

Ketzin in a nutshell – Europe's longest-operating on-shore CO₂ storage site

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Is long-term and safe storage of CO₂ in geological formations possible?

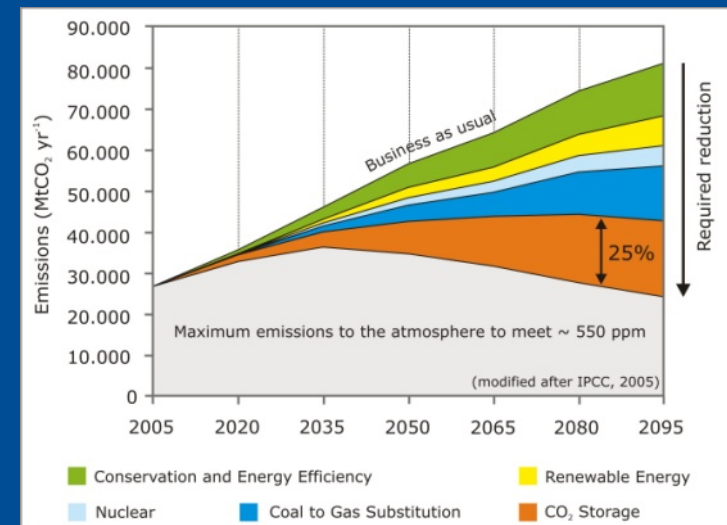
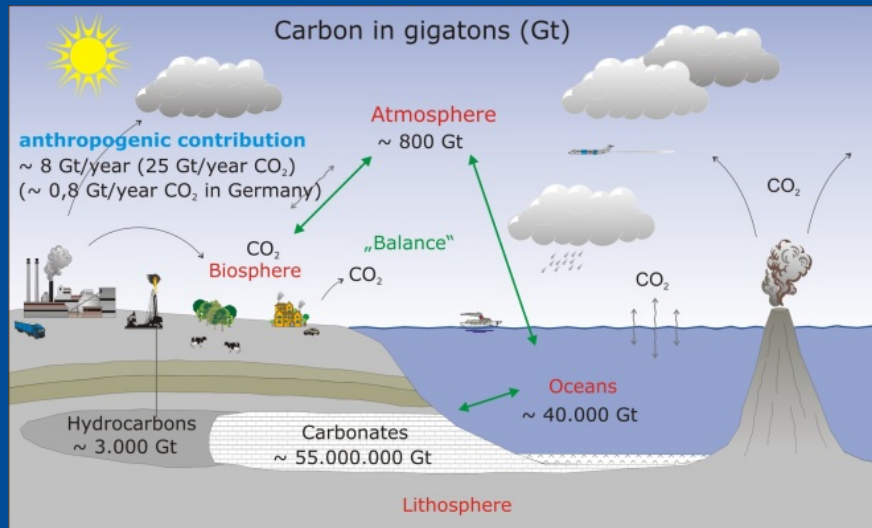
Climate politics: Why do we want to store CO₂ in the underground in geological formations?

Ketzin: Which results have been gained at the pilot site?

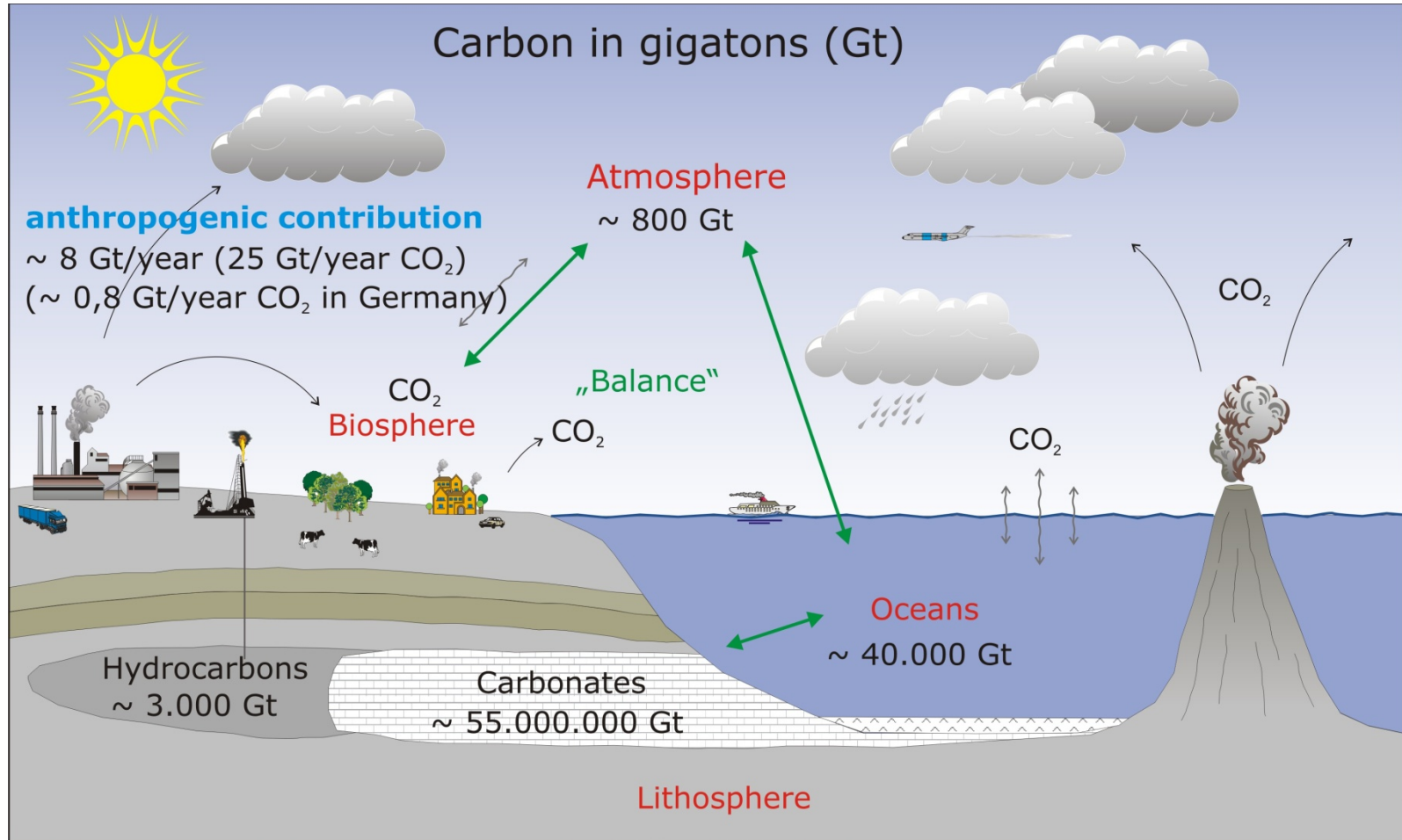


Why do we want to **store** CO₂? Measure of climate politics

- How do we interfere with the carbon cycle?
- Which contribution can CO₂ storage make?

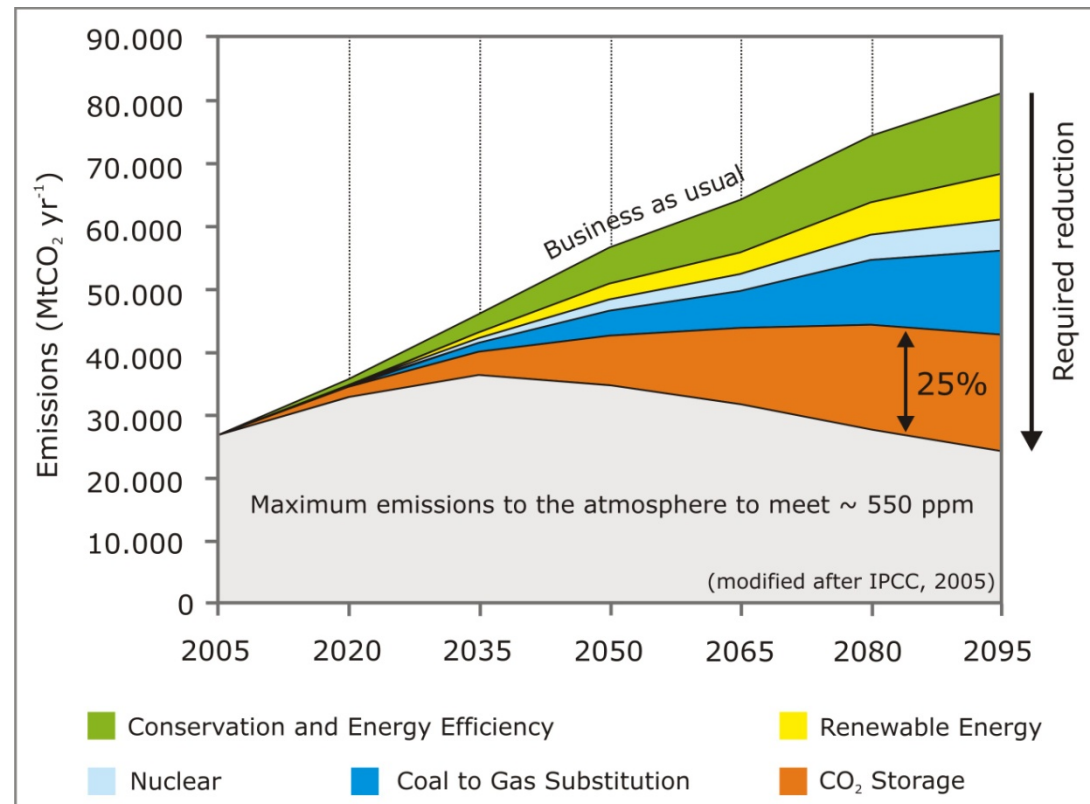


Anthropogenic emissions of CO₂ have significant impact on carbon cycle



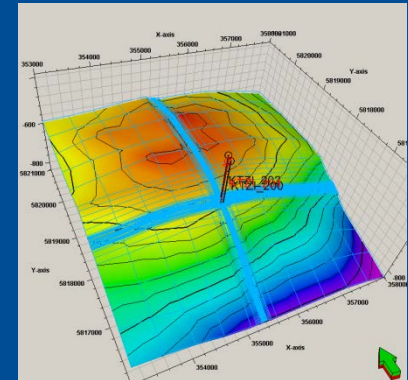
CO₂ storage (CCS) might provide 25 % of the emission reduction potential

- CO₂ storage one building block of portfolio.
- CCS not only for energy generation based on fossil fuels sources but as well for industry emissions (cement, steel and chemistry) and “bio CO₂”.
- If CCS shall make an impact it will be big!

