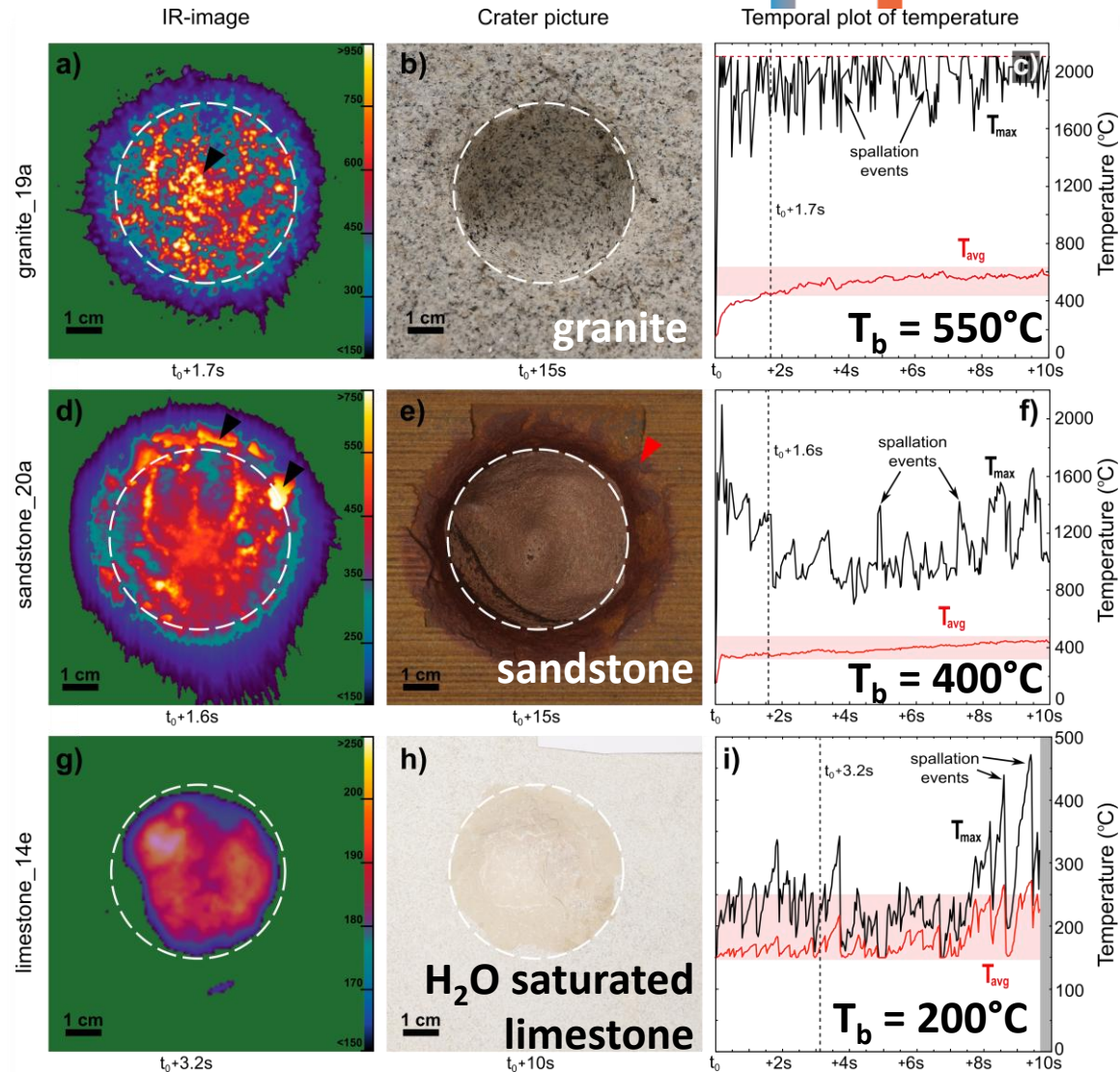
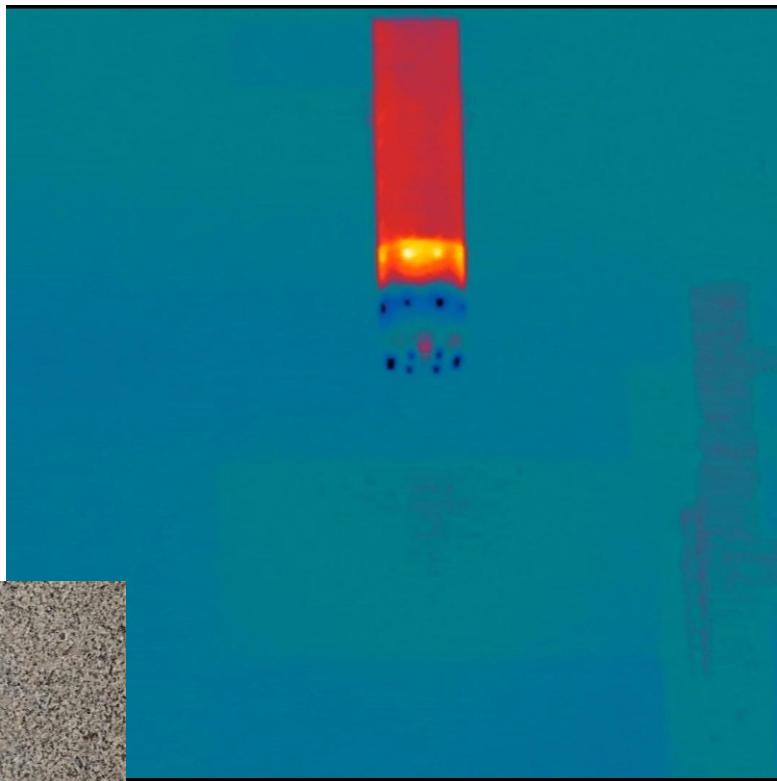
Thermal spallation laser drilling

