SCCER SoE

SWISS COMPETENCE CENTER for ENERGY RESEARCH
SUPPLY of ELECTRICITY

Rocks, water, and heat: 50 years of research at the center for hydrogeology and geothermics at UniNE

Stephen A. Miller
11/09/2015

unine
UNIVERSITÉ DE NEUCHÂTEL

In cooperation with the CTI

Energy funding programme
Swiss Competence Centers for Energy Research

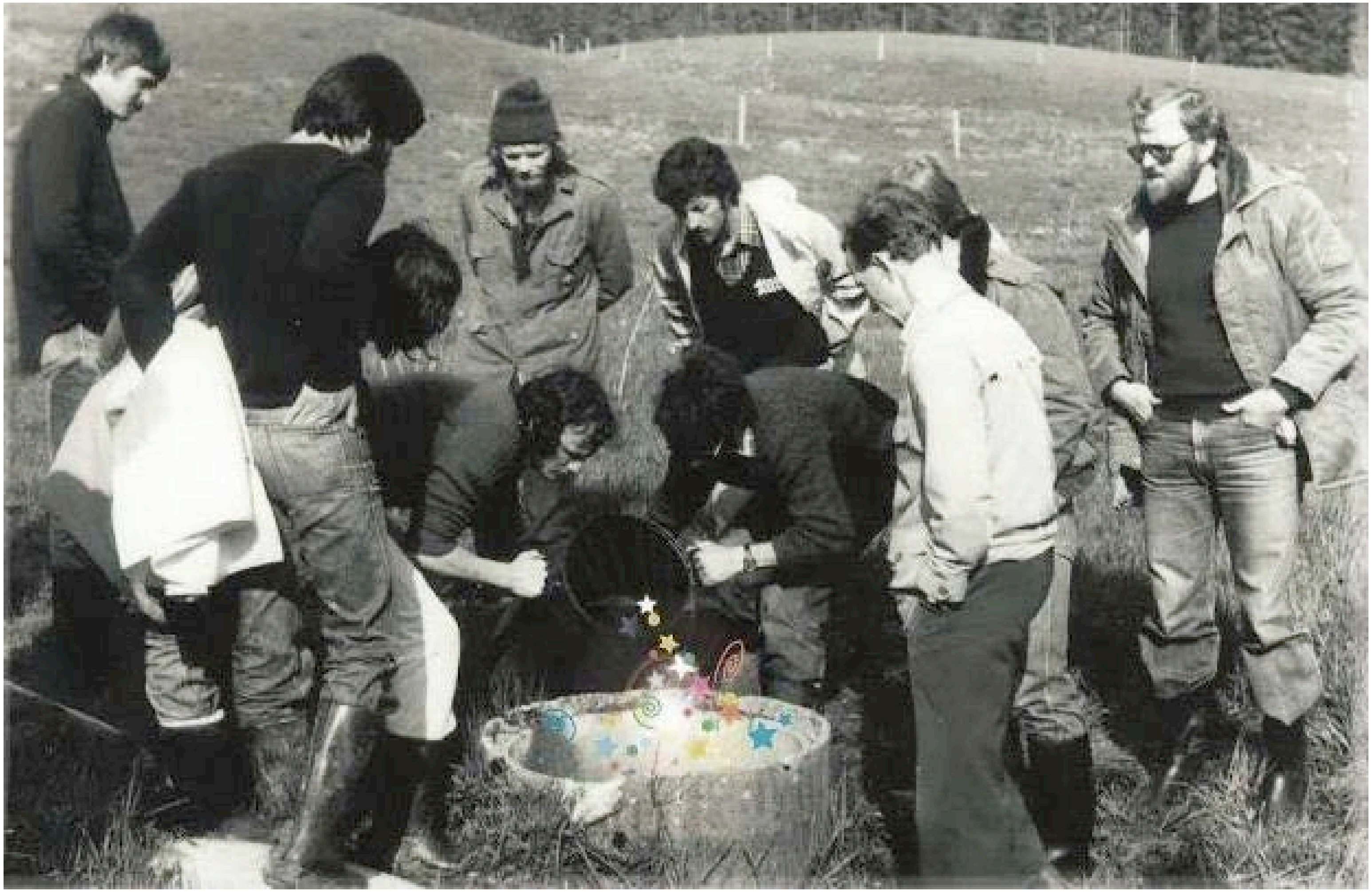
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Commission for Technology and Innovation CTI

A Brief History of CHYN

1965 : Creation of the Centre for hydrogeology – CHYN.



SCCER SoE

1978-1990 : First geothermal exploration projects, expertise on hydrothermal fluids for spas.

1990 - 2004 : Geothermal Group at the CHYN (Dr. F.-D. Vuataz with MSc and PhD students): various studies on hydrogeology and geochemistry of deep fluids.

2004 - 2009 : Creation of the Centre for Geothermal Research - CREGE, association working as a competence centre. This Swiss network of over 60 institutions (private & public) had a core team of 5 persons based at the CHYN.

2009 : Creation of a chair in geothermics at the CHYN and nomination of Prof. E. Schill. Since then, the CHYN is called Centre for Hydrogeology and Geothermics.

2010 : Creation of the Laboratory for Geothermics, c/o CHYN with 10-12 collaborators.

2011 - 2112 : 1st edition of the CAS DEGEOSYS

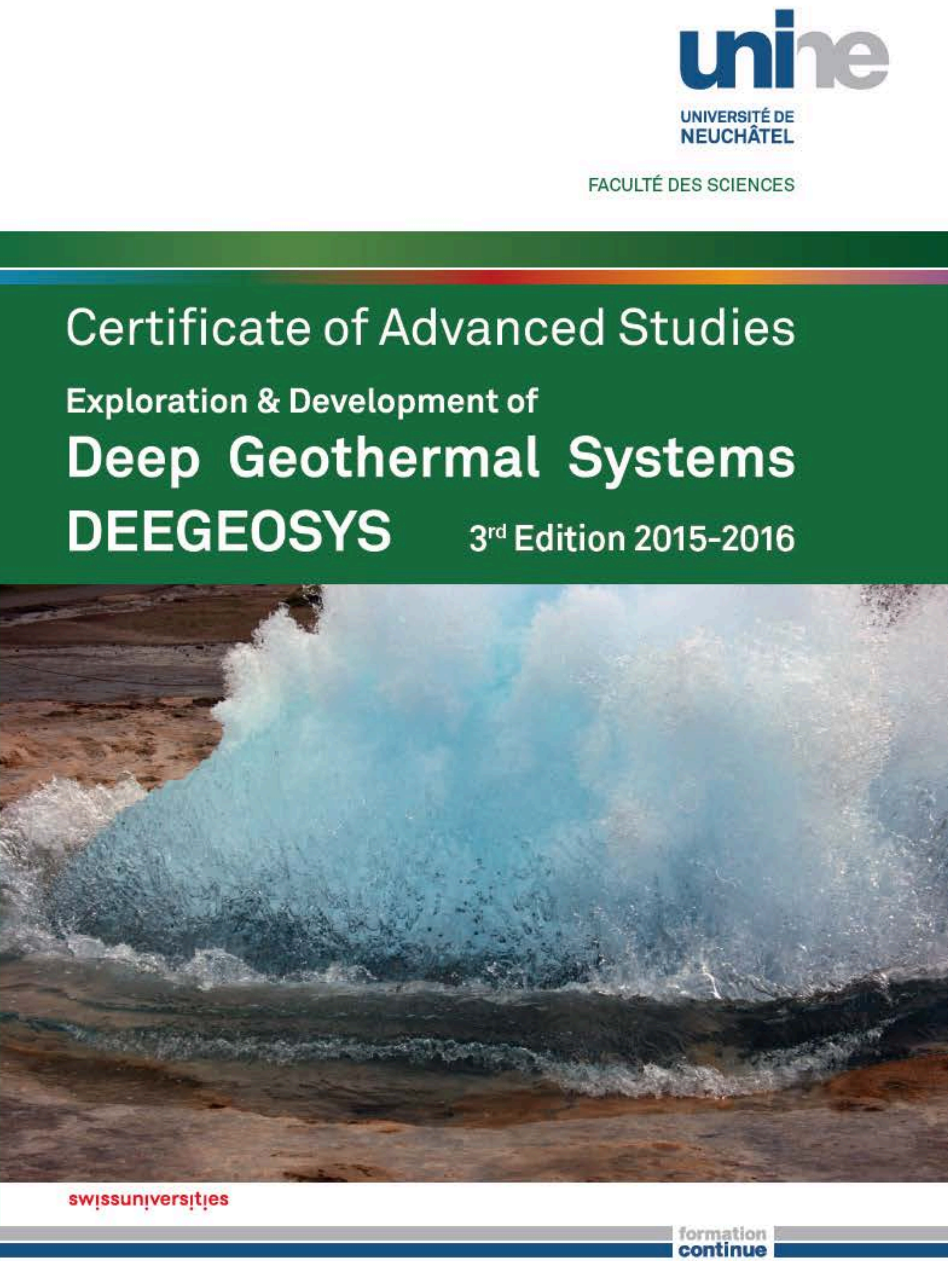
2013 - 2014 : 2nd ed. of the CAS DEEGEOSYS

2014 : Start of 2 new professors in Geothermics: **Steve Miller** and **Benoît Valley**

2015 : 3rd ed. of the CAS DEEGEOSYS, and … 50th anniversary of the CHYN !

SCCER SoE

Education and Outreach



That was then....and this is now
Activities of Geothermics Group at CHYN

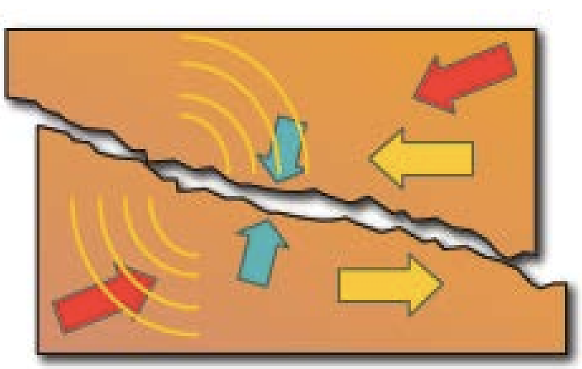
SCCER SoE

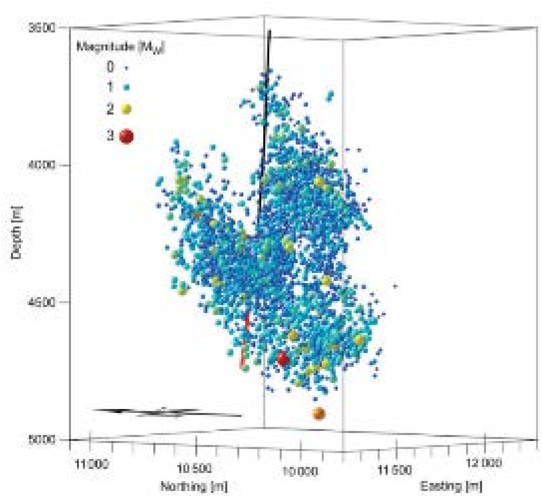
- Contributions to DUG Laboratory
- Collaborations with Mont Terri
- Eclépens (joint with UniFR): La Sarraz natural laboratory
- Gravity/magnetotelluric surveys (with Bundesamt für Energie)
- High Performance Computing (HPC) of THMC systems
- The newborn Lusi (Indonesia) hydrothermal system

