

SCCER SoE Annual Conference 2016

Hydropower and Geo-Energy in Switzerland
Challenges and Prospects

Challenges for stimulation *From science to engineering*

In cooperation with the CTI



Energy funding programme

Swiss Competence Centers for Energy Research



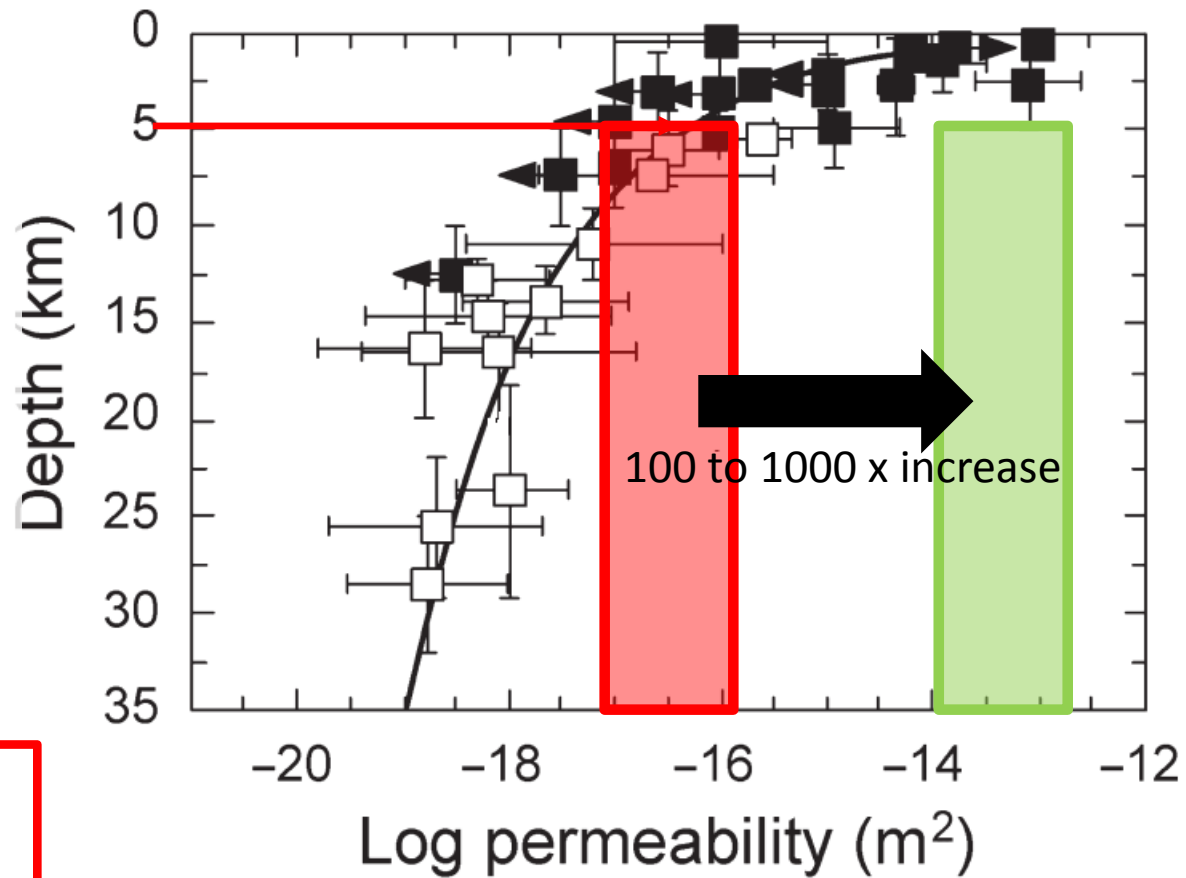
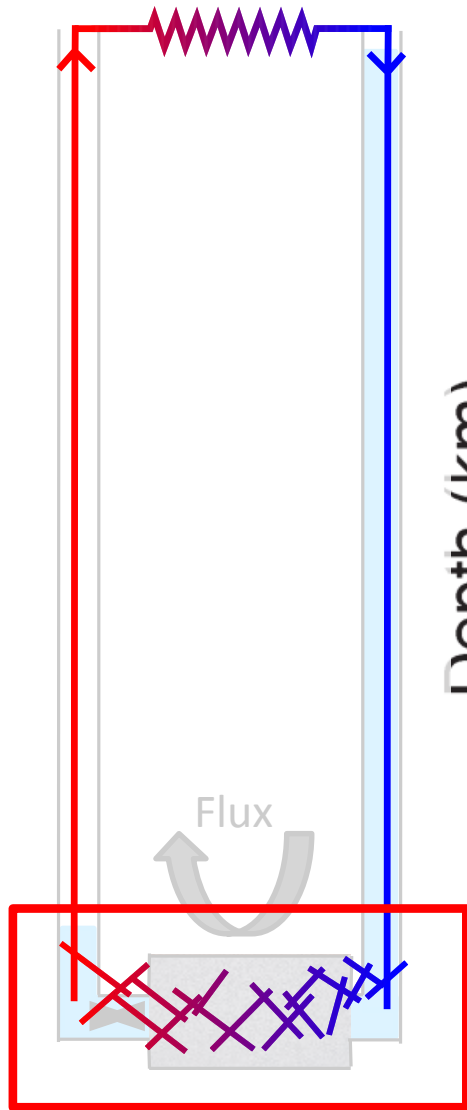
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Commission for Technology and Innovation CTI

Benoît Valley & Brice Lecampion
Sion / 13-September-2016

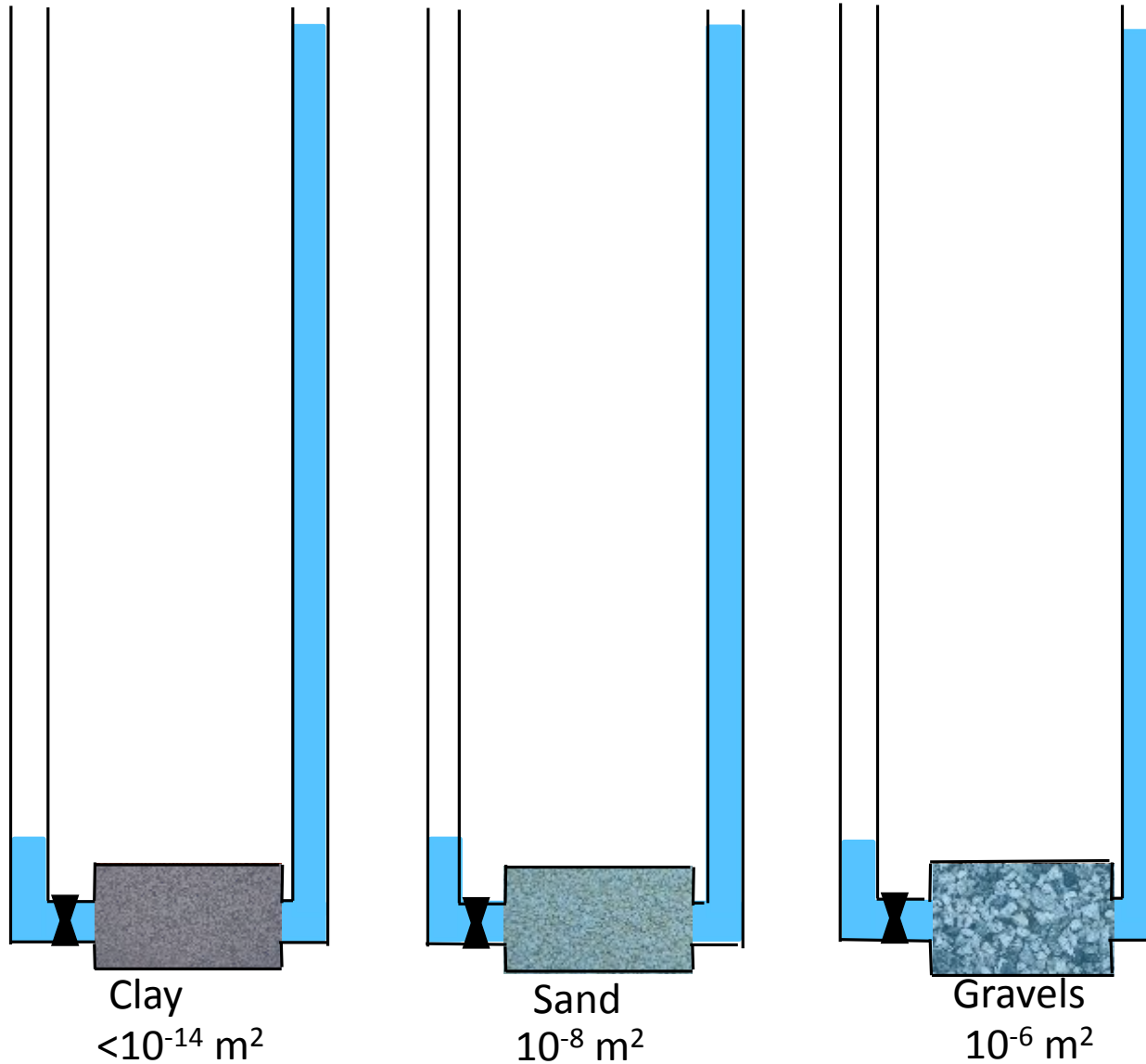
Stimulation → enhancement of permeability



Manning & Ingebritsen (1999) *Rev. Geophys.* 37 (1), 127-150.