DeepU laser system

- divergent beam
- N₂ flushing system



IR-record of DeepU laser thermal spallation





Take home message

- Drilling rocks with a laser is possible
- Laser-induced **thermal spallation is the most efficient** rock penetration process
- Laser-induced melting-vaporization require much more energy but **create a vitrified layer** on the rock surface
- **First** thermal spallation laser drilling system (DeepU) was successfully tested at laboratory scale



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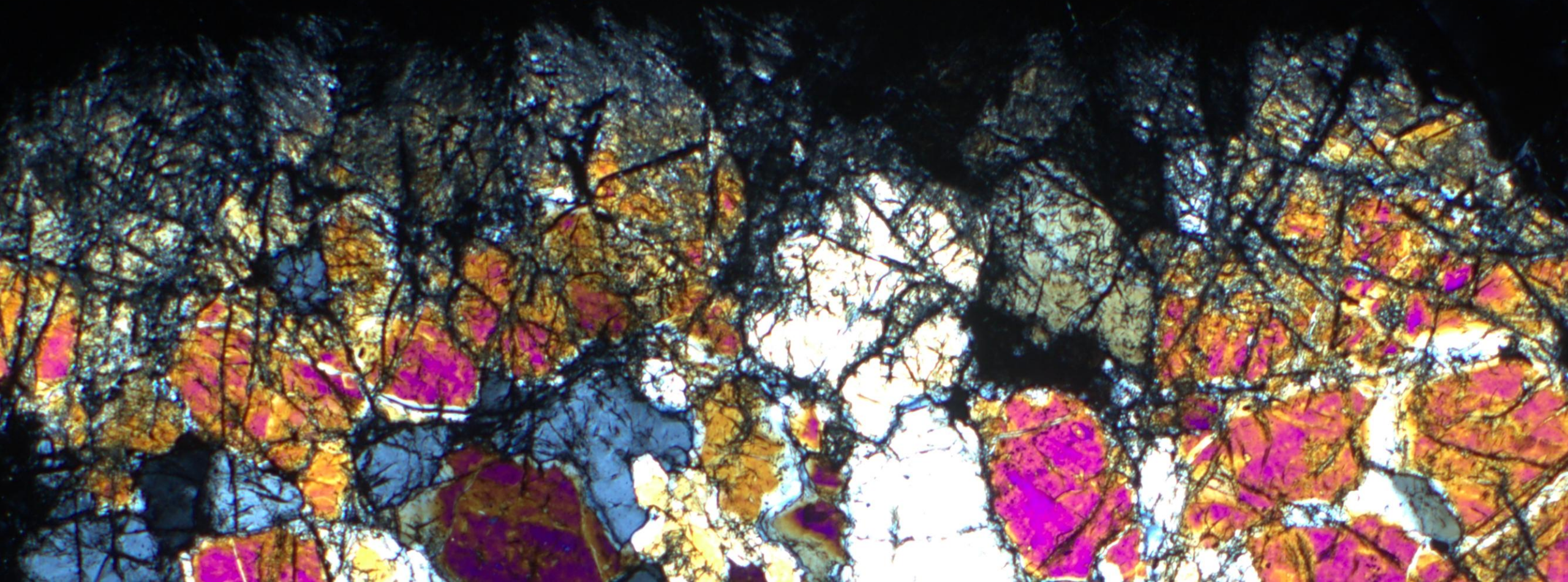