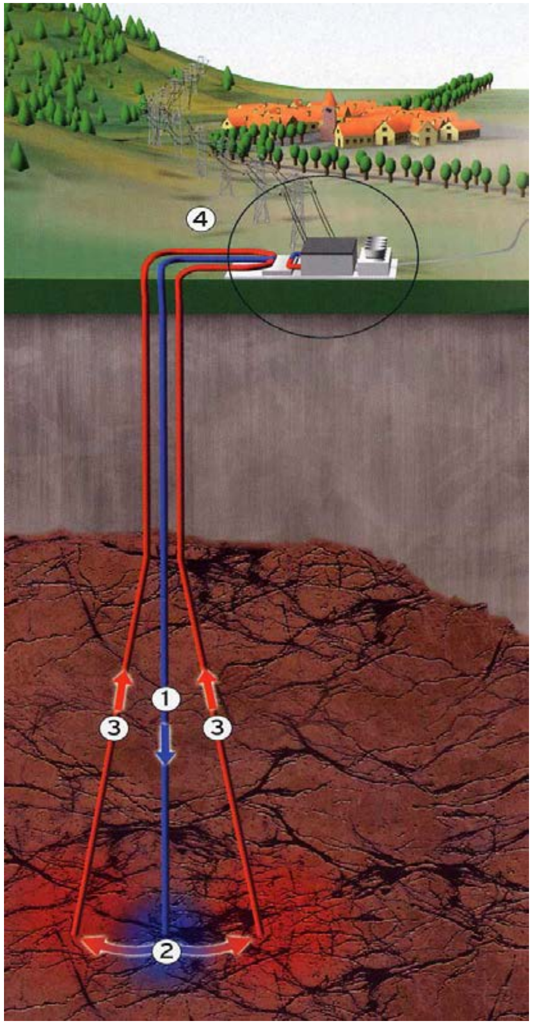
Key challenge: engineering the reservoir

- Create a sustainable heat exchanger at
- operate for 20-40 years with no or minimal loss in flow temperature and in efficiency.
- New approaches are required to enhance rock permeability, with optimal distribution of micro-cracks and porosity to maximize heat exchange and water circulation.

Requires improved understanding THMC processes at play during reservoir developement and exploitation.



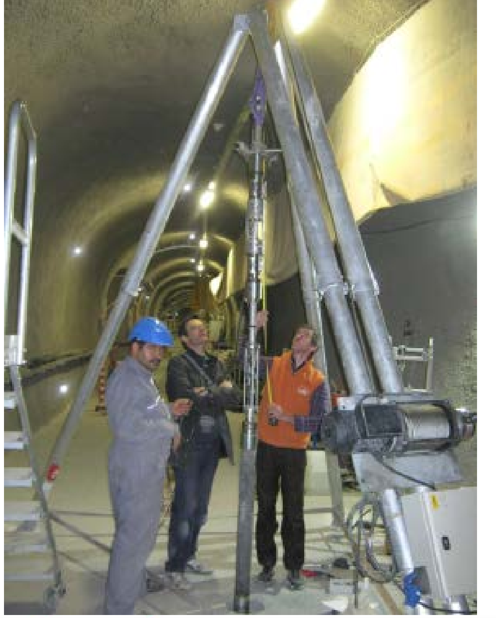


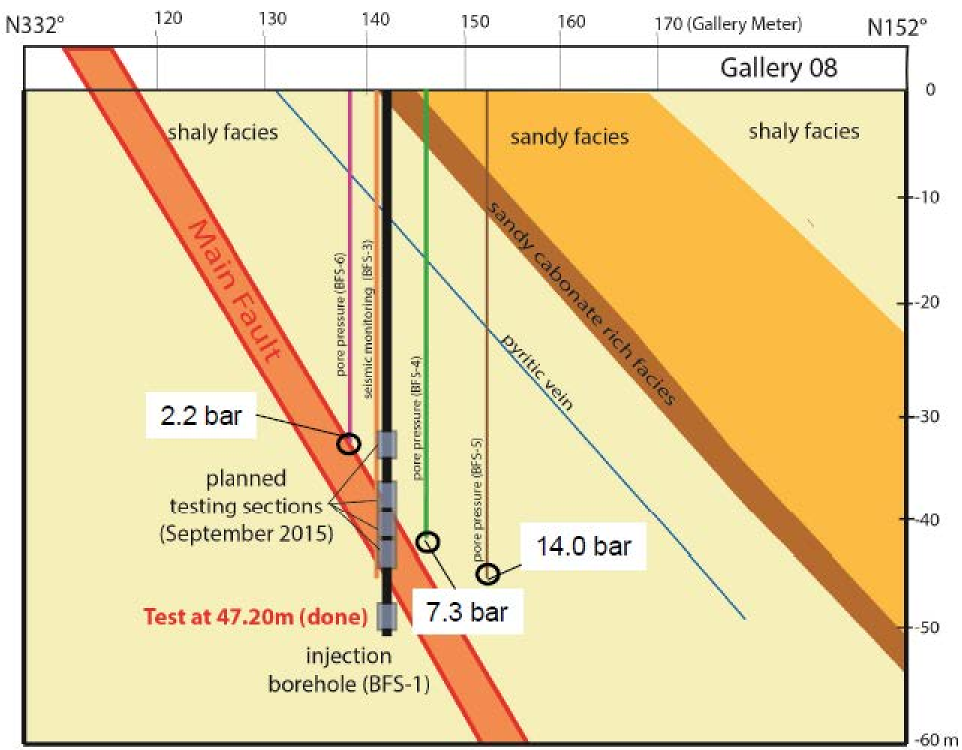


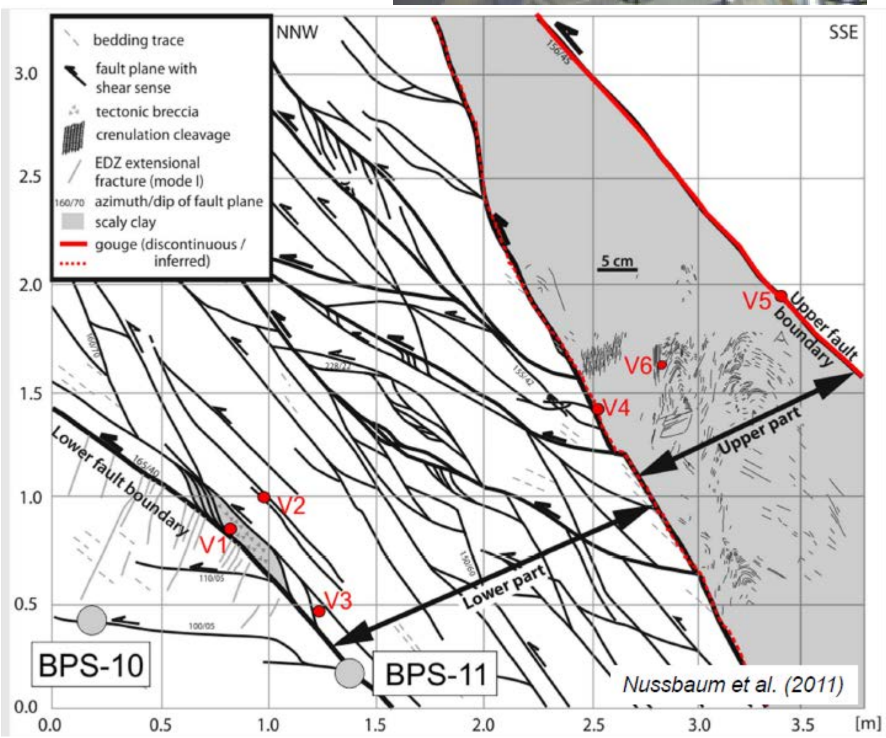
Mont-Terri FS experiment

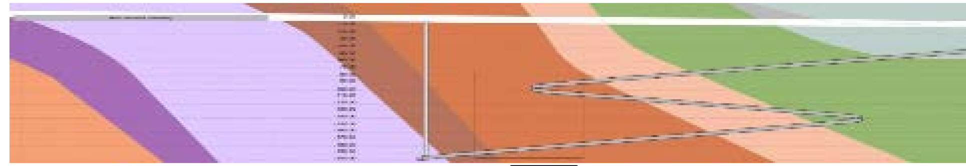
Objectives: understand effective stress change impact on fault stability in a clay shale formation

Status: First test made in June, 2015. Additional experiments planned for October, 2015. One PhD in CHYN-UniNe will be working on the project.



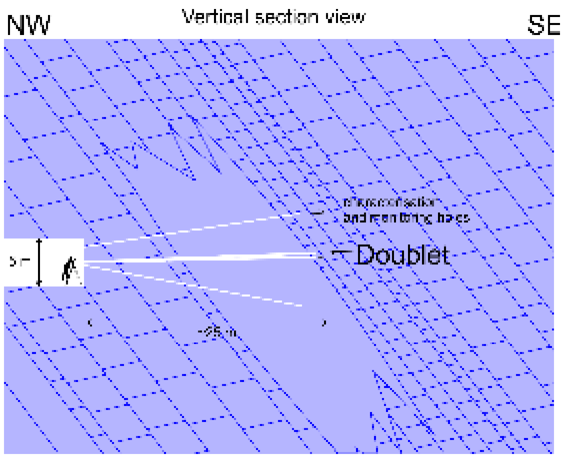




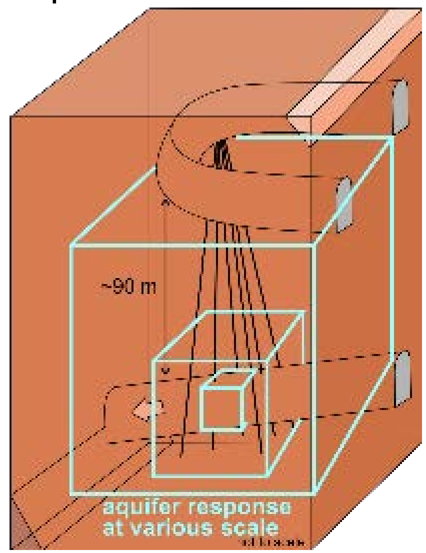


Mont-Terri next phases

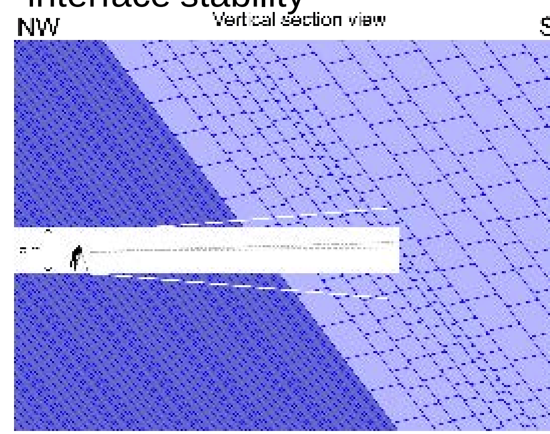
1 Decametric scale hydrodynamic, transport and heat exchange experiment in heterogeneous aquifer



2 Large scale flow pattern in heterogeneous limestone aquifers

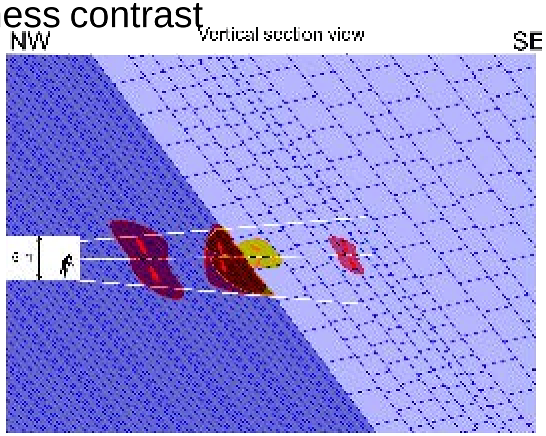


3 Impact of stiffness boundaries on the in-situ stress state in layered sequences and consequence for interface stability