+ good and sustainable heat exchange characteristics

Stimulation → enhancement of permeability



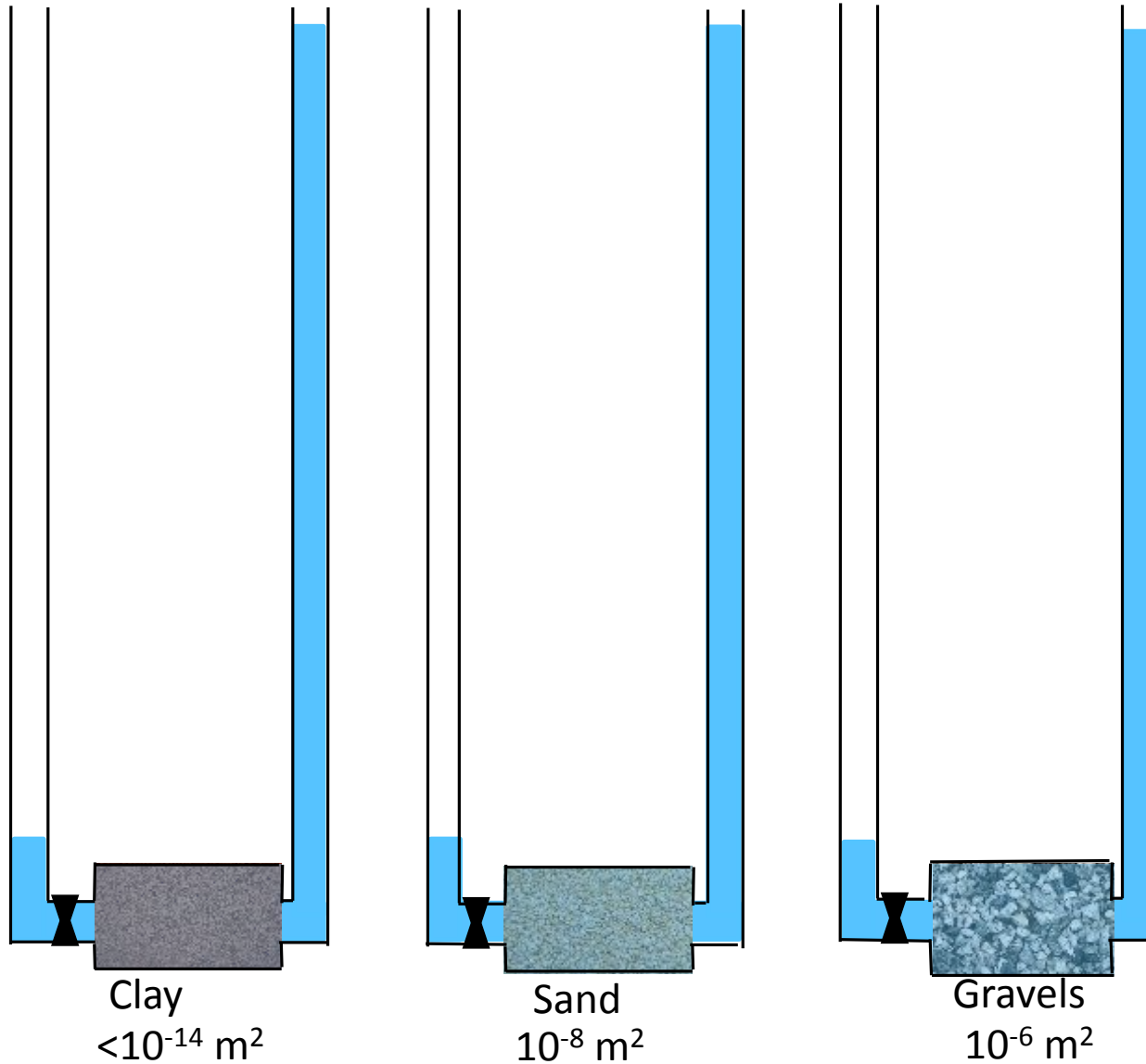
Permeability

Clay
 $<10^{-14} \text{ m}^2$

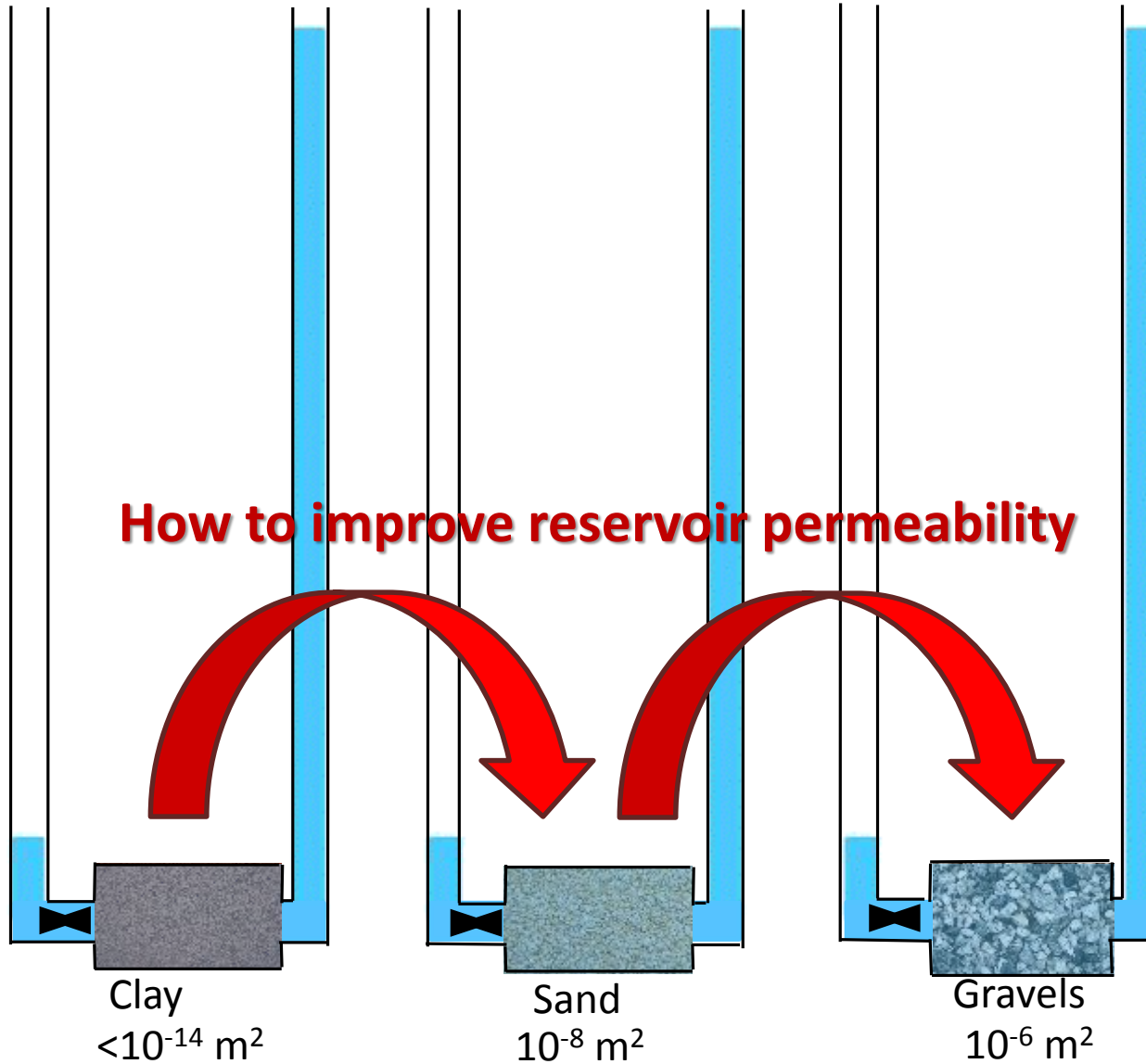
Sand
 10^{-8} m^2

Gravels
 10^{-6} m^2

