A new setup for studying thermal microcracking through acoustic emission monitoring

L.Griffiths*, M.J. Heap, P. Baud, J. Schmittbuhl, IPG Strasbourg

This presentation participates in OSPP

Outstanding Student Poster & PICO Contest

1. Studying thermal microcracking; why and how.

Thermal microcracks are common in nature and can affect the physical properties of rock, including elastic moduli, ultrasonic velocities, permeability, attenuation and strength (ex. Jones et al., 1997; David et al., 1999; Reuschlé et al., 2003; Vinciguerra et al., 2005; Heap et al. 2013). The mechanics involved may also be analogous to fractured rock at a larger scale i.e. the thermal stressing through heating and cooling of rock in a geothermal reservoir.

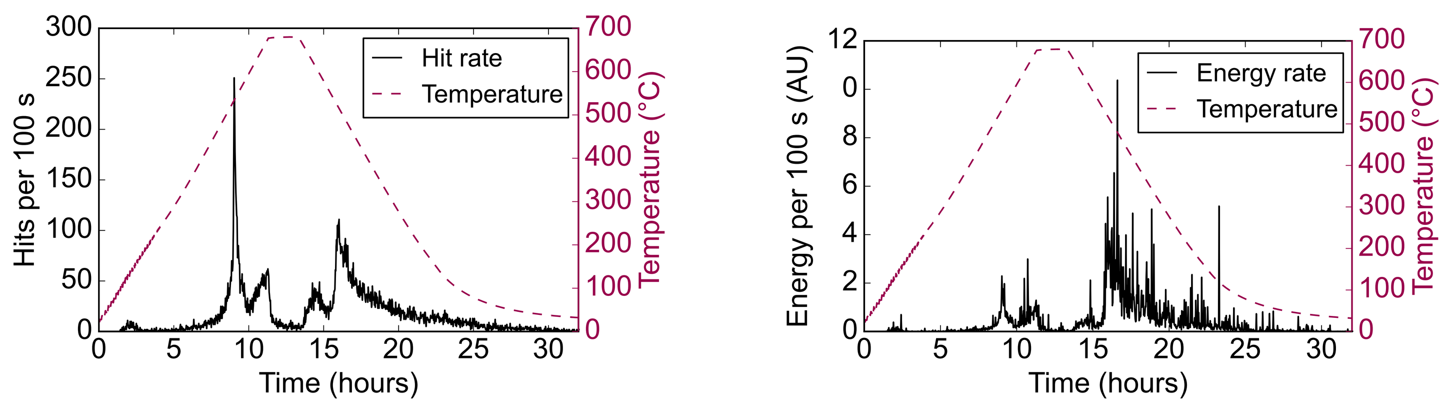
Thermal microcracks form as a result of thermal stresses due to:

- Thermal expansion **mismatch** between the different phases present in the material.
- Thermal expansion **anisotropy** within individual minerals.
- Thermal **gradients** across minerals.

