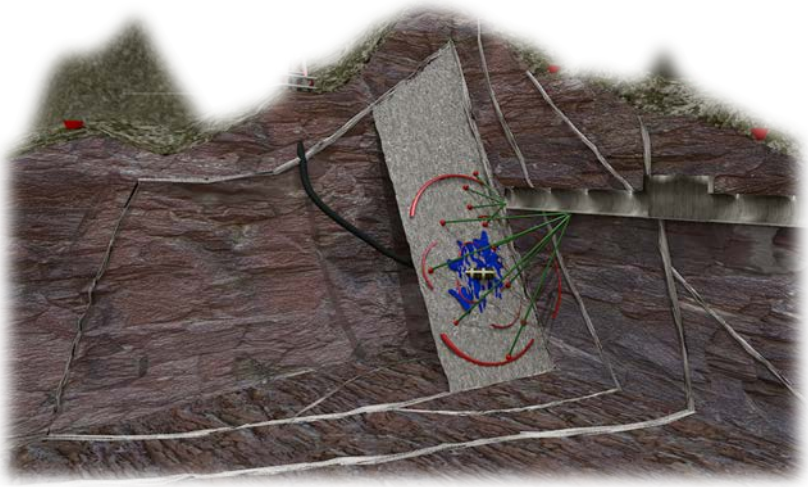
Effiziente und sichere Nutzung der Geothermie
Was kann das GeoLaB dafür leisten?

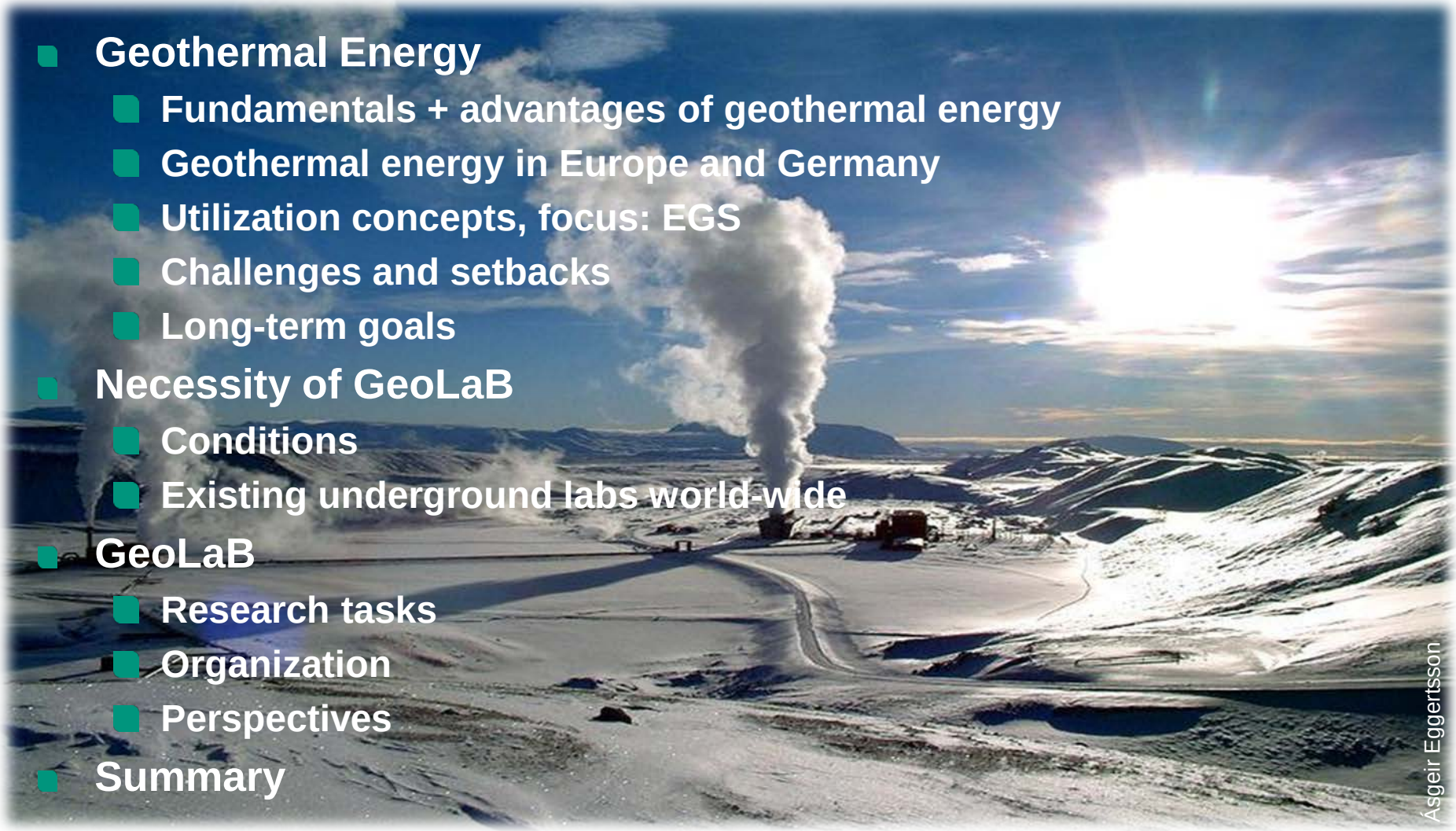
Dr. Carola Meller
Institut für Angewandte Geowissenschaften, KIT



Ideas about geothermal

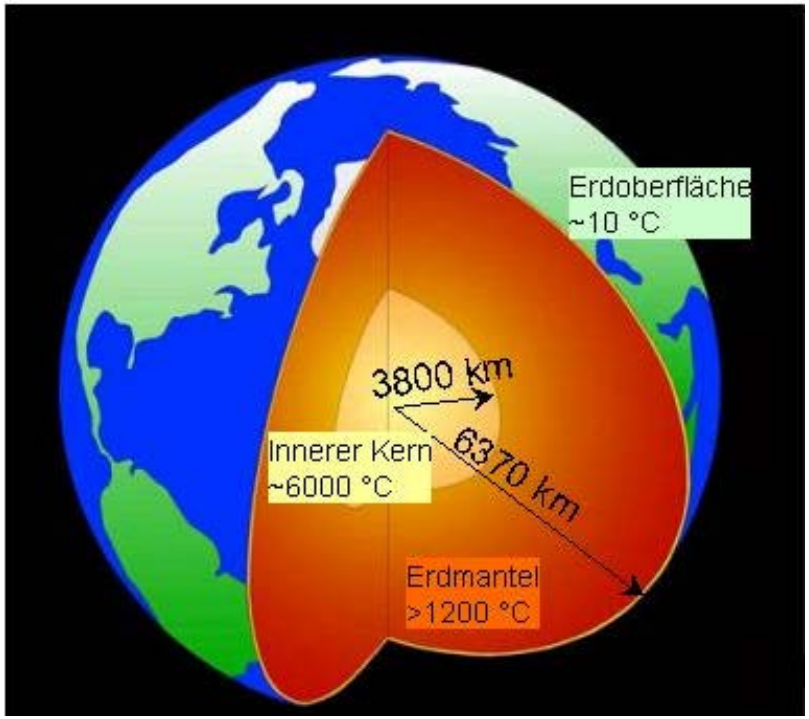
Outline

- Geothermal Energy
  - Fundamentals + advantages of geothermal energy
  - Geothermal energy in Europe and Germany
  - Utilization concepts, focus: EGS
  - Challenges and setbacks
  - Long-term goals
- Necessity of GeoLaB
  - Conditions
  - Existing underground labs world-wide
- GeoLaB
  - Research tasks
  - Organization
  - Perspectives
- Summary



