Annual Conference 2015

SCCER SoE

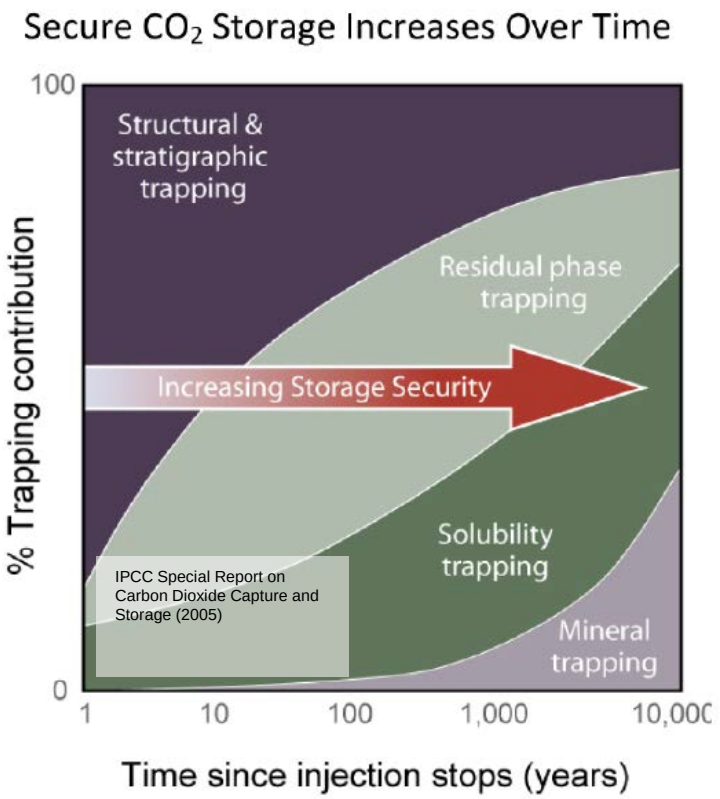
SWISS COMPETENCE CENTER for ENERGY RESEARCH
SUPPLY of ELECTRICITY

Challenges for CO_2 Storage

Martin Saar,
with help from Alba Zappone, Marco Mazzotti, Mischa Werner,
Xiang-Zhao Kong, Friedemann Samrock, Neeraj Shah, Markus Häring,
and several others

Challenges for CO_2 Storage

- Reservoir exploration and characterization (high-k reservoirs overlain by low-k caprocks)
  - injectivity
  - caprock integrity
  - poroelasticity
  - seismicity
- Understanding CO_2 trapping mechanisms (structural, residual, solubility, mineral)
- Fluid-mineral reactions and reservoir/caprock evolution (porosity/permeability evolution)
- Drilling, well completion, cementing
- Monitoring
- Costs
- Public acceptance



=> Significant research and progress has been made (see more later) but what is needed next is some sort of a field test (**pilot and demonstration project**).

Focus today: Pilot and demonstration project for CO_2 storage (+ some examples from the GEG Group)

CARMA: Carbon Management in Power Generation (Jan. 2009-Jan.2013)
→ Roadmap 2013

Then:

- ECCSEL
- ERA-NET Cofund
- CO_2 GeoNet
- Mont Terri
- SCCER-SoE: CO_2 Injection Pilot