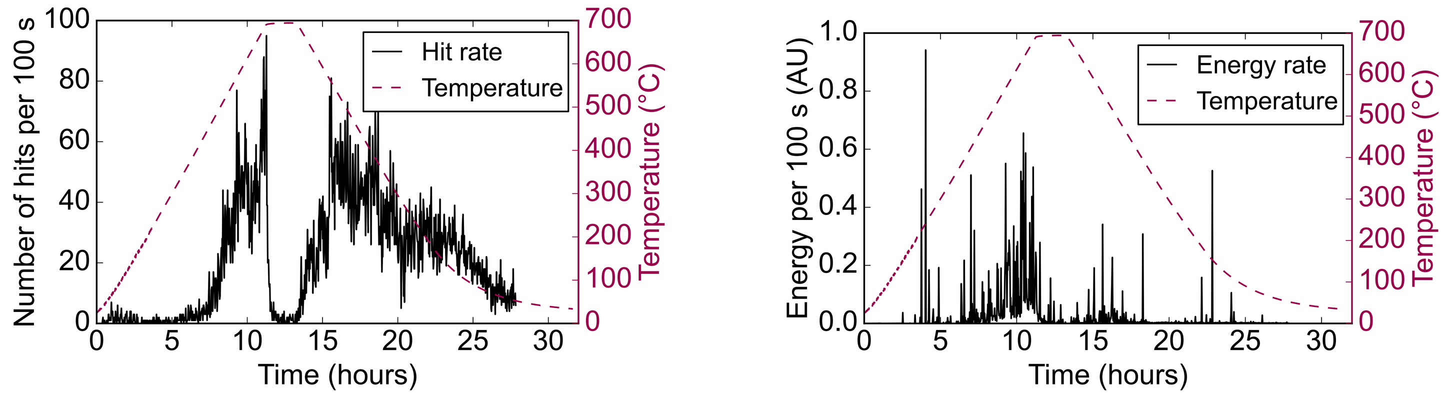
Previous laboratory studies have used acoustic emissions (AE) as a proxy for microcrack damage. AE are the elastic waves which are released as the material cracks and breaks. Here we present a new experimental setup which has been optimised to record AE from a thermally and mechanically stressed rock. We then show preliminary results of thermal stressing experiments on Darley Dale sandstone and Westerly granite.

4. Examples of acoustic emission data.

Westerly granite heated to 700 °C at 1 °C/min and 1 MPa constant uniaxial load (servo-controlled). The AE hit rate increases with temperature from around 100 °C with a sharp rise at the quartz alpha-beta transition (~573 °C). Most of the recorded acoustic energy is released during cooling.



Darley Dale sandstone heated to 700 °C at 1 °C/min and 1 MPa constant uniaxial load (servo-controlled). The hit rate increases with temperature from around 100 °C. The quartz alpha-beta transition (~573 °C) sees an increase in the hit rate. Most of the recorded acoustic energy is released during heating.