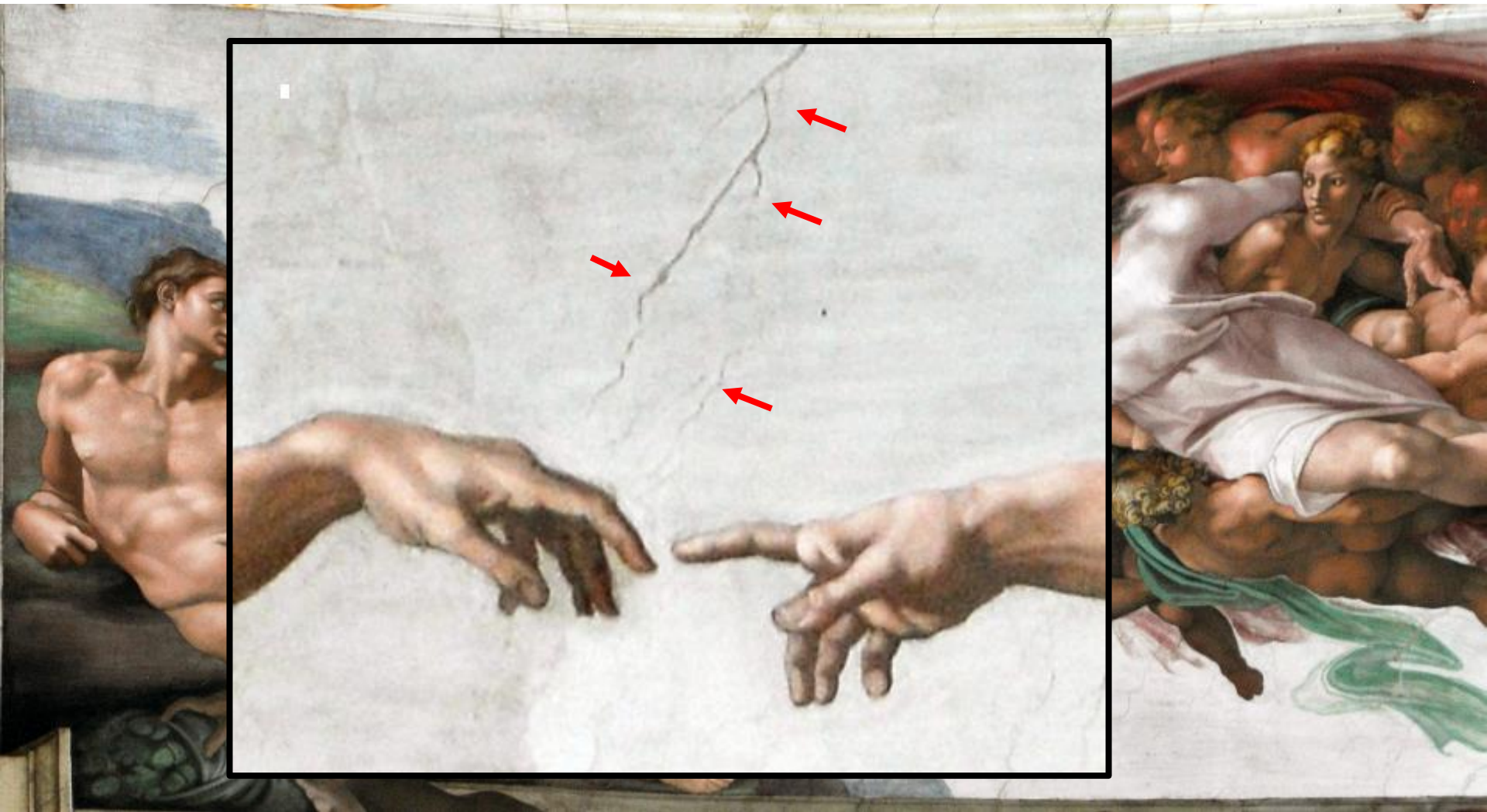
Stimulation → enhancement of permeability



Stimulation → enhancement of permeability



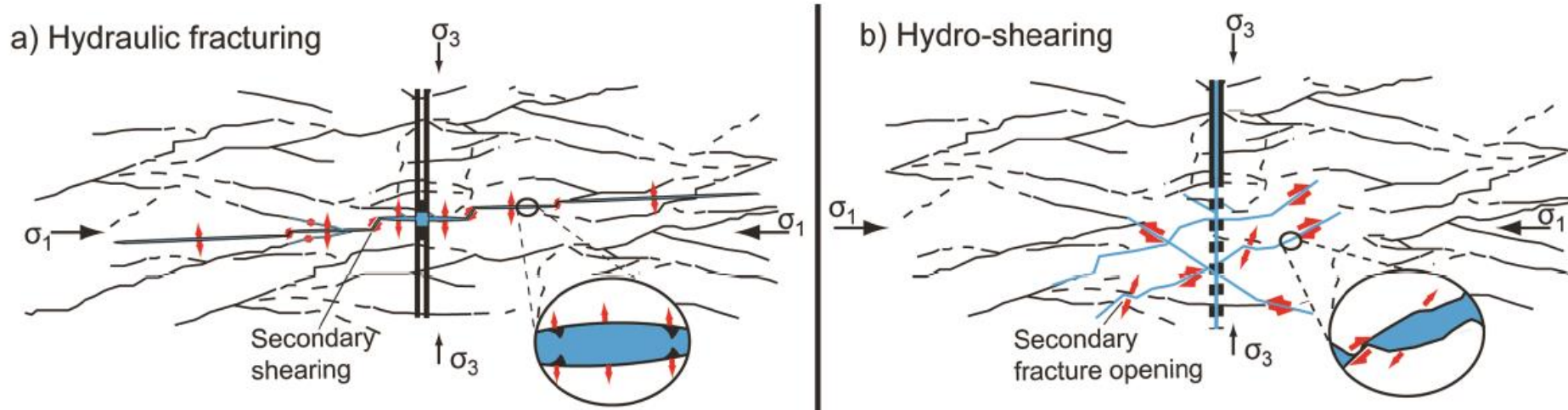
How to create permeability



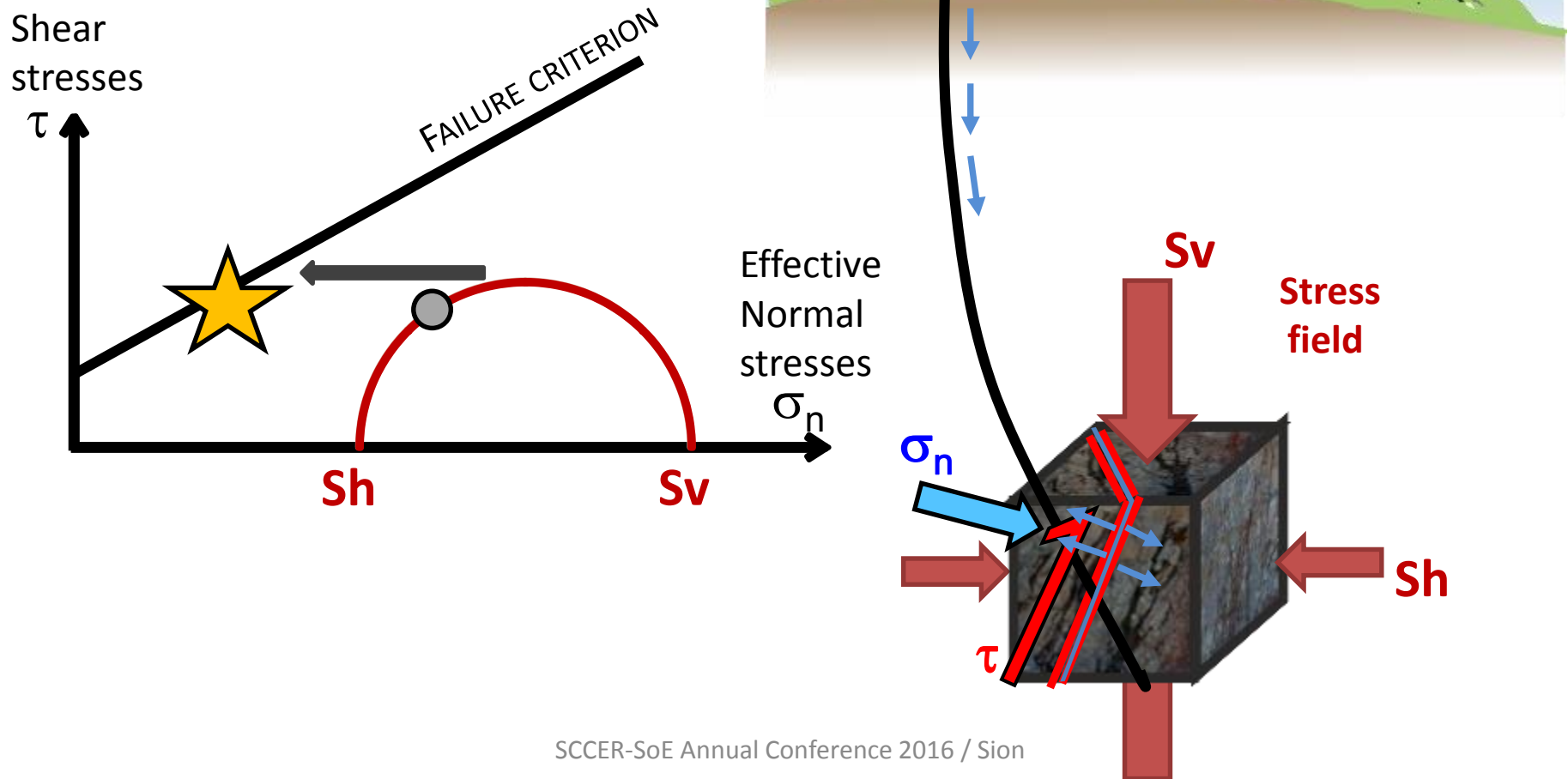
Permeability creation through massive fluid injection



