Karlsruhe Institute of Technology

EGS operational experience in Soultz - key for worldwide technology improvement

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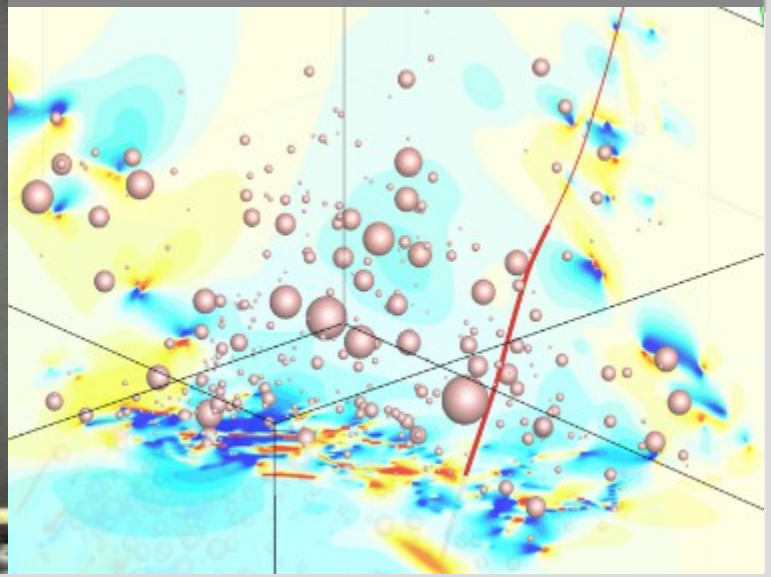
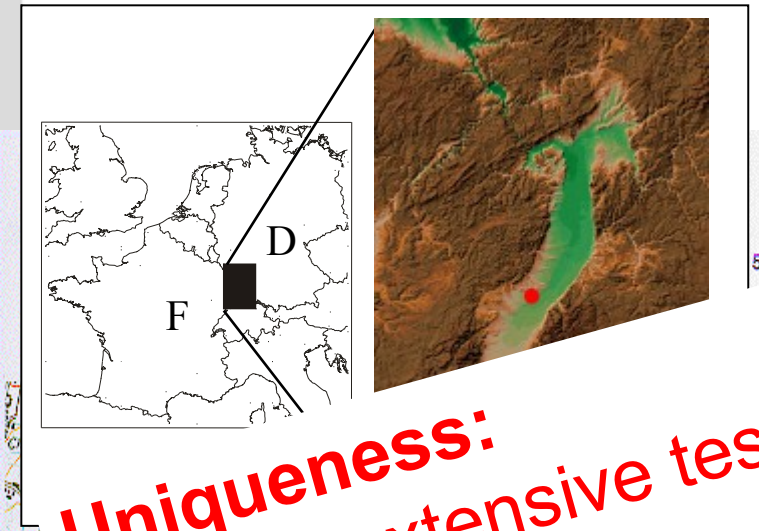


The Soultz-sous-Forêts project



Reservoir:

Fault system in Granitic Horst
3 wells at 650m dist
2 wells in > 3

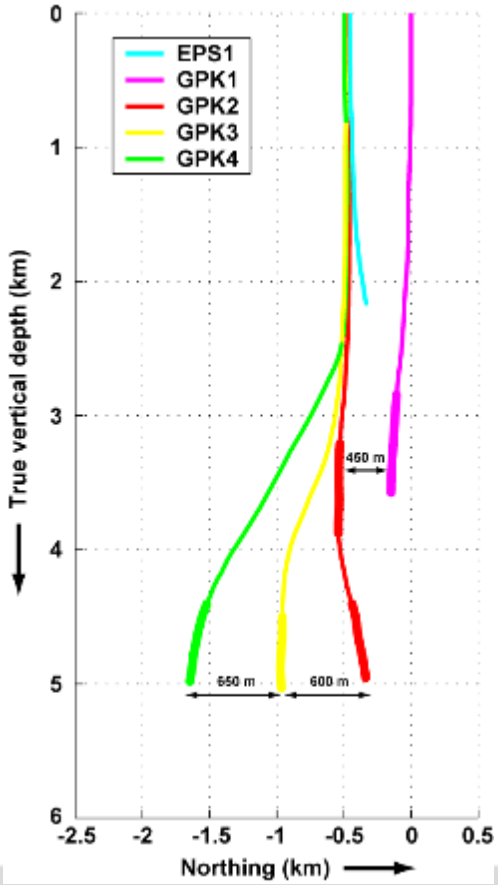
Uniqueness:

- Only extensive tested & documented EGS project worldwide
- Only 5 well system in central Europe
- Many years of operation experience

