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

Drilling geothermal wells with laser: Sci-Fi or new reality?

Slupski P. (1), Cerwenka G. (2), Chorowski M. (3), Di Sipio E. (1), Galgaro A. (1), Mallin K. (4), Manzella A. (5), Pasquali R. (4), Romanowski A. (6), Sassi R. (1), Steinmeier O. (2), Pockele L. (7),

(1) Department of Geosciences, UNIPD, Padova, Italy, (2) Fraunhofer IAPT, Hamburg, Germany, (3) Department of Cryogenics and Aviation Engineering, WUST, Wroclaw, Poland, (4) TERRA GEOSERV LIMITED, Ireland, (5) Istituto di Geoscienze e Georisorse, CNR, Pisa, Italy, (6) PREVENT GMBH, Viersen, Germany(7), R.E.D. SRL, Padova, Italy

Introduction

1. Why drill with a laser?

The potential of geothermal resources is currently constrained by existing drilling technology. To address this issue, **the DeepU Project is investigating the application of laser and cryogenic gas for drilling deep wells** (>4 km) to realise a U-shaped closed-loop geothermal heat exchanger.

Laser drilling offers a promising solution by enhancing efficiency and reducing well completion costs. Two drilling rock removal mechanisms were distinguished by Mauer (1980). **Thermal spallation** (Fig. 1a) and **melting-vaporization** (Fig. 1b).

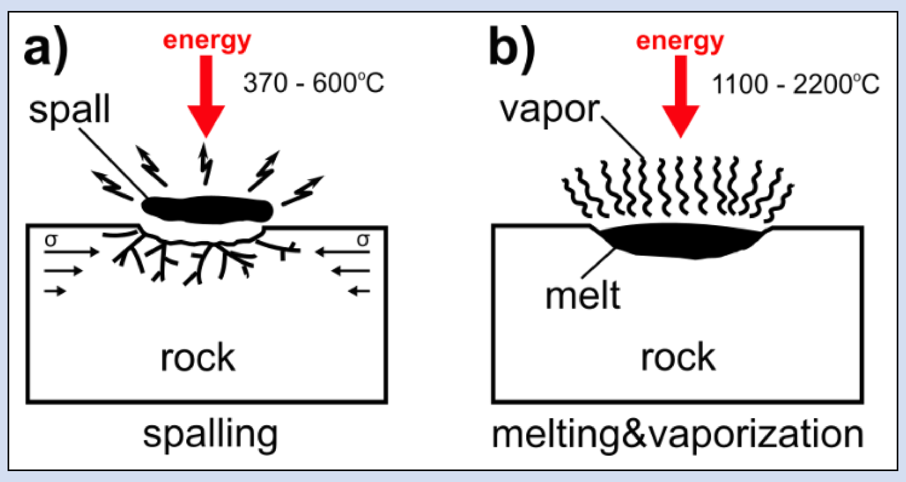


Fig. 1 Classification of non-contact drilling mechanism, modified after Mauer 1980. Thermal spallation drilling (a), and melting-vaporization drilling (b)

2. Laser drilling experiments

Two types of laboratory-scale laser drilling experiments were performed on granite, sandstone, limestone and basalt.

1) Preliminary laser tests performed on 5 cm cubes, beam diameter 1-10 mm, power 200-12500 W, shown in Fig. 2a

2) DeepU drill head tests performed on rock slabs 50x35x15cm, beam diameter 5-20cm, power 6-30 kW, with N_2 as a flushing medium, shown in Fig. 2b.

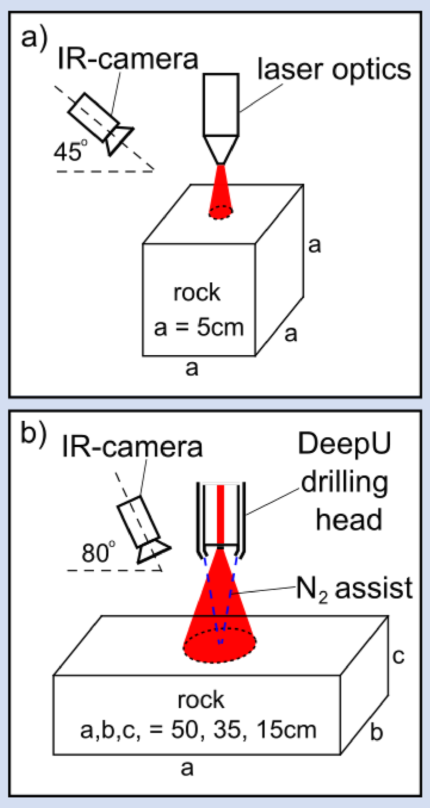


Fig. 2 Schematic drawings showing two experimental setups; preliminary laser tests (a), DeepU drill head tests (b)