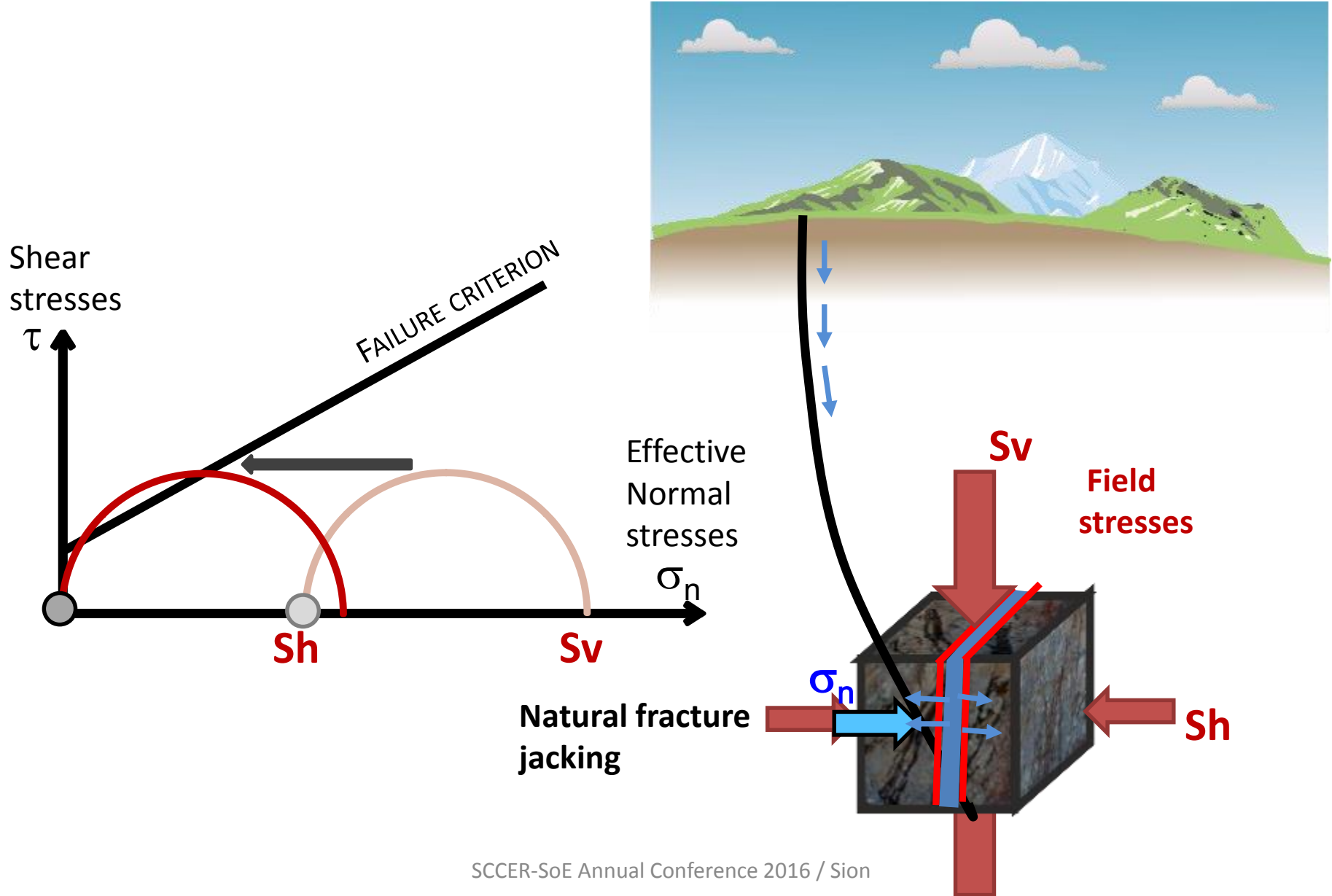
Two “end-member” rock mass response to fluid injections



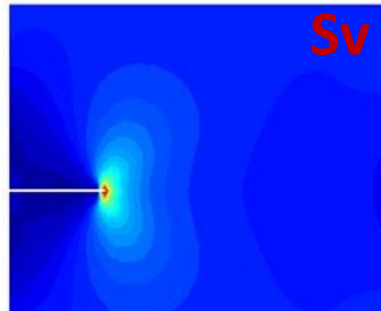
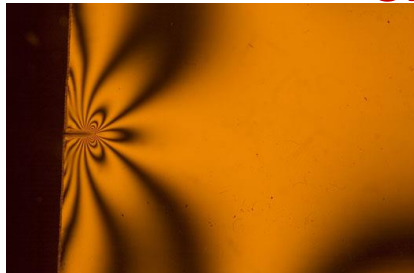
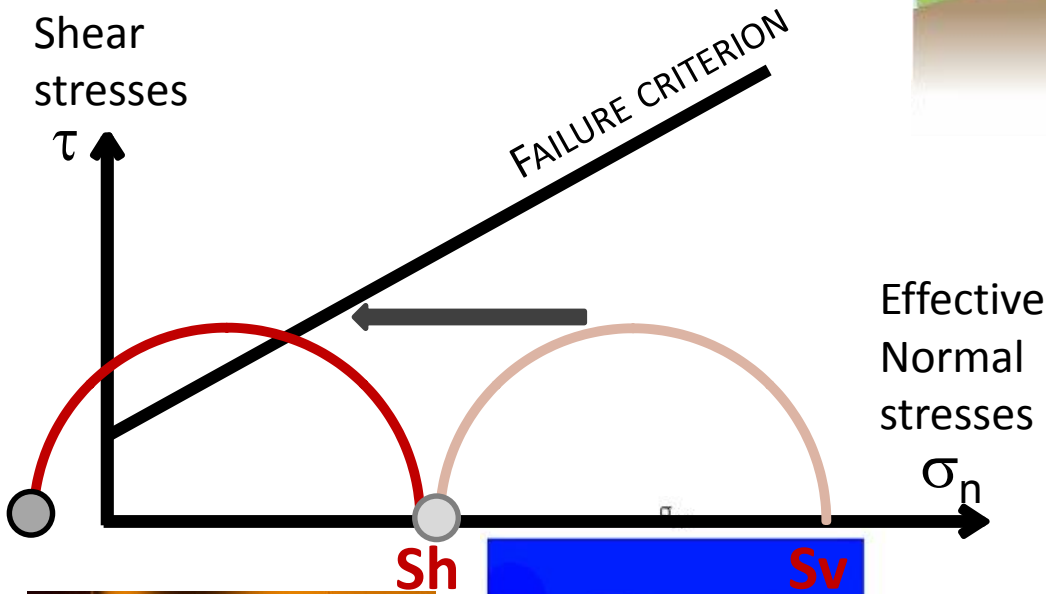
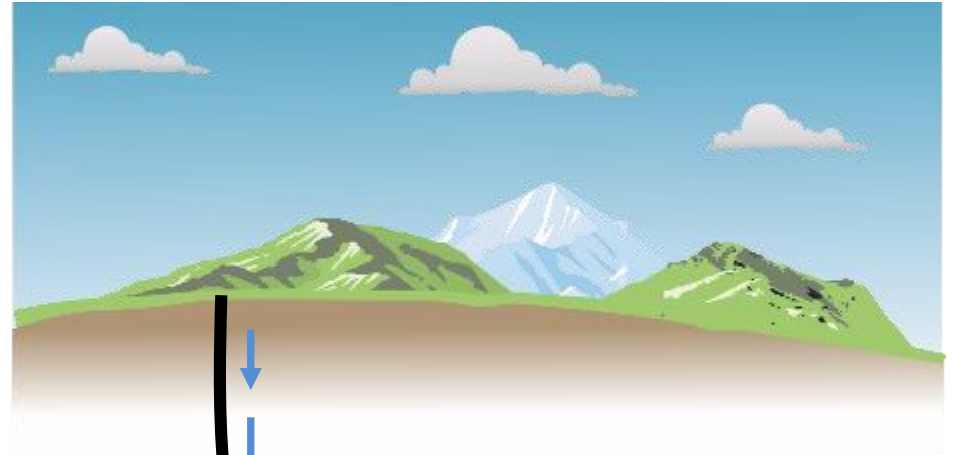
Mechanics of hydraulic stimulation