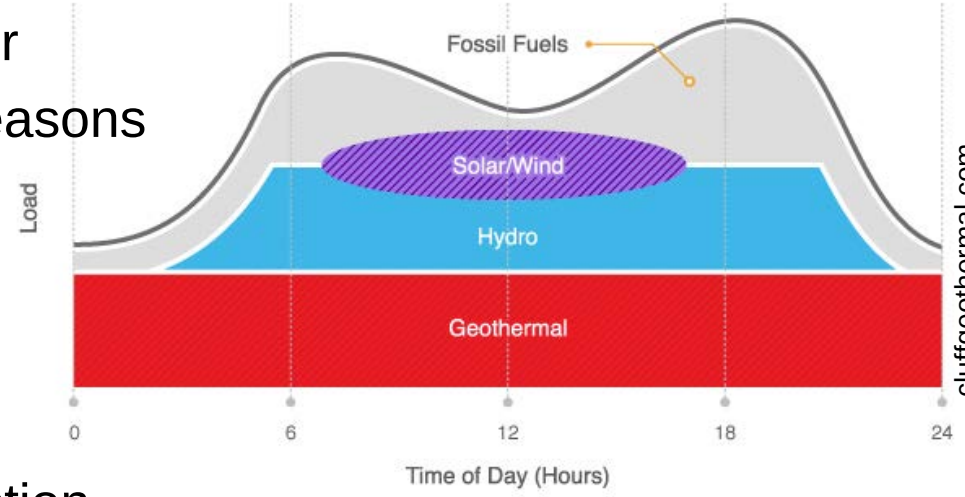
Geothermal energy

- Geothermal energy:
  =Heat stored in the Earth's interior
  - 99% of the earth >1000 °C
  - 0.1% of the earth <100°C.
- Geothermal heat flux
  - 60 mW m^{-2}.
  - ~< 0.1% of solar radiation
  - Total heat flux: 40×10^{12} W
  - ~power of approx. 40’000 nuclear power plants



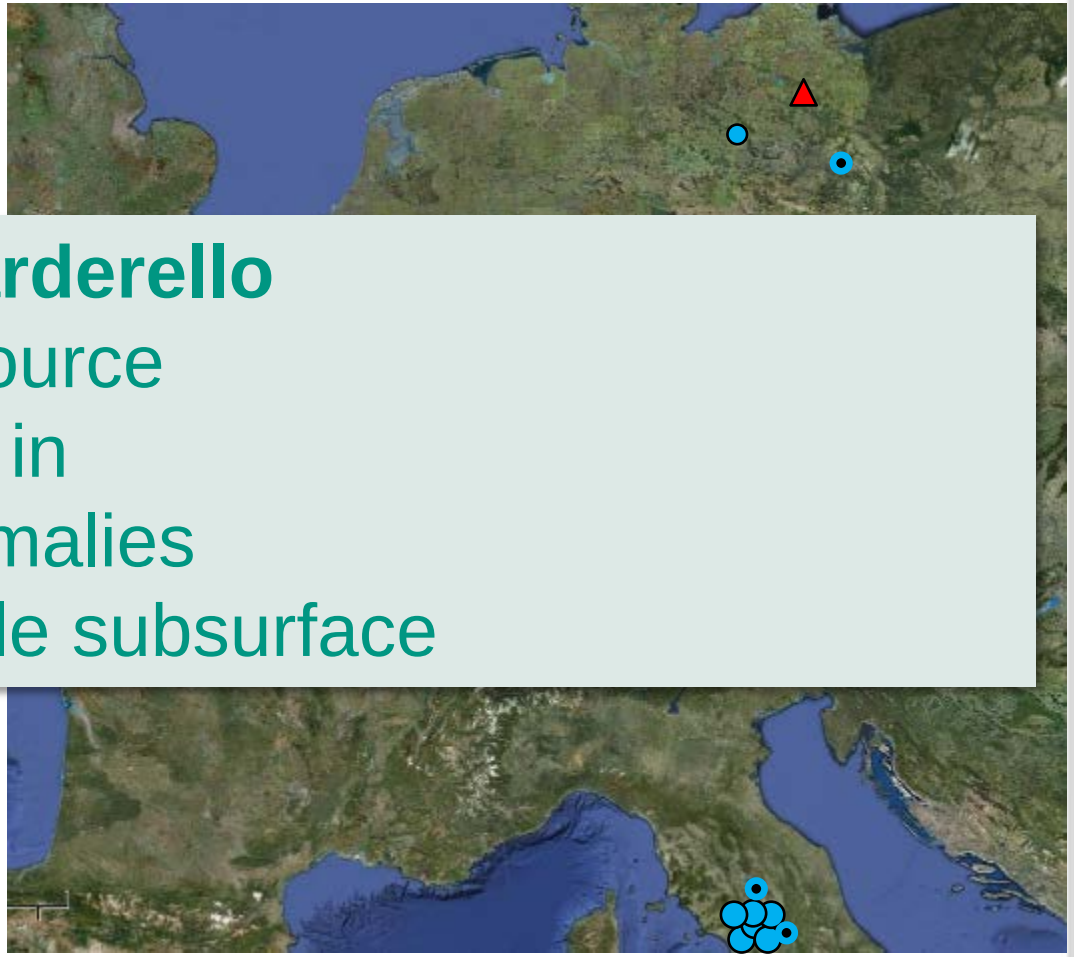
Geothermal energy

- Advantages of geothermal heat/power production
  - Can provide base-load power
  - is independent of weather/seasons
  - Low in CO_2
  - Huge energy potential
  - High availability
  - Low space demand
  - Decentralized energy production
  - Sustainable
  - Combined heat and power production
  - Shallow geothermal is fully competitive