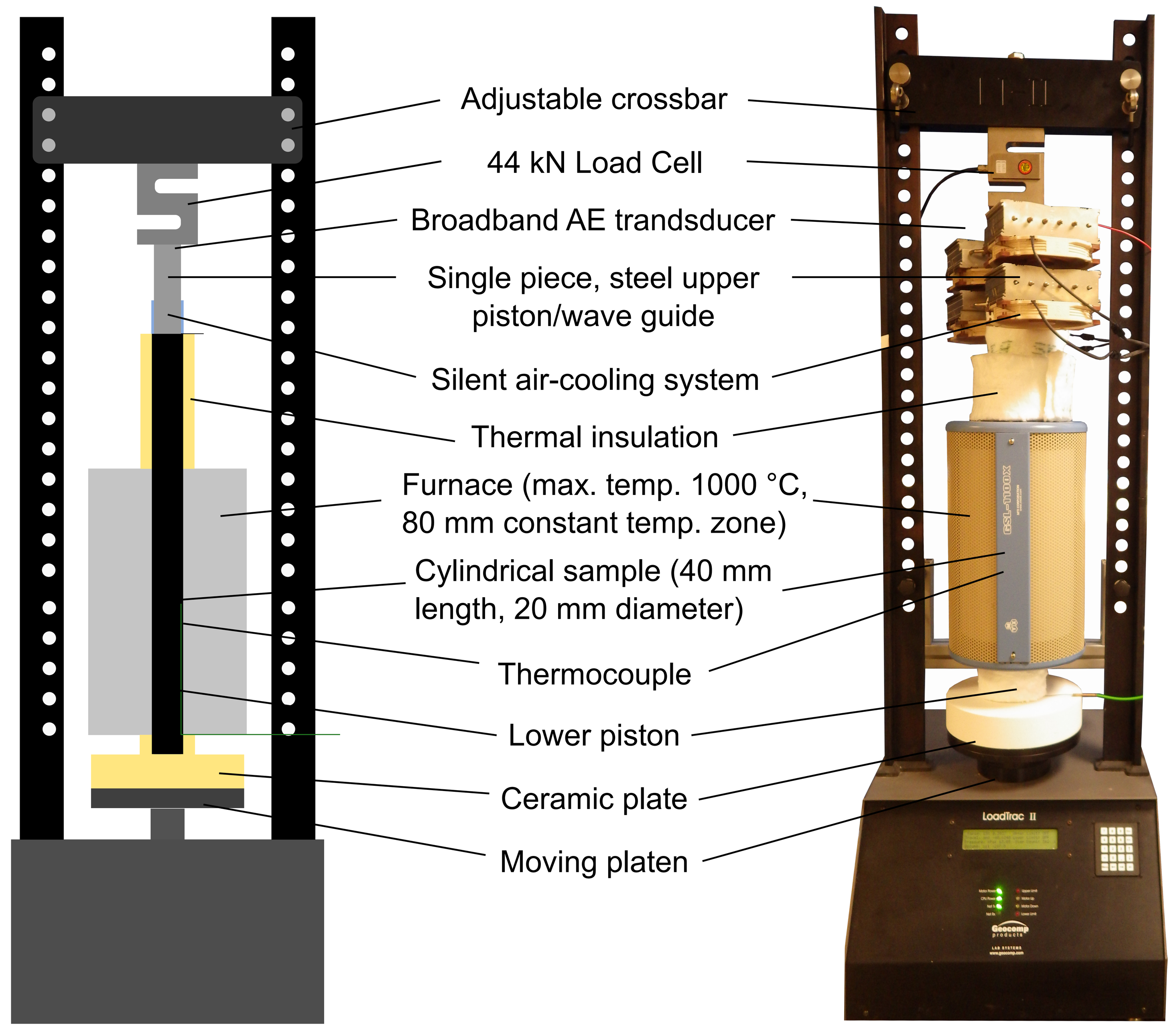


5. Effect of thermal stressing on rock physical properties.

	Pre-heating		Post 700°C	
Darley Dale Sandstone				
Porosity		15.1 %		16.9 %
P-wave velocity		3.0 km/s		1.8 km/s
Westerly Granite				
Porosity		1.0 %		3.4 %
P-wave velocity		4.9 km/s		1.7 km/s