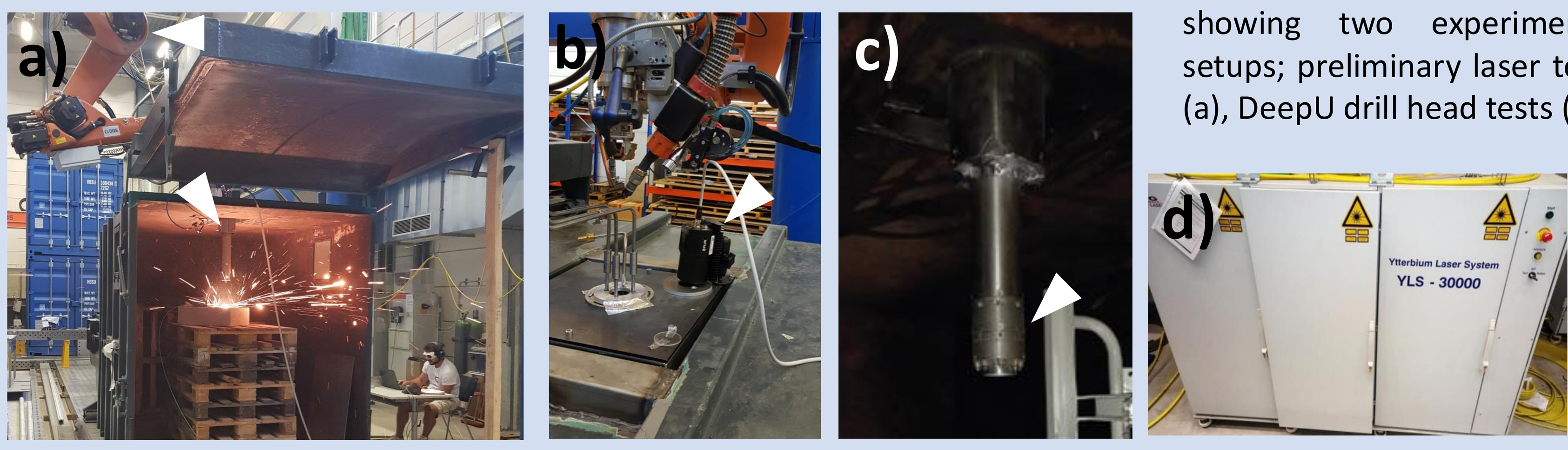


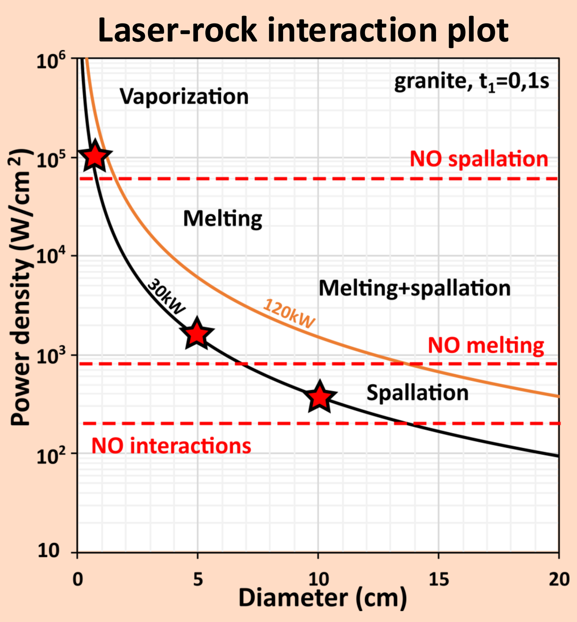
Fig. 3 Pictures of laboratory (a), IR camera (b), laser drilling head (c), and 30kW fibre laser (d).