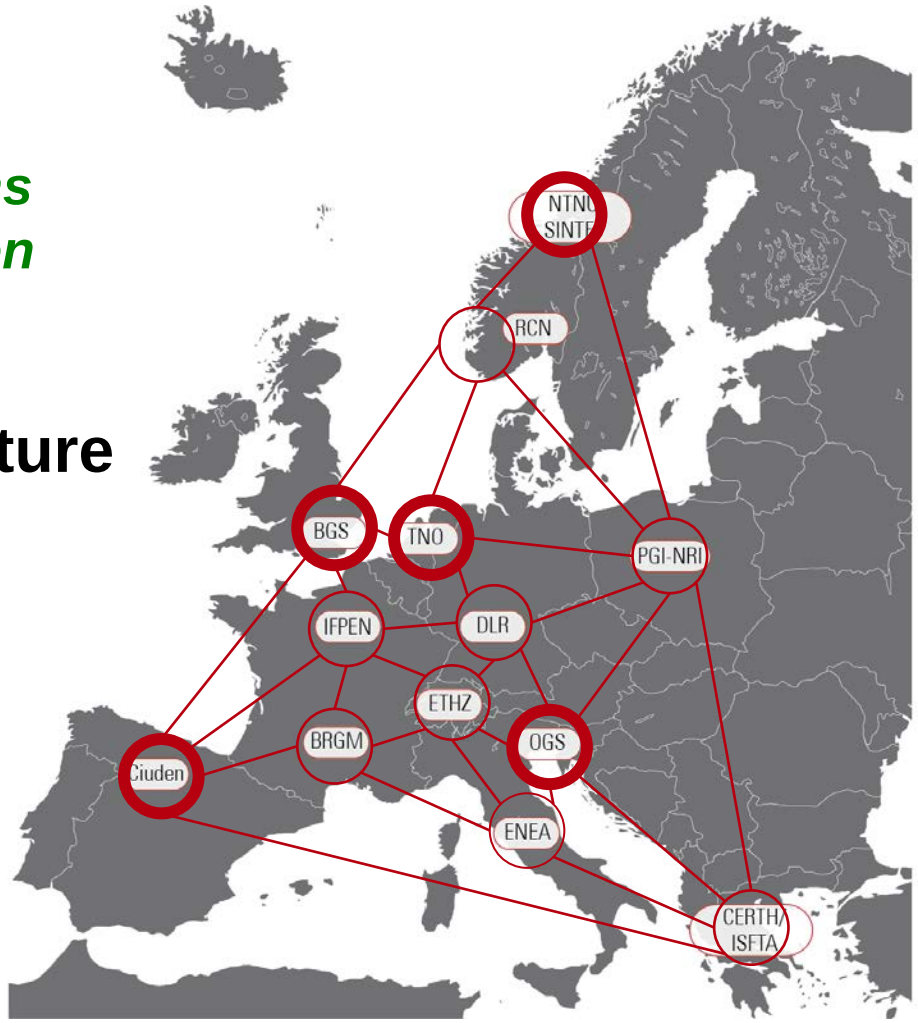
eccsel

Enabling low to zero CO_2 emissions from industry and power generation

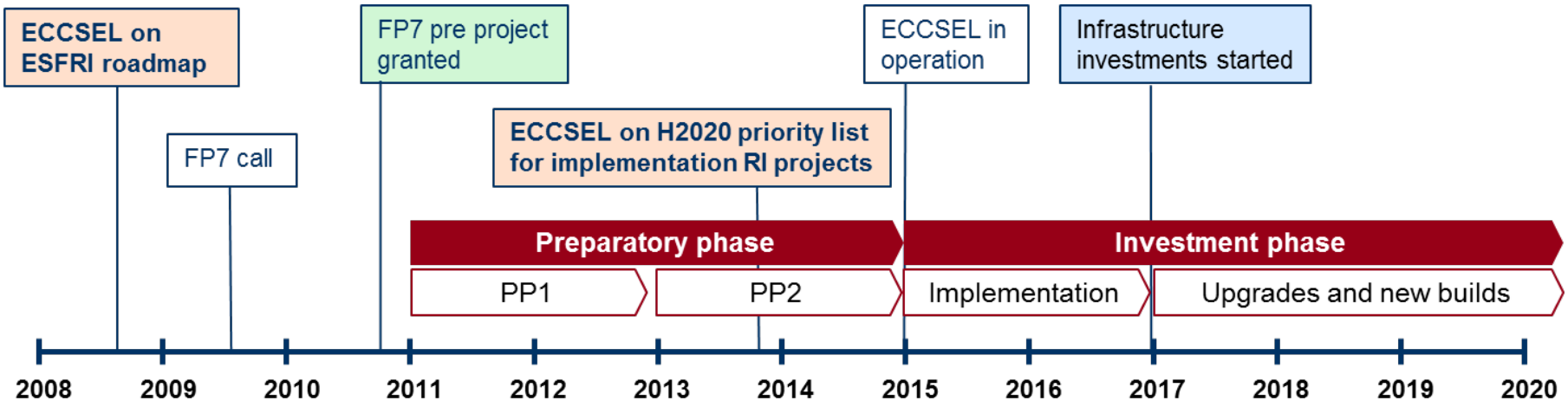
ECCSEL research infrastructure

European research infrastructure in CCS (mostly capture but also some storage)

Thought to be a link of laboratories.



ECCSEL timeline



Implementation Phase started 1.09.2015

Kick Off meeting & General Assembly Meeting – Oslo, 10.09.2015 (yesterday)

- For storage side: in PP2: Mont Terri is part of a list of 4 shared key laboratories
- ETH/CH is not part of the steering committee (leaders of work packages) but observer
- Investment Phase: Each country provides funds –Y distributed back to researchers
- Gap analysis during Phase 1: What is available in CCS and what are key questions

April 8th 2014

ERA-NET Cofund - joint forces on CCS

Norway and Germany have taken the initiative to establish an ERA-NET Cofund proposal on CCS under Horizon 2020 by April 2015.

The following countries, in addition to Norway and Germany, have expressed interest for joining the ERA NET Cofund on CCS; Czech Republic, Finland, France, Greece, Italy, The Netherlands, Poland, Romania, Spain, Switzerland, UK

Norway, Germany, Switzerland and Romania have shown their likely cash contribution, which is highly appreciated.

We foresee a total budget of approximately € 50 million for a period of 3 - 4 years, including top-up financing from the European Commission. We plan to establish a consortium with as many nations as possible. By April 8th 2014 we have the following member contributions:

Norway:	6-10 M €
Germany:	6-8 M €
Switzerland:	4-5 M €
Romania:	2 M €

Other MS are invited to participate at similar levels.

We **suggest** the following topics to be included in the *Cofund CCS :*

- **CO_2 storage pilots including CO_2 transport solutions. CO_2 storage in aquifers and CO_2 for EOR will be included and possibly also offshore storage.**
- **Cost effective CO_2 capture technology:**

Further detailing of topics for the Cofund CCS will be established among participating nations.

CO_2 GeoNet

10th CO_2 GeoNet Open Forum: "CO_2 storage - the cornerstone of our low carbon future" Venice, Italy 11-12 May 2015

European Commission | U.S. DEPARTMENT OF ENERGY

EERA European Energy Research Alliance

ETHZ/CH joined in 2015

Mont Terri, new research program for deep geological disposal and geo-energy experiments → current review of proposals