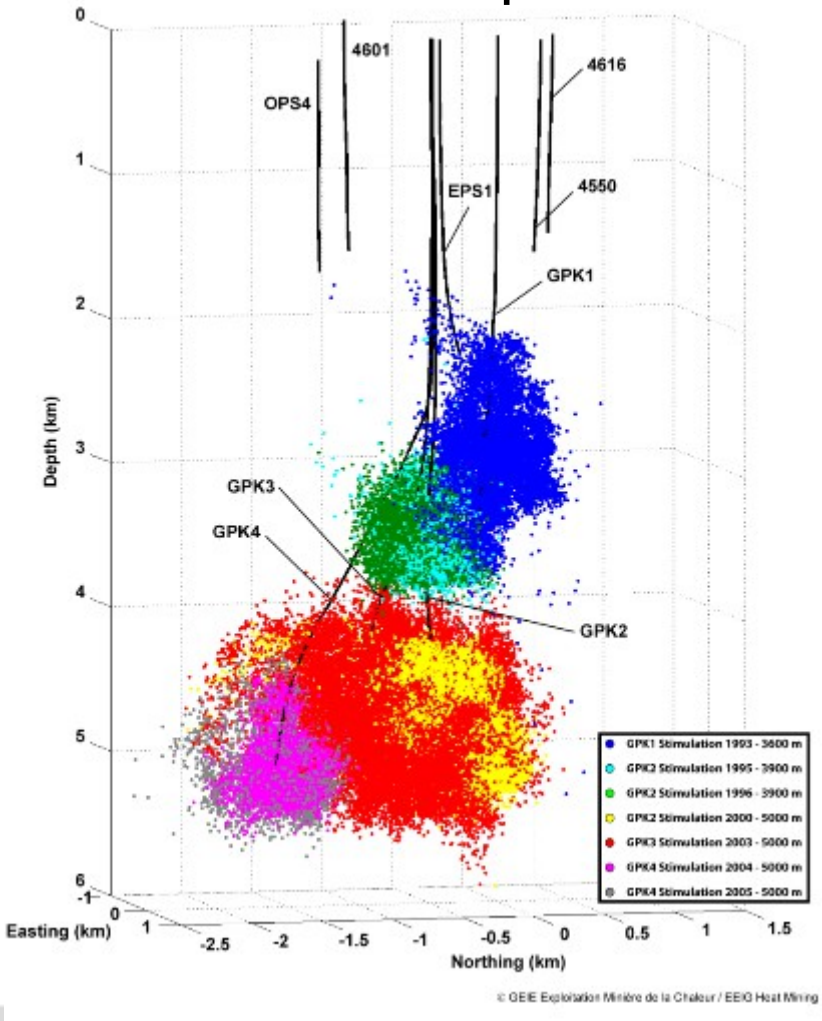
	Preparatory research
1992 (2200m)	Completion of 2 wells
1997 (3800m)	Completion of 2 wells successful circulation
2000	Drilling to 5km, reaching
200°C	
2005	Completion of 3 wells in 5
km	
2007	Circulation & construction of power plant
2008	test operation
2011	Commercial operation