Results

3. Laser-rock interactions

Image analysis of preliminary laser tests (Fig. 4) shows the occurrence of:

- **spallation (S),**
- **melting (M),**
- **vaporization (V)**



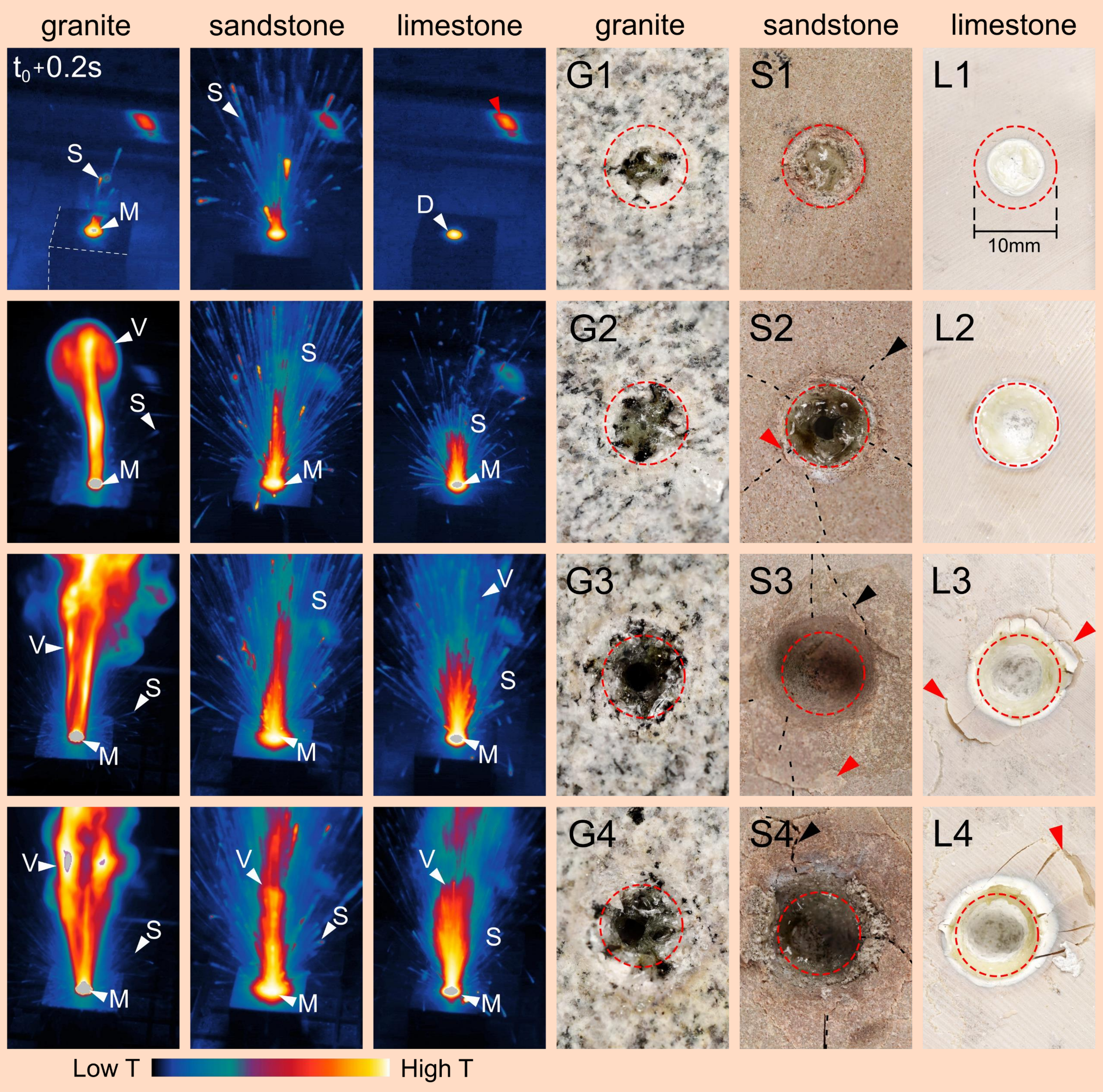


Fig. 4 IR images and craters formed during preliminary laser tests.

4. Thermal Spallation Laser Drilling

Thermal **spallation** is the most efficient rock removal process (Fig. 5).