Getohermal energy in Europe

- Production
  - Heat: ▲ 444 MW_{th}
  - Power: ● 720 MW_{el}



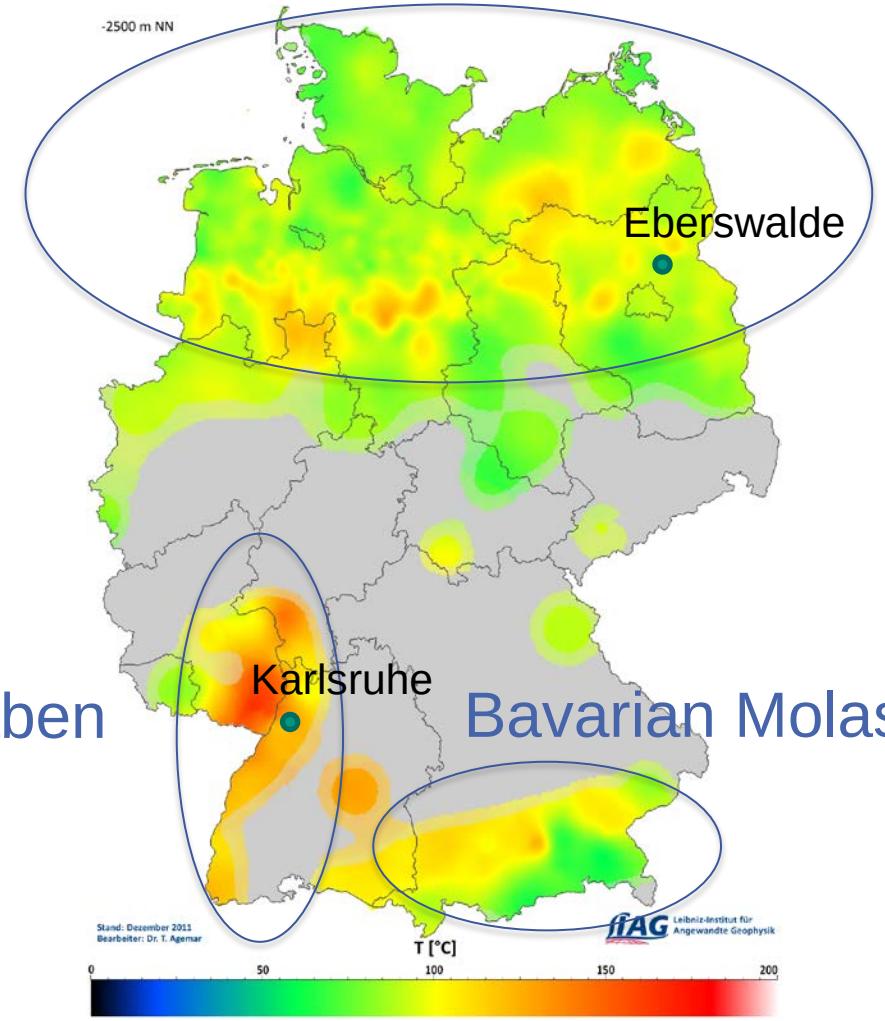
With exception of Larderello

- No volcanic heat source
- Established mostly in
  - Heat flow anomalies
  - High permeable subsurface

Unterföhring	Deutschland	9	0.0
Unterhaching	Deutschland	38	3.4
Unterschleißheim	Deutschland	7	0.0
Waren	Deutschland	1.3	0.0
Altheim	Österreich	12.4	1.0
Bad Blumau	Österreich	7.6	0.2
Lardarello (31 Anlagen)	Italien	0	720.0
Soultz	Frankreich	30	2.5
Paris (29 Anlagen)	Frankreich	200	0.0
Riehen	Schweiz	3.1	0.0
Summe		**443.6**	**734.0**