The Soultz-sous-Forêts project

Deep boreholes configuration



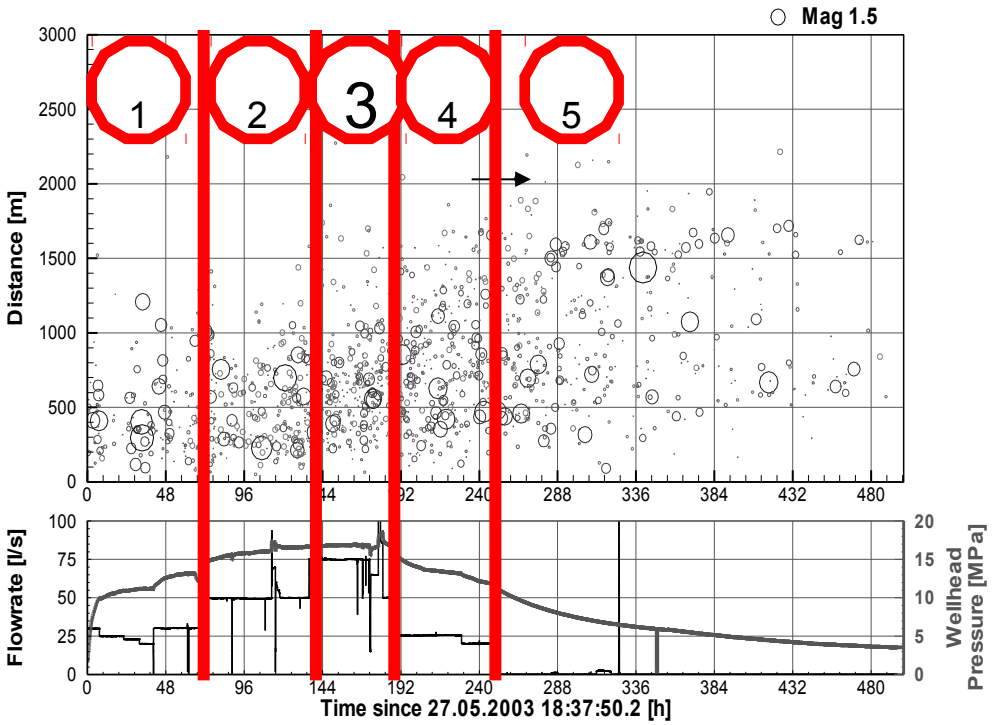
Reservoir Development



Observation 1:

Seismic activity can be characterized for a local rock mass

- Seismically released energy can be related to injected hydraulic energy during a stimulation period
- Stimulation GPK3:



- Ratio of M_0/E_h nearly constant
- Seismic activity at GPK3 / 5km can be characterized

- Phase 1: R = 180
  - $M_{max} = 2.7\ (M_0 = 10^{14} Nm)$
- Phase 2: R = 117
  - $M_{max} = 2.9\ (M_0 = 6x10^{13} Nm)$
- Phase 3: R = 96
  - $M_{max} = 2.8\ \ (M_0 = 5x10^{13} Nm)$
- Phase 4: R = 116
  - $M_{max} = 2.9\ (M_0 = 6x10^{13} Nm)$
- Observation Phase 5:
  - $M_{max} = 2.9\ (M_0 = 1.5x10^{14} Nm)$

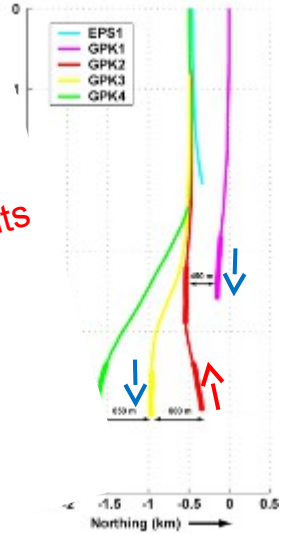
Kohl et al., 2011
Data from L. Dorbath

Observation 2:

Seismicity can be handled for constant hydraulic conditions during circulation

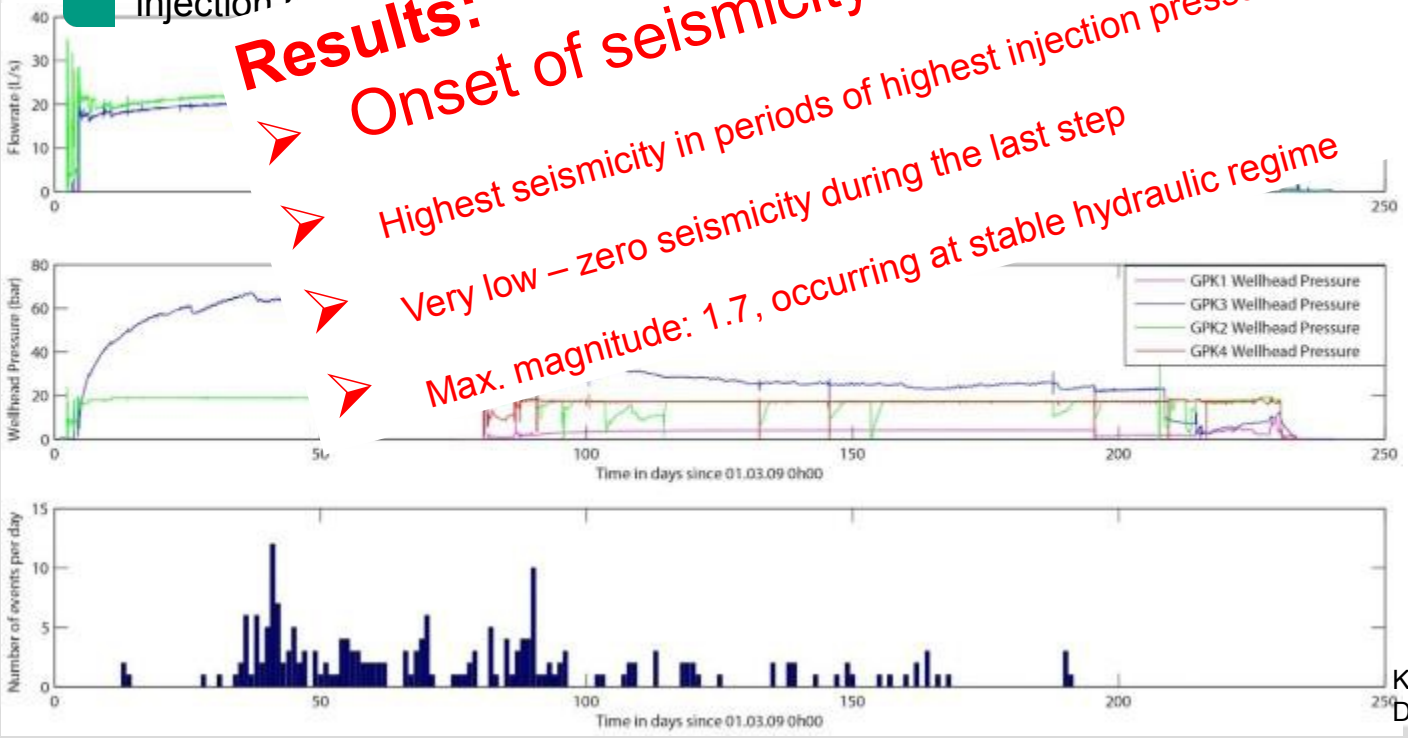
Circulation test of 2009

- 7 months, pump-assisted production from GPK2 / GPK4, into GPK1 / GPK3
- Flow rates
  - GPK2: 22 – 17; GPK4: 11 L/s
  - GPK3: 20 - 10 L/s
- injection



Results:

- Onset of seismicity at P_{GPK3} > 60 bar, 206 detected events
- Highest seismicity in periods of highest injection pressure,
- Very low – zero seismicity during the last step
- Max. magnitude: 1.7, occurring at stable hydraulic regime

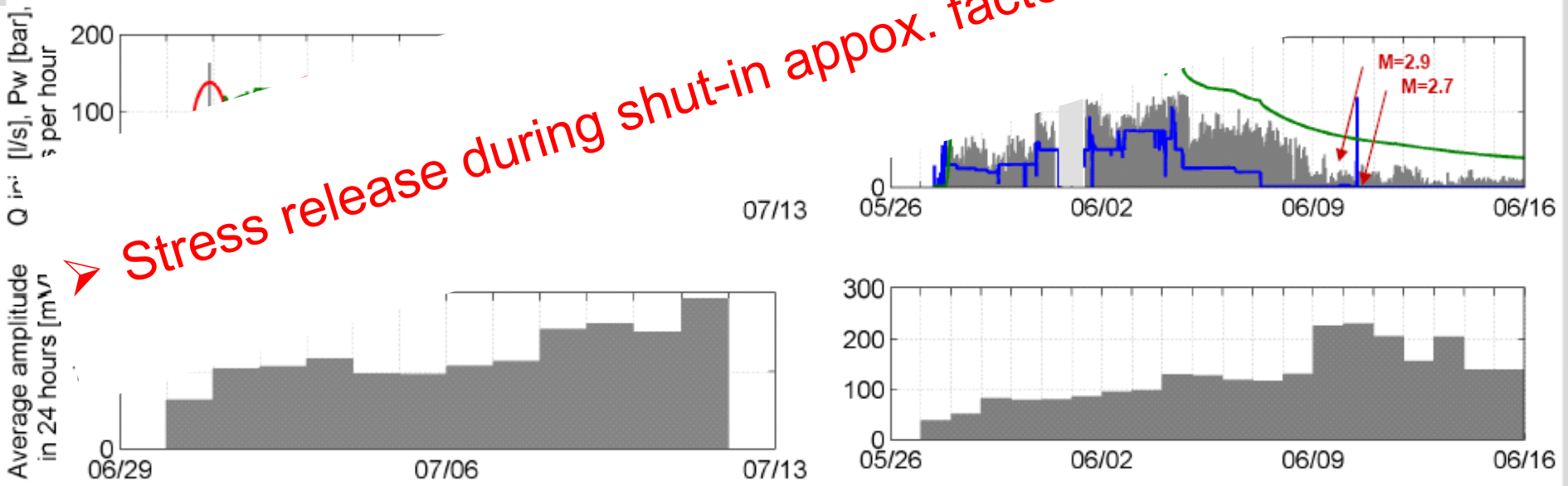


Kohl T., Genter A., Cuenot N., GRC 2012
Data: GEIE

Observation 3:
Seismicity during shut-in requires complex analyses

- GPK2 in 2000
  - Volume 23'400 m³,
  - max. well head pressure 150 bar
  - Mag. M2.4 (Shut-in)
- GPK3 in 2003
  - Volume 37'[illegible]
  - [illegible] 0 bar