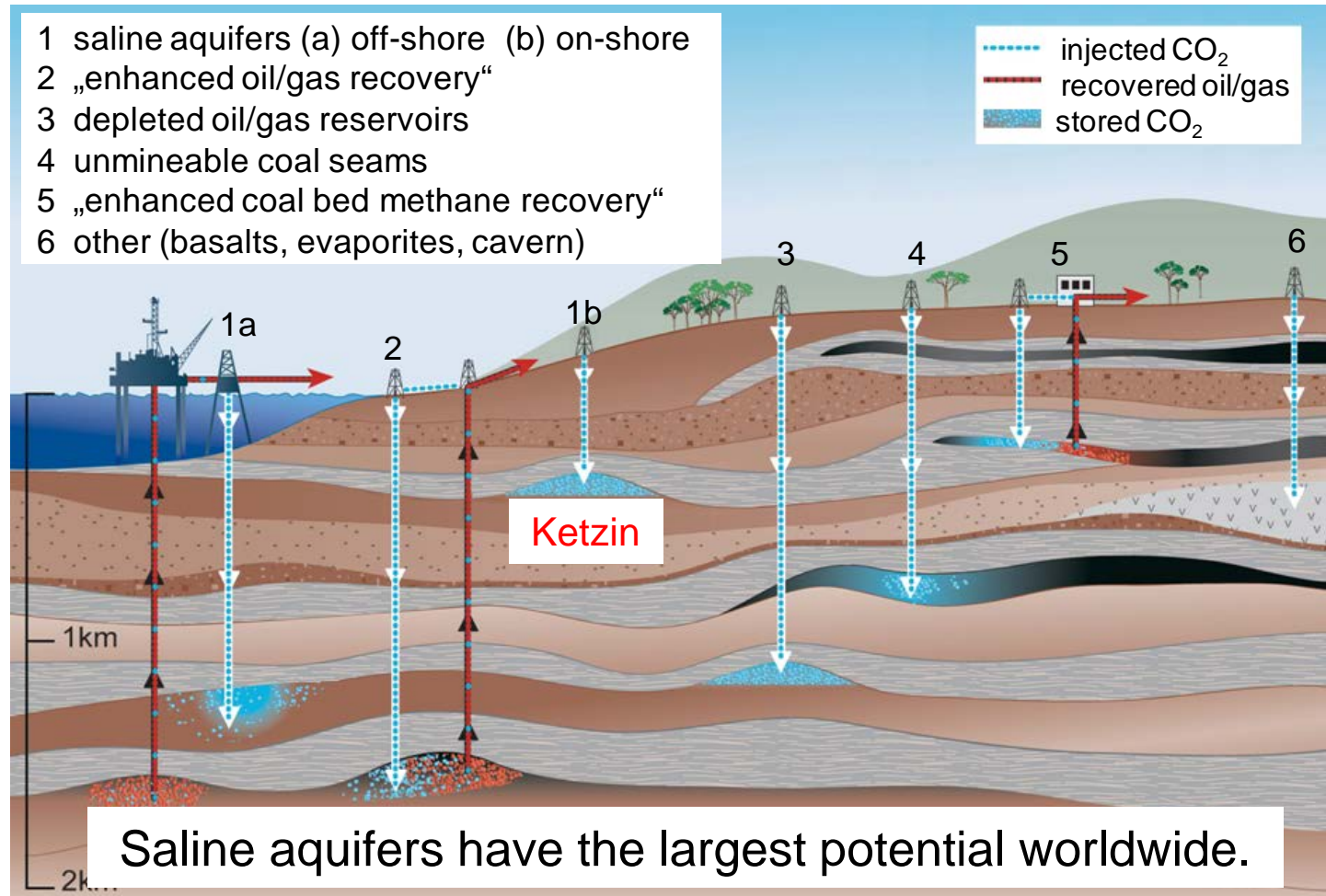


The Ketzin pilot site - Europe's longest operating on-shore CO₂ storage site

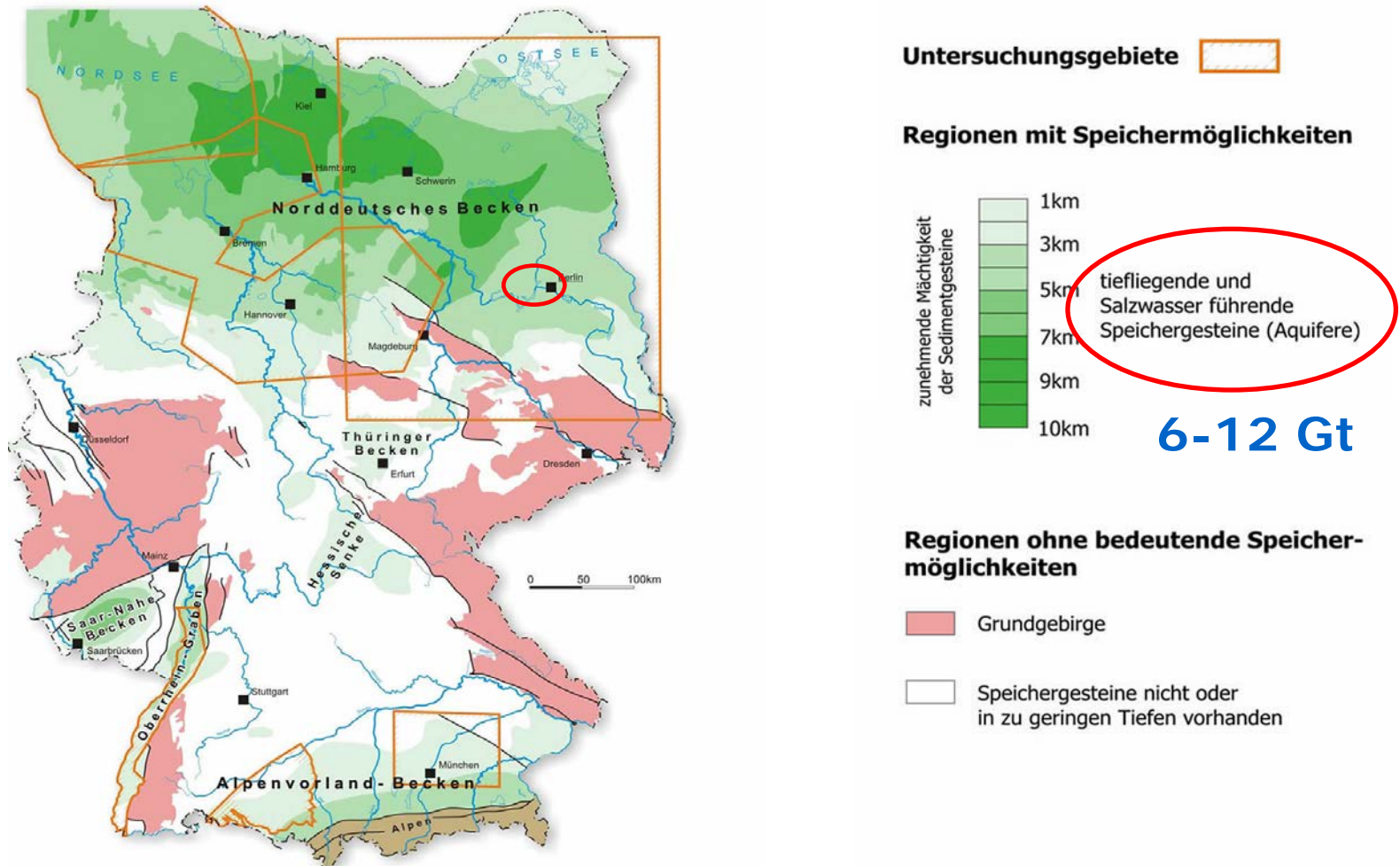
- What did we know before CO₂ injection started?
- How does the CO₂ injection work?
- Which monitoring techniques are applied?
- Which modelling activities are on-going?
- What do we learn from the Ketzin pilot site?



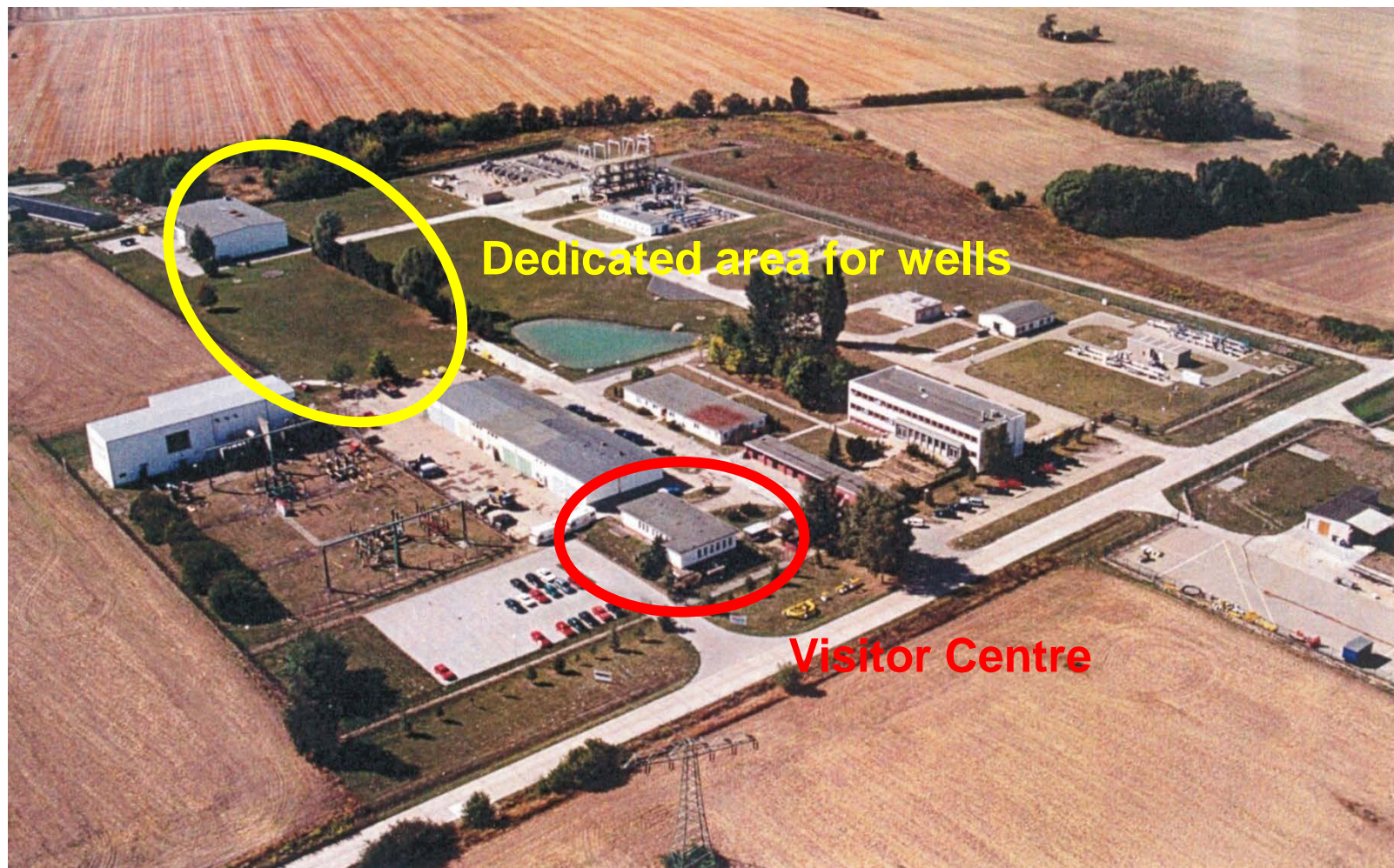
Deep sedimentary basins are the target for large scale CO₂ injections



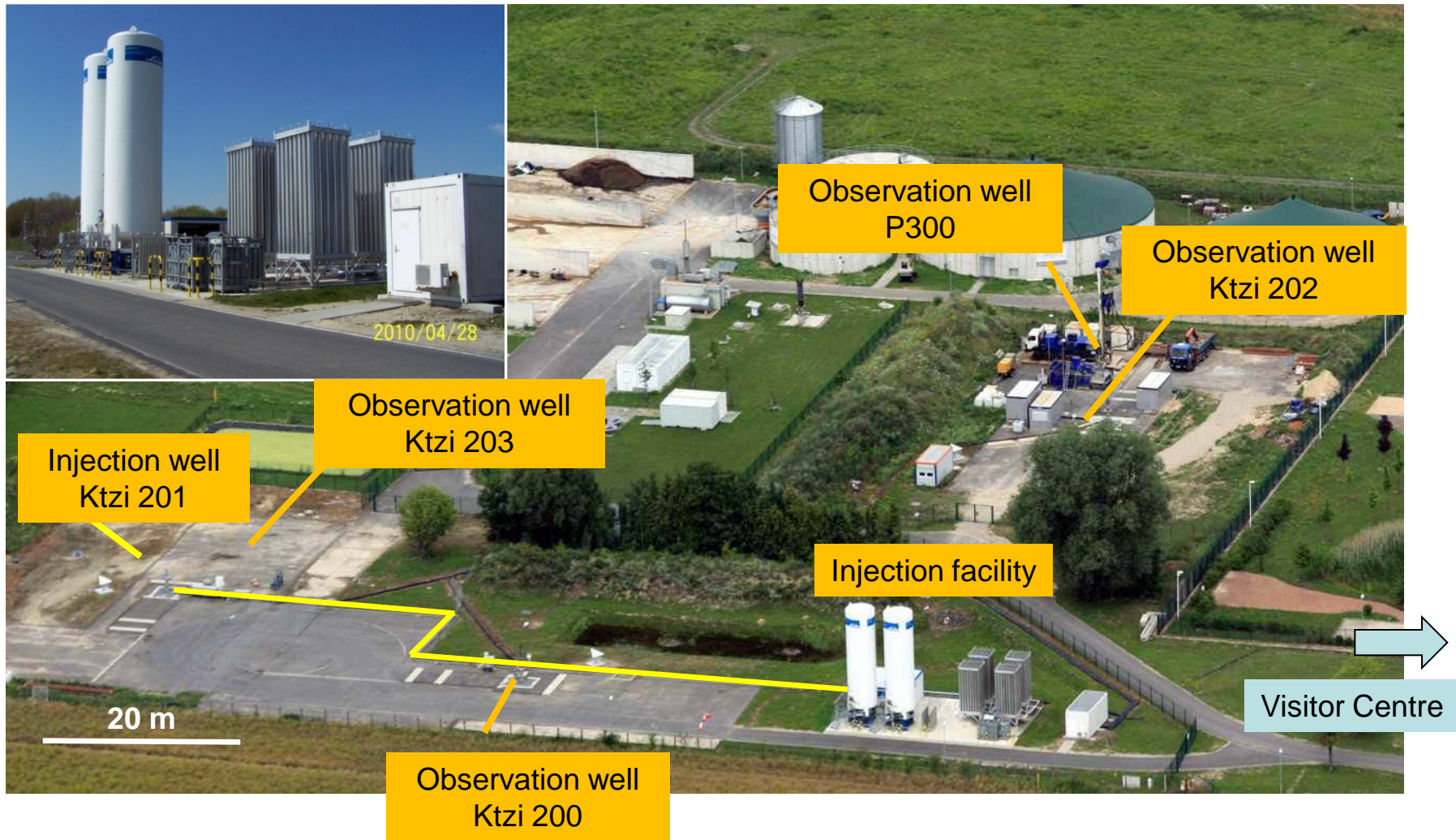
Most storage capacities in Germany are given in the northern part



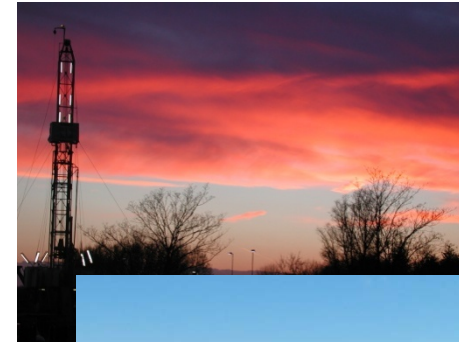
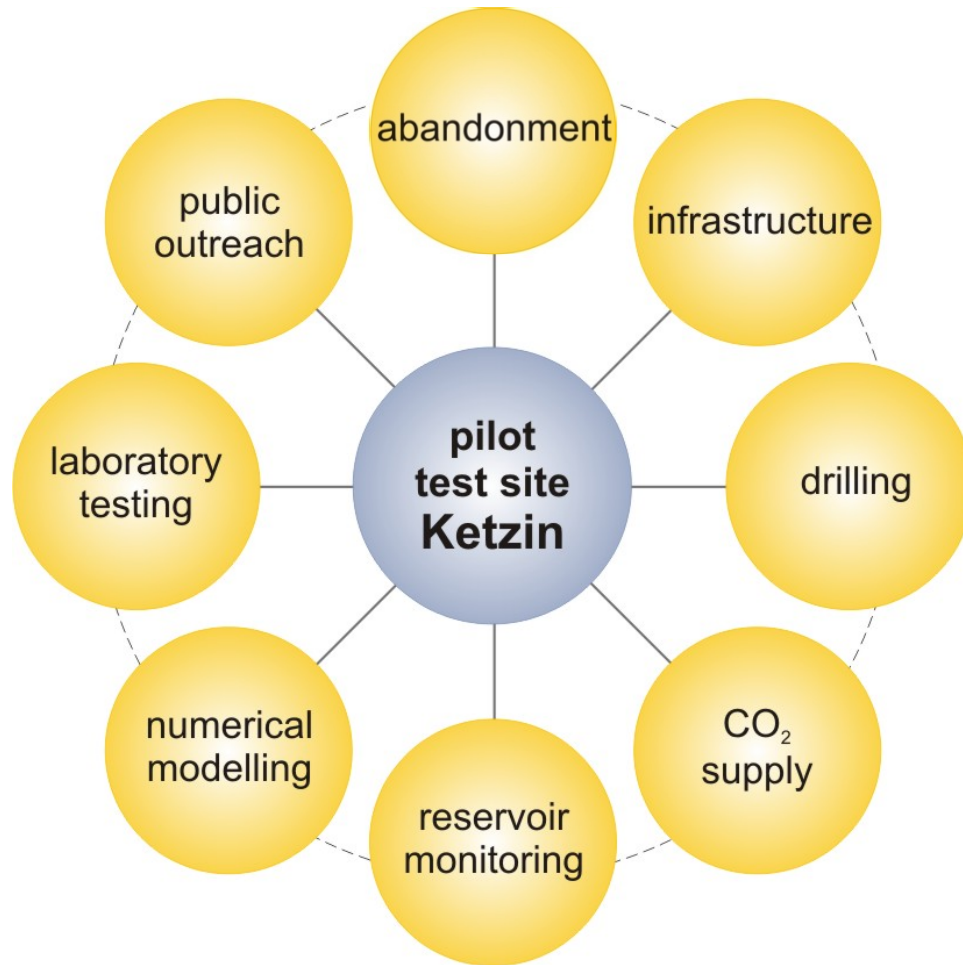
The Ketzin site before the infrastructure for CO₂ storage was developed