Geothermal Energy in Germany

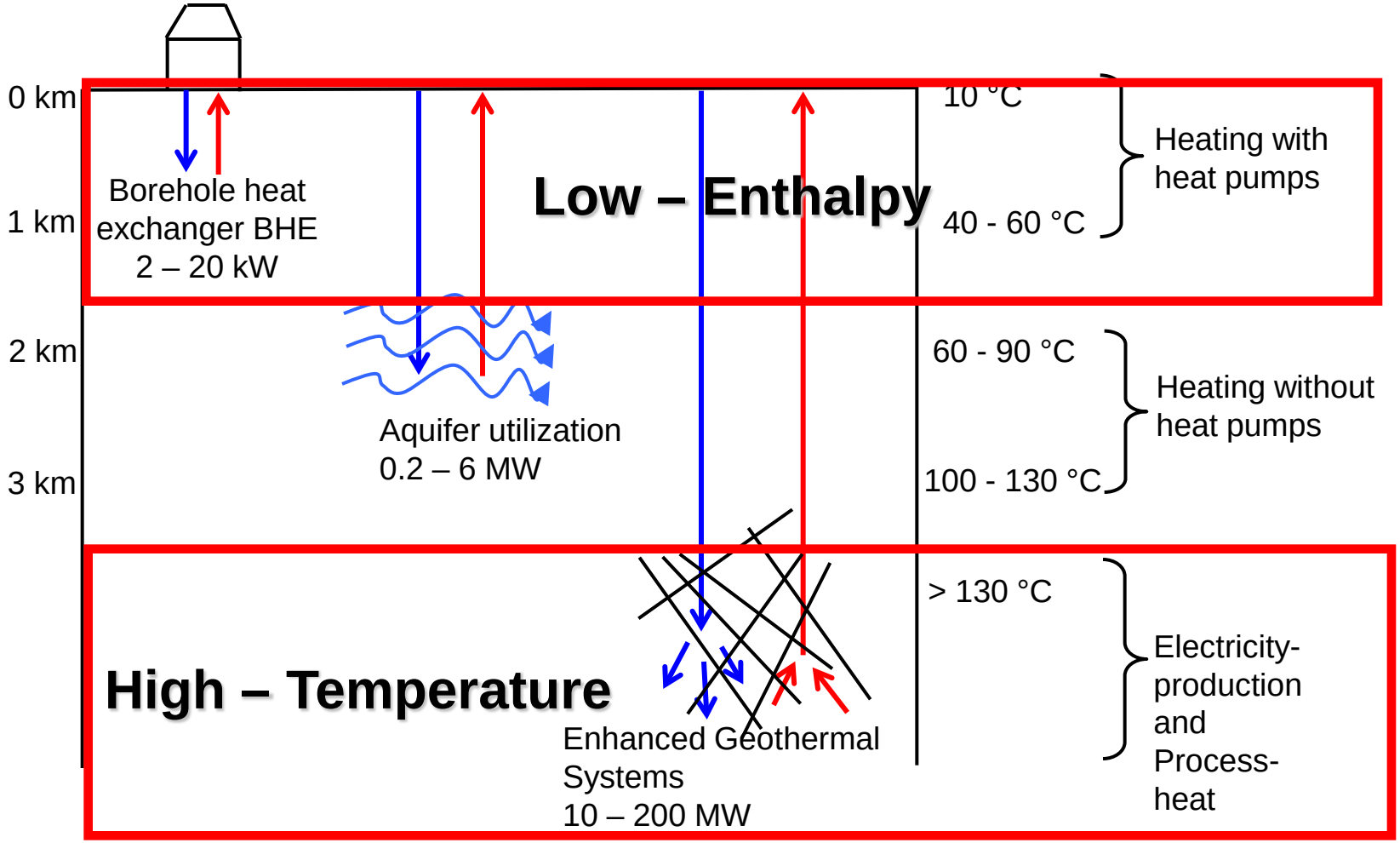
Northern German Basin



Upper Rhine Graben

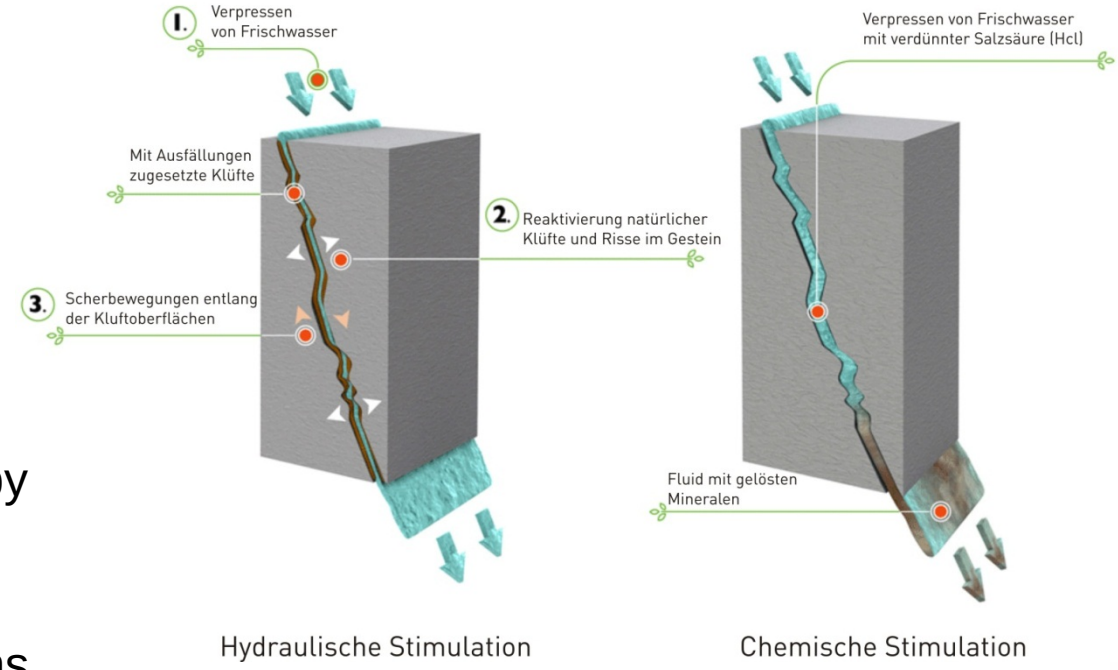
Bavarian Molasse

Geothermal Energy - Utilization



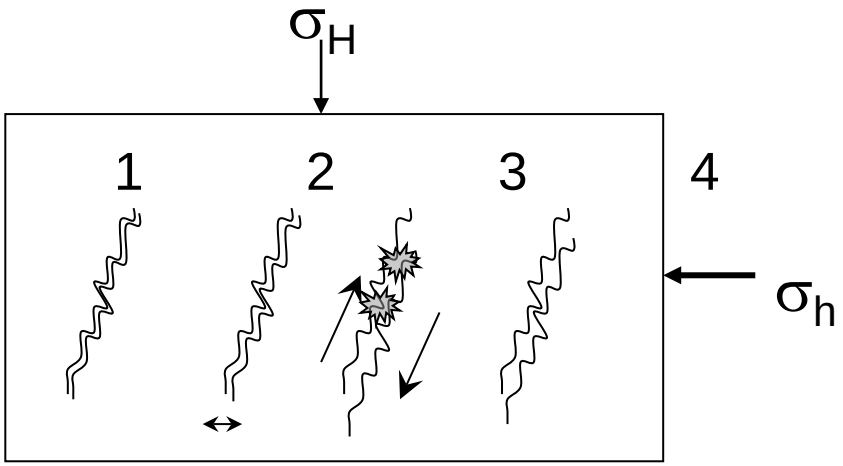
Geothermal Energy – EGS Concept

- What is EGS?
  - Usage of low-permeable rock formations
  - Improving productivity by stimulation
- Why EGS?
  - Application in low-enthalpy regions possible
  - Independent of highly permeable rock formations
  - Higher temperatures in deep boreholes >2km



Ref.: GEIE 2011

Hydraulic stimulation



- Hydraulic Stimulation
  1) Initial fracture in ambient stress field
  2) Pressurizing => fracture compliance (normal opening)
  3) Further pressurizing => shearing
  4) remaining fracture aperture higher than initial

Challenges and abandoned projects

- Sensible seismic events
- Economic feasibility – no investors
- Drilling costs
- Low acceptability due to project failures
  - Basel
    - Large magnitude 3.3 event
  - Landau
    - Sensible seimsicity
    - Casing damage caused uplifts around power plant
  - Stauffen/Böblingen
    - Faulty installation of borehole casing caused shortcut between aquifer and anhydrite→ swelling and uplift of city centre→ houses damaged
    - Pumping necessary for long time period
  - St. Gallen
    - Gas cavity was hit during drilling→ blow-out caused seismic events

Basel-example of a failed project

Photo:Geopower, 2006

- Operator: geopower AG
- Reservoir:
  - Granitic rock
  - no exploration
  - production [illegible] ting system)
  - [illegible]
  - [illegible]
  - 5000 m
  - temp. 200ºC
  - capacity 6 MW_{el} & 17 MW_{th} (planned)
- Activities:
  - 15 Mai 2006 start of drilling operations
  - October 2006 1st well completed
  - December 2006 Major stimulation
  - Pressure
  - 8 Dec 2006 Earthquake Mag 3.4 / 2.4
    subsequent Mag 3.1/3.2/3.3/2.9
    → project on standby
  - 12 Dec 2009 → project suspended