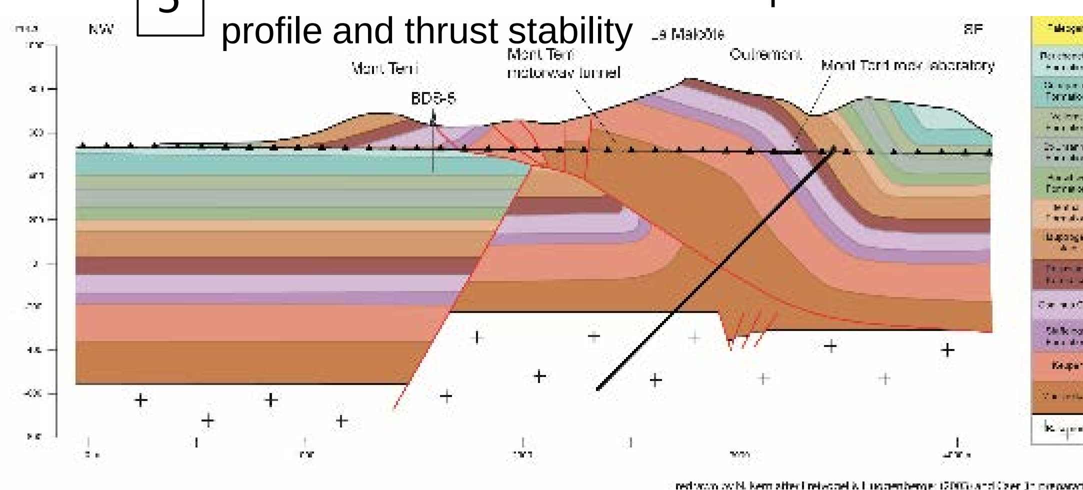


Propagation of hydraulic fracture across stiffness contrast interfaces

4

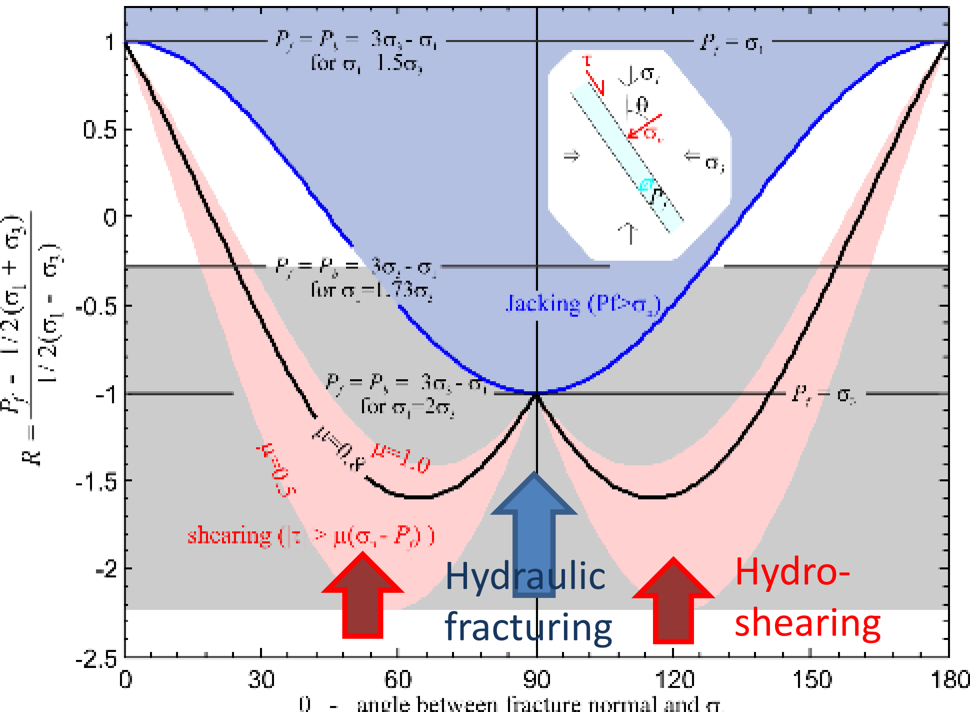


5 Multi-decollement level and its impact stress profile and thrust stability

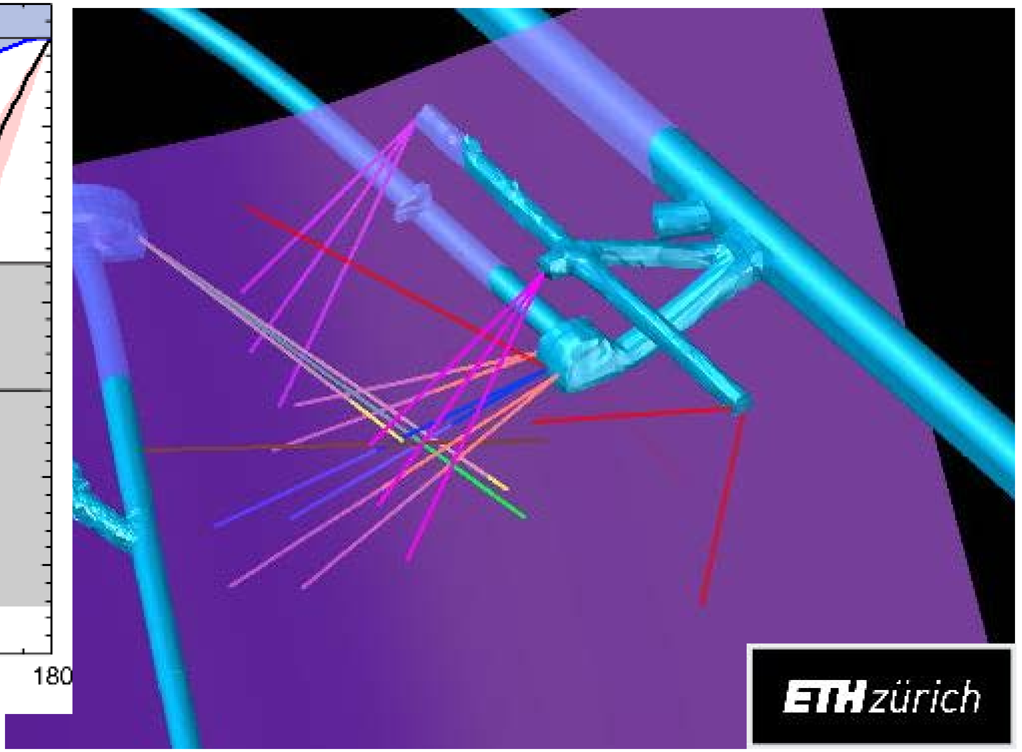


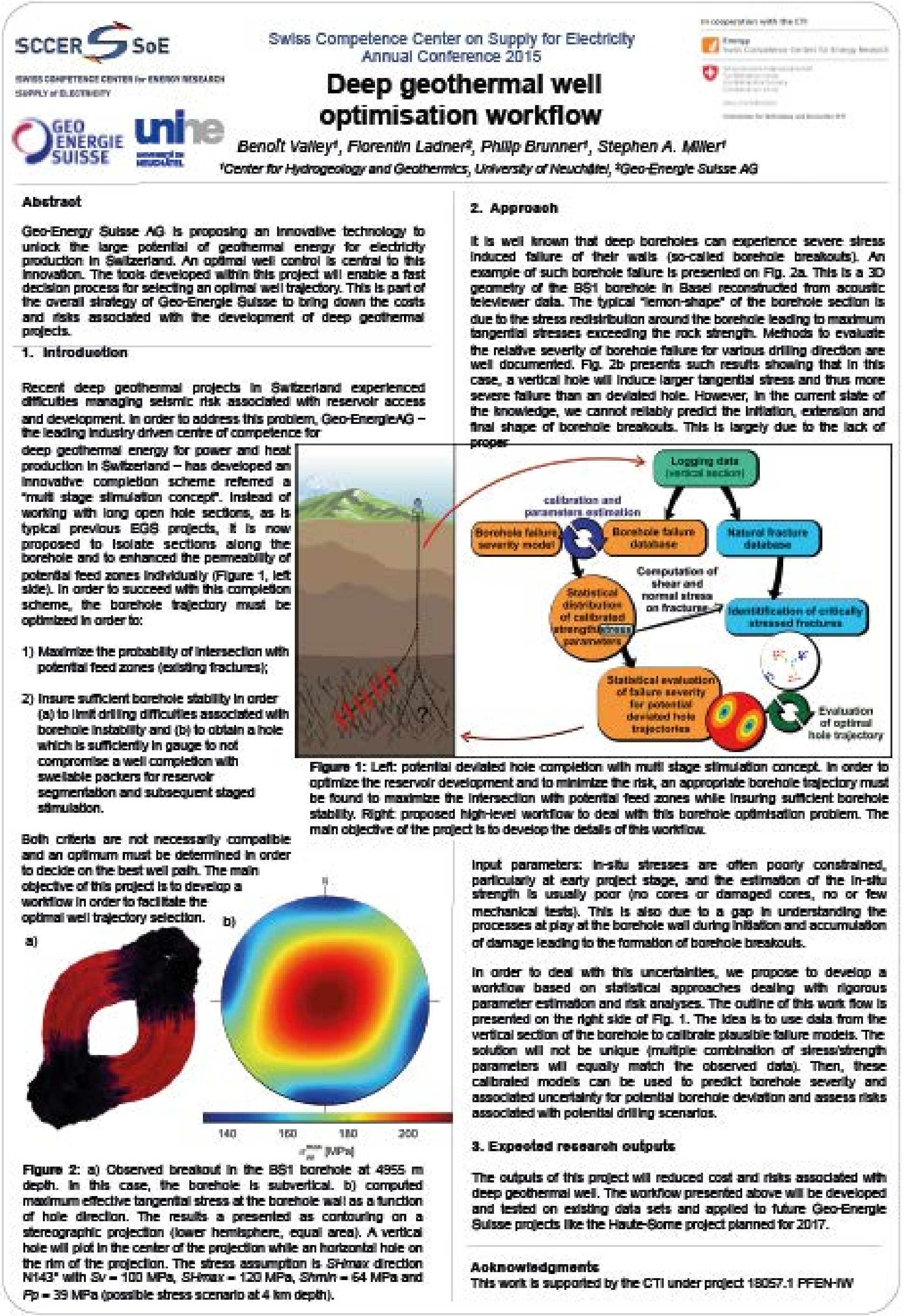
ISC – hydraulic fracturing plans

- Complementary experiment to the brittle shear zone stimulation experiment:
  - How far/efficiently can we propagate hydraulic fractures (mode I) in tough crystalline rock ?
  - How does injection metrics (flow rate, volume) influence hydraulic fracture propagation ?
  - What is the aperture history (during propagation, shut-in and bleed-off) of a propagated hydraulic fracture ?
  - What is the microseismic signature of a propagating hydraulic fracture ?
  - Can we estimate hydraulic fracture area using tracers ?
- …



(Kaiser et al., 2014, modified after Pine and Batchelor, 1984)





Swiss Competence Center on Supply for Electricity
Annual Conference 2015

Deep geothermal well optimisation workflow

Benoît Valley[1], Florentin Ladner[2], Philip Brunner[1], Stephen A. Miller[1]
[1]Center for Hydrogeology and Geothermics, University of Neuchâtel, [2]Geo-Energie Suisse AG

Abstract

Geo-Energy Suisse AG is proposing an innovative technology to unlock the large potential of geothermal energy for electricity production in Switzerland. An optimal well control is central to this innovation. The tools developed within this project will enable a fast decision process for selecting an optimal well trajectory. This is part of the overall strategy of Geo-Energie Suisse to bring down the costs and risks associated with the development of deep geothermal projects.