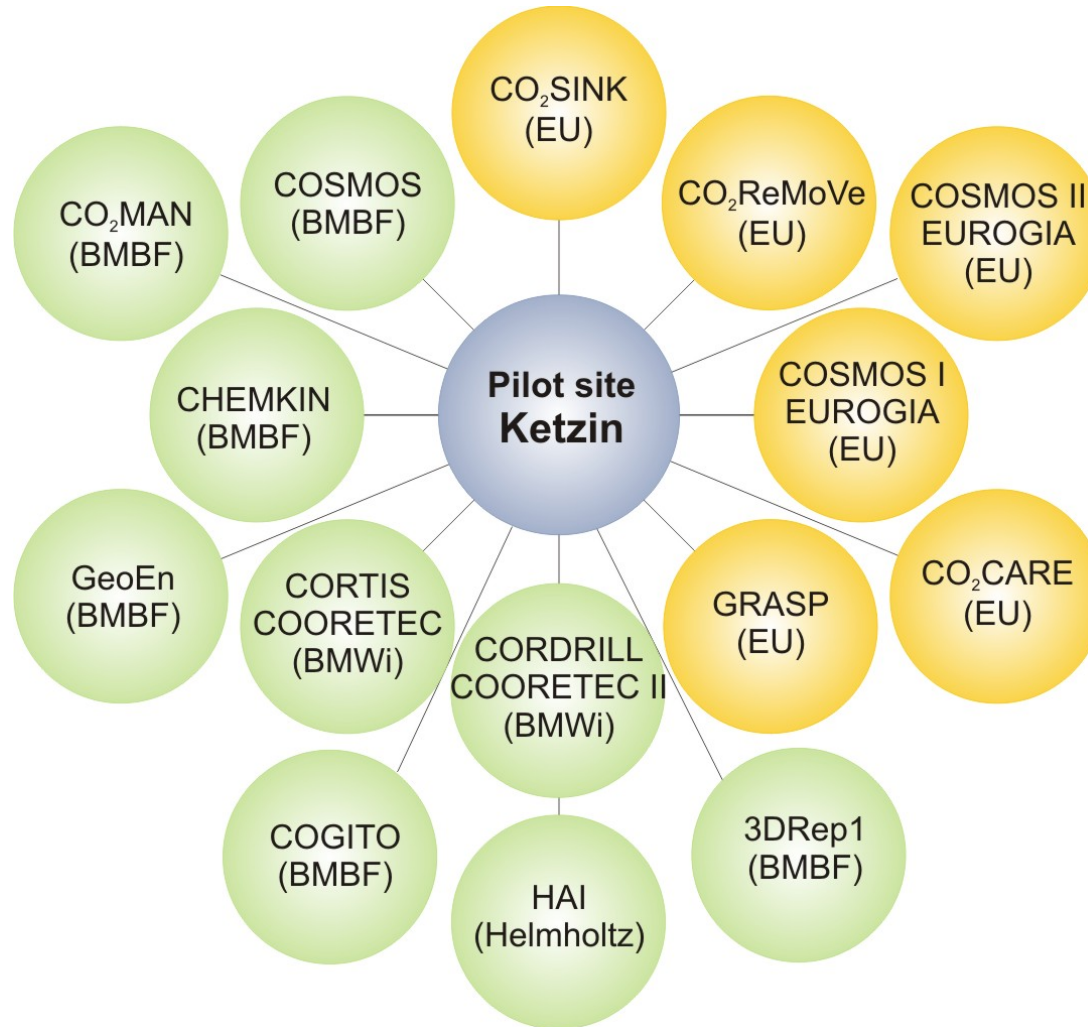
How the Ketzin pilot site looks today



Today Ketzin covers all aspects of a CO₂ storage site with a focus on monitoring



R&D activities at Ketzin are conducted within many projects



Federal Ministry of Economics and Technology



Federal Ministry of Education and Research



SIXTH FRAMEWORK PROGRAMME



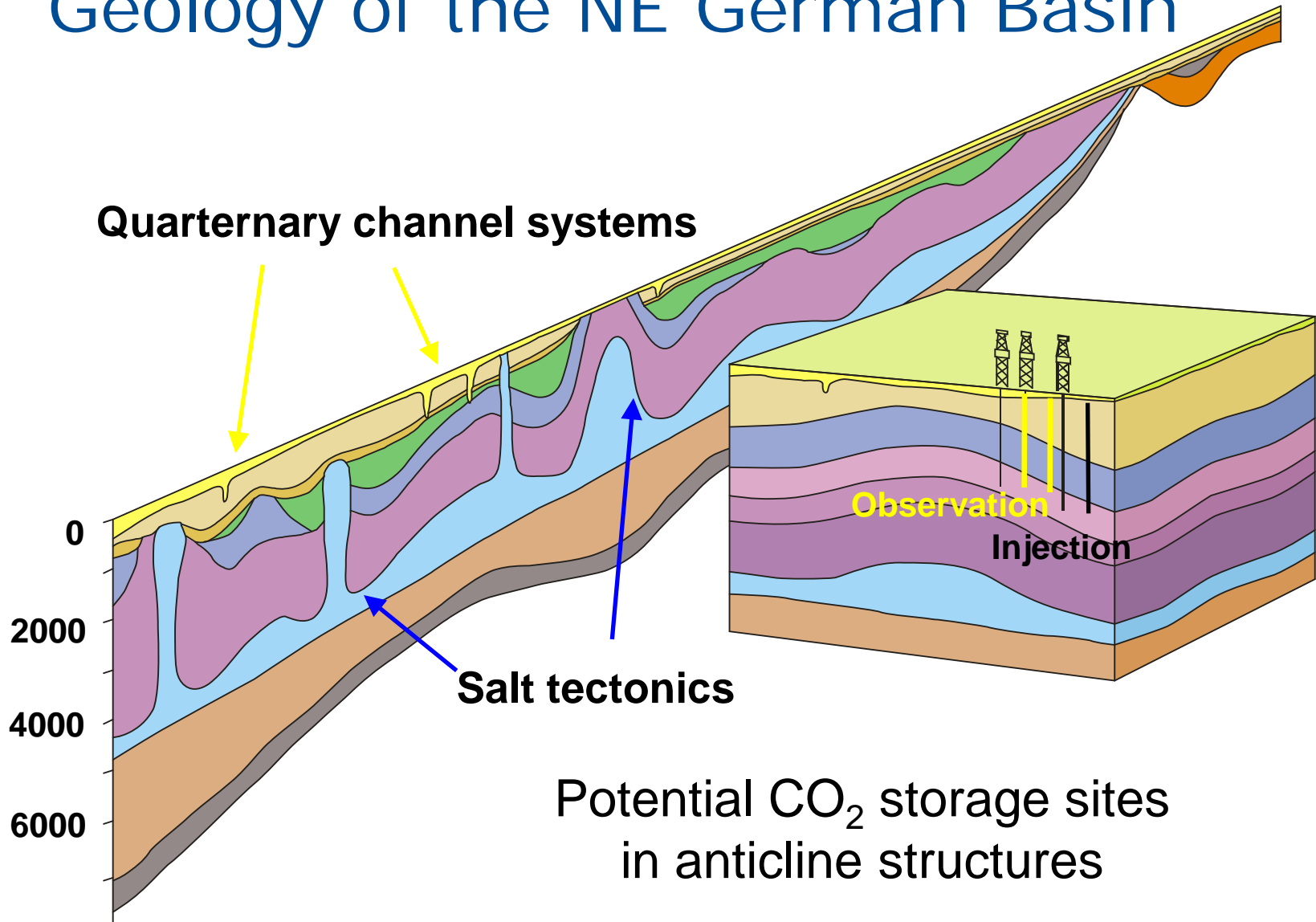
SEVENTH FRAMEWORK PROGRAMME

Many project partners support the R&D activities at Ketzin since 2004



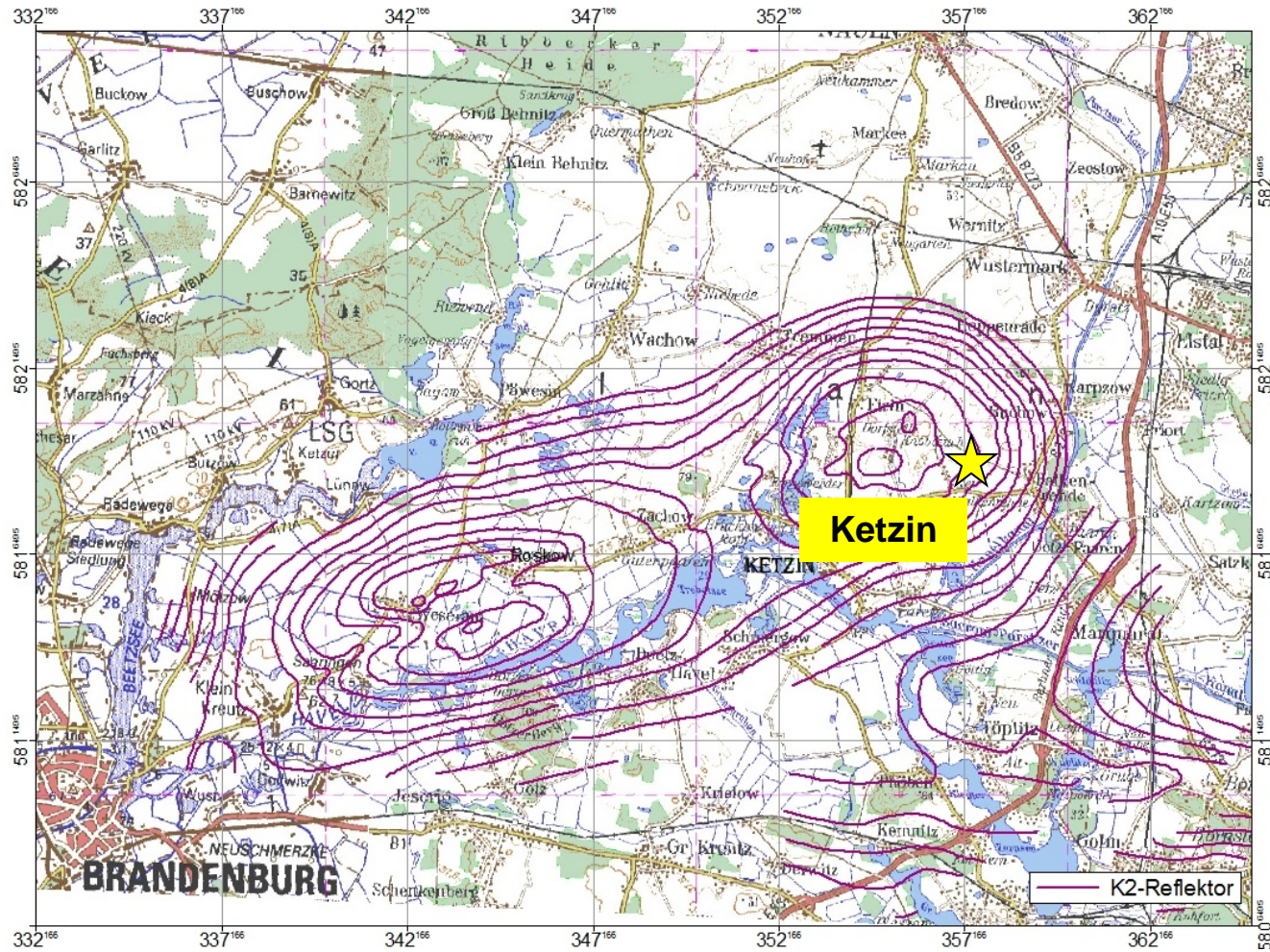
Geology and Drilling

Geology of the NE German Basin

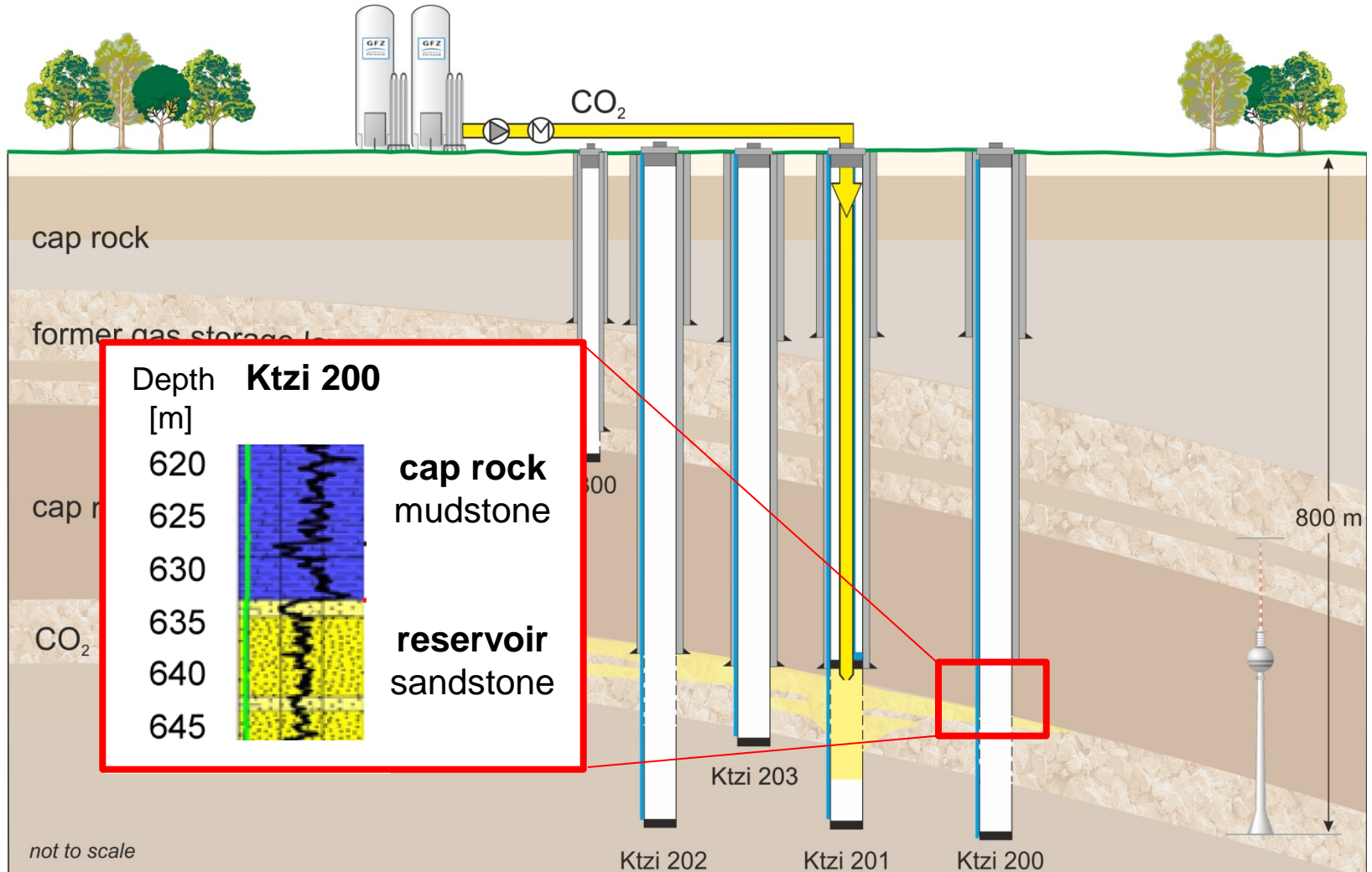


Potential CO₂ storage sites
in anticline structures

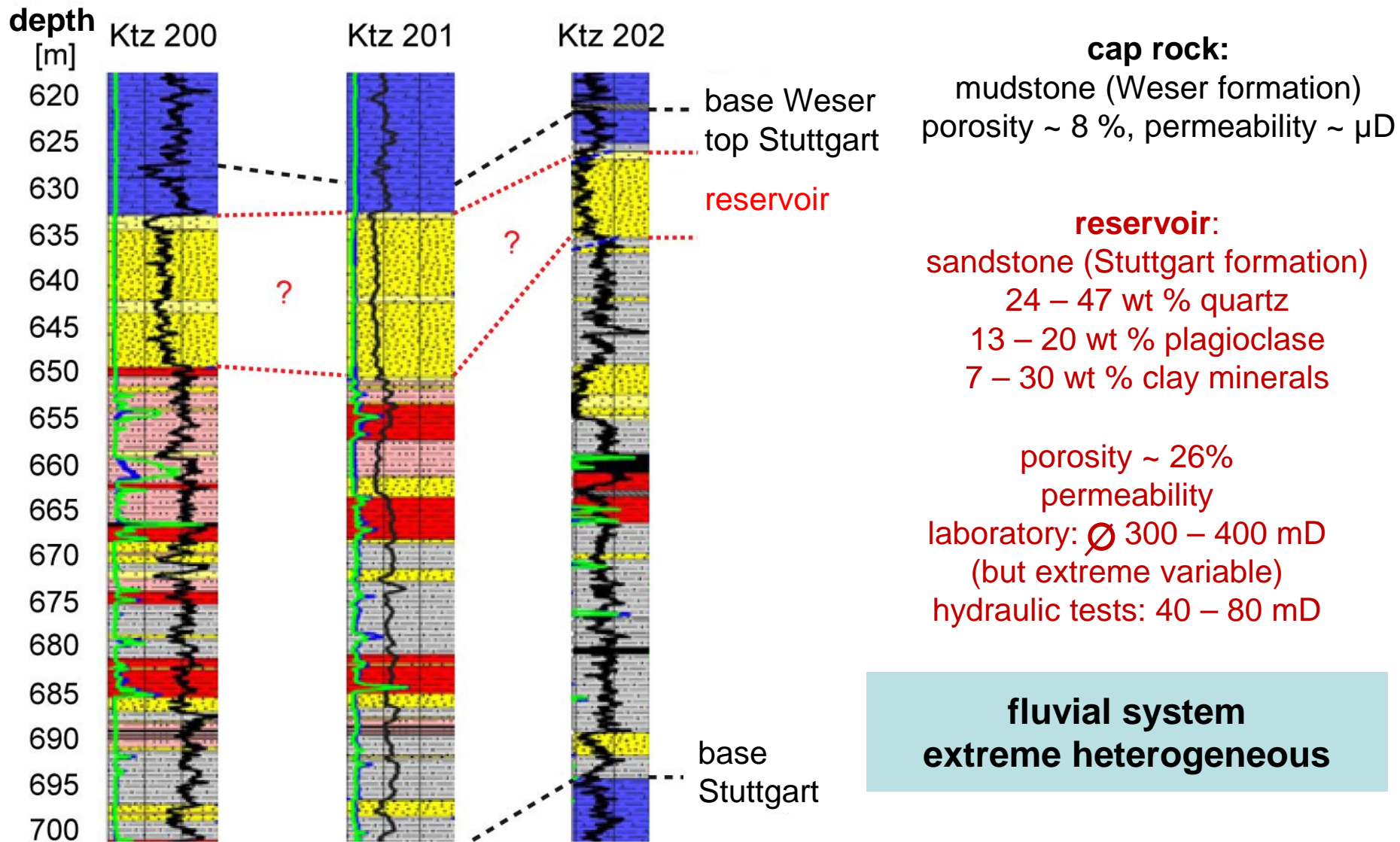
Ketzin is located at the SE flank of a double anticline



How the Ketzin site looks in a schematic cross-section