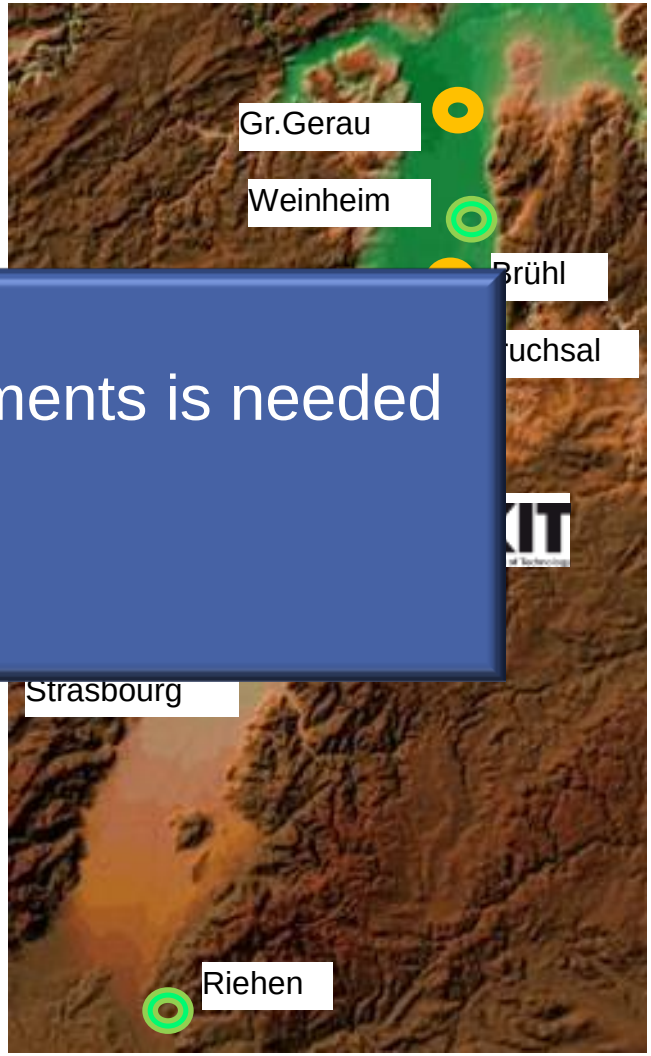
Exploration and understanding of related processes is essential for success of EGS

Long-term goals for EGS

- Science
  - Impact of massive hydraulic flow in fractured medium
  - C
- Eco
  - C
  - I
  - Achieving 3D EGS, long time reliability, ...
- Society
  - Public acceptance
  - Mitigate the environmental impact

Research facility for in situ experiments is needed

→ necessity for a GeoLaB



Necessity of an URL

- Observation of processes in situ
  - 3D/4D
- Laboratory experiments not transferrable
  - Experiments on ~reservoir scale
- Bundling of knowledge
  - International
  - Science + industry

Ideal conditions for GeoLaB

Prerequisite: Site conditions must be close to conditions in typical reservoir rocks (crystalline basement)

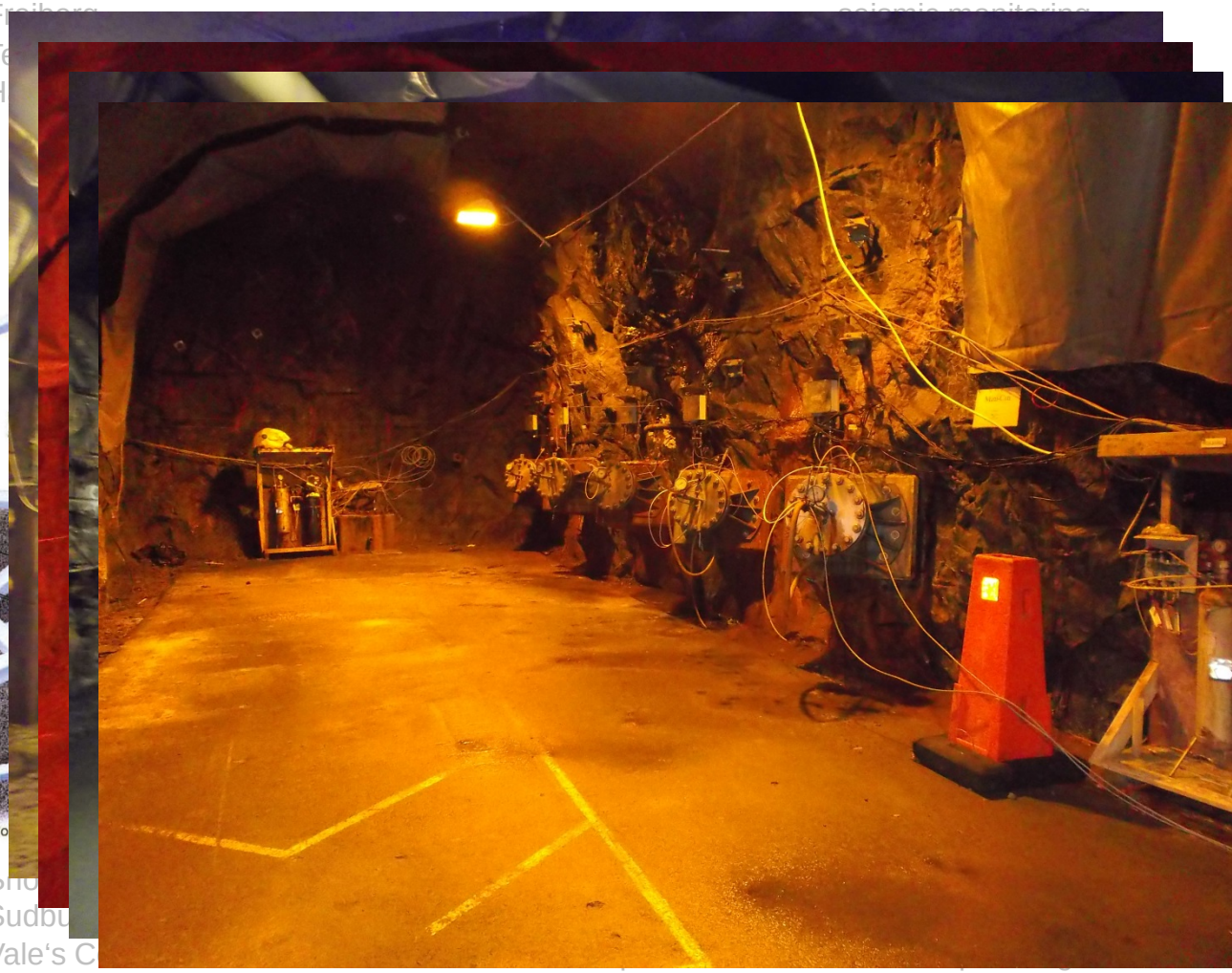
- Hydraulically undisturbed fracture zones
  - Alteration, transmissivity, boundary conditions of the system known, low environmental impact of experiments
- High differential stress (tectonic forces)
  - Depth ~500m
- Accessibility/infrastructure and low environmental impact