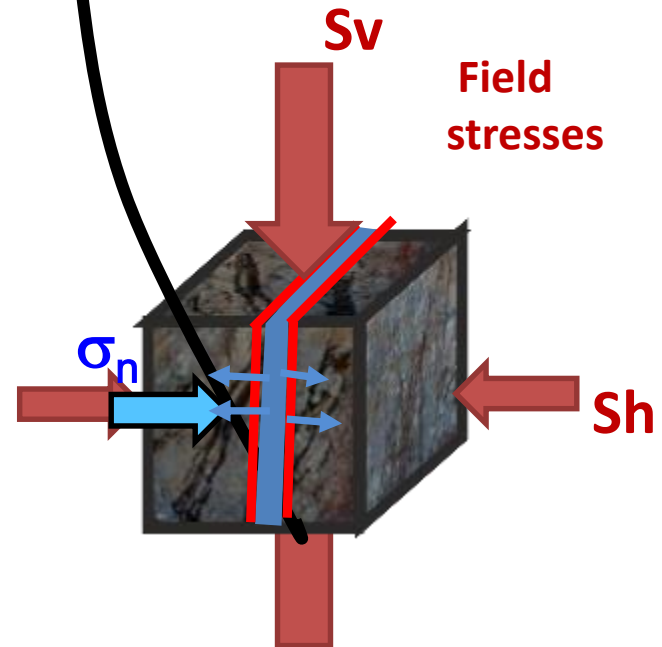
Mechanics of hydraulic stimulation



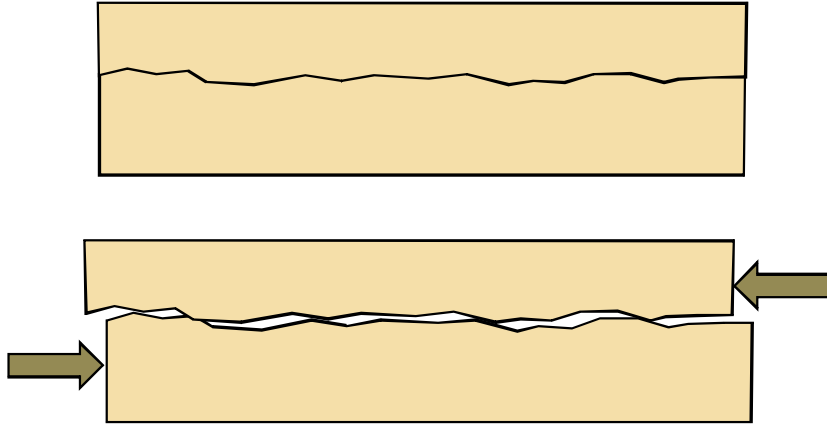
Mechanics of hydraulic stimulation



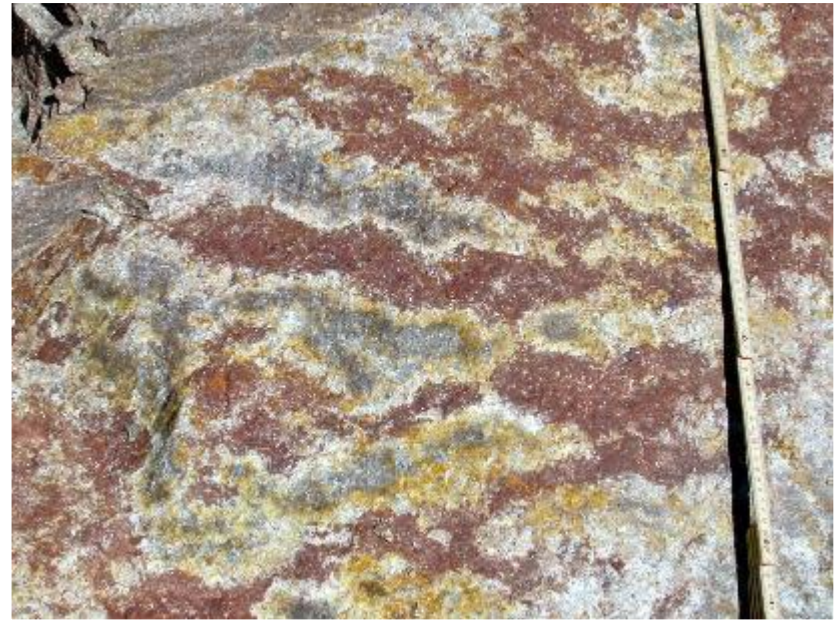
Creation and propagation of new fractures



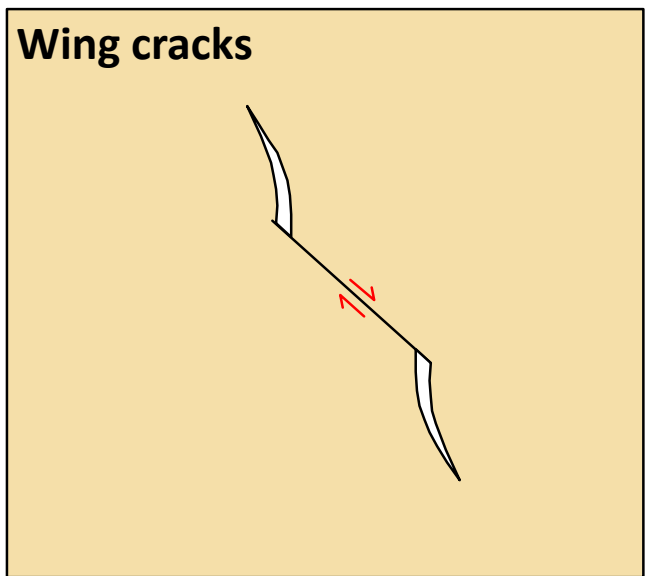
Permeability creation processes



Shearing of rough fractures



Wieslet, Forêt-Noire



Wing cracks

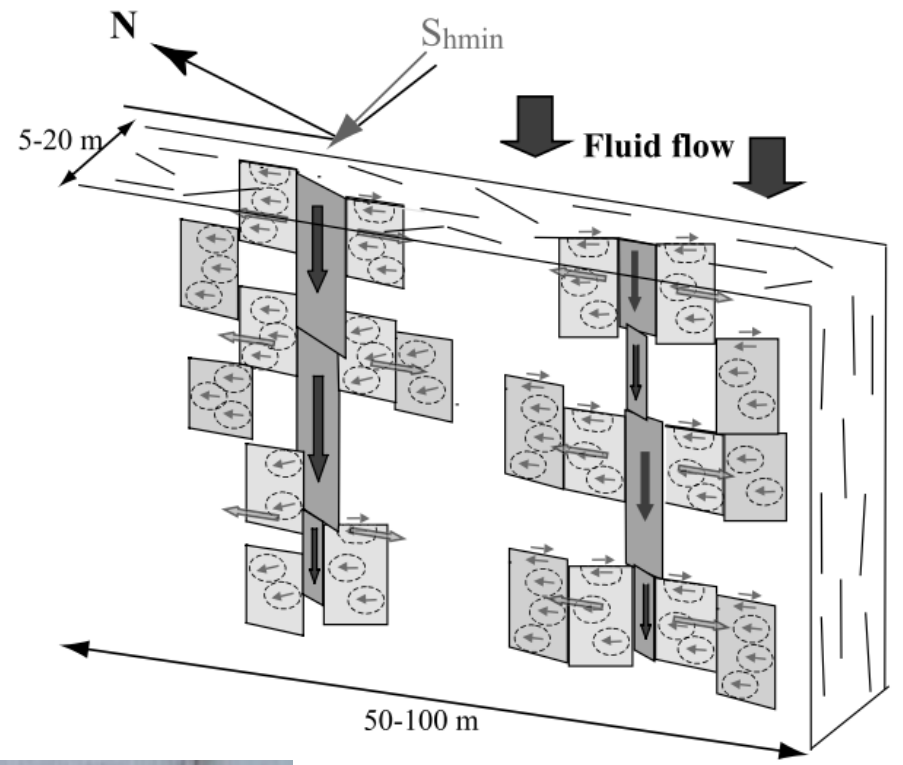
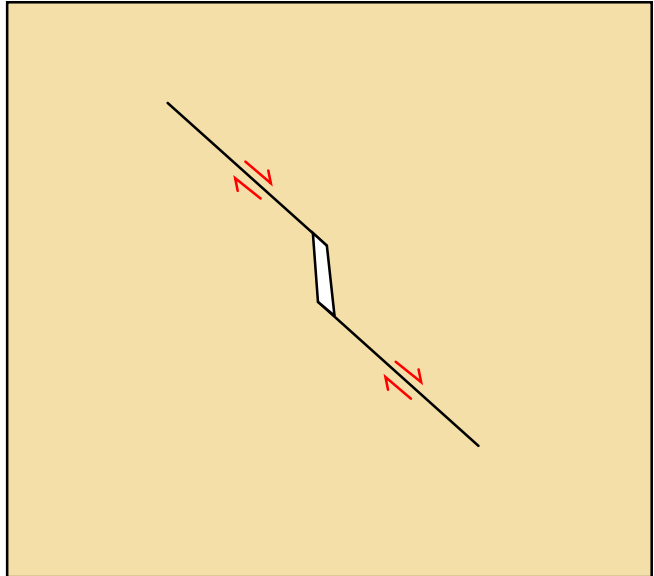


Oman
(photo: RWTH Aachen)

Any brittle process that increases void space (dilation) has the potential for permeability creation.

Permeability creation processes

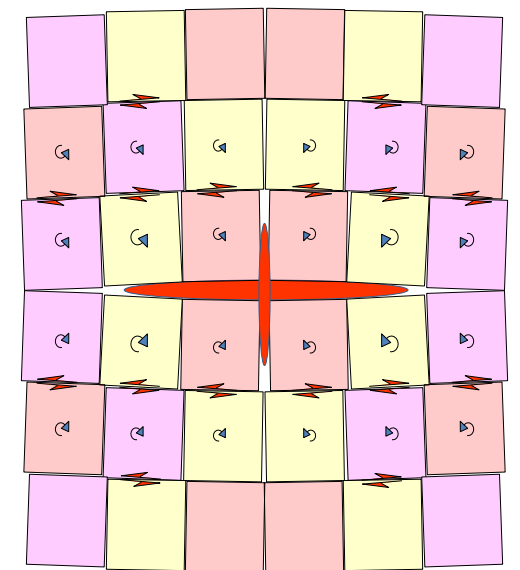
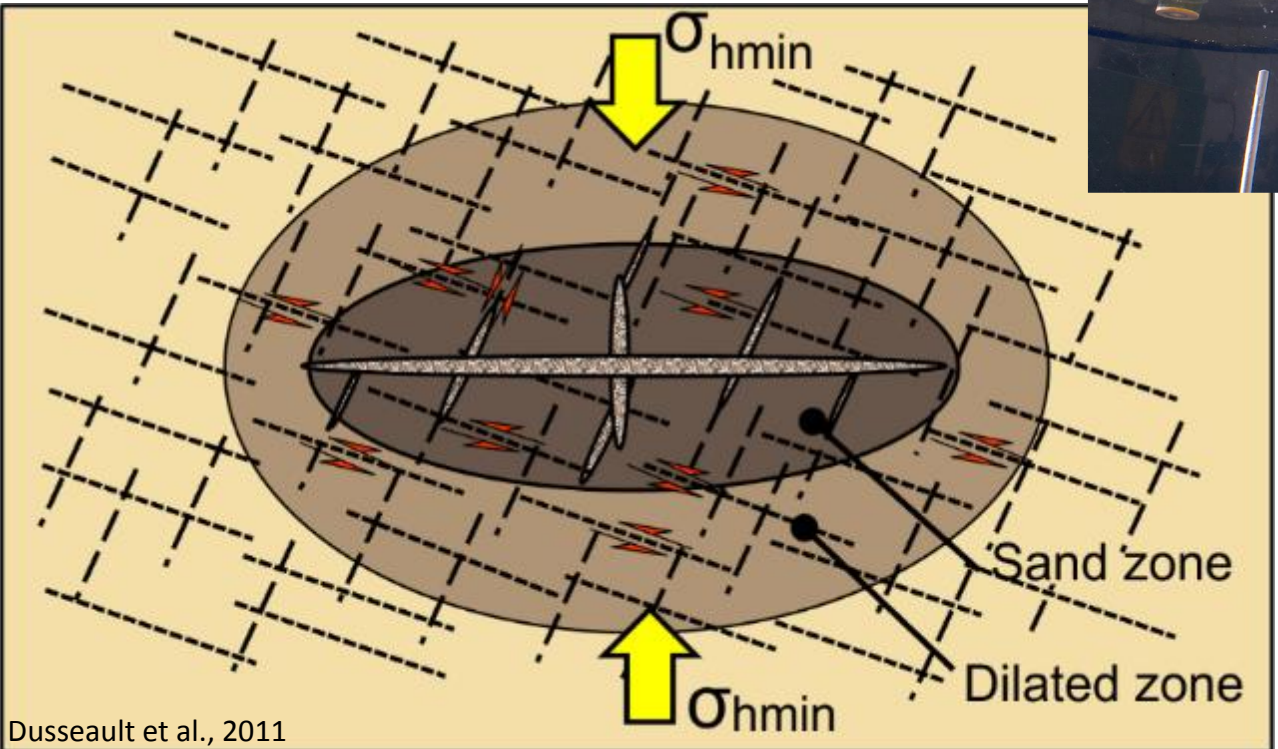
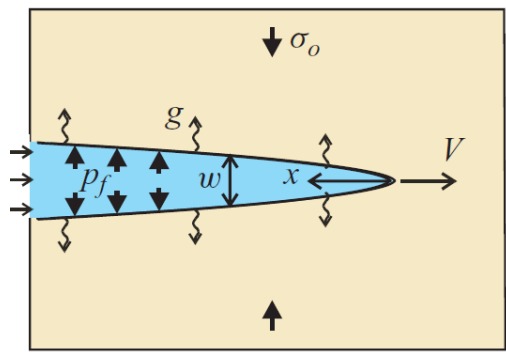
Relays and pull-apart structures