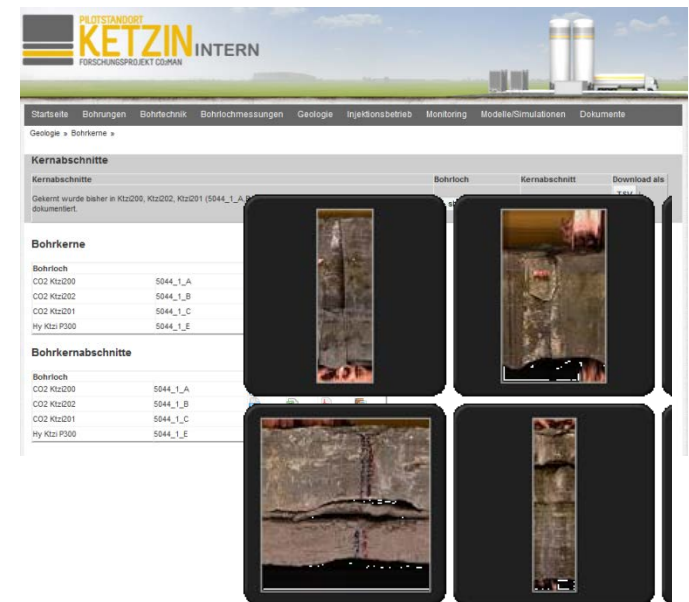
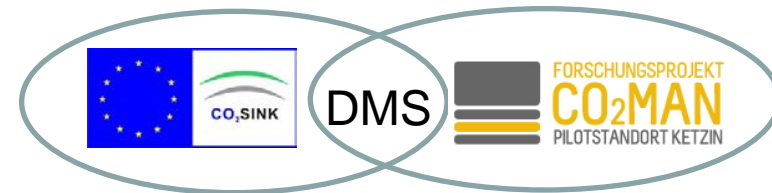


Different rock types were characterized



Management of technical and scientific data is a key aspect for the Ketzin project

- Data from CO₂SINK and CO₂MAN are integrated in one common **Data Management System (DMS)**
- **Services** for dissemination, archiving, communication and collaboration are provided
- Data was acquired while drilling using the **ICDP Drilling Information System**



Injection and Monitoring at Ketzin

The CO₂ injection runs safely and reliably

- Start of CO₂ injection: 30.06.2008
- 14.07.2013: 66,243 t CO₂ injected
- CO₂ sources and quality:
 - Primary source: food-grade CO₂ (Linde), purity > 99.9%
 - Secondary source (1,515 t from May 05 to June 12, 2011):
Schwarze Pumpe pilot plant (Vattenfall), purity > 99.7%
- Injection rate: currently ~ 1,000 t CO₂ /month