1. Introduction

Recent deep geothermal projects in Switzerland experienced difficulties managing seismic risk associated with reservoir access and development. In order to address this problem, Geo-EnergieAG – the leading industry driven centre of competence for deep geothermal energy for power and heat production in Switzerland – has developed an innovative completion scheme referred a "multi stage simulation concept". Instead of working with long open hole sections, as is typical previous EGS projects, it is now proposed to isolate sections along the borehole and to enhanced the permeability of potential feed zones individually (Figure 1, left side). In order to succeed with this completion scheme, the borehole trajectory must be optimized in order to:

1) Maximize the probability of intersection with potential feed zones (existing fractures);

2) Insure sufficient borehole stability in order (a) to limit drilling difficulties associated with borehole instability and (b) to obtain a hole which is sufficiently in gauge to not compromise a well completion with swellable packers for reservoir segmentation and subsequent staged stimulation.

Both criteria are not necessarily compatible and an optimum must be determined in order to decide on the best well path. The main objective of this project is to develop a workflow in order to facilitate the optimal well trajectory selection.

2. Approach

It is well known that deep boreholes can experience severe stress induced failure of their walls (so-called borehole breakouts). An example of such borehole failure is presented on Fig. 2a. This is a 3D geometry of the BS1 borehole in Basel reconstructed from acoustic televiewer data. The typical "lemon-shape" of the borehole section is due to the stress redistribution around the borehole leading to maximum tangential stresses exceeding the rock strength. Methods to evaluate the relative severity of borehole failure for various drilling direction are well documented. Fig. 2b presents such results showing that in this case, a vertical hole will induce larger tangential stress and thus more severe failure than an deviated hole. However, in the current state of the knowledge, we cannot reliably predict the initiation, extension and final shape of borehole breakouts. This is largely due to the lack of proper

Figure 1: Left: potential deviated hole completion with multi stage stimulation concept. In order to optimize the reservoir development and to minimize the risk, an appropriate borehole trajectory must be found to maximize the intersection with potential feed zones while insuring sufficient borehole stability. Right: proposed high-level workflow to deal with this borehole optimisation problem. The main objective of the project is to develop the details of this workflow.

input parameters: in-situ stresses are often poorly constrained, particularly at early project stage, and the estimation of the in-situ strength is usually poor (no cores or damaged cores, no or few mechanical tests). This is also due to a gap in understanding the processes at play at the borehole wall during initiation and accumulation of damage leading to the formation of borehole breakouts.

In order to deal with this uncertainties, we propose to develop a workflow based on statistical approaches dealing with rigorous parameter estimation and risk analyses. The outline of this work flow is presented on the right side of Fig. 1. The idea is to use data from the vertical section of the borehole to calibrate plausible failure models. The solution will not be unique (multiple combination of stress/strength parameters will equally match the observed data). Then, these calibrated models can be used to predict borehole severity and associated uncertainty for potential borehole deviation and assess risks associated with potential drilling scenarios.

Figure 2: a) Observed breakout in the BS1 borehole at 4955 m depth. In this case, the borehole is subvertical. b) computed maximum effective tangential stress at the borehole wall as a function of hole direction. The results a presented as contouring on a stereographic projection (lower hemisphere, equal area). A vertical hole will plot in the center of the projection while an horizontal hole will plot in the rim of the projection. The stress assumption is *SHmax* direction N143° with *Sv* = 100 MPa, *SHmax* = 120 MPa, *Shmin* = 64 MPa and *Pp* = 39 MPa (possible stress scenario at 4 km depth).

3. Expected research outputs

The outputs of this project will reduced cost and risks associated with deep geothermal well. The workflow presented above will be developed and tested on existing data sets and applied to future Geo-Energie Suisse projects like the Haute-Sorne project planned for 2017.

Acknowledgments
This work is supported by the CTI under project 18057.1 PFEN-IW

Deep Well Optimization workflow

(see poster Valley et. al.)

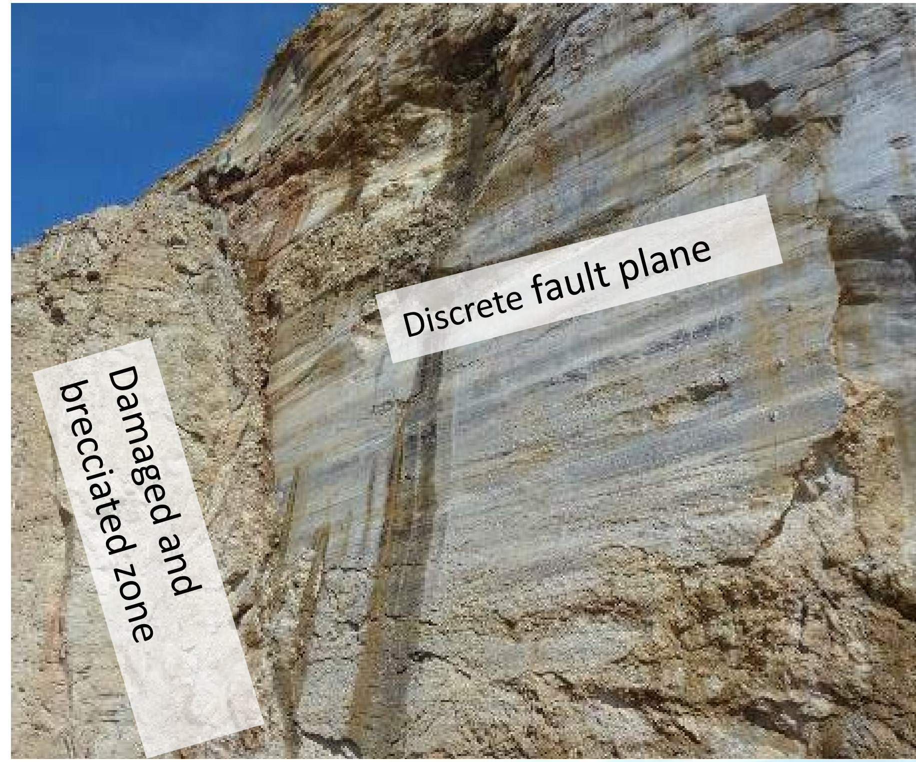
La Sarraz natural laboratory

Study of a fault system in an outstanding " natural laboratory" at the quarry of Éclépens.

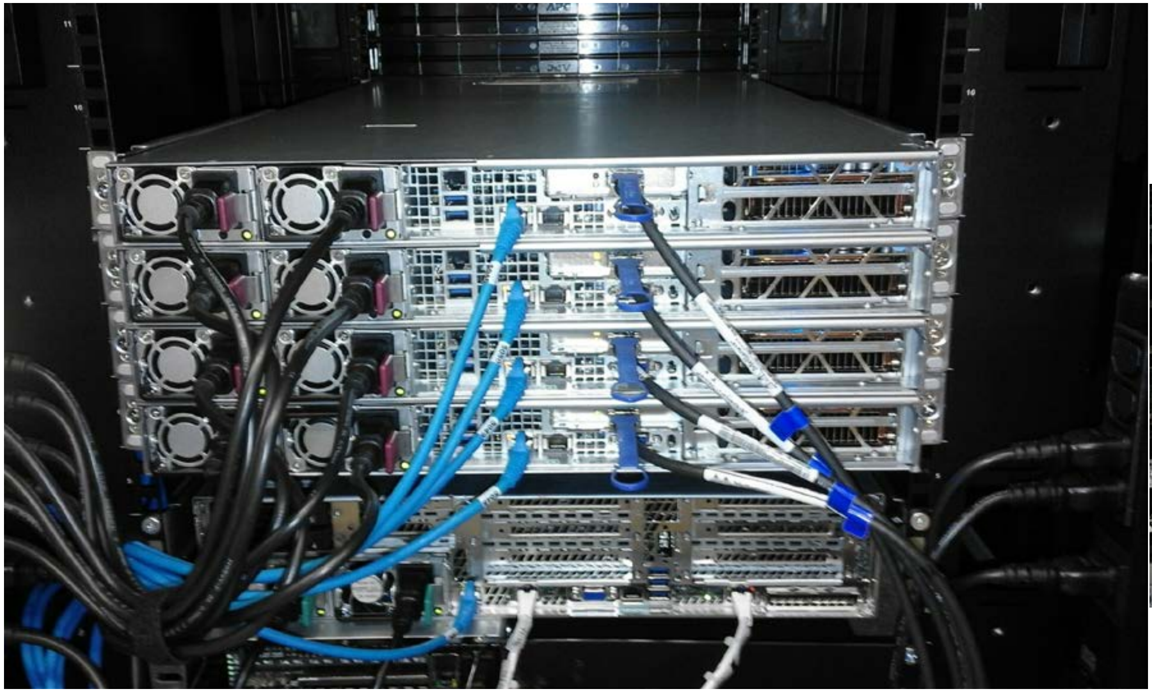
Key questions this study will address:

- Are all faults in the Alpine foreland critically stressed ?
- What is the influence of fluid circulation on the fault criticality ?
- How does fault complexity (relays, jogs,…) inflences damage characterisatics and fluid flow?

…

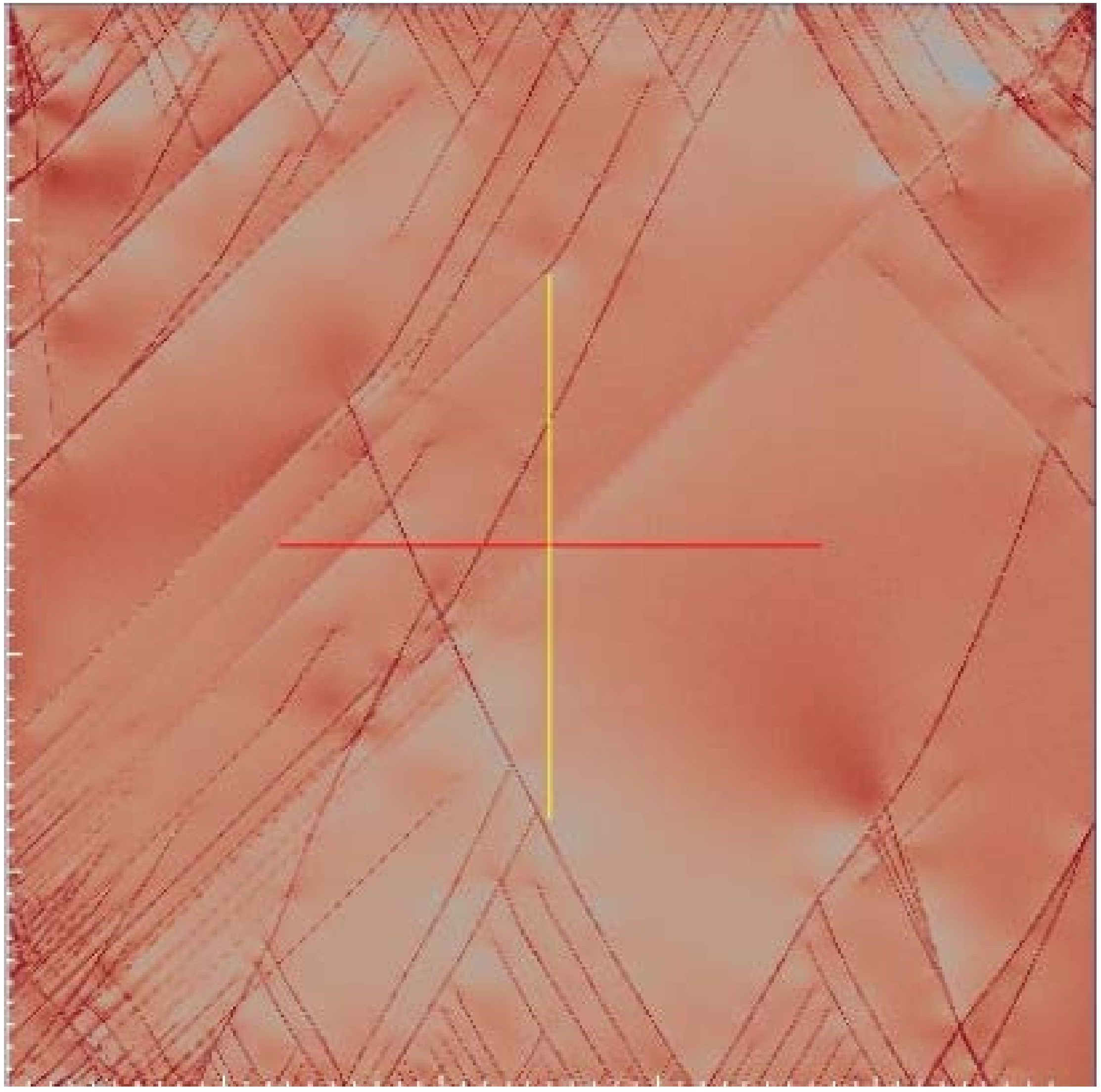


Recent Acquision at CHYN of „Thor“, GPU/MIC cluster



- 4 nodes
- each equipped with two GPU Tesla 40K cards,
- one Intel Xeon Phi (MIC) coprocessor card,
- two 2 CPU 10 core Intel Xeon E5-2650
- Infiniband connection at 56 Gbits/s.
- about 1TB RAM and 20TB storage.