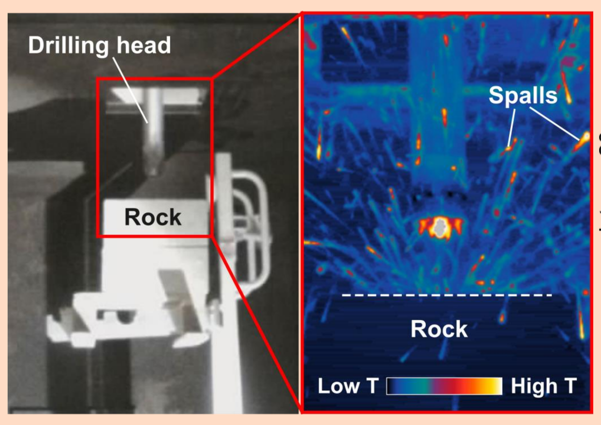


Fig. 5 Thermal spallation drilling in DeepU drill head test and IR image of the process.

The avg. temperature of spallation was measured for **granite, sandstone,** basalt and limestone and it was **550°C,** **400**°C, >1400°C, and >1100°C, respectively.

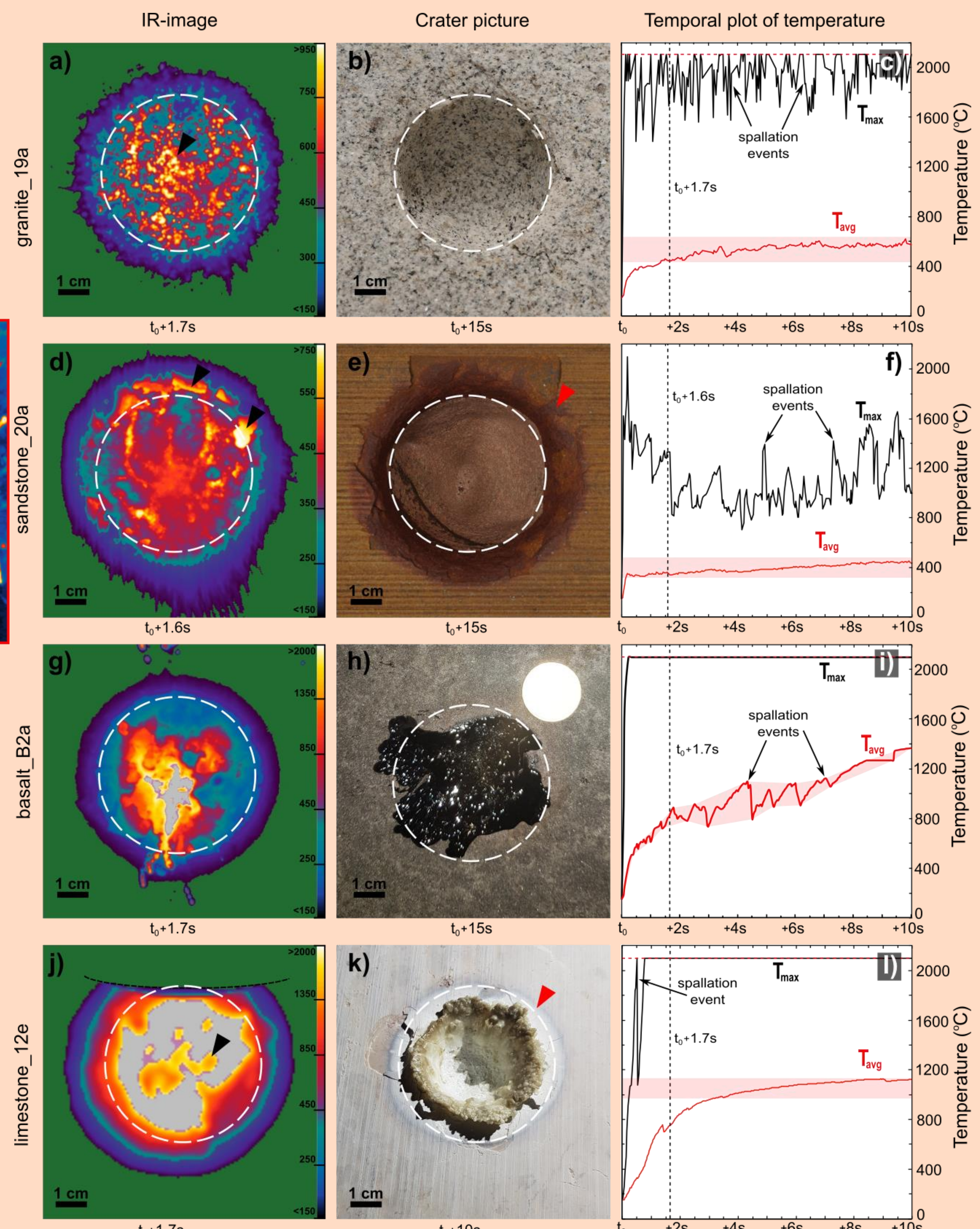


Fig. 6 IR images, pictures of craters, and records of temperature from DeepU drill head tests for granite (a-c), sandstone (d-f), basalt (g-i), and limestone (j-l).

5. Vitrification

Vitrification has been archived where the beam diameter was <10mm, and laser drilling occurred in the melting-vaporization