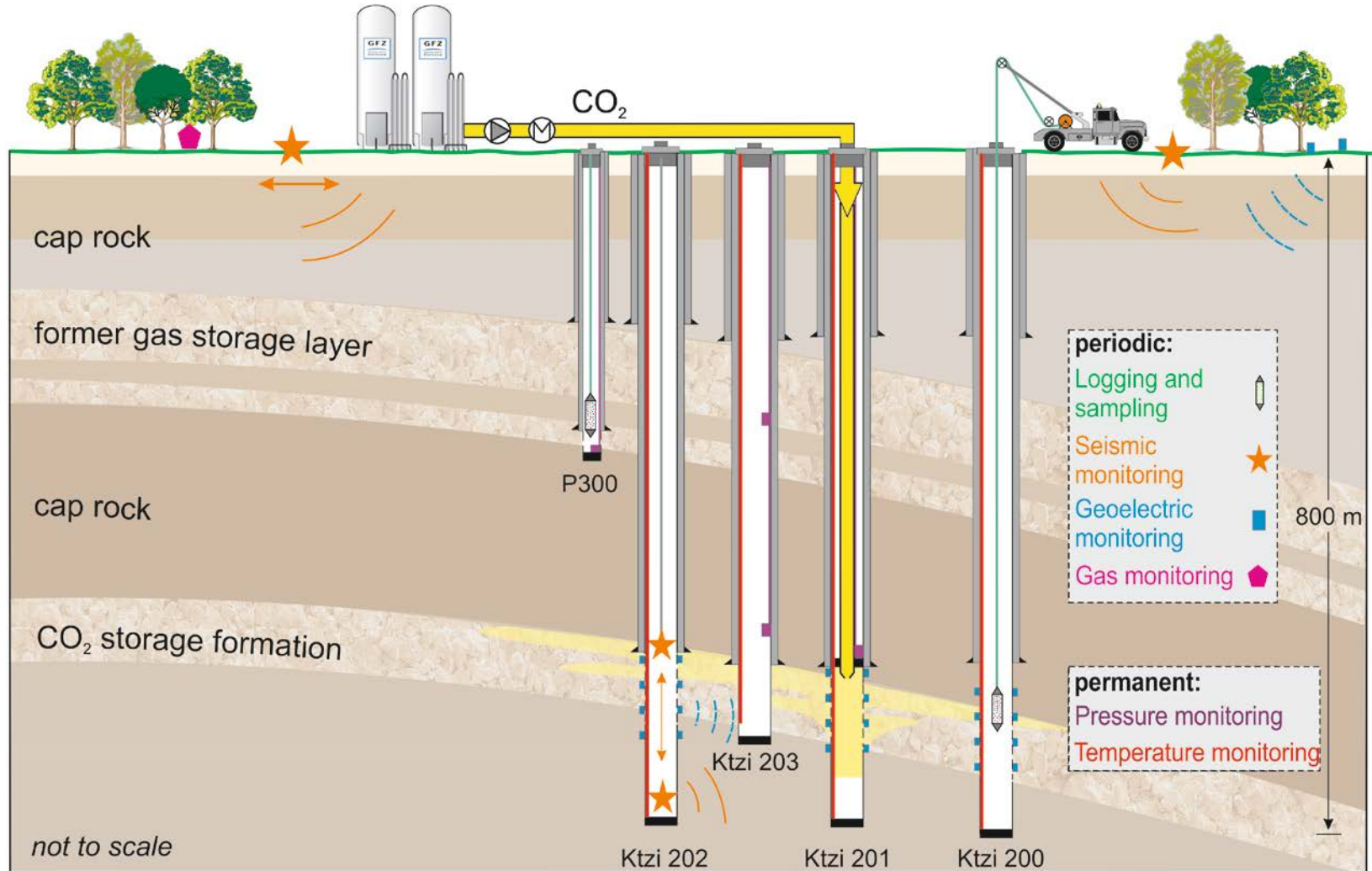


The components of the injection facility

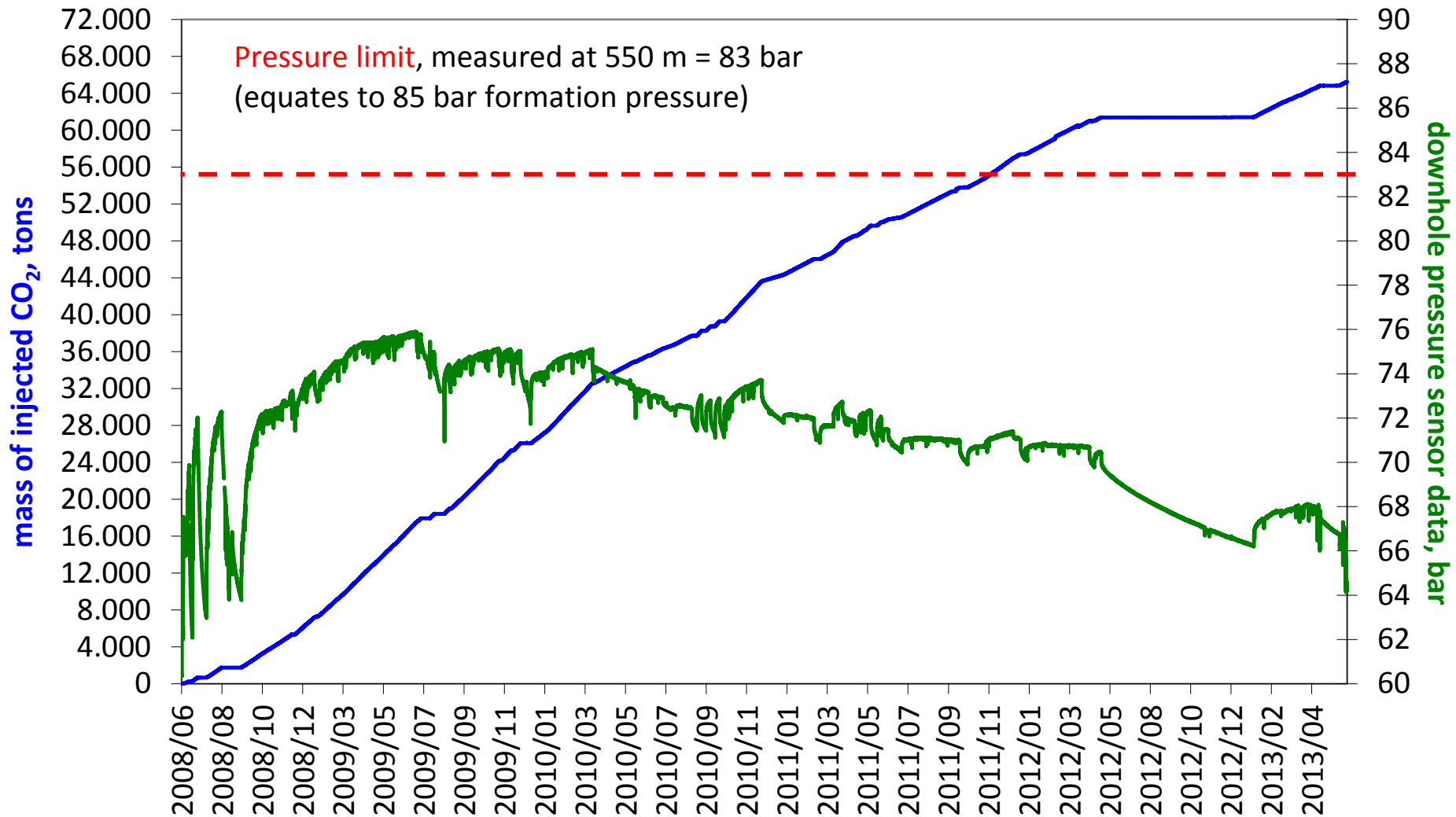
- 2 storage tanks (50 tons each)
(liquid: -18°C , 19 bar)
- 2 ambient air heaters for pressure keeping within the tanks
- 5 plunger pumps for rates of 0 ... 1,000 kg/h liquid CO_2
- 1 electrical heater, 300 kW el., operating range 10°C ... 70°C
- 150 m insulated piping to injection well
- Flow meter prior to injection well



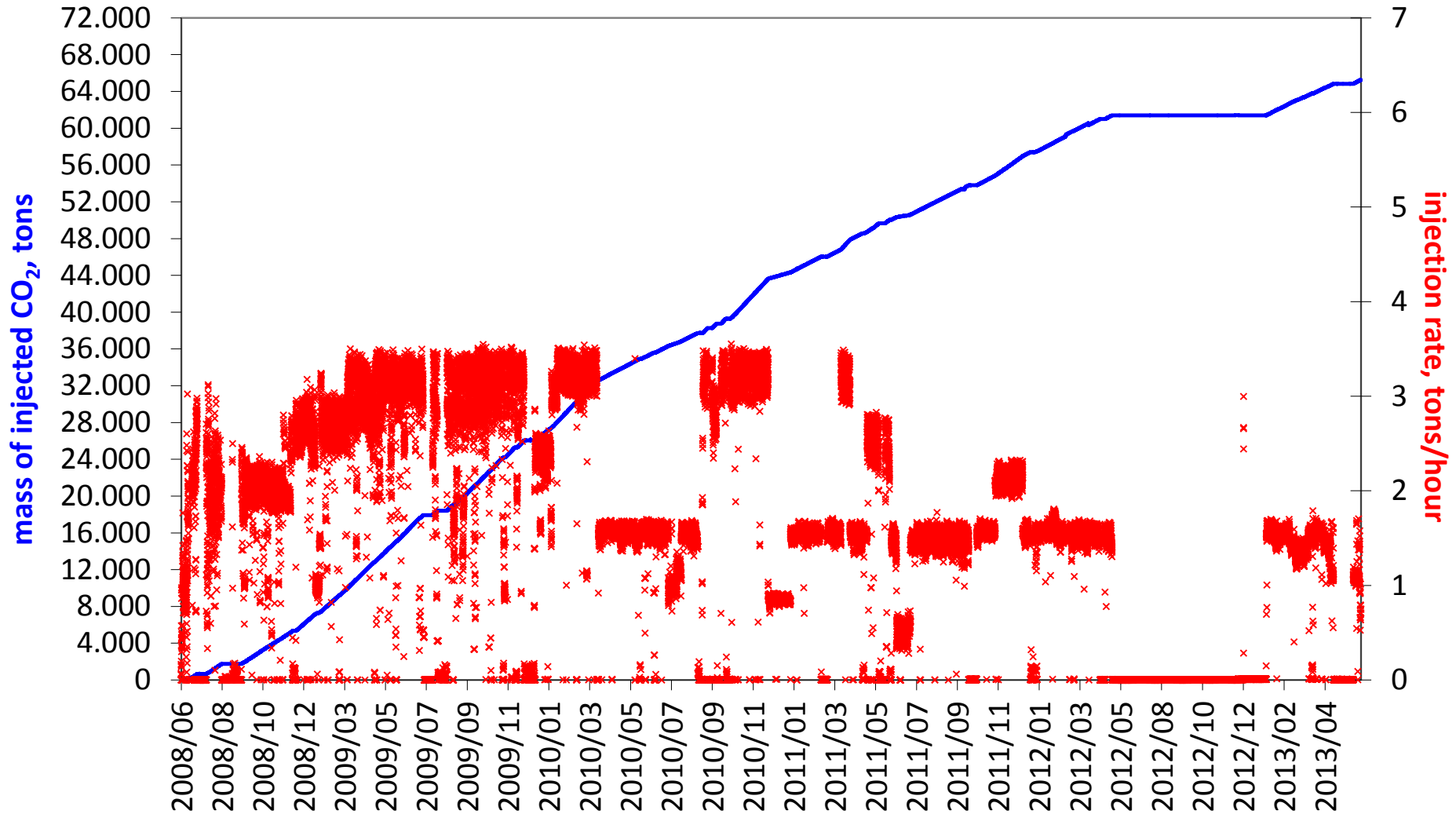
An interdisciplinary monitoring concept is applied



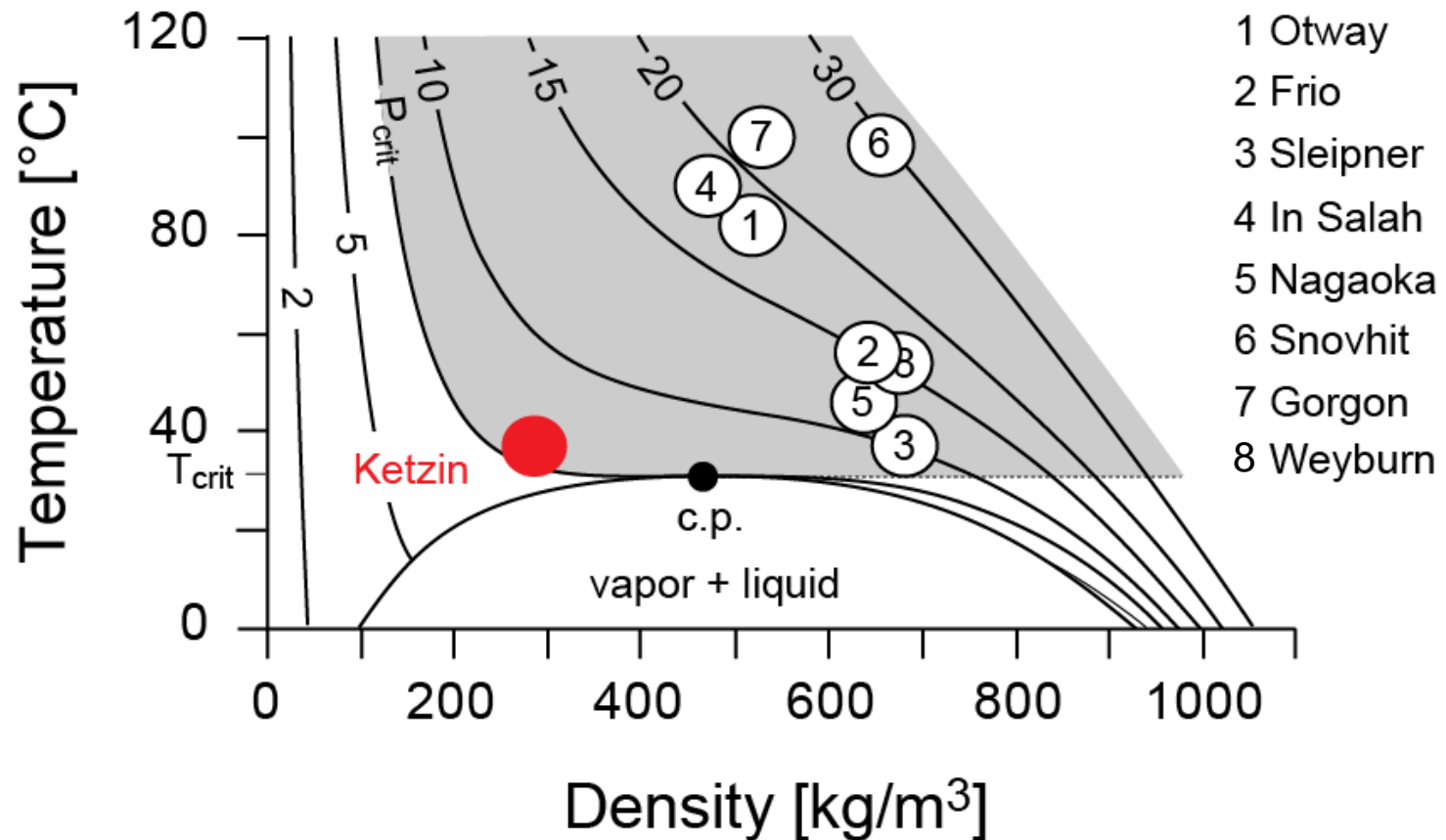
Formation pressure and injected mass of CO₂



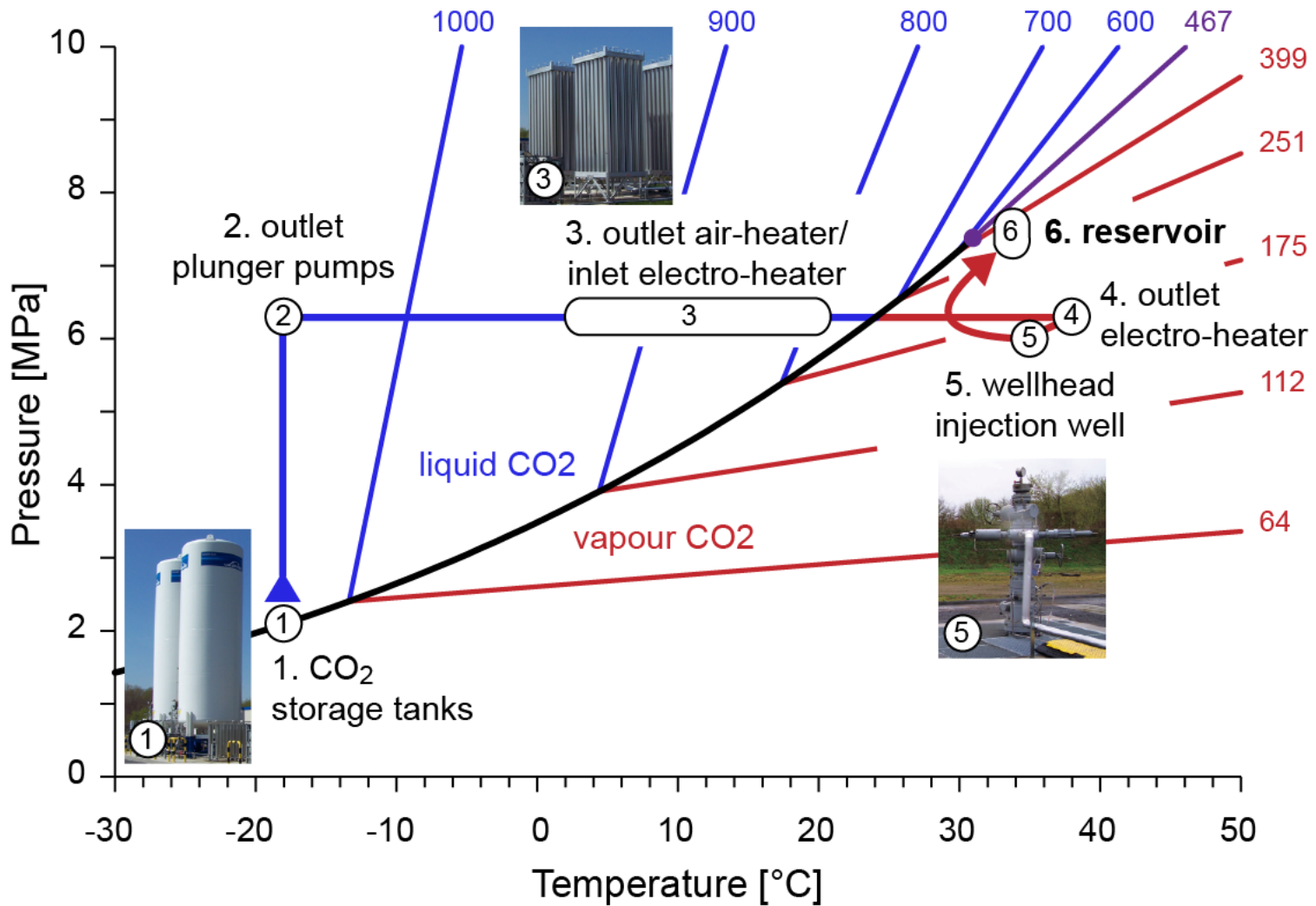
Injection rates and injected mass of CO₂