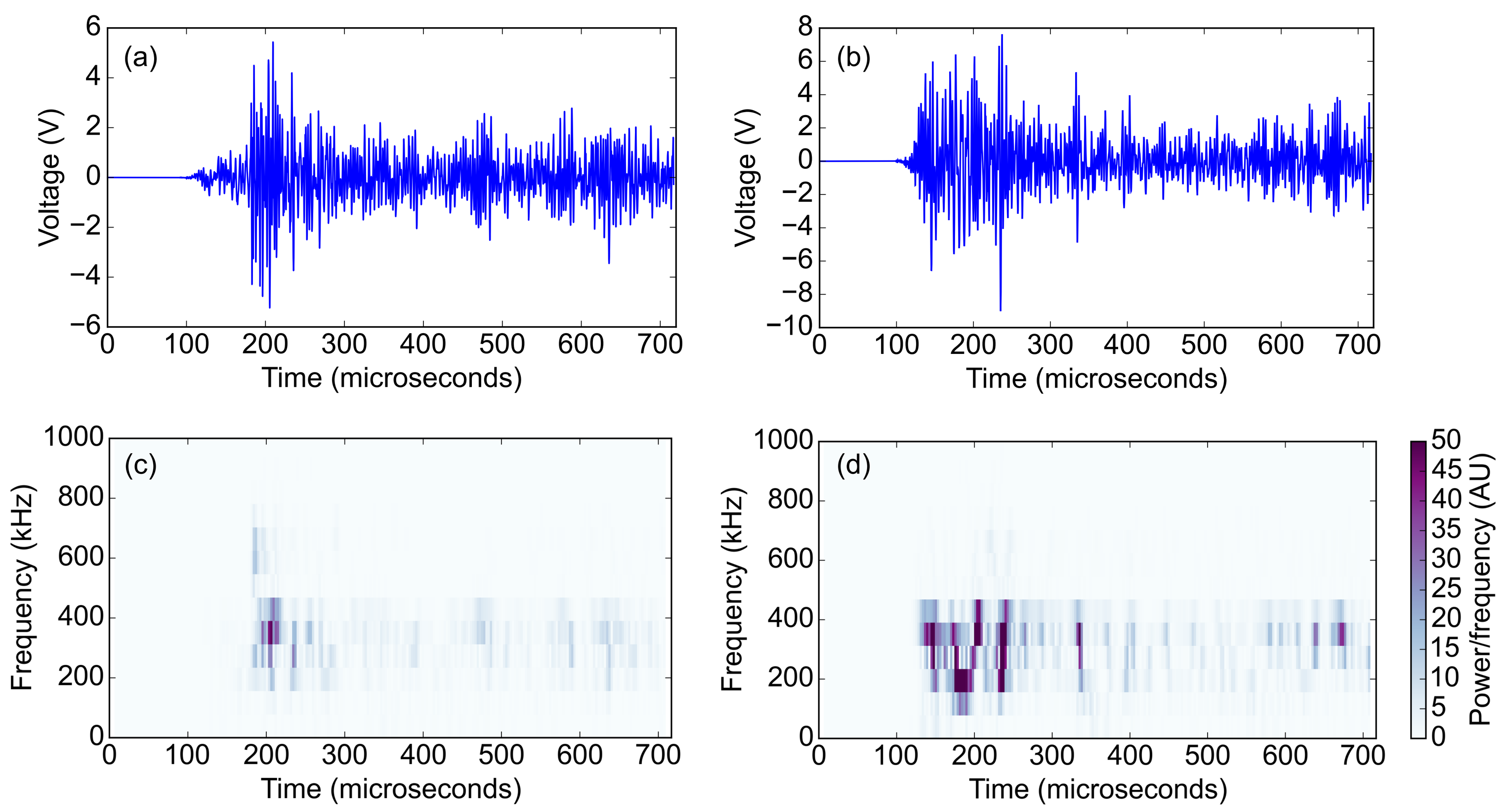
Thermal stressing causes microcracks to form which contribute to the connected porosity and have a strong negative effect on acoustic wave velocities (left, samples to scale).

2. Overview of the experimental setup.



6. Transducer location and recorded waveforms.

To test the choice of embedding the trandsucer inside the piston, a Hsu-Nielson source (lead break) at the sample was recorded simultaneously by two identical AE sensors. One (a) was attached to the side of the upper piston at the same level as the the second transducer (b) which was embedded in the piston as in (3).



The signals (a), (b) and their corresponding frequency spectograms (c) and (d) show how the first arrivals are recorded with a higher amplitude and broader spectrum when the AE transducer is within the waveguide.

3. Optimisation for acoustic emission acquisition.

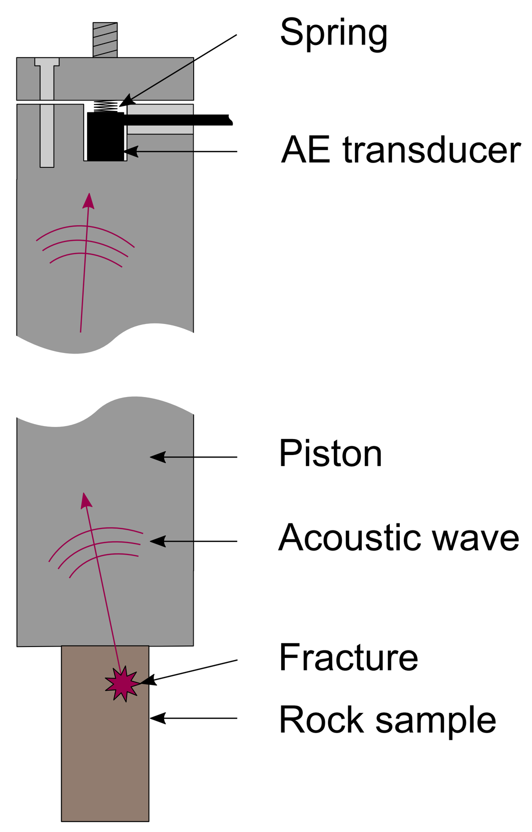
Various steps were taken to maximise the quality of the recorded signal :

- The piston acts as a **continuous waveguide** made from a single piece of heat resistant stainless steel. This means there is very little attentuation in the recorded signal at the top of the piston.