Evans et al. 2005 GJI. 160. 388-412

Permeability creation processes

Hydraulic fractures (with proppants)



Permeability creation through massive fluid injection



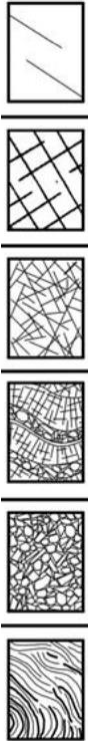
engineering

How to **design** an hydraulic stimulation in order to maximize our chances of creating sufficient and persistent permeability increase ?

Parallel with tunneling approaches

Rock mass characterization

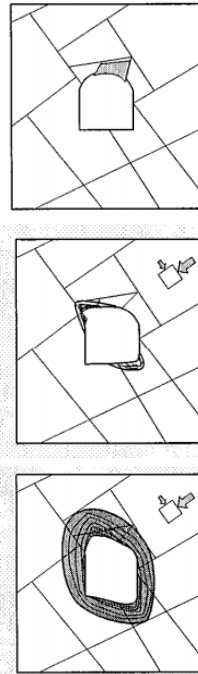
Putting numbers on geology



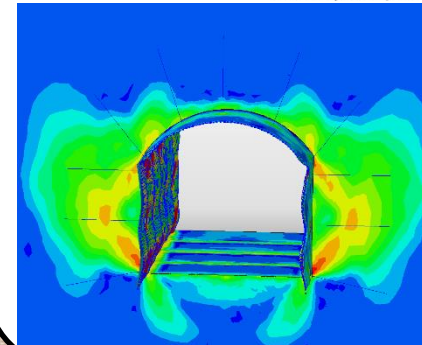
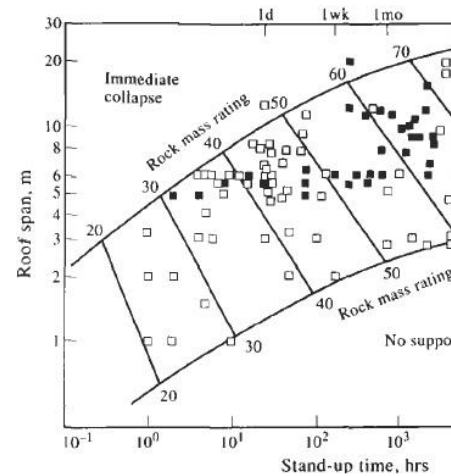
- Rock type
- Rock strength
- RQD
- Fracture network characteristics including orientation and joint surface conditions
- Interlocking
- Alteration
- In-situ stress
- Presence of faults or other structures

Anticipation of rock mass behavior

Failure modes



Empirical design charts and numerical methods



Tunnel design and mitigation measures

- Tunnel alignment
- Exc. methods
- Round length
- Face fractioning
- Destress blasting
- Ground freezing
- Umbrella
- Injection grouting
- Support: bolt, mesh, shotcrete, arches,...



Iterations at each project stage

Concept / pre-feasibility / feasibility / implementation

Risk / Uncertainty / cost analyses

Stimulation design

Rock mass characterization

Putting numbers on geology

- Rock type
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Stimulation design

- Wells siting
- Well trajectory
- Well completion
- Interval isolation
- Injection rate, pressure and volume
- Interval sequence
- Shut-in management
- Fluid properties
- Proppants
- Response to incident



Iterations at each project stage

Concept / pre-feasibility / feasibility / implementation

Risk / Uncertainty / cost analyses

Stimulation design challenges

What shall I do to get sufficient permeability and heat exchange characteristics?

Stimulation design

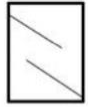
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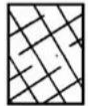
Stimulation design challenges

Rock mass characterization

Putting numbers on geology



- Rock type
- Rock strength



- RQD
- Fracture network characteristics



- Interlocking
- Alteration



- In-situ stress
- Presence of faults or other structures



- Initial hydraulic conditions and permeability



- Fault strength
- Background seismic level

What shall I do to get sufficient permeability and heat exchange characteristics?

Anticipating rock mass behavior:
What processes will be activated during stimulation ?

Design:
What methodology to decide on the optimal stimulation parameters ?

What do I need to know to take the right decisions ?

How do I measure or estimate the required parameters?

Stimulation design

- Wells siting
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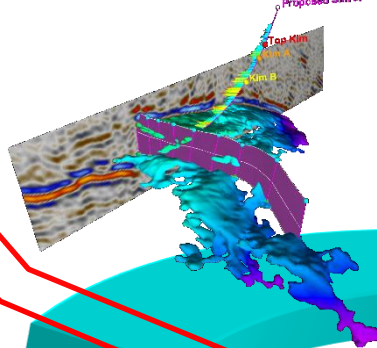
Uncertainty / risk analyses framework
at successive project stages

O&G stimulation work flow

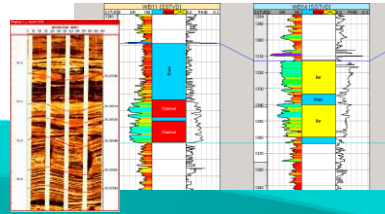
Rock mass characterisation:

focus on sedimentary basin

Reservoir Characterization



Log interpretation
Rock properties



Well tests

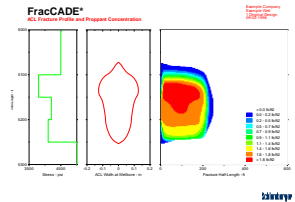
Stresses, Pore pressure



Design tool:

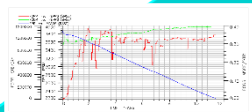
Focus on HF with proppants in stratabound environment

Fracture Modelling
Injection schedule design



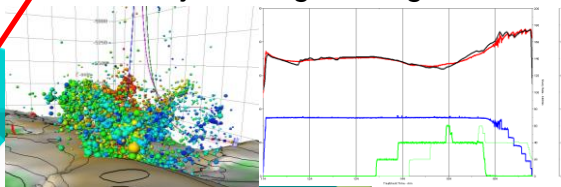
Need for P&D !