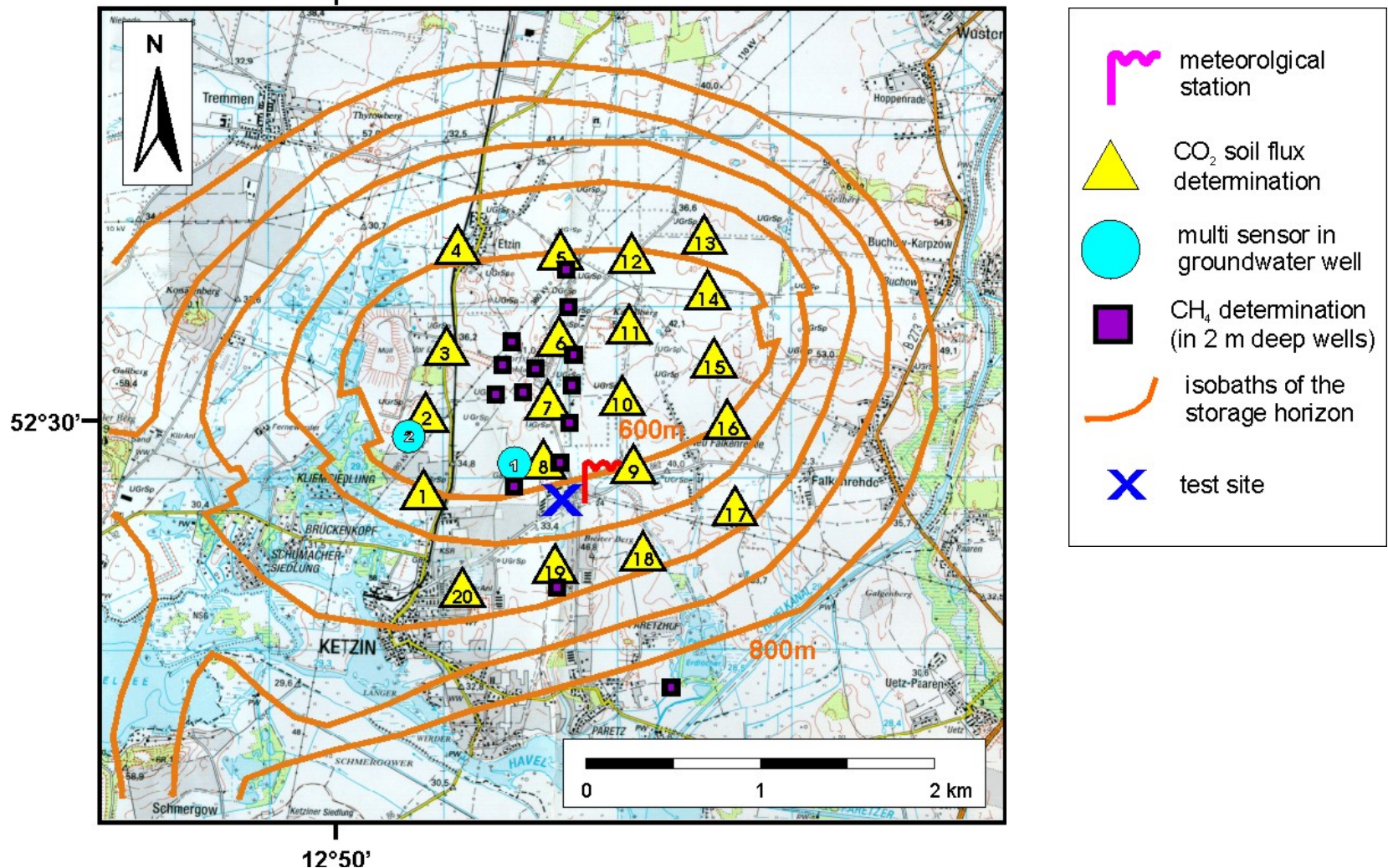
The Ketzin site has comparably low pressure and density conditions



Injection process



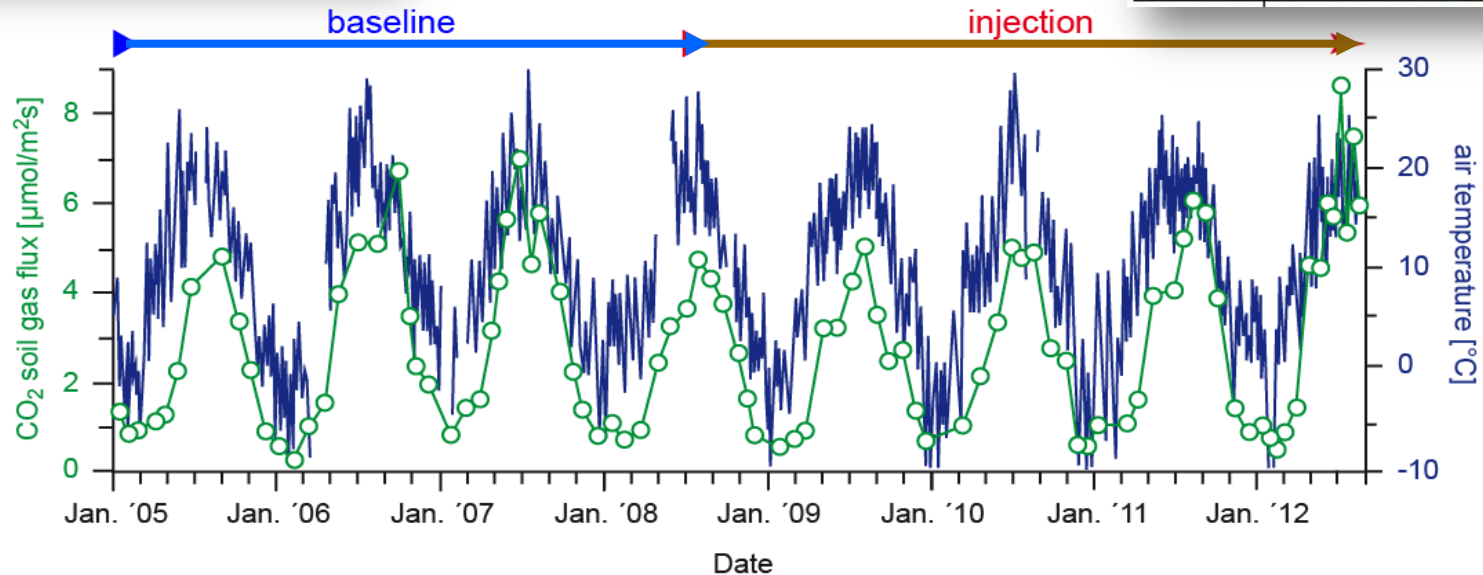
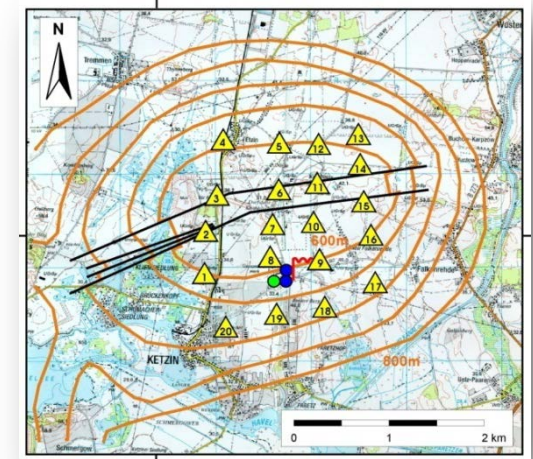
Network of surface and shallow subsurface monitoring locations



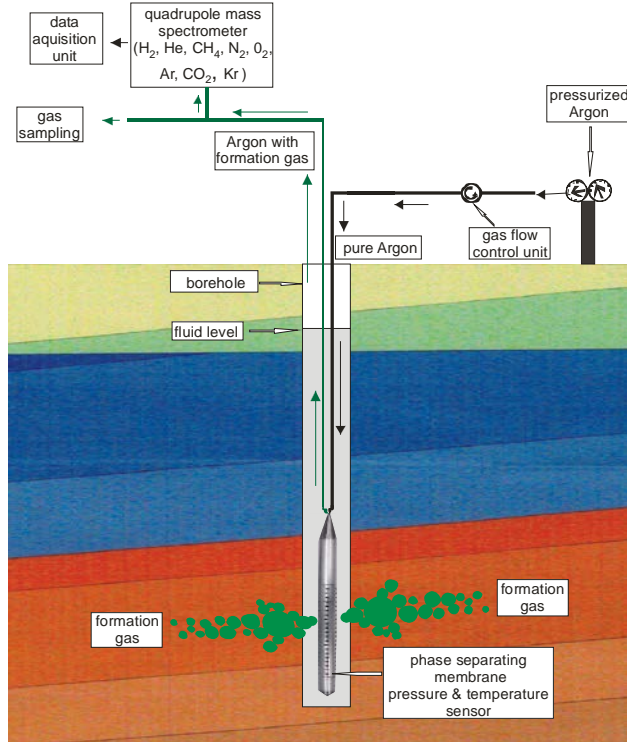
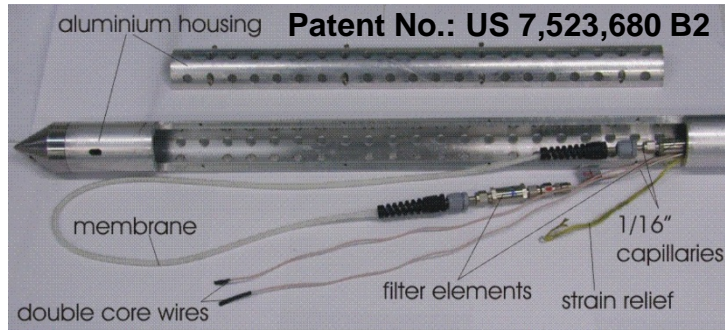
CO₂ flux and temperature show typical seasonal variations



Monthly soil flux measurements
at 20 sampling locations

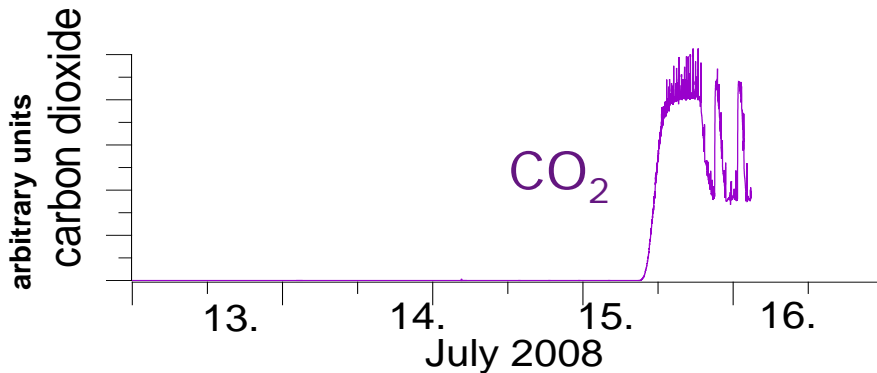
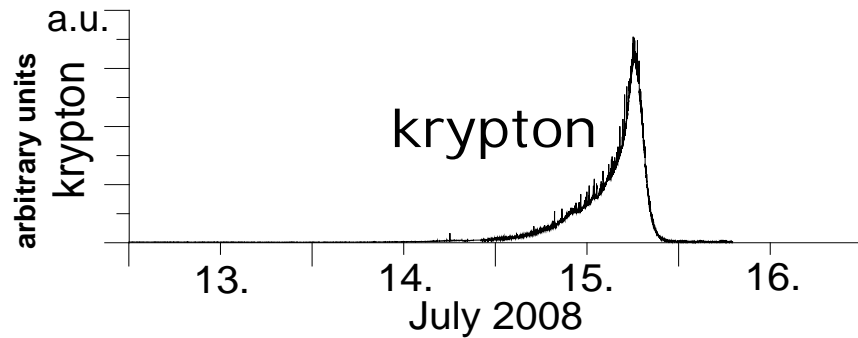


Monitoring with the Gas Membrane Sensor



Gas monitoring - Arrival of tracer and CO₂

Observation Well (Ktzi 200)



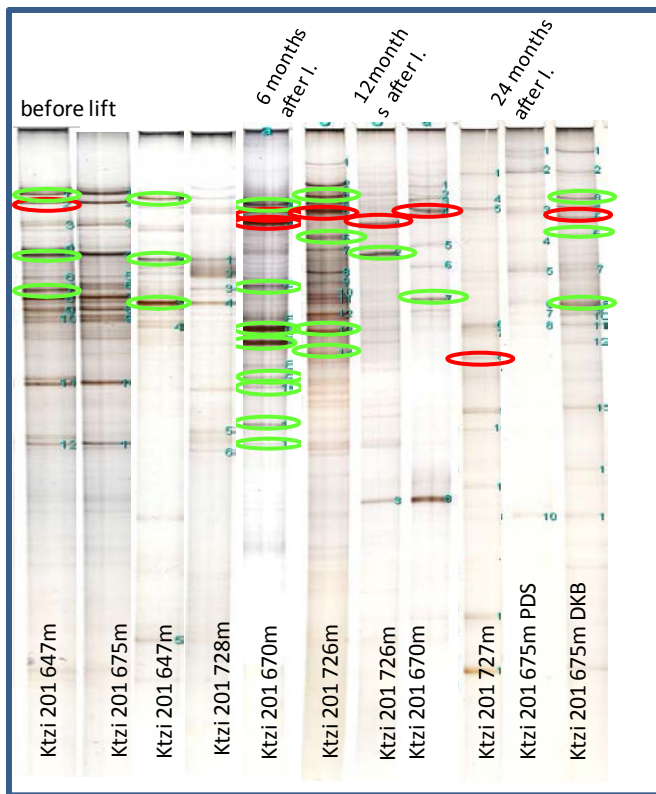
arrival at Ktzi 200 (50 m way from injector)
after ~ 500 t CO₂ injected