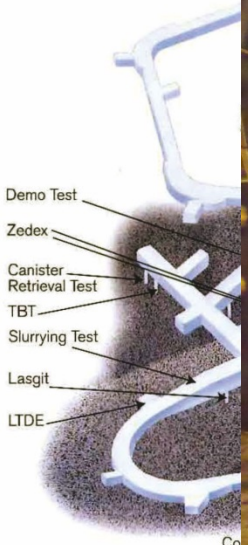
Selected Worldwide Underground Research Labs

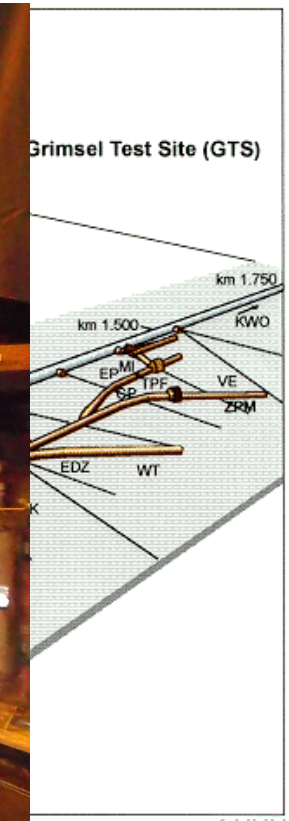
Germany	Teach./Res. Mine Reiche Zeche Freiberg	fractured gneiss	drilling technology seismic monitoring	230
Switzerland	Test adit Hagerbach	clay / marl limestone	tunnel technology	
	Mont Terri Project Saint-Ursanne	marl/clay (Opalinus) limestone/dolomite	geoscientific & geotechnical disposal of radioactive waste	250-320
	Grimsel Test Site Grimselpass,	granite	engineered rock barriers disposal of radioactive waste	450
France	Lab. Souterr. Bas Bruit (LSBB) Rustrel (Provence)	fractured carbonate rock	geophysics	200-500
	Meuse/Haute-Marne Bure	claystone	disposal of radioactive waste	490
	Tournermire Auvergne,	claystone	disposal of radioactive waste	250
Sweden	Äspö Hard Rock Laboratory Oskarshamn,	fractured granite	disposal of radioactive waste	500
Finland	ONKALO Eurajoki	gneiss	disposal of radioactive waste	420-520
Belgium	HADES-URF Mol/Dessel,	clay	disposal of radioactive waste	225
USA	Sanford Underground Lab. Lead S.D.	metamorphic rocks	physics, biology, geophysics	
Canada	AECL Underground Res. Lab. Lac du Bonnet	granite	disposal of radioactive waste	240-420
	SnoLab Sudbury	Metamorphic Impact structure	nuclear physics	2000
	Vale‘s Coleman Mine Sudbury	Metamorphic Impact structure	ultra-deep mining	planned
Japan	Mizunami Undergr. Res. Lab. Mizunami,	sediments granite	geoscientific, waste disposal (in progress)	up to 1000

Selected Underground Research Labs

Germany	Teach./Res. Mine Reiche Zeche Freiberg	fractured gneiss	drilling technology	230
Switzerland	Te… H…			
	Sudbu… Vale's C… Sudbury	Impact structure sediments granite		planned
Japan	Mizunami Undergr. Res. Lab. Mizunami,		geoscientific, waste disposal (in progress)	up to 1000







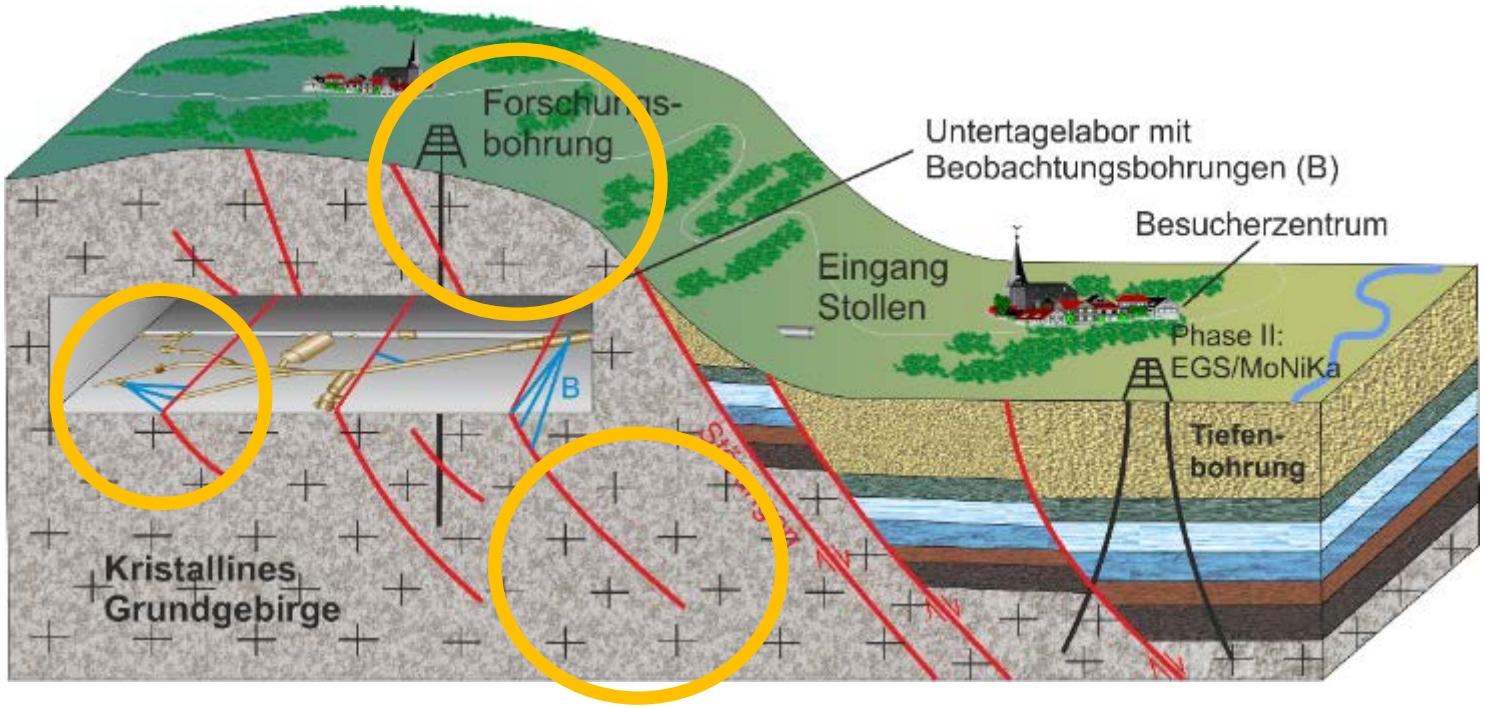
GeoLaB

"Geoscientific laboratory for Large scale monitoring of THMC coupled processes in the crystalline Basement"