regime. **The vitrified layer has 1-5 mm of thickness and it is composed of homogenous glass and partially molten minerals** (see Fig. 7).

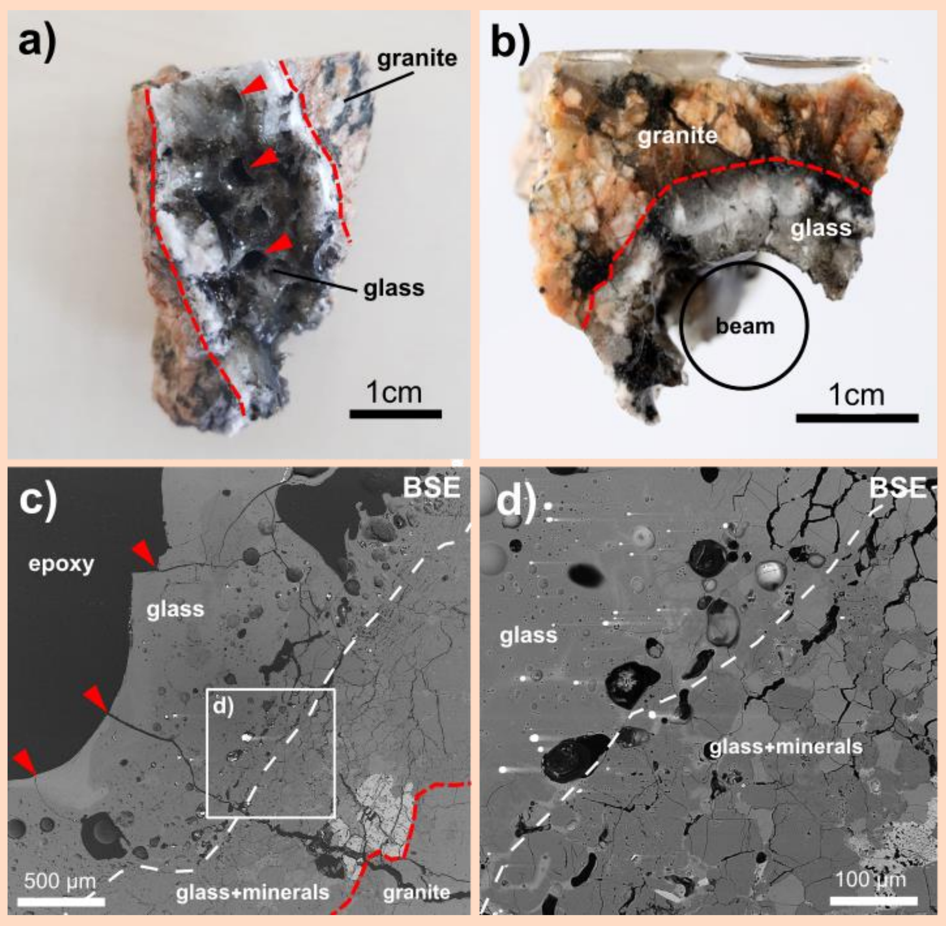


Fig. 7 Images of borehole drilled in granite with vitrified layer (a, b), and BSE images showing glass and partially molten minerals on the borehole wall (c, d).

6. Laser induced damage

Laser-induced damage was studied by proxy, measuring Vp and thermal conductivity up to 6cm and has not shown any change in the rock. Electron microscope images (BSE) show the borehole's edge with **fractures reaching 1 mm deep into the rock** in all studied lithologies (see Fig. 8).