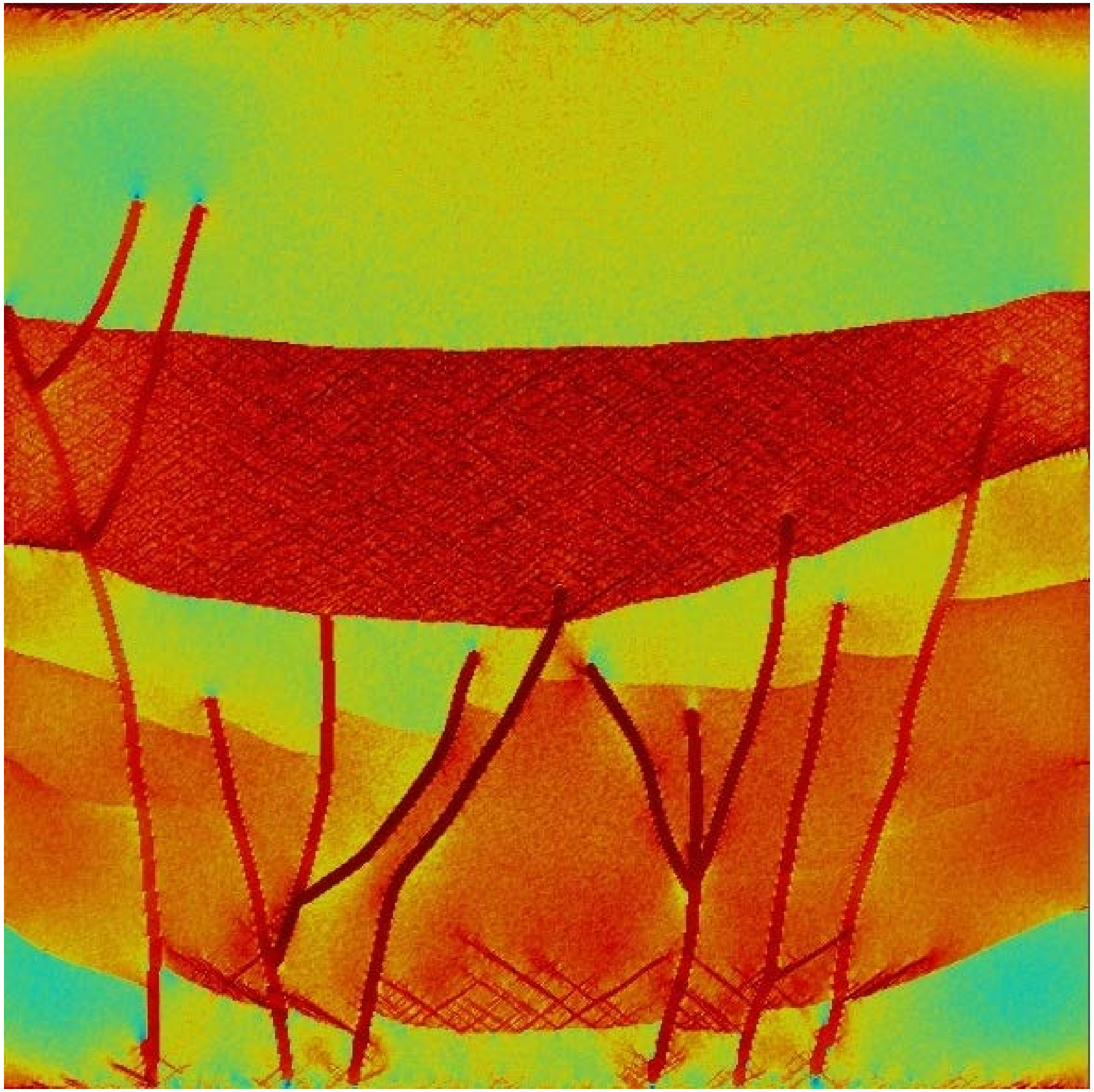
Fracture Evolution Simulated Entirely on GPU-Cluster



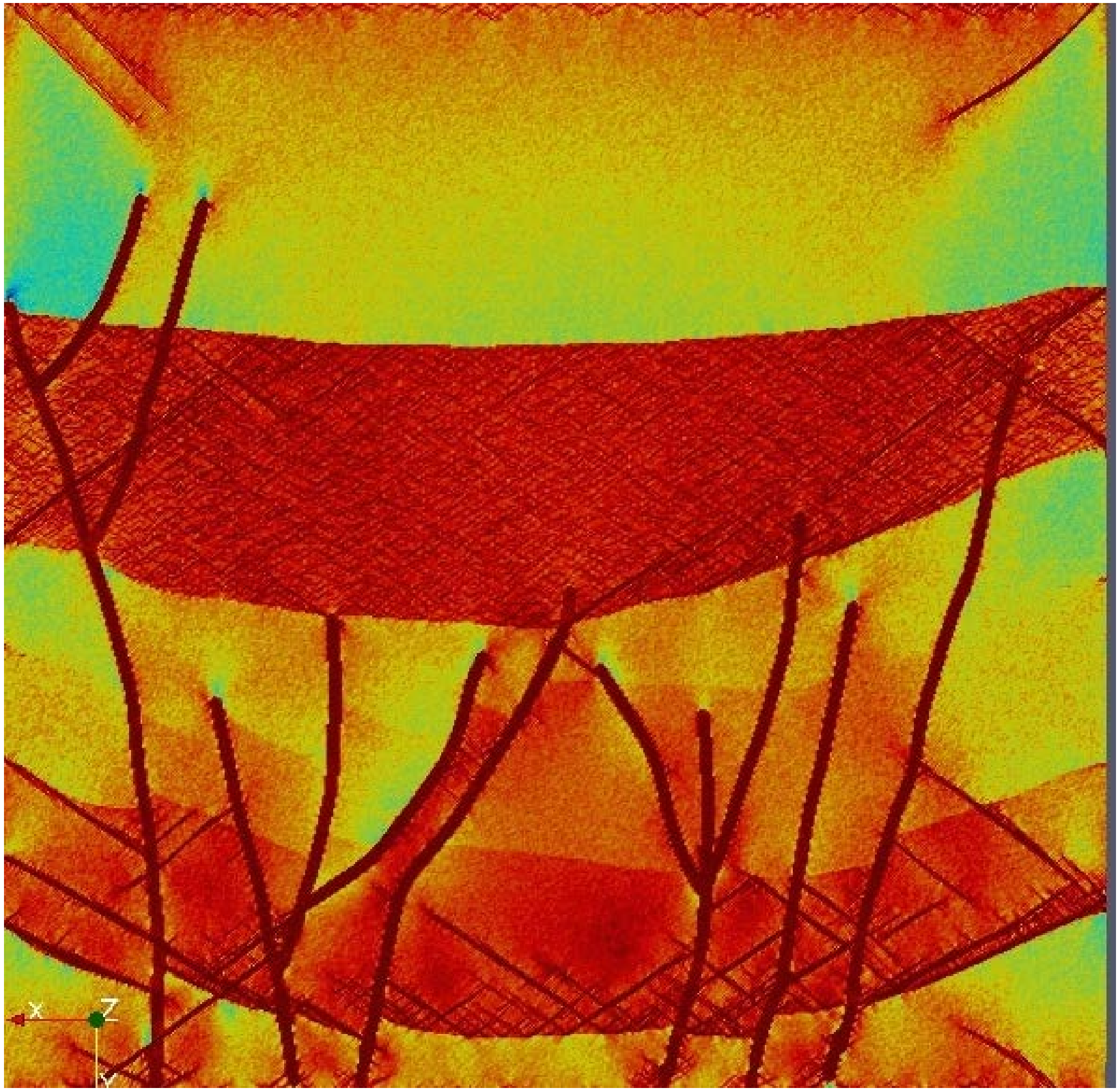
Galvan and Miller, in prep.

Application developed for quickly generating numerical mesh for geologically complex geometries