Majority of microbes are able to adapt to changed conditions

Fermentative and sulfate reducing bacteria prevail in fluid samples from Ktzi 201

Long-term experiments with new samples (P300)



Detected microbes:

Depth 647m before lift:

Halanaerobiaceae bacterium (Band 1, 4, 7)
Desulfotomaculum salinum (Band 2)
Moorella perchloratireducens (Band 3)
Anaerophaga (Band 10)

Depth 647m after lift:

Halanaerobiaceae bacterium (Band 1, 2, 3)

Depth 670m 6 months after CO₂ injection:

Halanaerobium bacterium (Band 1, 5-12)

Desulfovibrionales spp. (Band 2, 3)

Depth 670m and 726m, 12 months after CO₂ injection:

Halanaerobium spp. (Band 3, 6, 12, 14)

Desulfovibrionales spp. (Band 5, 4)

Depth 675m and 727m, 24 months after CO₂ injection:

Halanaerobium spp. (Band 3, 6, 8)

Desulfotomaculum acetoxidans (Band 8)

Desulfovermiculus halophilus (Band 5)

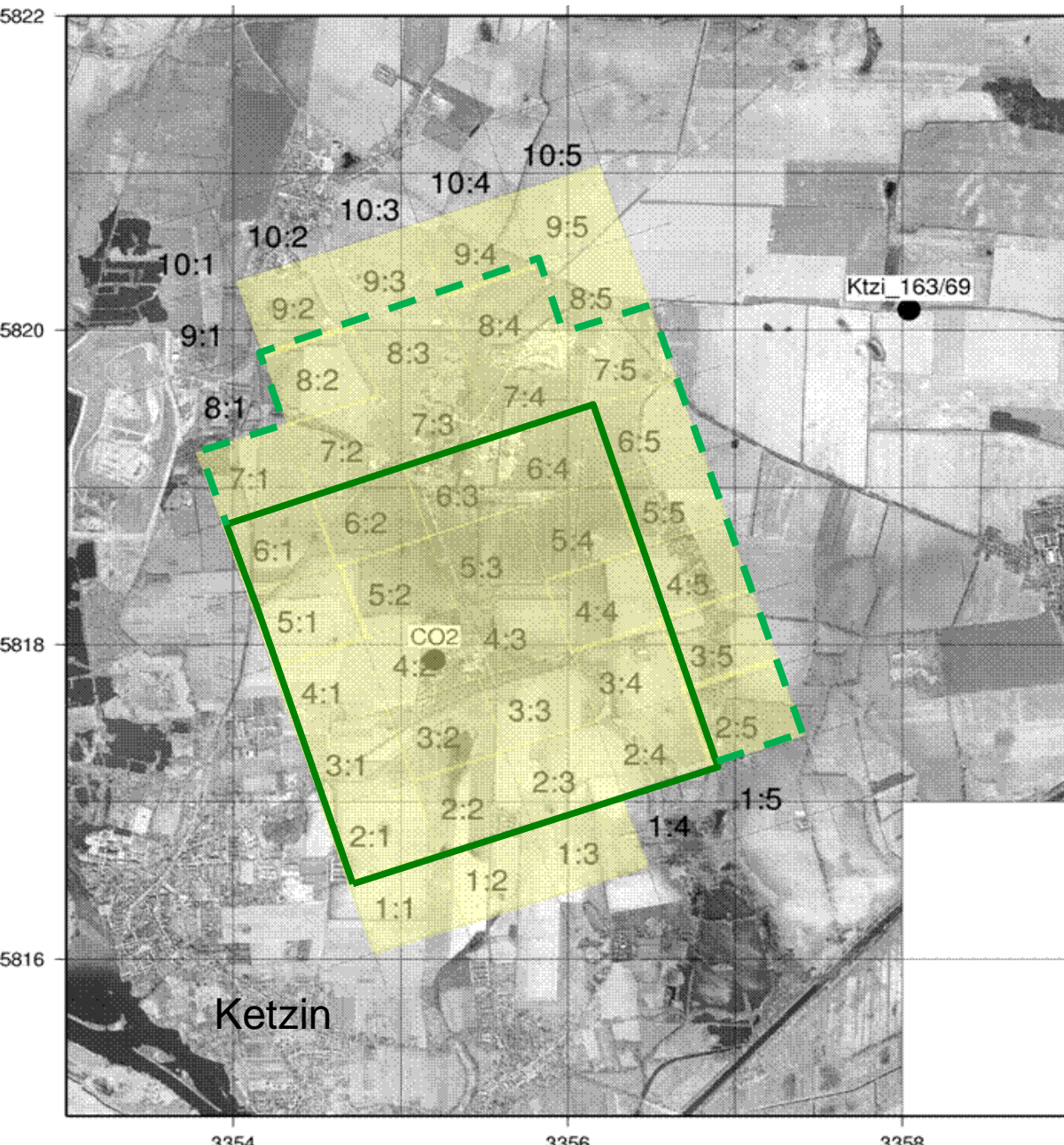
Thermotoga (Band 9)

Anaerophaga thermophila (Band 10, 11, 12)



Geophysical monitoring

4D Seismic Observations



3D Baseline 2005:
41 Templates
~12 km²

3D Repeat 2009:
20 Templates
(after ~23 kilotons
CO₂ injected)

3D Repeat 2012:
33 Templates
(61 kilotons injected)

1 Template:
240 geophones, 5 lines
180 shotpoints, 12 lines

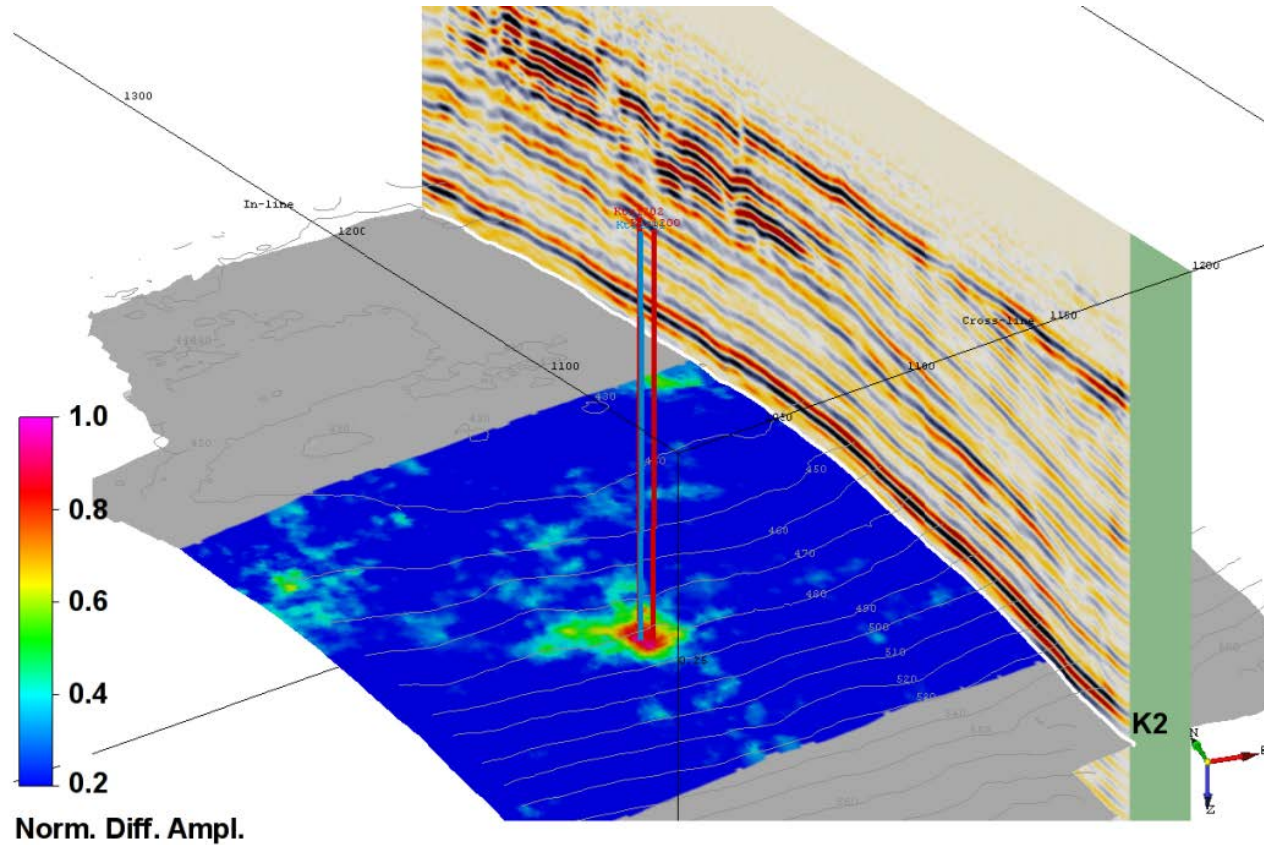
Courtesy of S. Lueth

Vibrators used for 3D seismic baseline



3D seismics: Time-lapse amplitude analysis visualizes the CO₂ signature

Normalized amplitude variation (3D Baseline 2005 vs. 3D Repeat 2009)



Geophysical monitoring

Seismic

Geoelectric

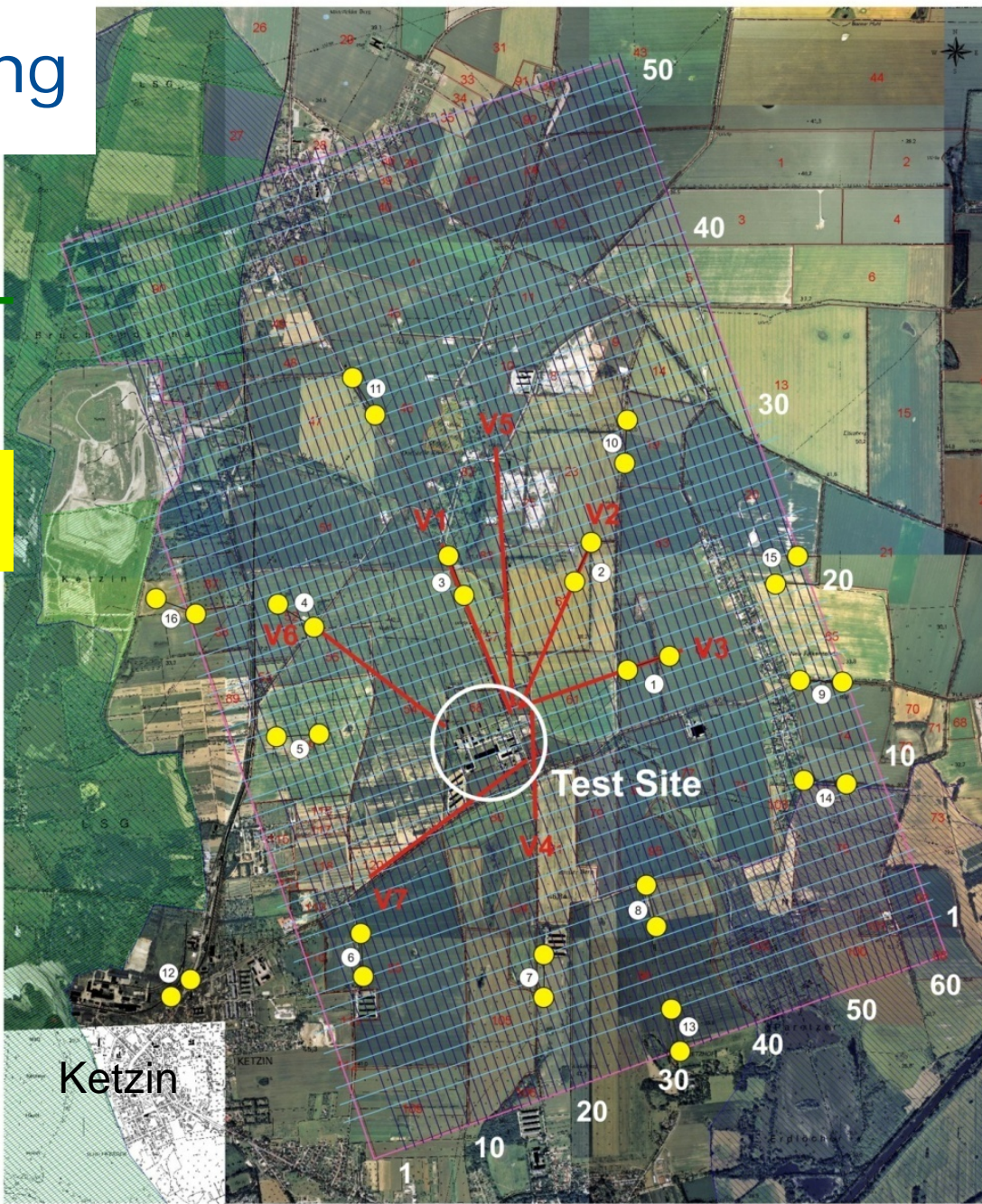
3D

Star, MSP/VSP

Surface-downh.
ERT

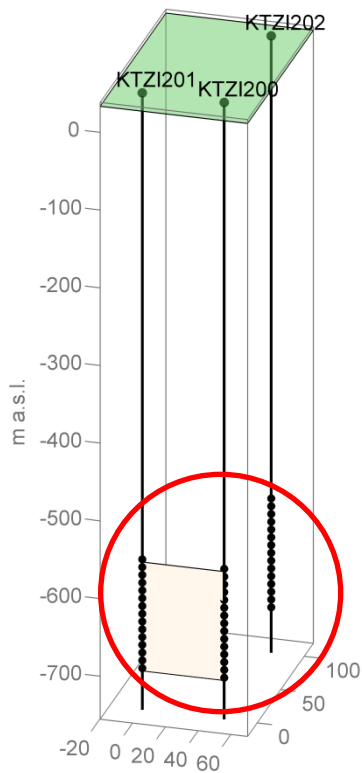
X-hole Tomogr.