Stress release during shut-in appox. factor "2" higher



(Schindler et al., 2008, EHDR Sc. Conf, Correlation of hydraulic and seismic observations during stimulation experiments in the 5 km deep crystalline reservoir at Soultz)
Data: GEIE

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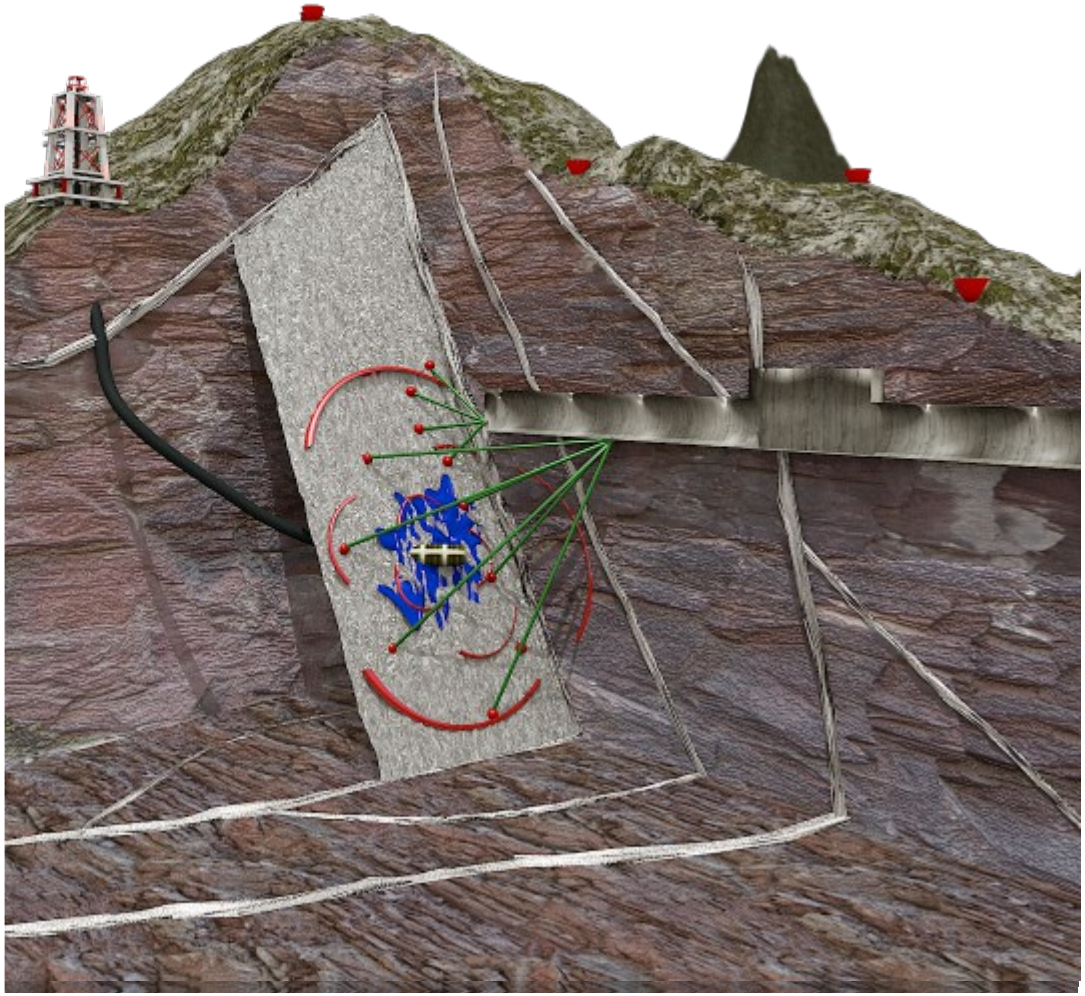
GeoLaB: a perspective geo-scientific infrastructure project

Institut für Angewandte Geowissenschaften

GeoLaB Concept: Controlled High Flow Rate Experiments - CHFE

- Effects of massive injection in fractured rock

- **Parameter distribution and variability f(x, t)**
  - Transmissivity
  - Tracer permeability
  - Electric conductivity
  - Clay content
  - Geochemistry
  - Size / extension
  - Micro seismicity
  - Rock mechanical parameters
  - Stress field
  - …



Conclusion

- **Soultz experience is essential for future EGS projects**
- **Seismicity shows typical pattern**
- **Fundamental Research facilities will improve the technology**