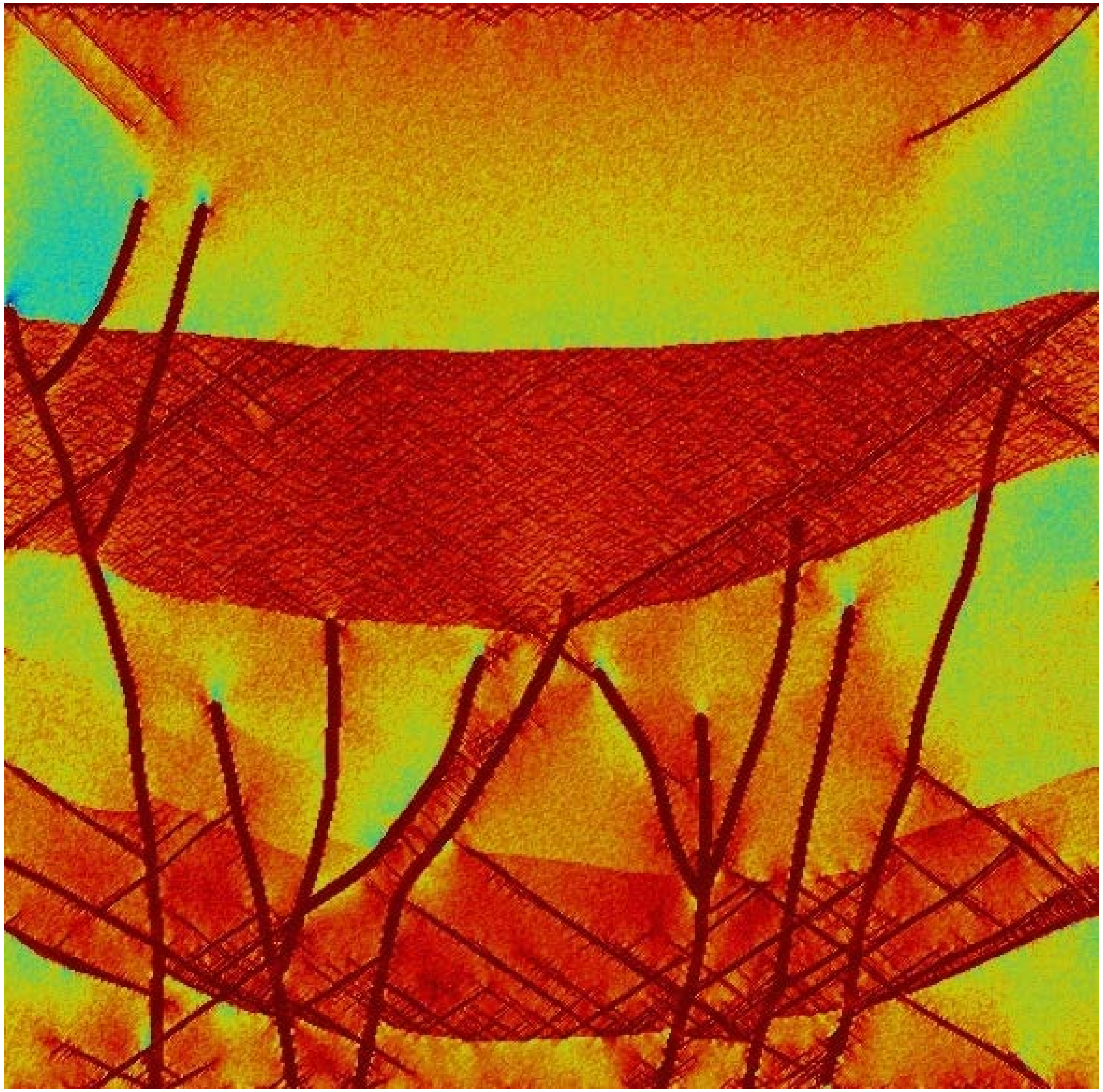
SCCER SoE



Galvan and Miller, in prep.

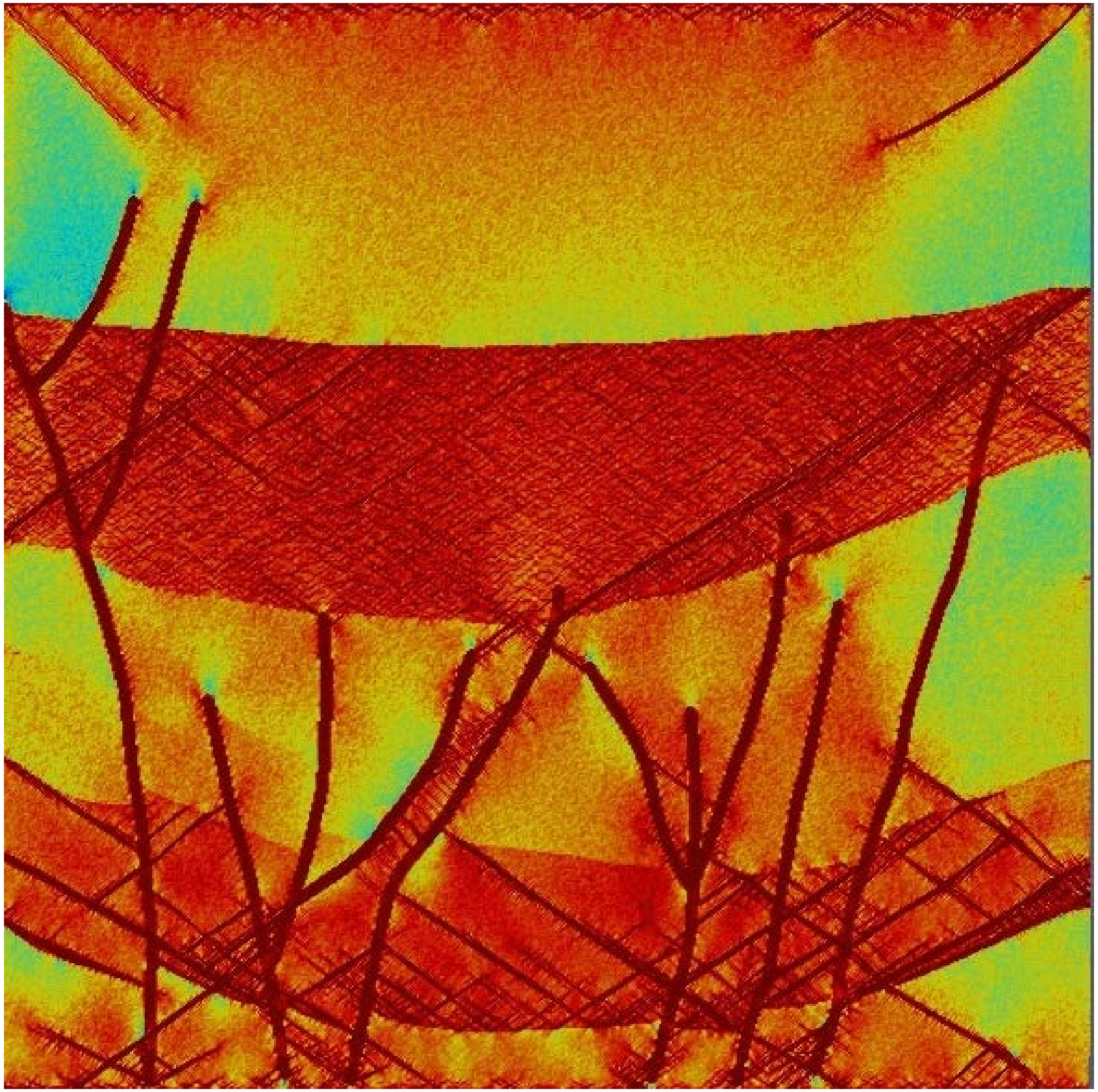


Galvan and Miller, in prep.

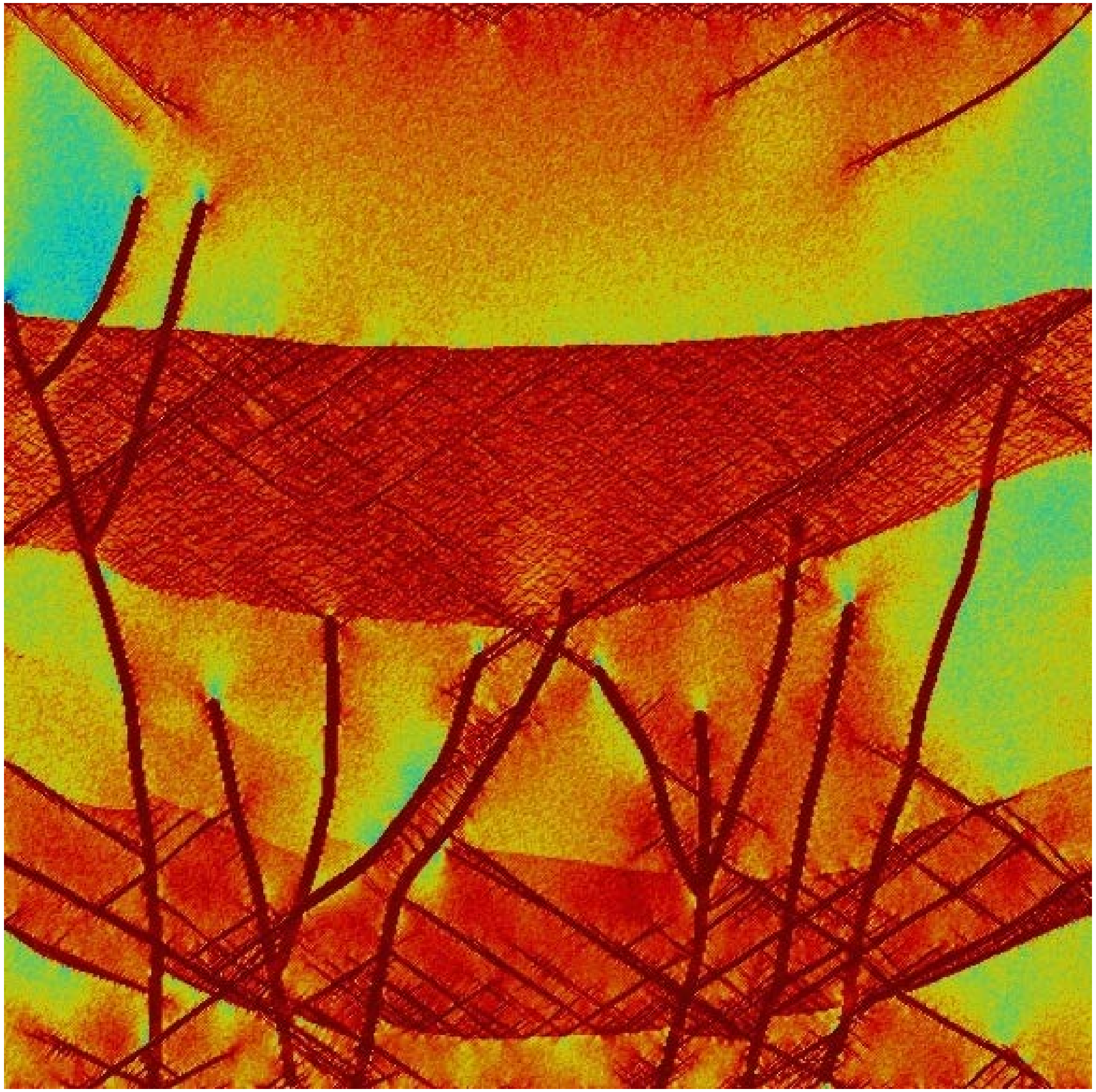


Galvan and Miller, in prep.