Example 1: (Zappone, Mazzotti):
Testing of a fault subjected to CO_2 injection

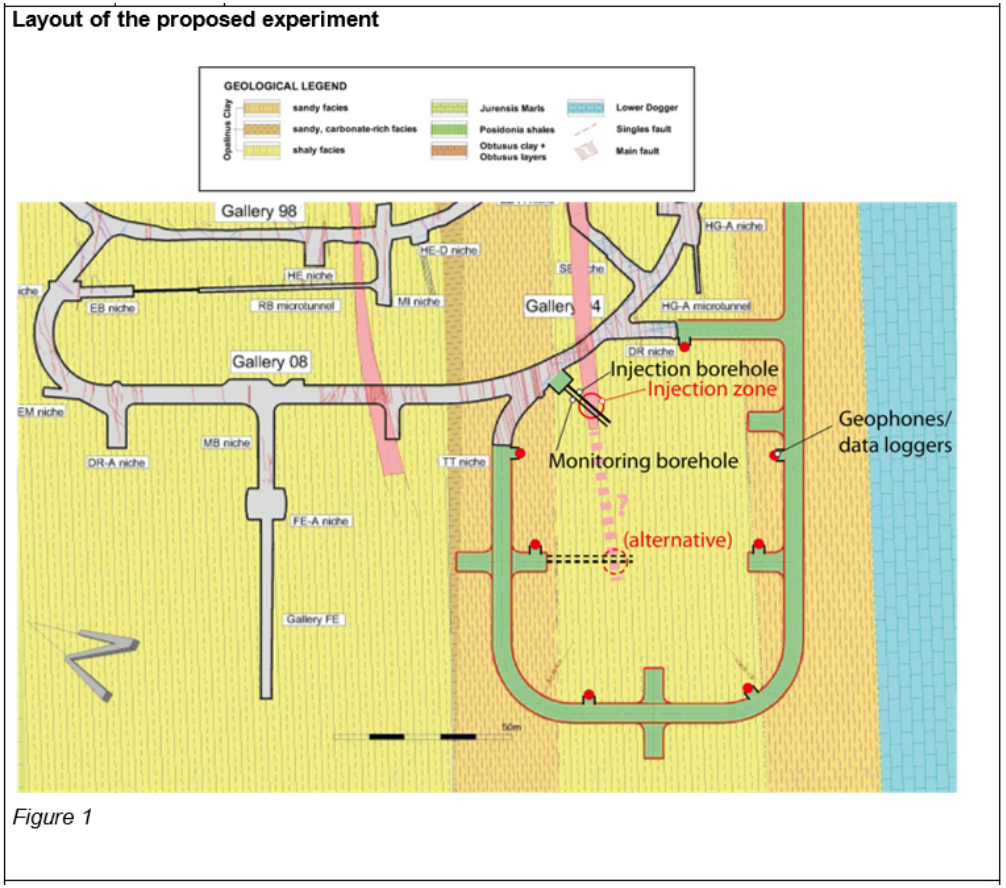
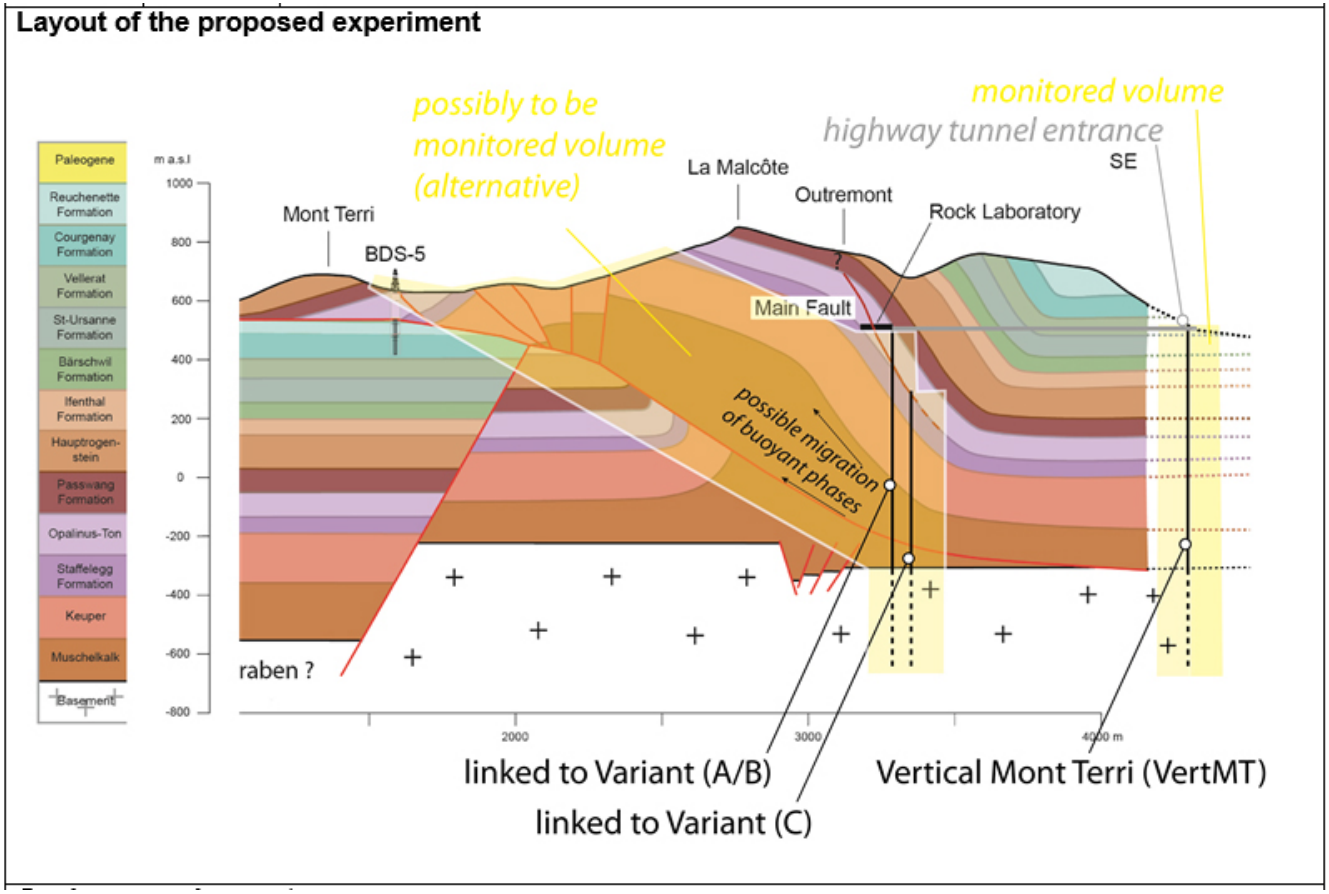