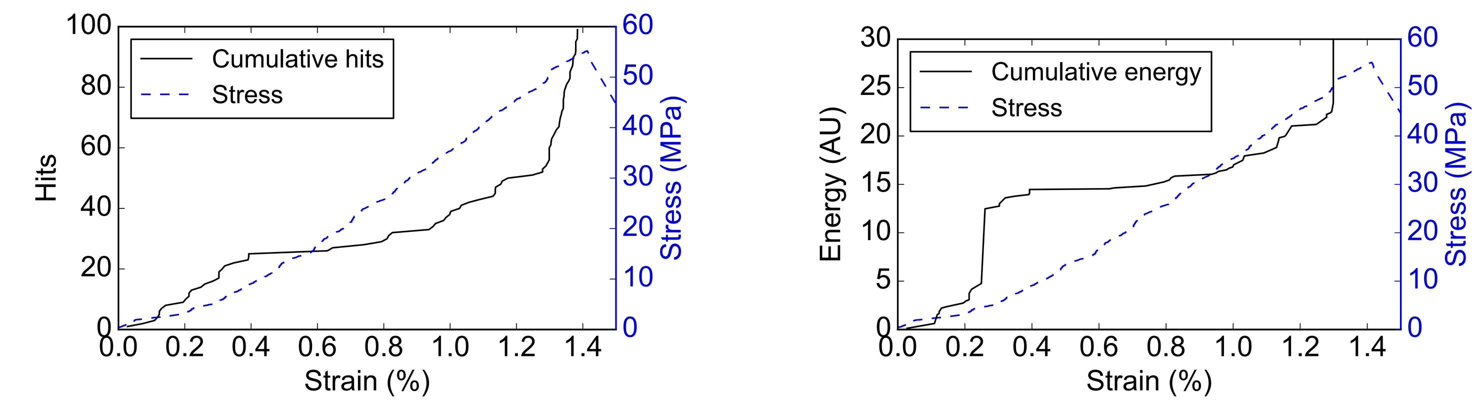
- The broadband AE transducer is **embedded in the piston** and coupling is assured by a spring and gel couplant.

- The piston is air-cooled by two dual heatsinks, each equipped with two **silent, high-airflow fans**. The heat flow from the piston to the fins is assured by heatpipes.

- The AE transducer remains at temperatures of around 30 °C during a test, **avoiding any thermal effects on the piezoceramic** which could otherwise be dramatic.



7. Uniaxial deformation.



These graphs show the results of AE monitoring of a uniaxial test at room temperature on Darley Dale sandstone and are presented to underline the wide spectrum of possible tests combining mechanical and thermal stress with this setup.

8. Conclusion.

This apparatus was designed for the AE monitoring of thermally and mechanically stressed geomaterials. The results presented here show AE activity during heating and cooling in two rock types. Future efforts will be concentrated on the analysis of the recorderd waveforms themselves to try and understand their source mechanisms.

9. Acknowledgements.

This work has been published under the framework of LABEX grant ANR-11-LABX-0050_G_EAU-THERMIE-PROFONDE and therefore benefits from state funding managed by the Agence National de la Recherche (ANR) as part of the "Investissements d'avenir" program. It is also part of the ANR CANTARE project "Transformations et usages efficaces de l'énergie".

Université de Strasbourg · Ecole et Observatoire des Sciences de la Terre · IPGS · LABEX G-Eau-Thermie Profonde

Institut de Physique de Globe de Strasbourg, Université de Strasbourg/EOST, CNRS UMR 7516, France. *Luke Griffiths : luke.griffiths@unistra.fr