- Geothermal Underground Research Lab for reservoir technology development
- Crystalline = largest geothermal resource
  - Corresponds to current technological development, EGS
  - Long term investment
    - Preparing an area-wide application
    - Technological progress

Concept of a large-scale geothermal research in crystalline

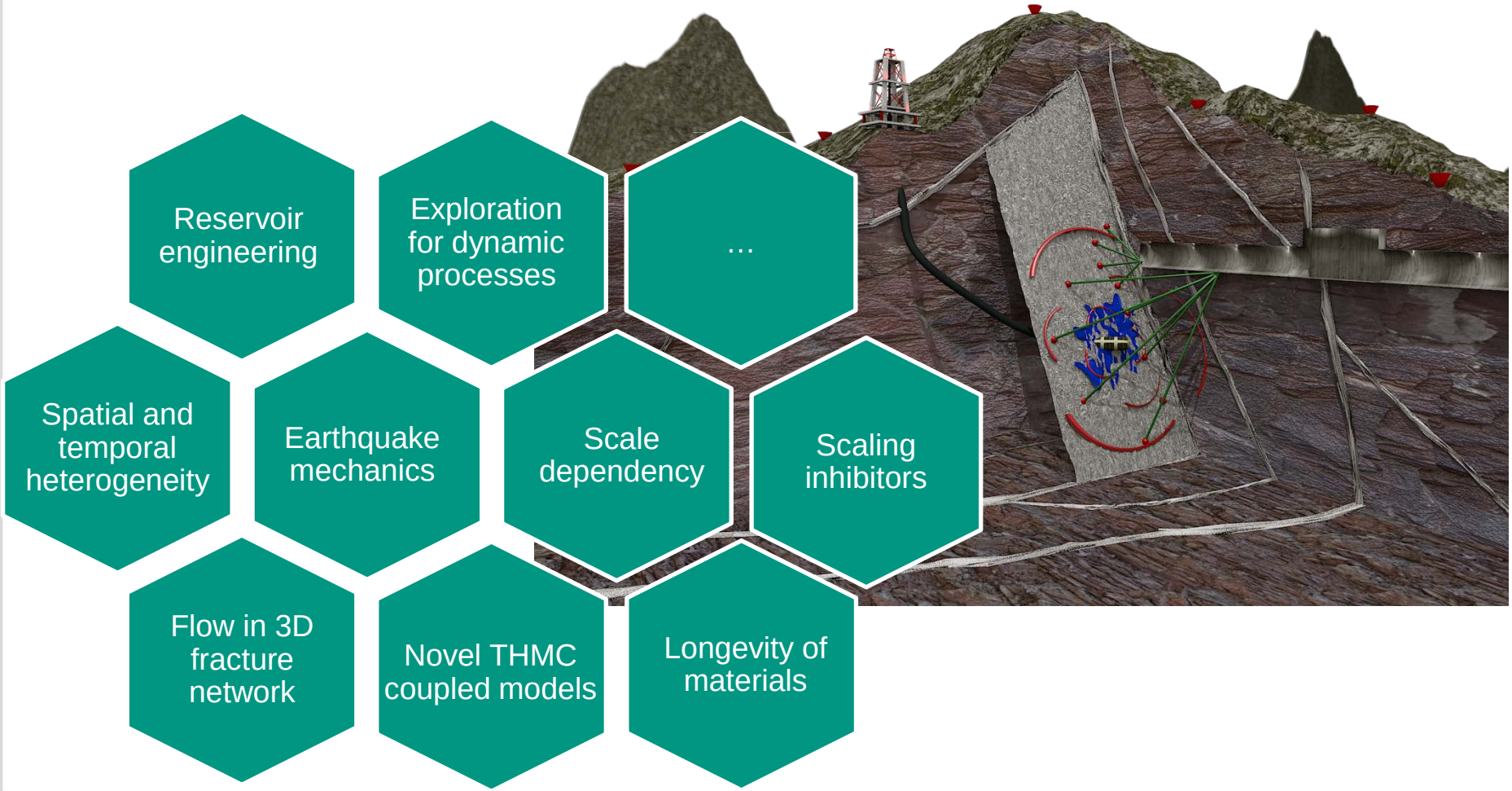
- Features:
  - Fractured rock
  - 3D coverage of measurements
  - Controlled injection experiments



Key Questions:
Resolving current restrictions

- Closing scale gap (Lab – GeoLaB – reservoir)
- Effects of complex geometries
  - Evaluate by 3D measurements instead of 1-D wells
- Hydro-thermal regime in fractured rocks
  - Rough fracture surfaces vs. Parallel plate model
  - Darcy flow vs. Navier-Stokes
  - Heat transfer
  - Fluid-rock interaction
- Hydro-mechanical interaction
  - In heterogeneous rock
  - In heterogeneous fracture networks
- Improving reservoir engineering