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pawelmichal.slupski@unipd.it

www.deepu.eu

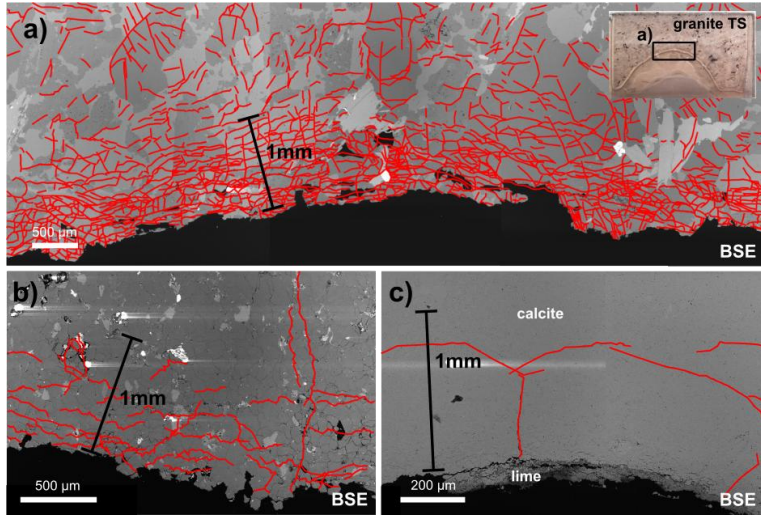
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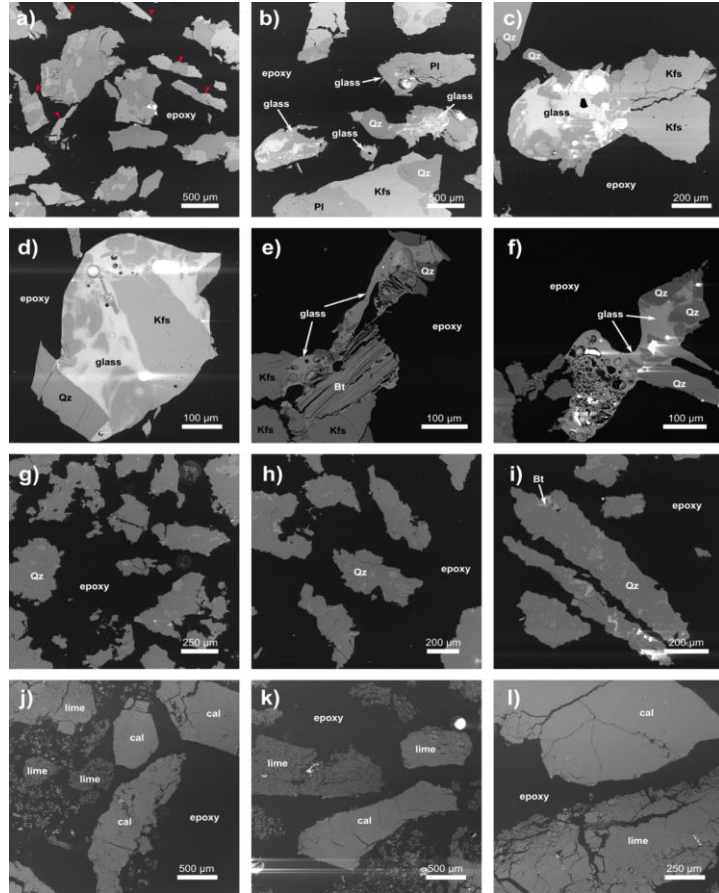