X-hole ERT



Installation of the VERA system for geoelectrical monitoring

The Vertical Electrical Resistivity Array-system

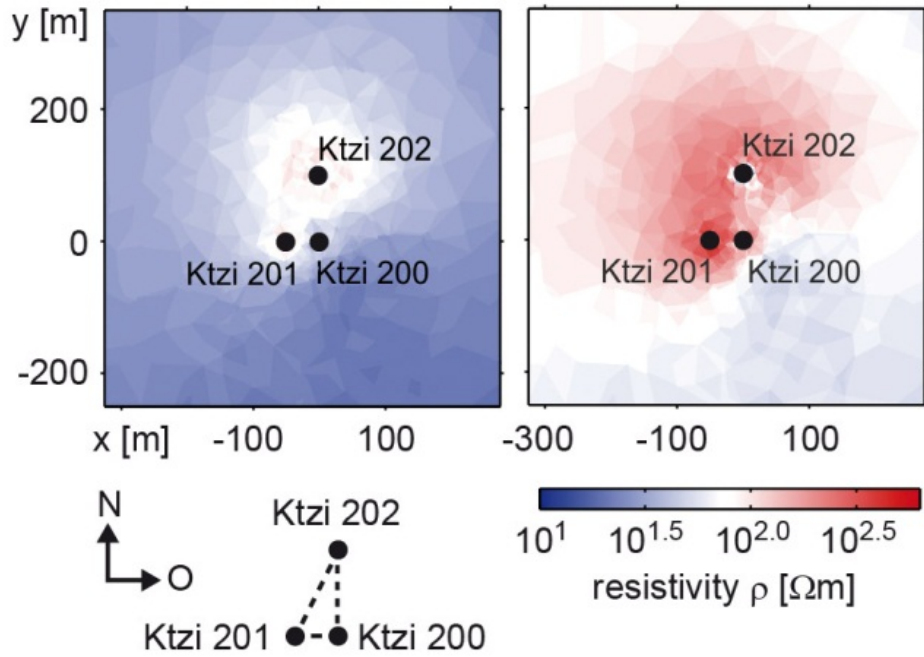


Geoelectrical measurements show resistivity increase at reservoir level

depth slices $z = -630$ m

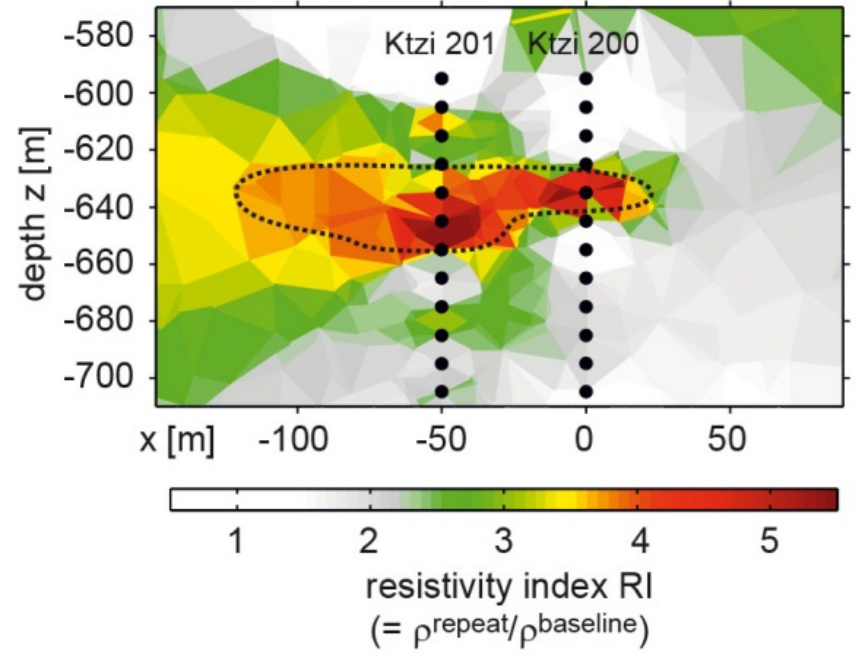
baseline

3. repeat
(after 13.5 kt CO₂)



vertical profile Ktzi 201-Ktzi 200

relative resistivity changes
(3. repeat vs. baseline)



Persistent Scatterer Interferometry

- **Displacement monitoring** is based on TerraSAR-X Stripmap image data (3 m resolution)
- Deformation rates in the order of **mm/year** are detectable
- Acquisition since **April 2009** every 11 days
- Installation of **4 corner reflectors** as artificial scatterers due to rural character of the site
- **Data processing** in progress

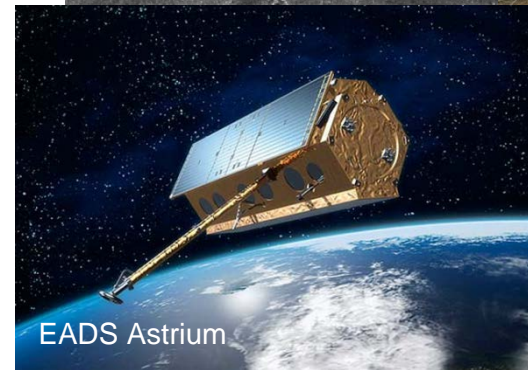
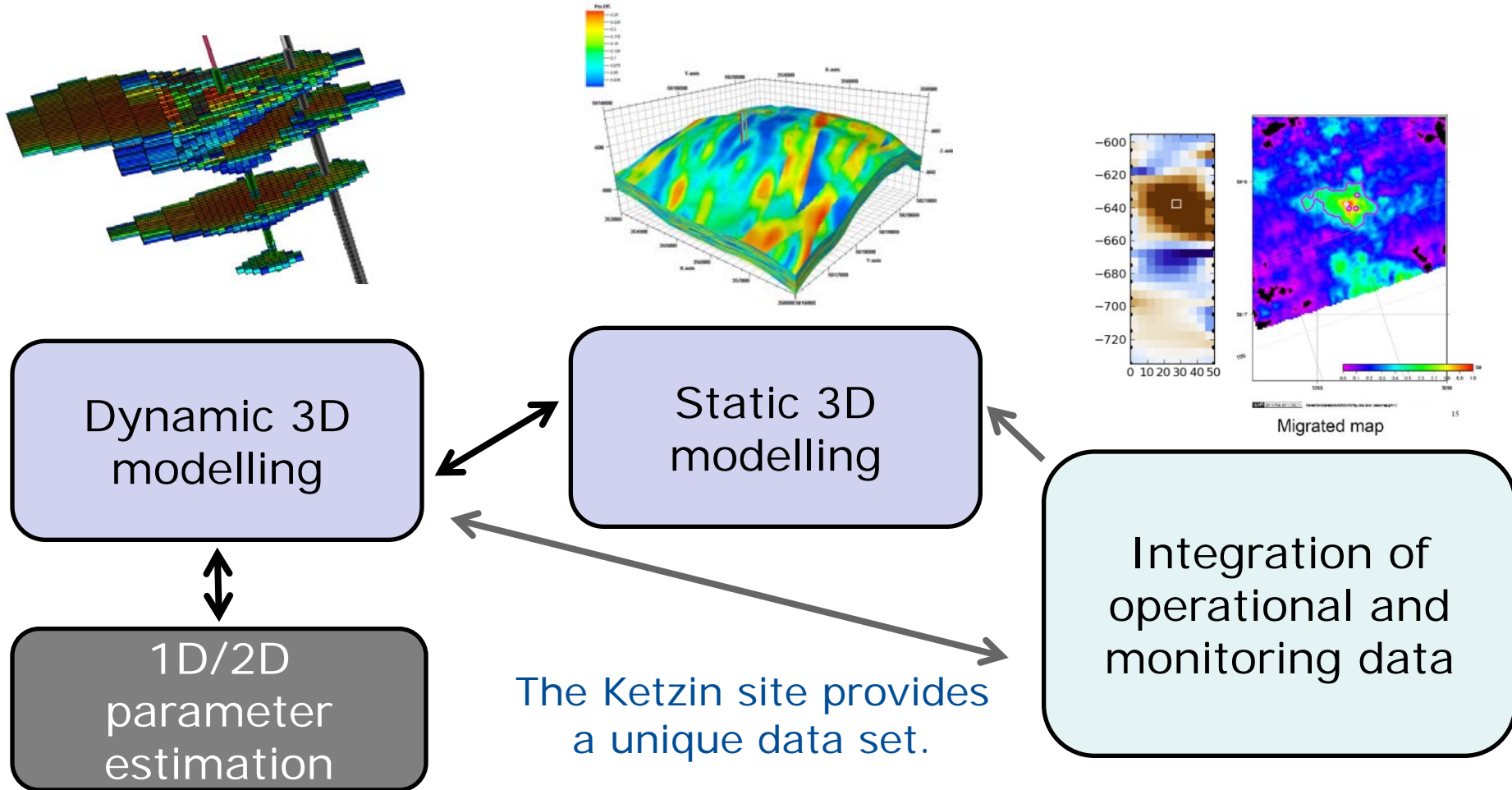


Photo: C. Lubitz

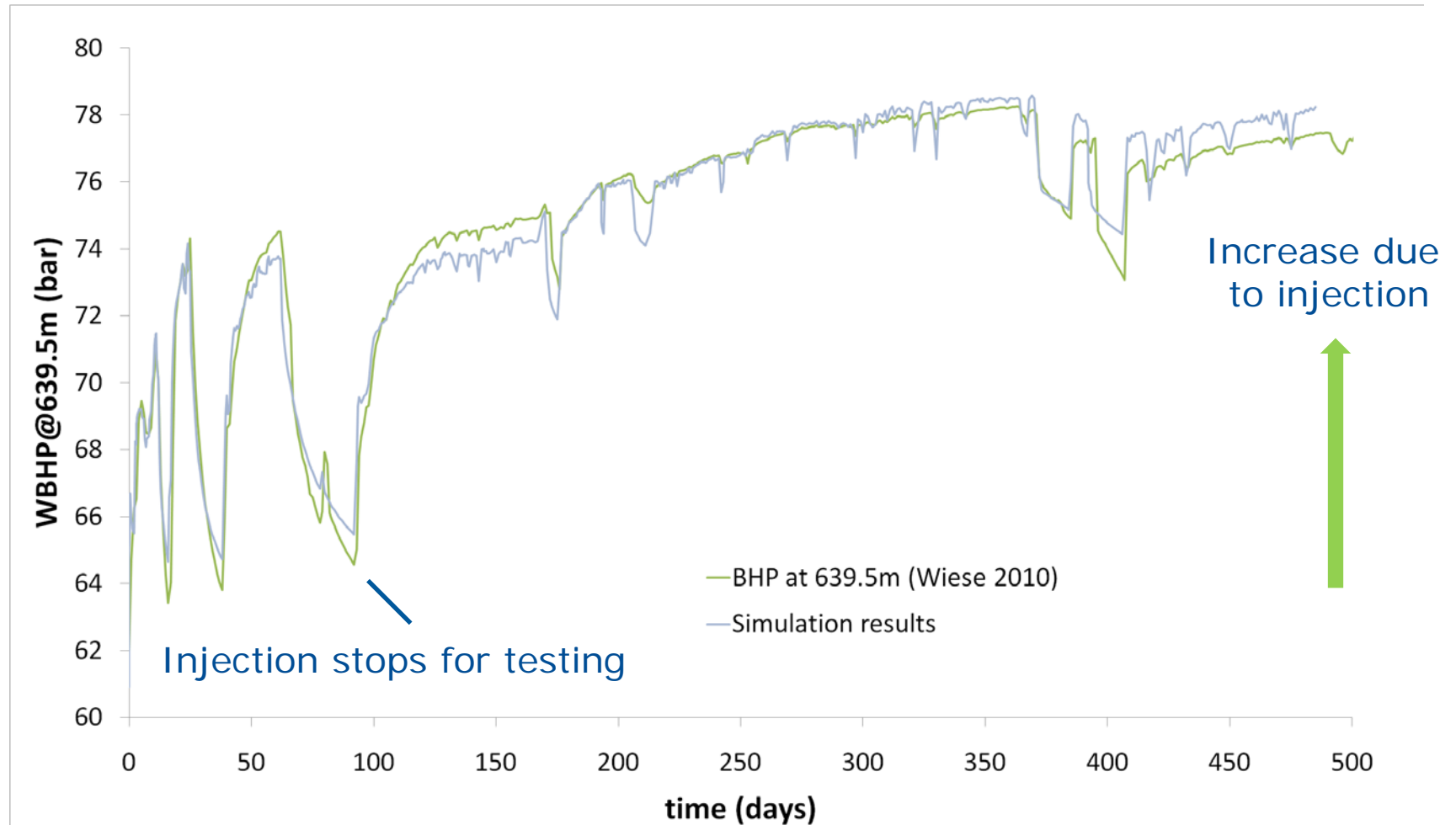
Modelling the Ketzin site

*“Match the history of observations
to be able to trust your predictions”*

Current status of modelling activities - Integrated *History Matching* process



Static geological Ketzin model validated by dynamic simulations



Dynamic model matches pressure and arrival times of CO₂ at observation wells

well Ktzi 201

well Ktzi 202

100 m

TIMESTEP: (1) 24/Jun/2008 (02:24:59)

KTzi_202

KTzi_200

well Ktzi 200

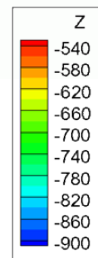
Gas saturation

0.00000 0.14044 0.28088 0.42131 0.56175

Simulated arrival times

Ktzi 200: 23 days (measured 21 d)

Ktzi 202: 257 days (measured 270 d)



5 km x 5 km

Public outreach and conclusion

A key premise of communication is an open and transparent dialogue

- **Transparent information** about Ketzin and the monitoring concept and results from the very beginning
- Large and **positive resonance** in the media and continuous **visitor groups** to the pilot site
- “Peaks” for requests at **special events**, e.g. first delivery of CO₂ from Schwarze Pumpe pilot plant in May 2011



The world visiting the pilot site Ketzin



Information are made available through multiple communication types

- **Visitor centre Ketzin** as most important contact point
- **Annual Open House** at Ketzin site brings the researchers and the local community together.
- Project status and progress are covered at the website www.co2ketzin.de.
- **Videos** and **brochures** are provided.



Conclusion

- We learned how to **inject CO₂** into a **saline aquifer** – daily operation to regulation.
- **Geophysics** is able to **detect** the **CO₂ signature** on various - even very small - scales.
- **Geochemistry** is able to **follow** the trace of the **CO₂**.
- Dynamic **model matches** the field **observations** (CO₂ arrival times and pressures).