Figure 1

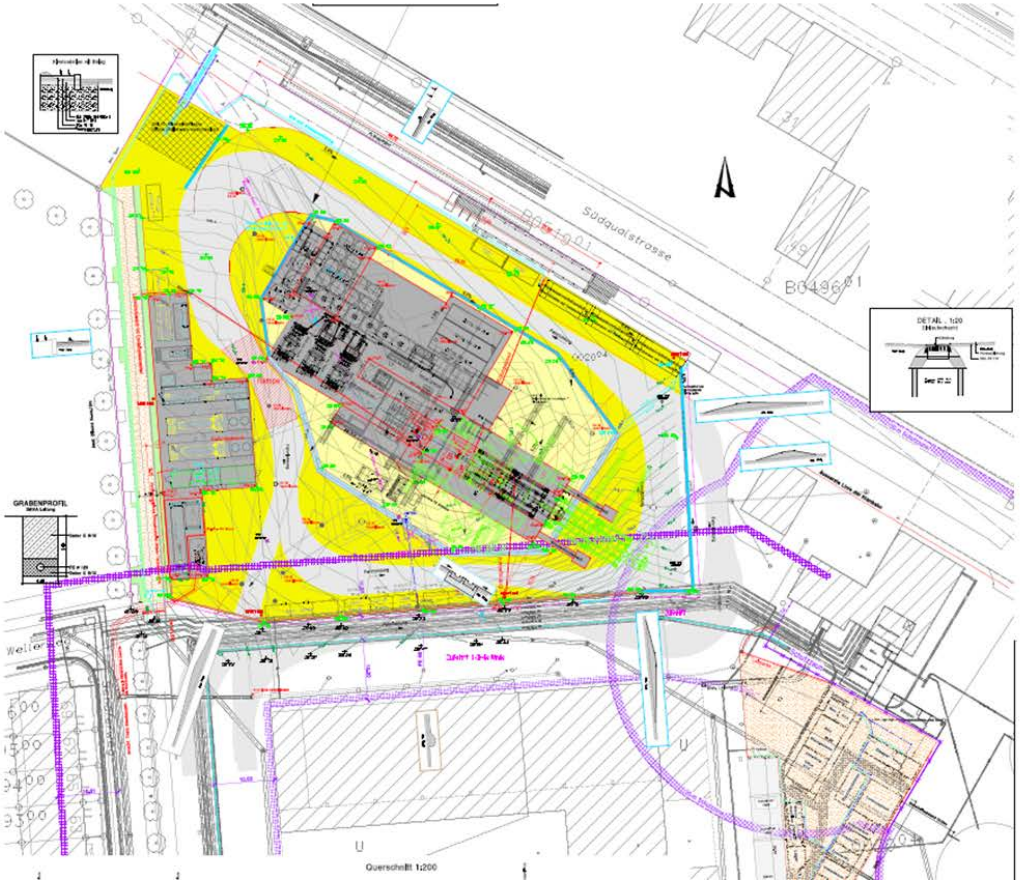
Mont Terri, new research program for deep geological disposal and geo-energy experiments → current review of proposals

Example 2: (Zappone, Mazzotti):
Vertical Mont Terri



CO_2 Injection Pilot (Information Meeting, July 3, 2015, Swiss National Bank, Bern) (organized by Markus Häring)

Generic well site



Example: Well site 5'000 m well Basel 1

CO_2- Injection well:

technically less complex:
- smaller rig size
- smaller foot print
- less immissions

technically possibly more complex:
- less developed infrastructure
- access to water
- access to power
- access heavy loads

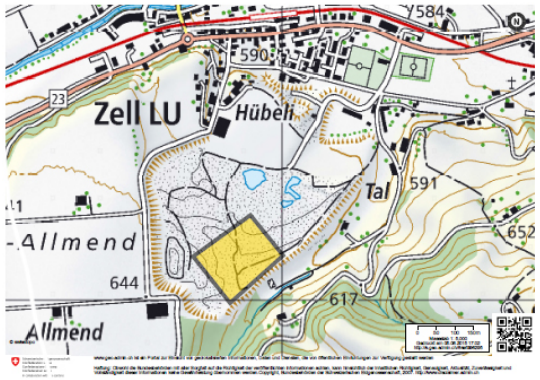
courtesy M. Häring

CO_2 Injection Pilot (Information Meeting, July 3, 2015, Swiss National Bank, Bern) (organized by Markus Häring)

Outcomes:

- Master plan
  - Follow Roadmap 2013
  - Test all potential aquifers
- Organization
  - Access to all Unis
  - Geochemical, geomechanical, hydraulic aspects
  - Need of an operator (continuity for management and operations)
- Owner/liability:
  - Consortium involving the owner of the mineral rights, i.e. Canton
  - Swiss confederation as partner (public acceptance.)
- Funding
  - Separate funding for construction, operation drilling and individual experiments

Generic test site



Generous lay out for
- drilling injection well 2'500 m + 1-2 monitoring wells
- injection operations without rig
- on site operation management
- on site monitoring labs
- additional on site lab facilities
- storage space solids
- storage space liquids
- storage space gas
- pipe stack
- warehouse
- car parking
- security / site control
- service staff accomodations

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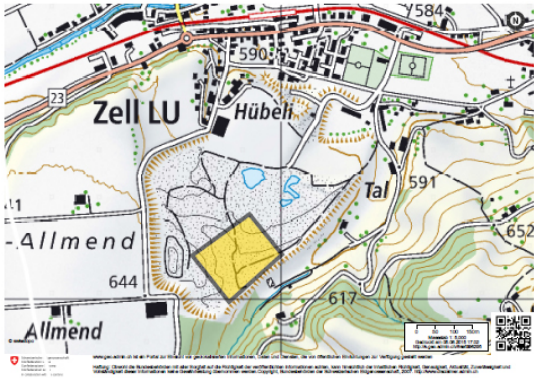