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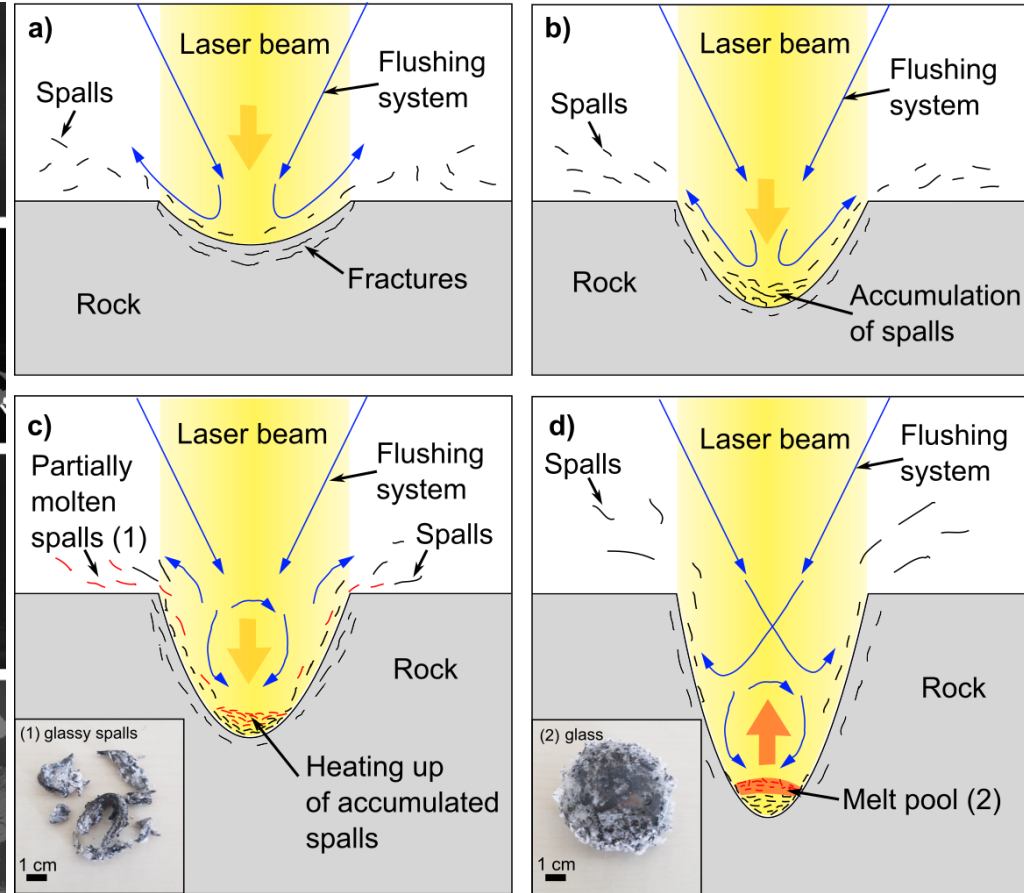
Thermal spallation laser drilling



Crater wall BSE images



Spalls BSE images



Penetration by thermal spallation