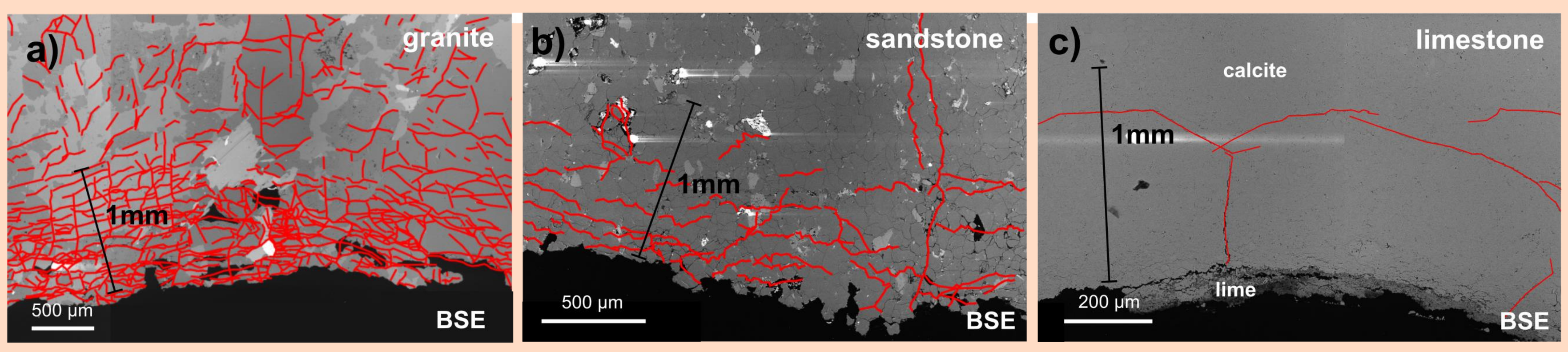


Fig. 8 BSE images showing fractures in borehole wall induced by thermal spallation for granite (a), sandstone (b), and limestone (c).

Conclusions

7. Summary

The laser-induced thermal spallation might revolutionize the drilling operations, as the archived ROP was up to 25m/h. The DeepU drilling concepts are shown in Fig. 9

Tab. 1 Summary of laser drilling experiments at 26kW, 5 ⌀cm, N_2 flux. # - H_2O saturated sample.

Lithology	ROP (m/h)	SE (kJ/cm³)
granite	10,0	5,6
sandstone	14,8	4,1
limestone	2,5	86,7
limestone#	4,5	16,3
sandstone#	25,1	2,3

Thermally spalled boreholes

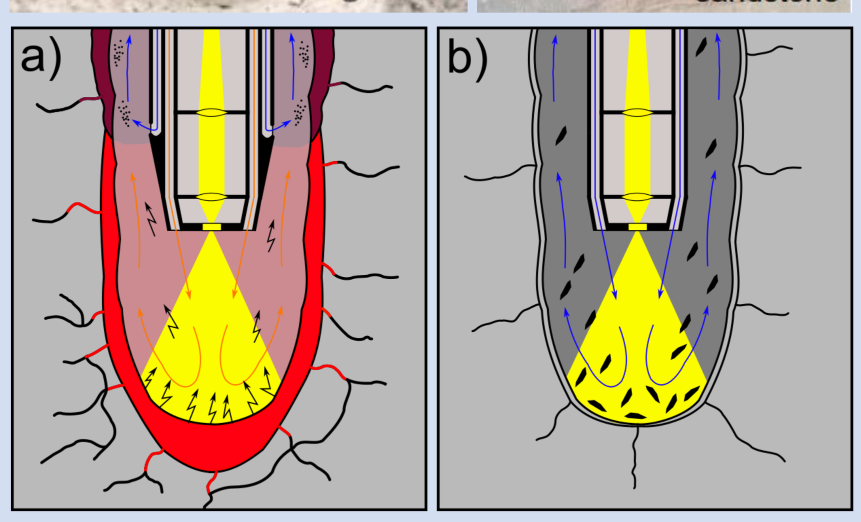


Fig. 9 DeepU drilling concepts for melting-vaporization (a), and thermal spallation (b).

Visit our website! www.DeepU.eu

This research is funded by the European Union (G.A. 101046937). However, the views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or EISMEA. Neither the European Union nor the granting authority can be held responsible for them.