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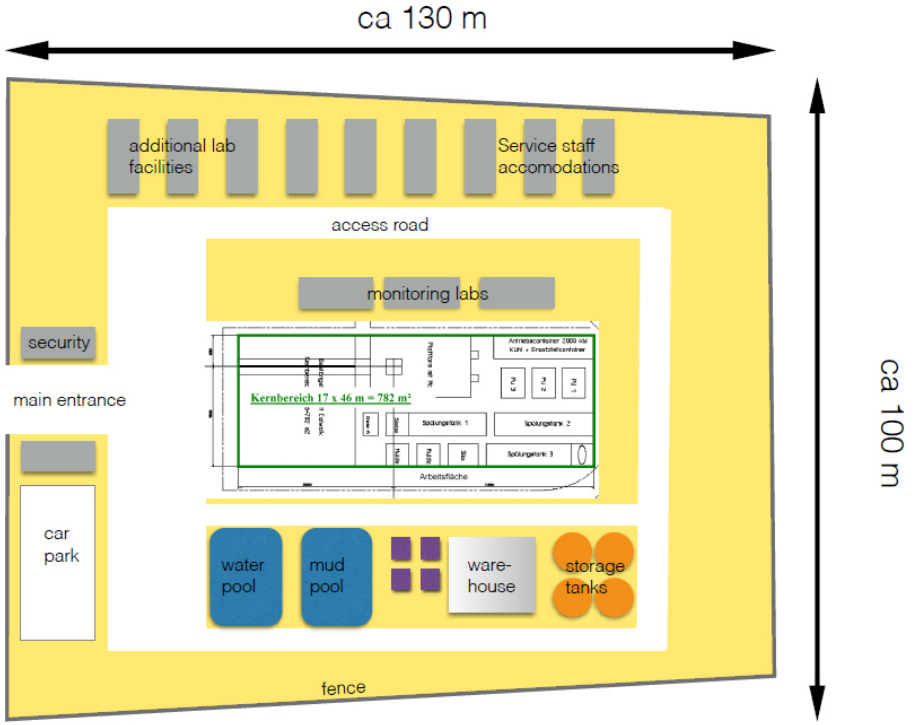


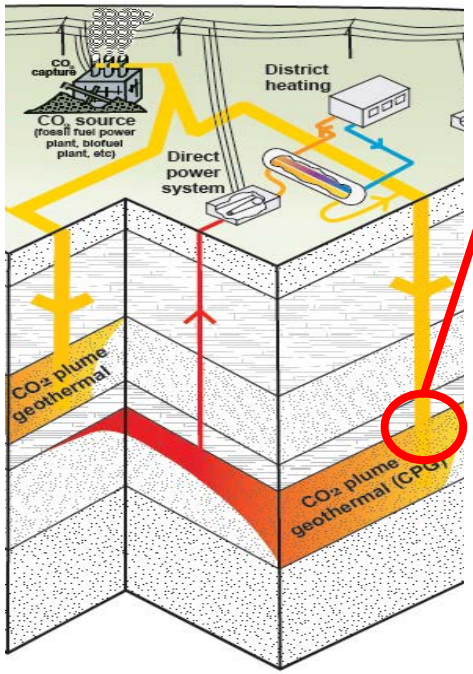
Next meeting: November 24, 2015:
Topic: discuss realistic field experiments that can be carried out at a CO_2 injection pilot

courtesy M. Häring

CO_2 Storage Research in the Geothermal Energy and Geofluids Group

- Reactive flow-through experiments (bench-top scale)
- Reactive flow-through numerical simulations (bench-top to reservoir scale)
- Coupling CCS with geothermal energy utilization
- Reservoir exploration (for geothermal, CCS, and CCS-geothermal)

Reactive flow-through experiments (bench-top scale) → see also Poster by Xiang-Zhao Kong

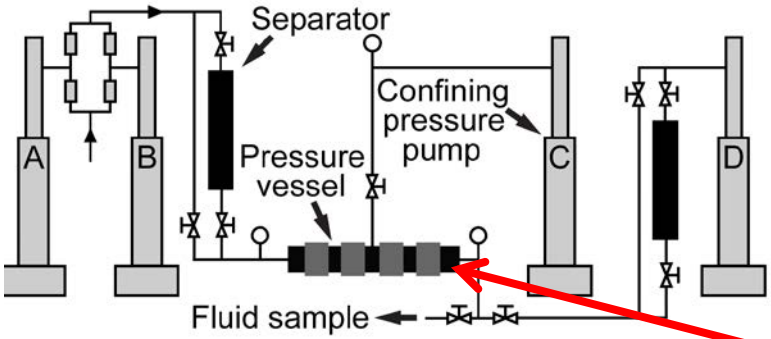


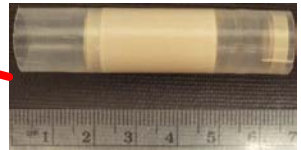
Pore-size distribution affects:

- Injectivity
- capacity
- security

Quantify (mechanical, reactive) changes to porosity + permeability

→ Pore size distribution and permeability need to be determined





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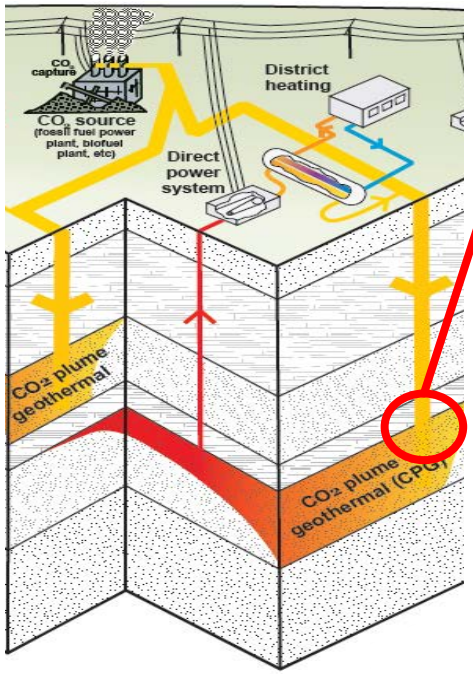