Calibration /
Lessons learned



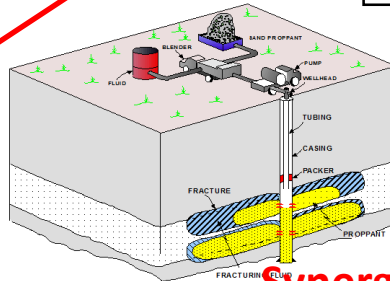
Real-time monitoring

On the job design changes



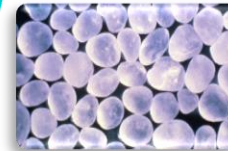
Stimulation Design

Operations



- 1 – Data Frac
- 2 – Main injection

Perforation / Completion
Selection & design



Materials selection
Fluids & proppant

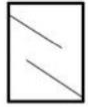
Synergies for geothermics for operational questions

Complexity depends on criticality of the job: from days to months of preparation

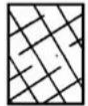
Stimulation design challenges

Rock mass characterization

Putting numbers on geology



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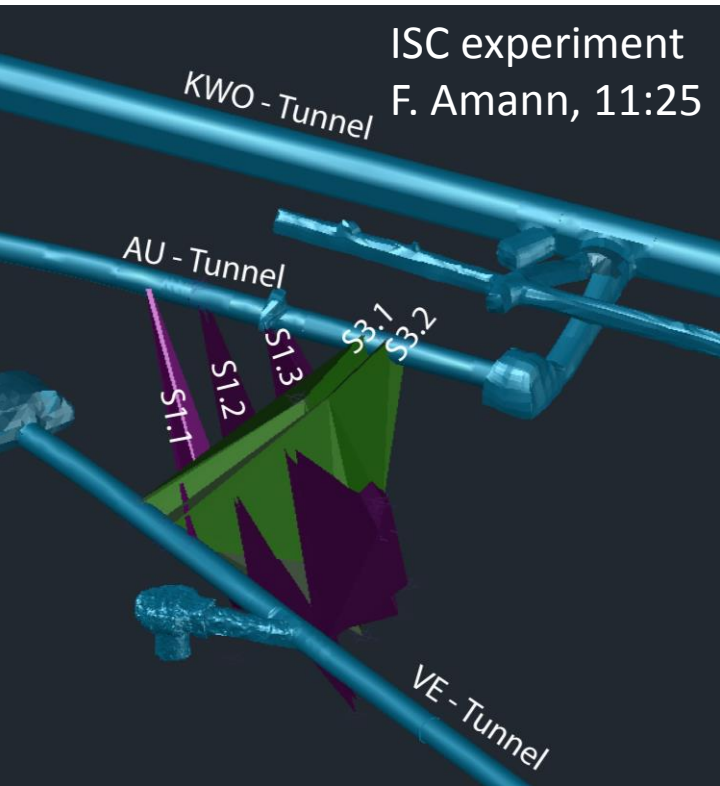
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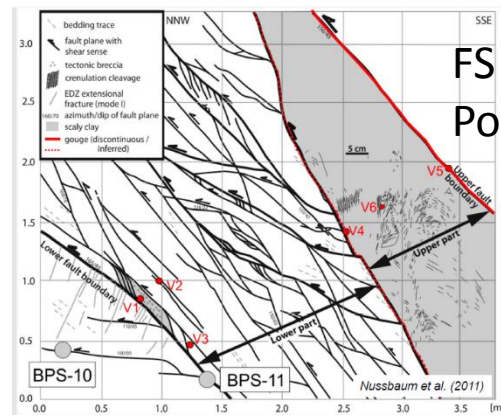


Uncertainty / risk analyses framework at successive project stages

Stimulation design challenges: filling the gap



ISC experiment
F. Amann, 11:25

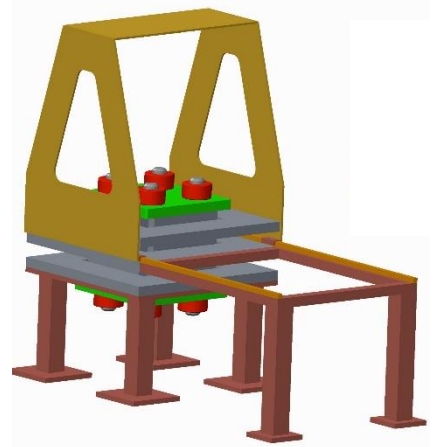


FS experiment / Mont-Terri
Poster: Kakurina et al.



Anticipating rock mass behavior:
What processes will be activated during stimulation ?

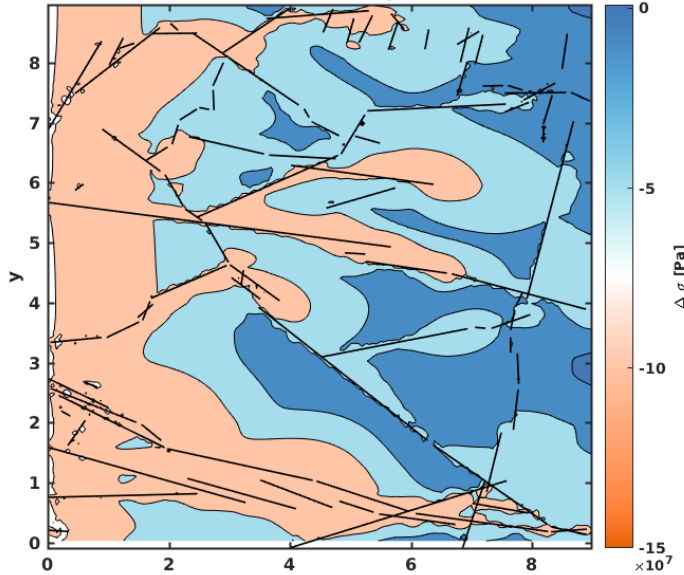
Design:
What methodology to decide on the optimal stimulation parameters ?



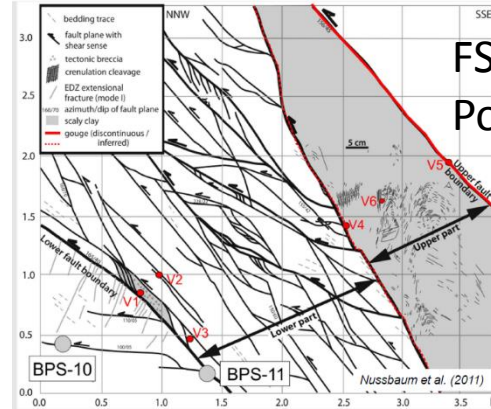
- Experiments on 30-30-30 centimeters block under true tri-axial stresses (up to 20 MPa) & pore-pressure
- Extensive *active* acoustic monitoring of fracture growth (32 sources / 32 receivers) on top of pressure – rate measurements
- Injection from a wellbore (cemented or not, inclined or not...)
- Any materials could be tested
- Up and running in mid/late 2017

Stimulation design challenges: filling the gap

Total stress change $\Delta\sigma$



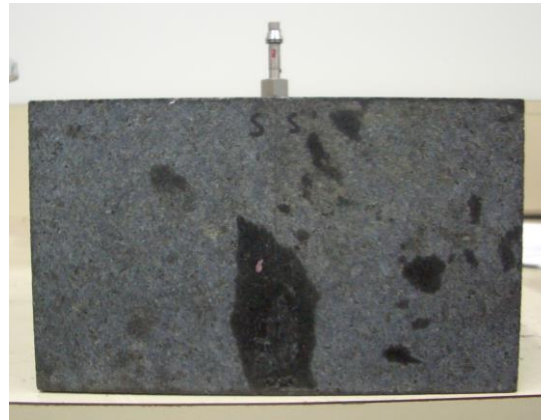
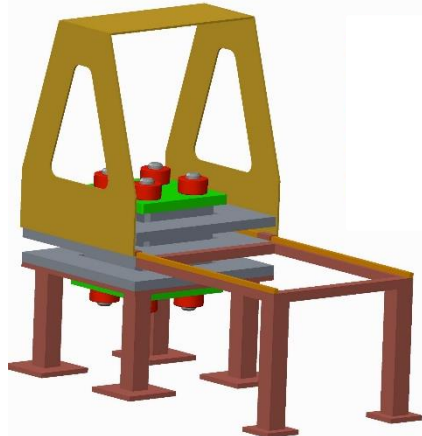
Numerical methods that captures stimulation processes
Poster: Jansen et al.



Anticipating rock mass behavior:
What processes will be activated during stimulation ?

Design:
What methodology to decide on the optimal stimulation parameters ?

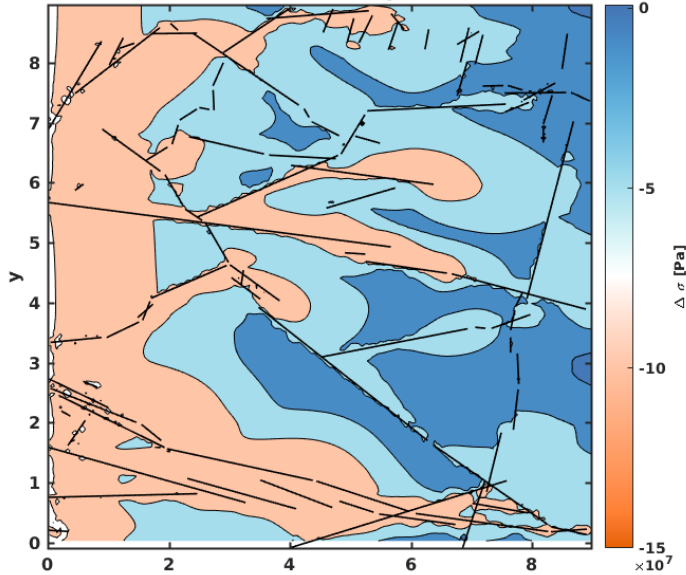
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Stimulation design challenges: filling the gap

Total stress change $\Delta\sigma$



Proppant transport /
effect of complex fluid
rheology on fracture growth

c.f. poster F. Moukhtari on fracture
asymptotic driven by power-law fluids

Anticipating rock mass behavior:
What processes will be activated
during stimulation ?