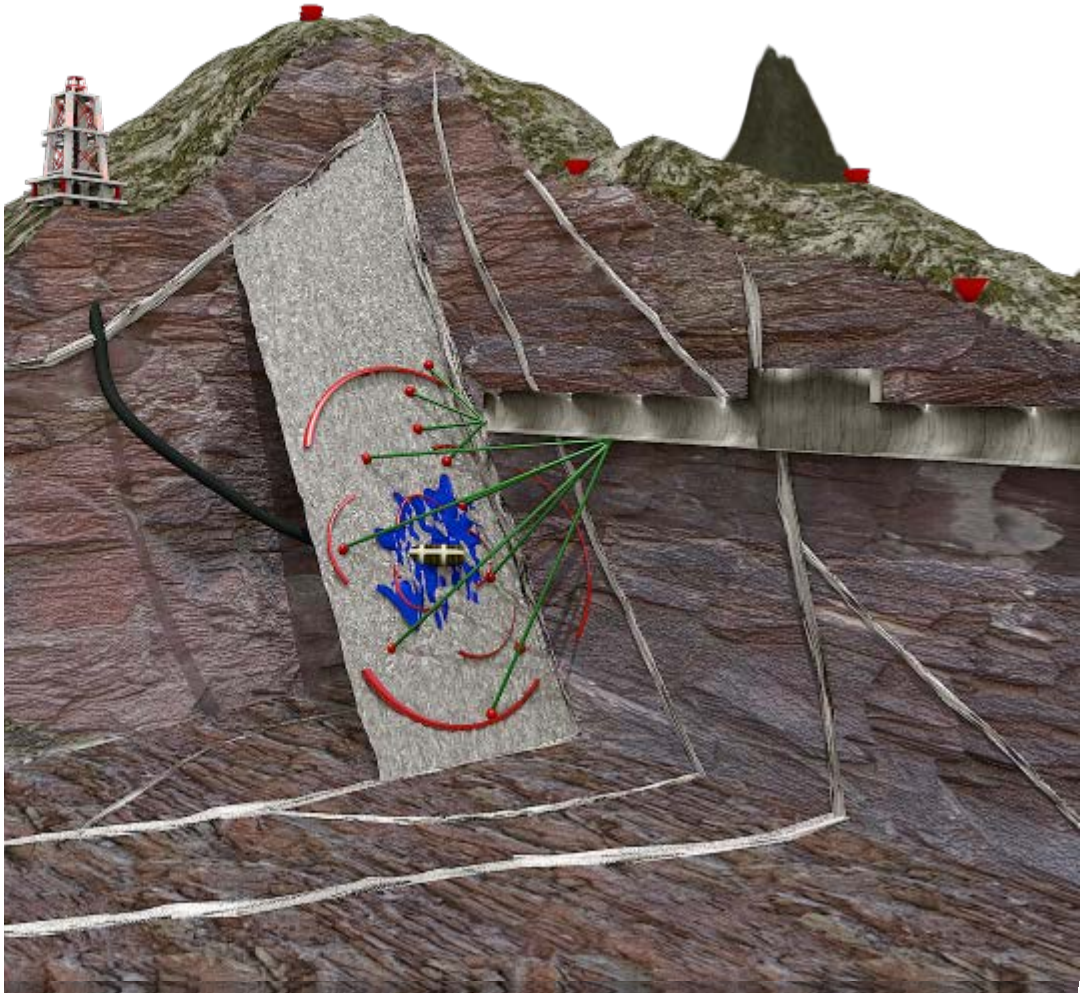
GeoLaB experiments



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
  - …

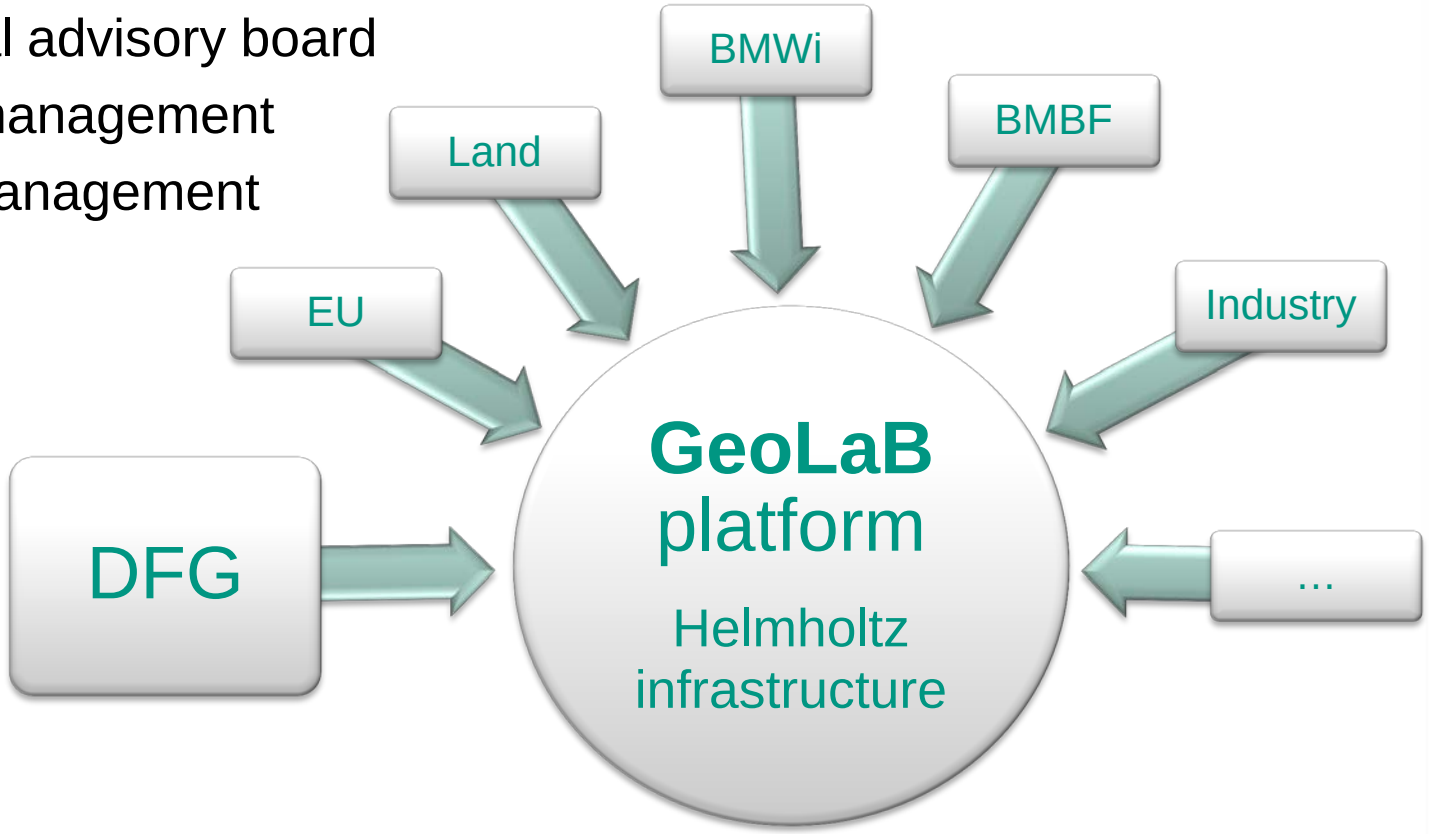


Perspectives of GeoLab

- Science
  - Impact of massive hydraulic flow in fractured medium
  - Characterization of coupled processes, …
- Economics
  - Optimized reservoir engineering
  - Achieving 50 L/s, Long time reliability, …
- Society
  - Public acceptance
  - Environmental friendly technology development
  - Improved quality assurance
    - Risk assessment of induced seismicity
    - controlling processes at high flow rate, …

Organization & Structure

- Management by Helmholtz institutions (KIT / GFZ / UFZ)
- Supported by DFG and international partners
  - International advisory board
  - Technical management
  - Scientific management



Summary

- Geothermal Energy can contribute to the future energy mix
- Safe and economic use of geothermal energy requires profound understanding of related processes

GeoLaB…

- is essential for systematic large scale research,
- Complements existing large-scale projects and laboratory experiments
- Offers a common platform for international community (University and Industry)
- Boosts technological innovation
- Requires competences of the whole geo-community


Thank you for your attention.