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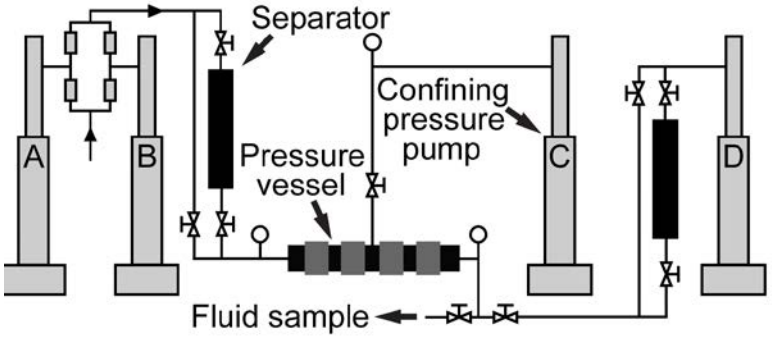
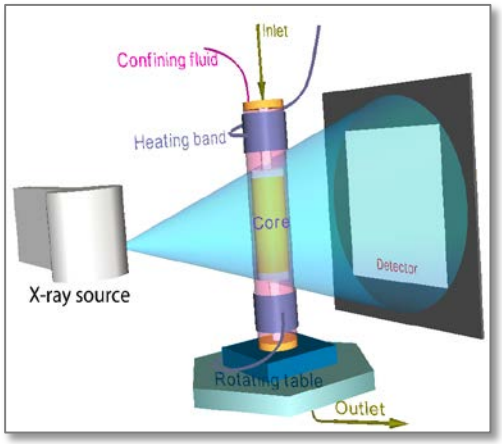
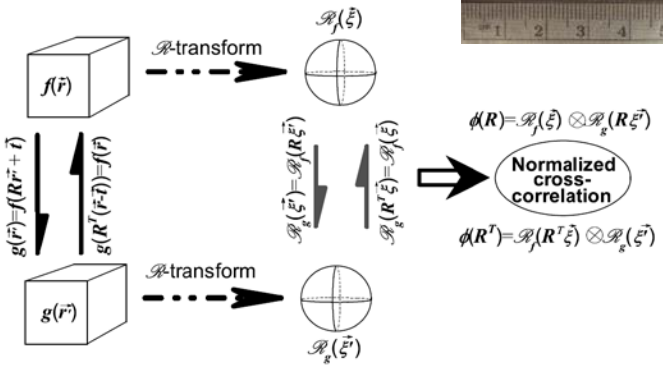
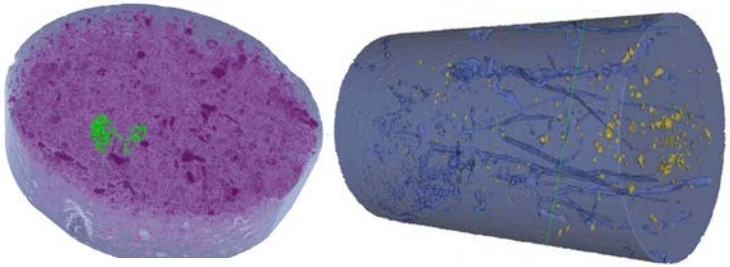


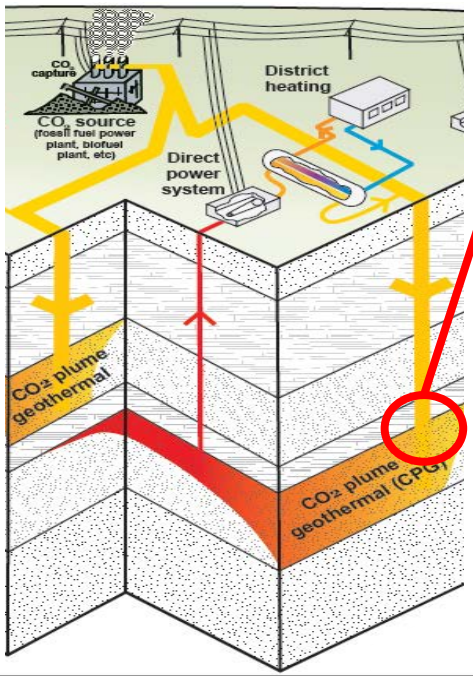


Before and after reaction XRCT imaging + Radon Transform for volume registration





Reactive flow-through experiments (bench-top scale) → see also Poster by Xiang-Zhao Kong



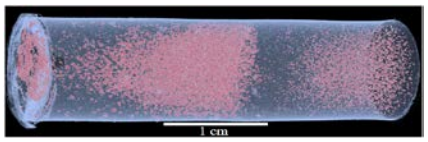
Pore-size distribution affects:

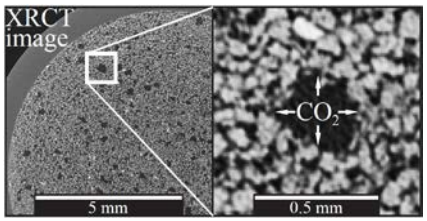
- Injectivity
- capacity
- security

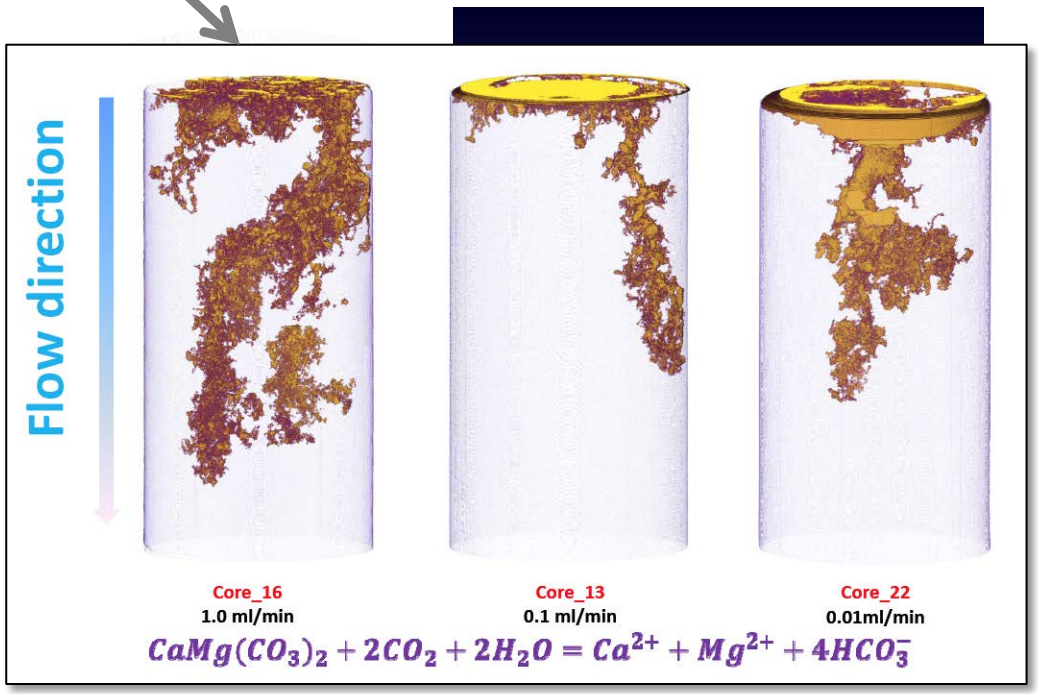
→ Pore size distribution and permeability need to be determined