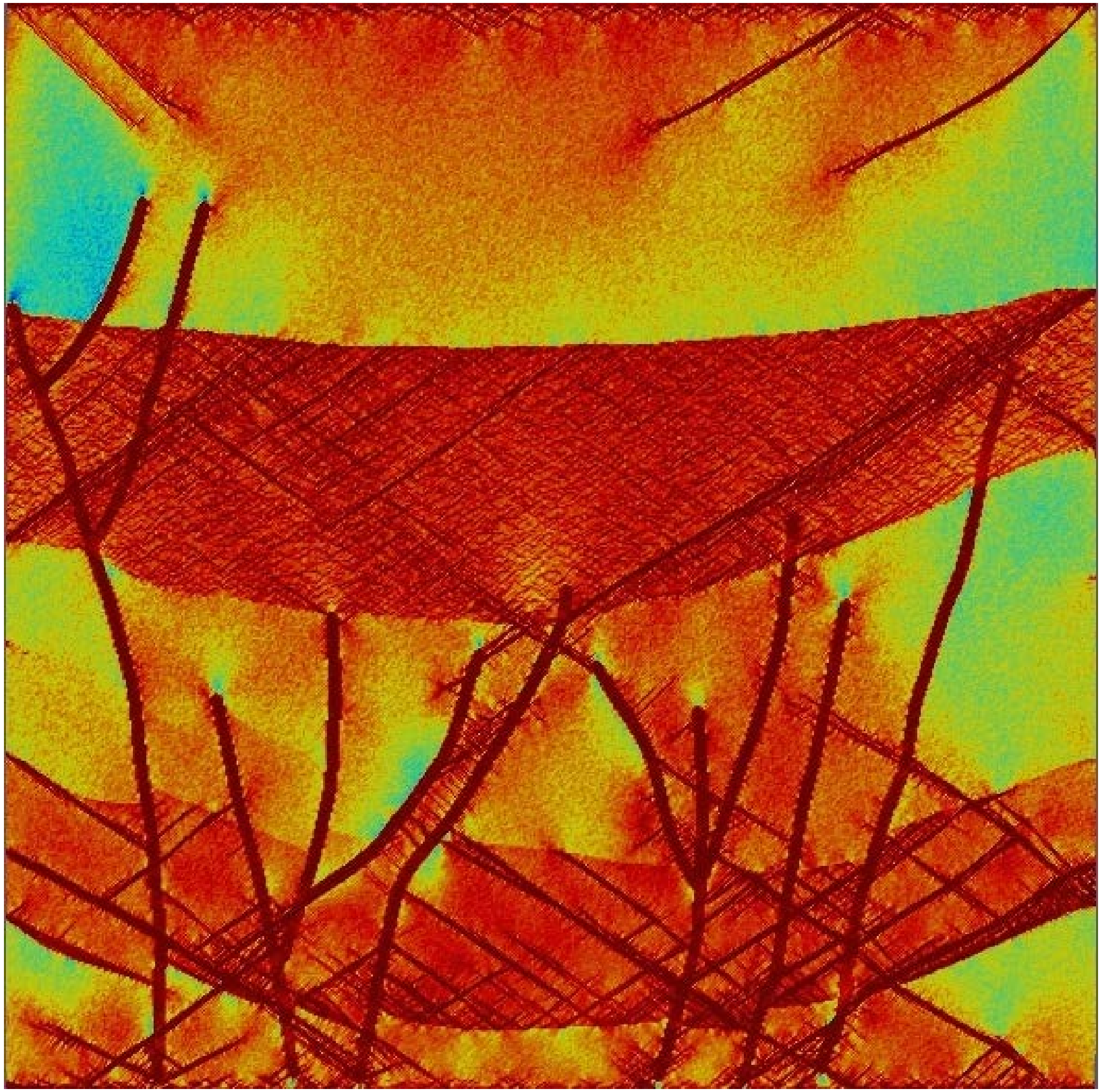
SCCER SoE



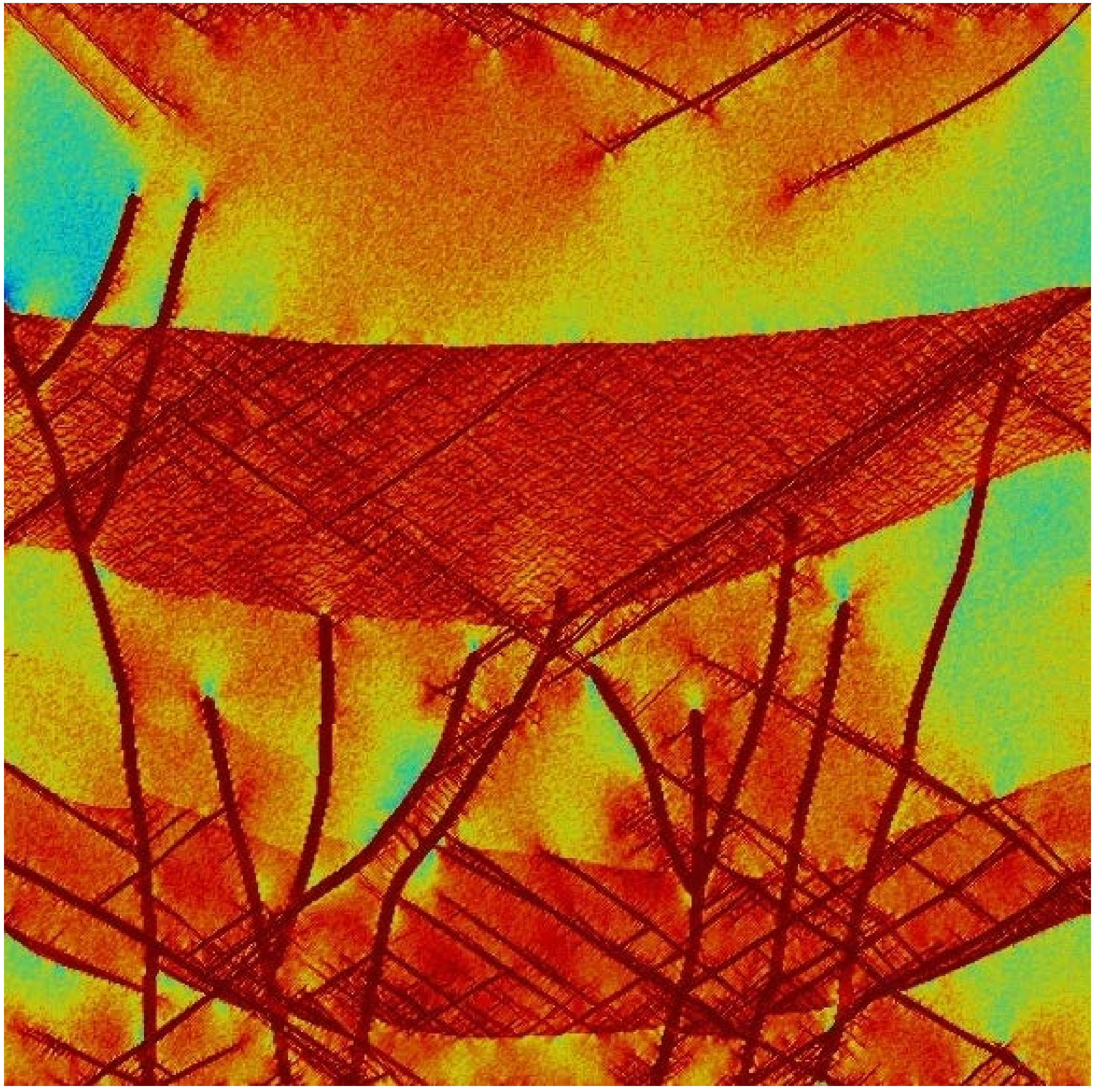
Galvan and Miller, in prep.



Galvan and Miller, in prep.

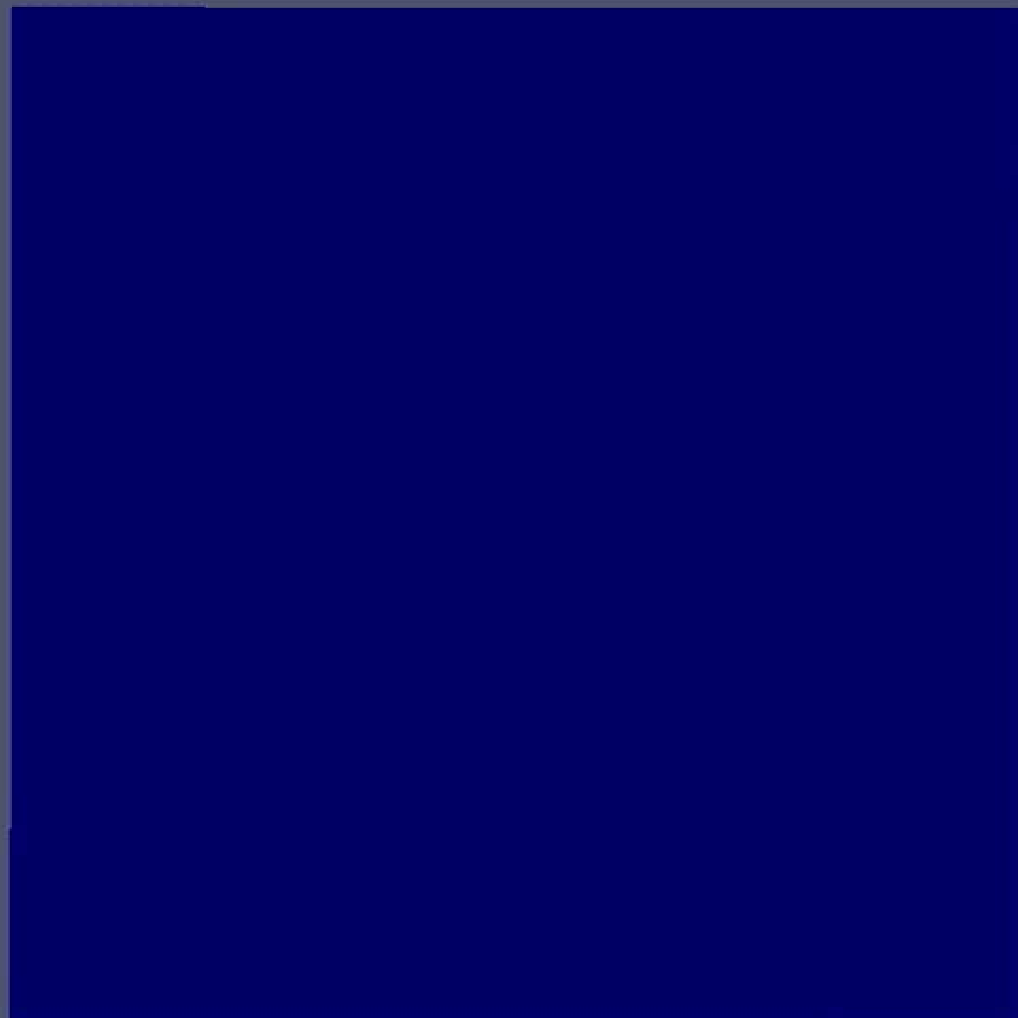


Galvan and Miller, in prep.

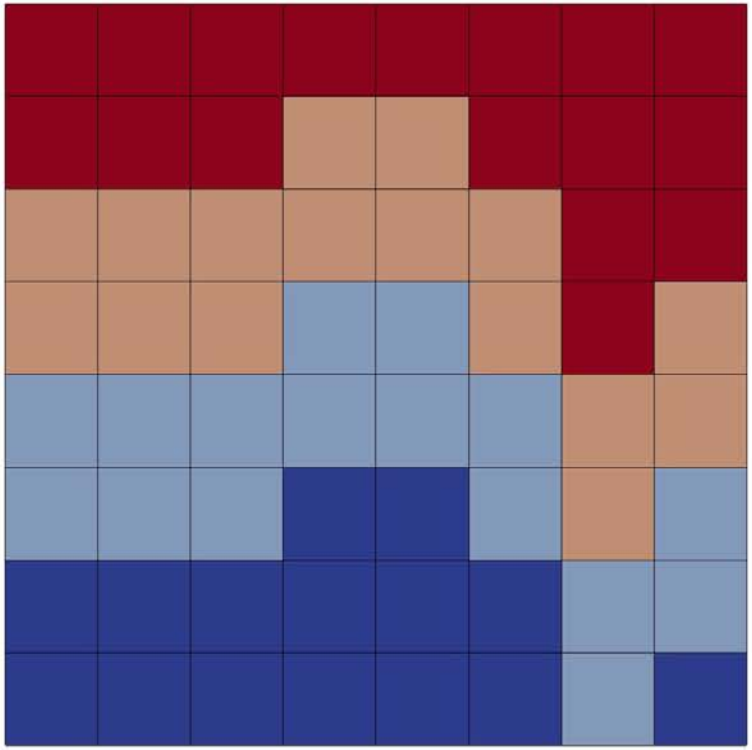


Galvan and Miller, in prep.