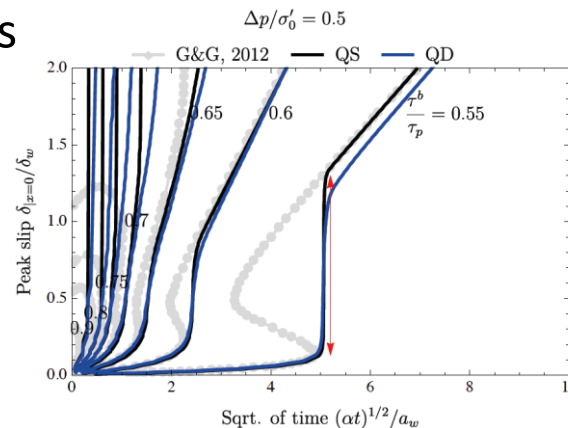
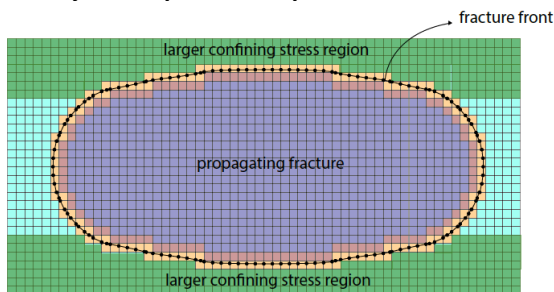
Design:
What methodology to decide
on the optimal stimulation
parameters ?

Properly modeling
the propagation of
fluid driven *shear*
fractures
(and the possible
nucleation & arrest of
dynamic slip)

Numerical methods that captures
stimulation processes
Poster: Jansen et al.

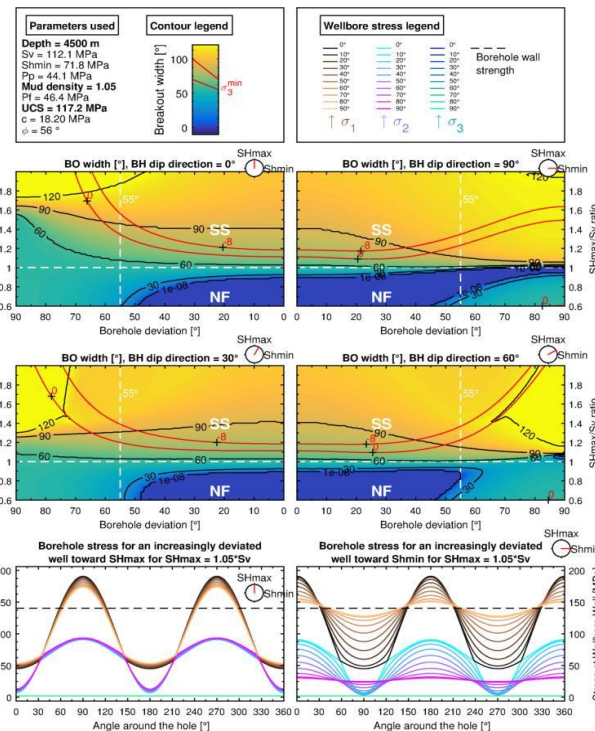
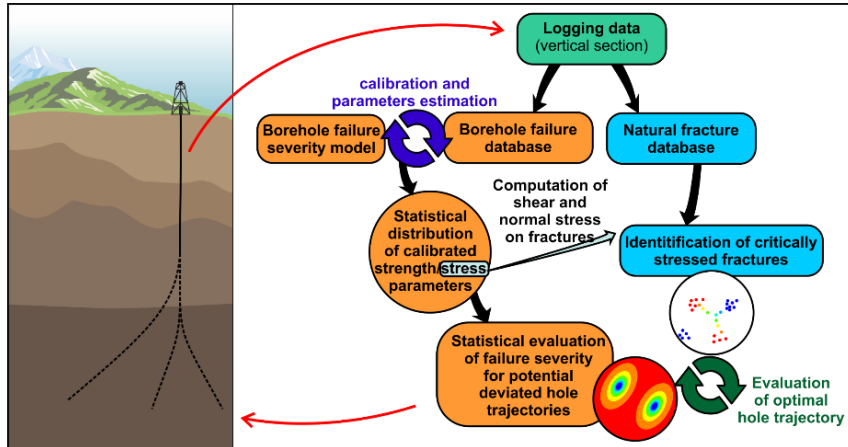
Modeling planar 3D hydraulic fractures

Fully-coupled implicit level set scheme



c.f. poster
F. Ciardo

Stimulation design challenges: filling the gap

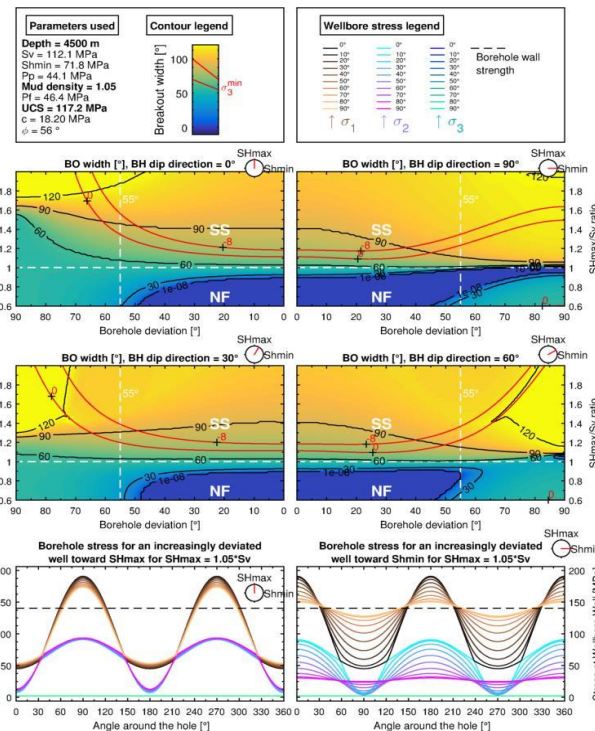
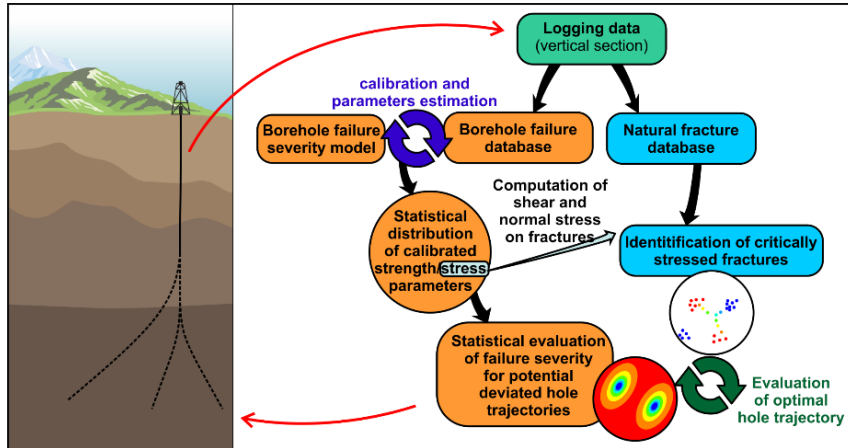


Deep Geothermal Well Optimisation Workflow (DG-WOW)
Poster: Dahrabou et al.

What do I need to know to take the right decisions ?

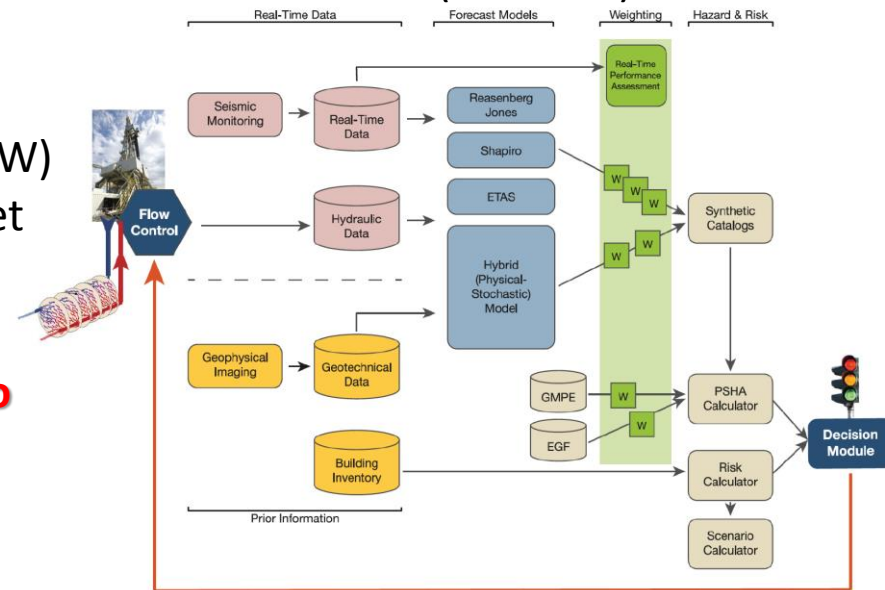
How do I measure or estimate the required parameters?

Stimulation design challenges: filling the gap



Deep Geothermal Well Optimisation Workflow (DG-WOW)
Poster: Dahrabou et al.

S. Wiemer et al (next talk)



What do I need to know to take the right decisions?

How do I measure or estimate the required parameters?

Uncertainty / risk analyses framework at successive project stages

Challenges for stimulation

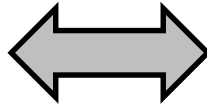
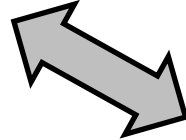
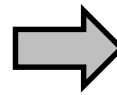
From science to engineering

What processes are activated during stimulation ?

Which processes are most efficient for reservoir creation ?

How to measure reservoir parameters at depth ?

New modeling tools and techniques



How to **control** what processes are activated during stimulation ?

What parameter is **required** to make engineering decisions ?
To what precision ?

We need to develop stimulation **design workflow** for deep geothermal reservoirs, applicable at the different **project stage** and including **uncertainty risk analyses framework**.

Thank you !



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Brice Lecampion / brice.lecampion@epfl.ch