Quantify (mechanical, reactive) changes to porosity + permeability

Mechanical changes in unconsolidated sediment due to CO2 exsolution and grain movement → a new CO2 trapping mechanism





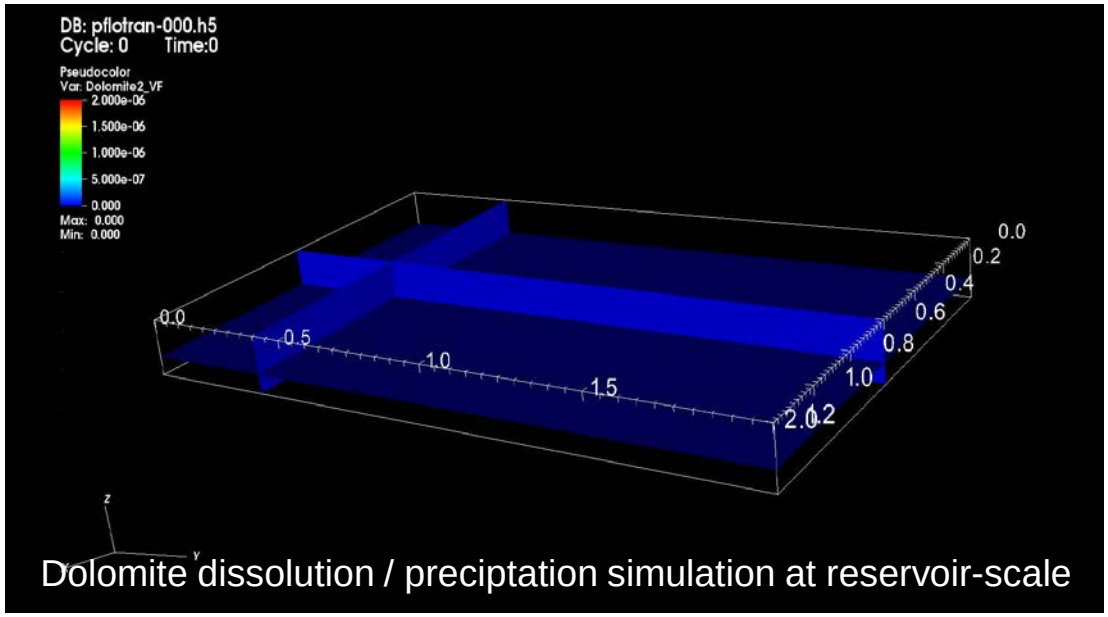


Reactive flow-through numerical simulations (bench-top to reservoir scale):Example: Injection of CO_2 in carbonate aquifer

Massively parallel simulations using PFLOTRAN

PFLOTRAN

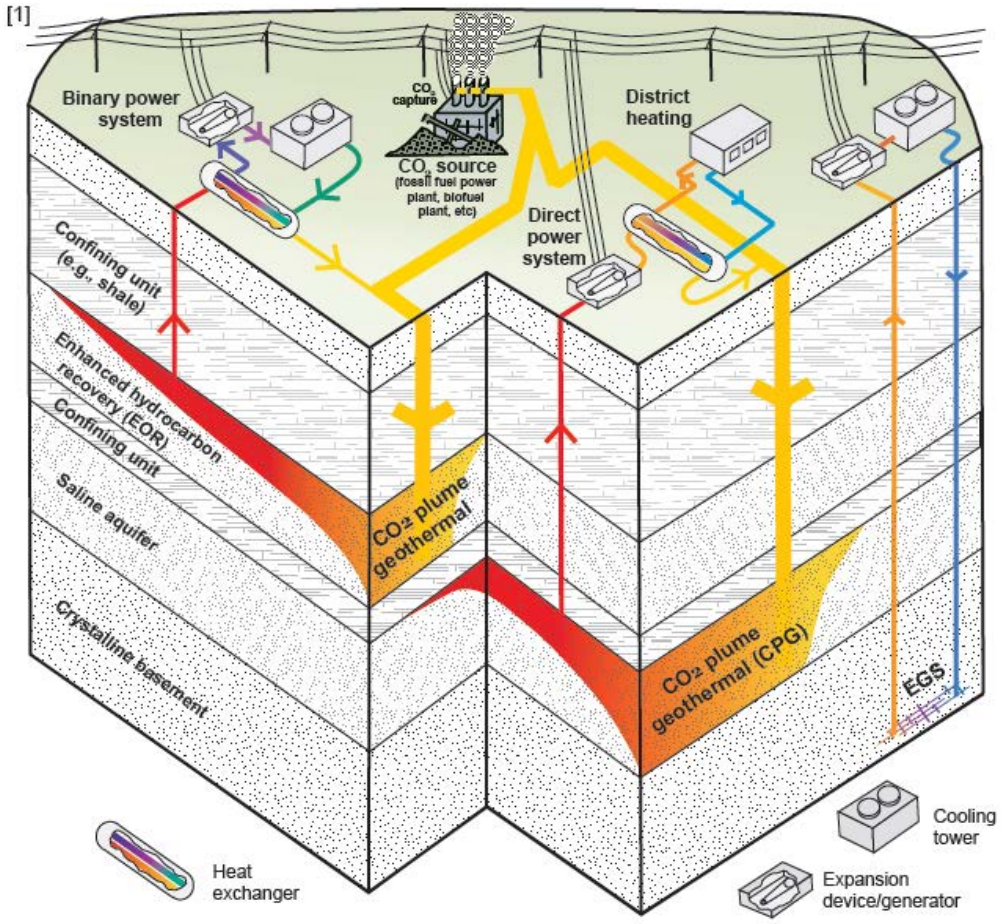
by Dr. Ben Tutolo (formerly in GEG Group, now at Oxford)