oE



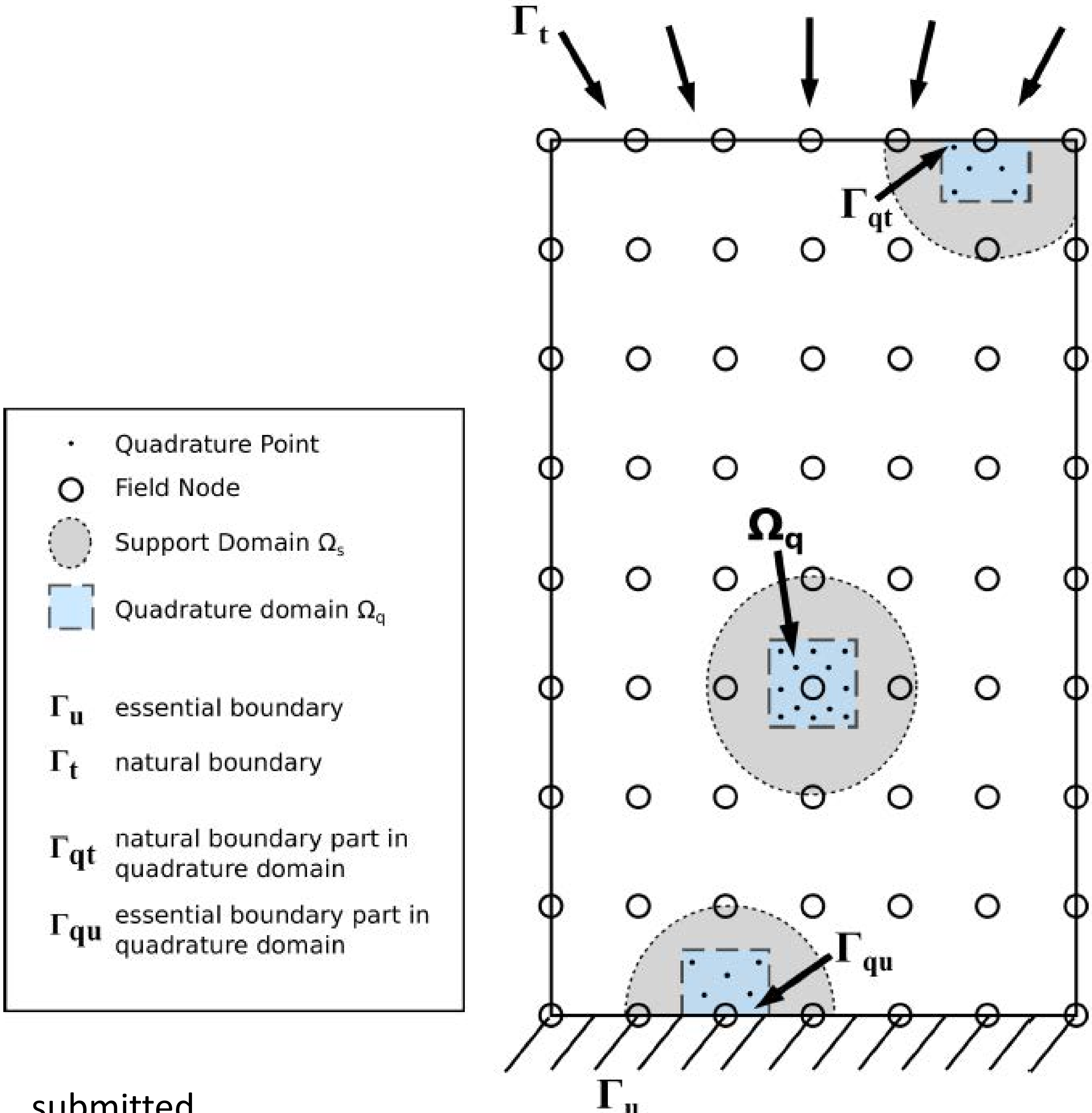
Implementing Automatic Mesh Refinement



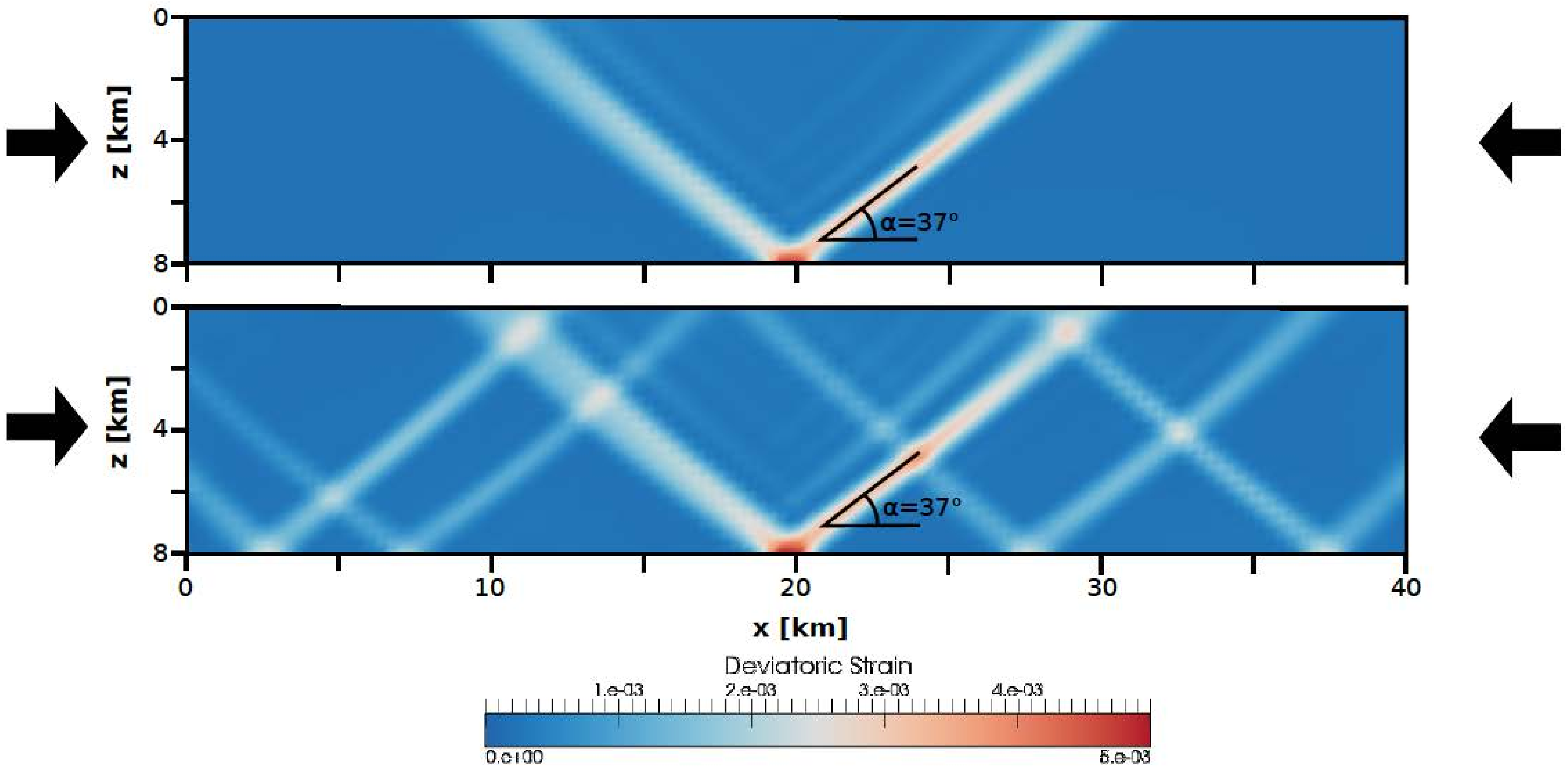
See poster of Gunnar Jansen

Implementing Automatic Mesh Refinement

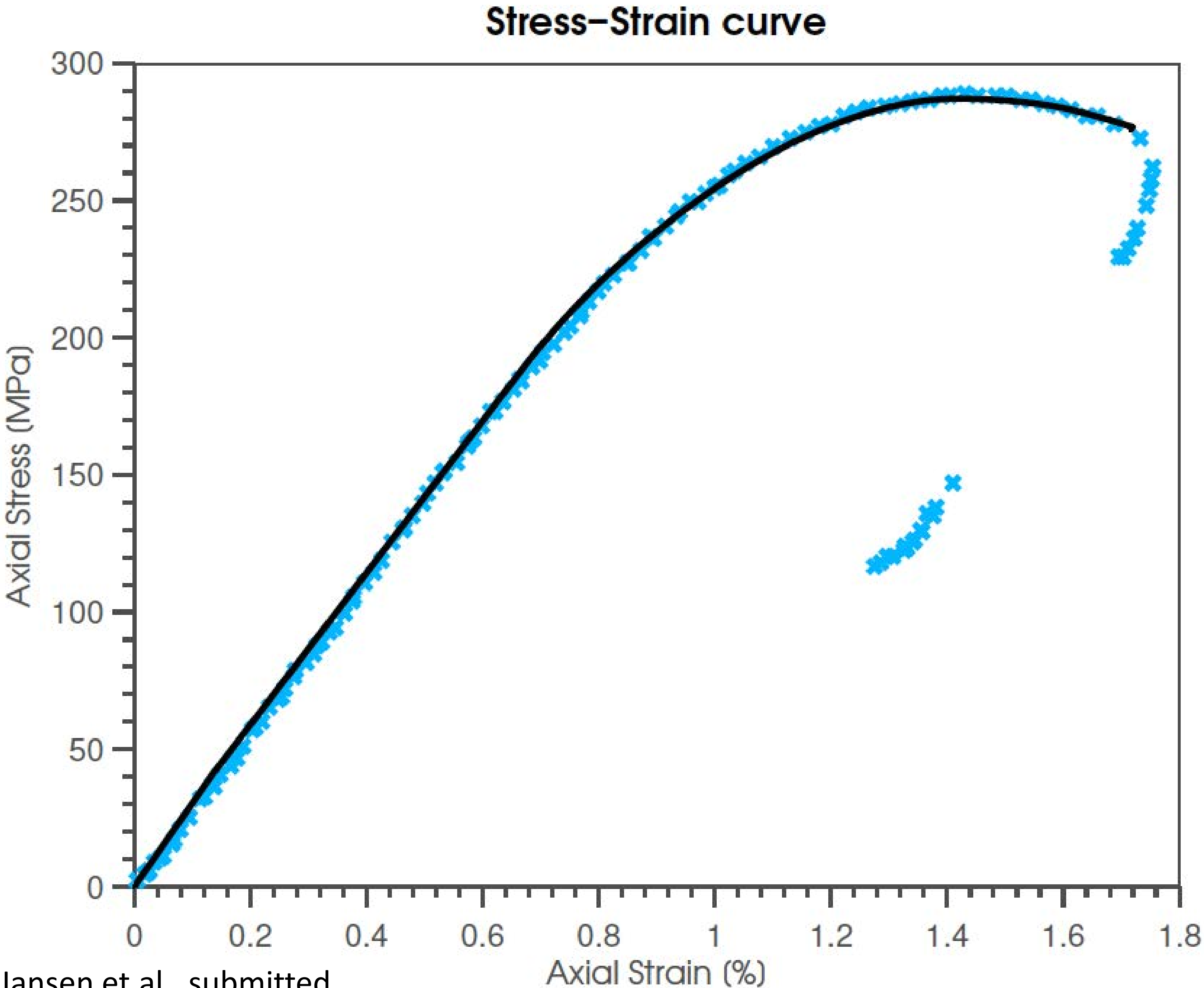
See poster of Gunnar Jansen



Jansen et.al., submitted



Jansen et.al., submitted



Jansen et.al., submitted

Newborn Hydrothermal System (Lusi) in Java, Indonesia

SCCER SoE

FNSNF
SWISS NATIONAL SCIENCE FOUNDATION


At its peak Lusi spewed up to 180,000 m³ of mud per day.

- Geophysical Investigations (gravity, magnetotellurics, etc.)
- Numerical modeling of hydrothermal system
- Raman spectroscopy shows evidence for temperatures approaching 300°C at 1.2km to 1.5 km (Mavloisin et. al., in prep.)

Lusi a High Enthalpy System

SCCER SoE

MERCI POUR VOTRE ATTENTION

Enjoy Neuchâtel