Dolomite dissolution / preciptation simulation at reservoir-scale

Coupling CCS with geothermal energy utilization

CO_2-Plume Geothermal (CPG)



Randolph and Saar, 2011

Reservoir exploration (for geothermal, CCS, and CCS-geothermal)
→ see also Poster by Friedemann Samrock and Neeraj Shah

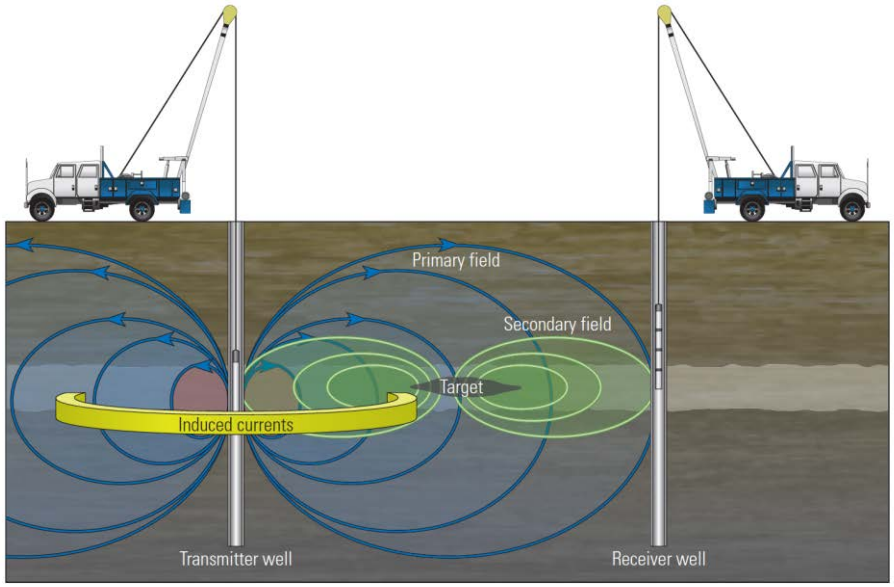
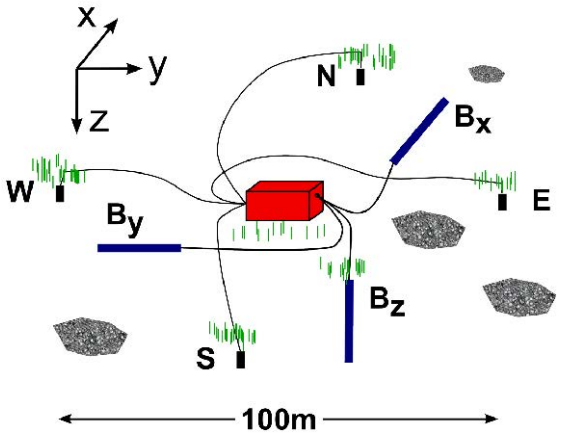
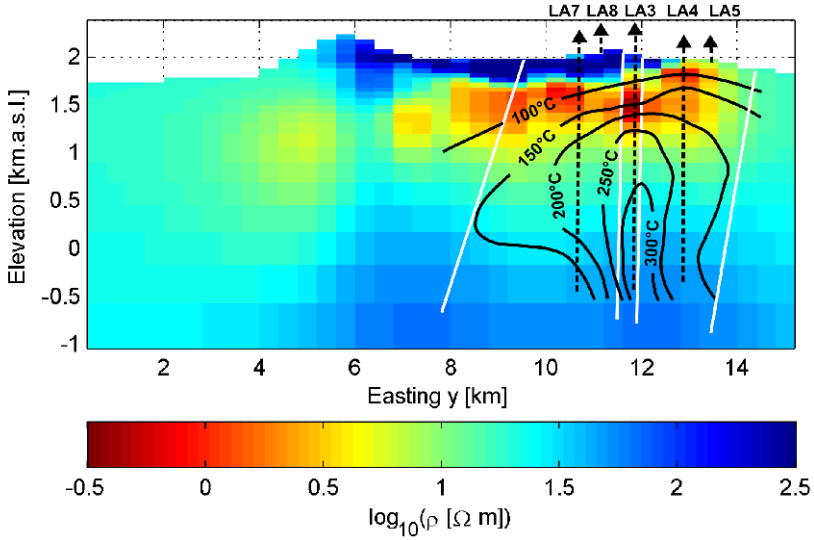


Fig. 4: Basic setup and principle of crosswell EM (Oilfield review summer 2009, 21, no. 2. Schlumberger).

$$\begin{pmatrix} E_x(\omega) \\ E_y(\omega) \end{pmatrix} = \begin{pmatrix} Z_{xx}(\omega) & Z_{xy}(\omega) \\ Z_{yx}(\omega) & Z_{yy}(\omega) \end{pmatrix} \cdot \begin{pmatrix} H_x(\omega) \\ H_y(\omega) \end{pmatrix}$$





Summary

- CCS research is being conducted worldwide.
- A few field-scale (test) sites exist but more test sites are needed to investigate different conditions, including in CH.
- Thus, a pilot and demonstration plant in CH is needed to make significant further progress in CO_2 storage research and eventual widespread implementation.
- Planning for specific pilot CO_2 storage field tests has started (e.g., for Mont Terri and the SCCER-SoE efforts) but is very much in the beginning stages and funding is not secured.
- Need to secure funding, determine and plan sites, and integrate these efforts in a European framework.
- Information of the public and public engagement is critical. One way CO_2 storage (research and implementation) may be more acceptable to the CH public is to combine it with geothermal energy extraction. → this was also suggested by several people at the meeting in Bern on July 3, 2015, with Markus Häring.