

Ketzin Collaboration

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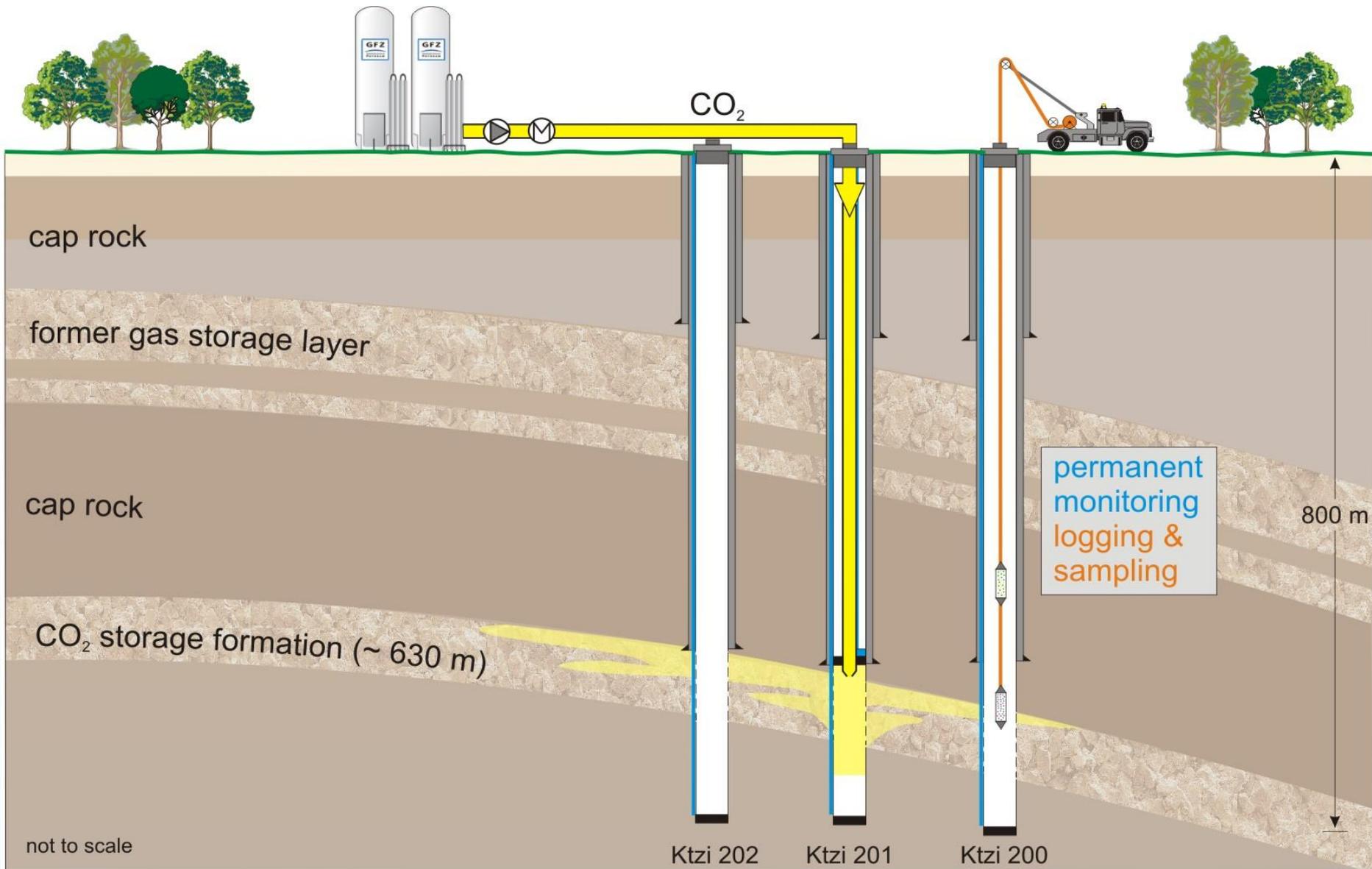
Carbon Storage R&D Project Review Meeting

Developing the Technologies and Building the
Infrastructure for CO₂ Storage

August 21-23, 2012

Presentation Outline

- Goals and objectives
- Success Criteria
- Technical Status
- Latest developments in Integrated Monitoring
- Summary and Lessons Learned



Benefit to the Program

- Program goal being addressed:
 - Develop technologies to demonstrate that 99 percent of injected CO₂ remains in the injection zones.
- The Ketzin collaboration leverages information gained through the mid-scale geological sequestration experiment in Ketzin, Germany. The project consists of an injection of approximately 100,000 tonnes of CO₂ in a saline formation situated in the eastern part of the double Roskow-Ketzin anticline. As part of the Ketzin Collaboration, Berkeley Laboratory is involved in:
 - (1) development of well-based heat-pulse monitoring systems for the Ktzi203 well
 - (2) commercialization of advanced multifunction monitoring systems

Project Overview: Goals and Objectives

- The Ketzin Collaboration project objective is to develop and advance the technology readiness level of critical well-based CO₂ plume monitoring technologies
- From EPA Class VI Well Regs:
 - EPA clarifies that direct geochemical monitoring is not required in the target formation itself, although sampling via wells in the target formation may be desirable in some circumstances, *e.g.*, to perform geochemical monitoring in wells used for direct pressure monitoring to meet requirements of 146.90(g). Furthermore, **EPA believes that the benefits of direct monitoring using wells outweigh the risks of unintended fluid migration. Monitoring wells provide important information that confirms injectate confinement.**
 - **146.89 Mechanical integrity.** (c) At least once per year, the owner or operator must use one of the following methods to determine the absence of significant fluid movement under paragraph (a)(2) of this section: (1) An approved tracer survey such as an oxygen-activation log; or **(2) A temperature or noise log.**

Success Criteria

- Subtask 6.1.1 Heat-pulse Measurements - The periodic acquisition of heat-pulse data that is applicable towards analysis of phase saturation in the subsurface. Success relies on the proper functioning of equipment and coordination with other field activities.
- Subtask 6.1.2 Interpretation of heat-pulse measurements - This subtask will be successful if a TOUGH2 coupled thermal hydrological model can be used to interpret the acquired data and the data is corroborated with other measurements such as RST logs and seismic data.
- Subtask 6.2.1 Development of tube-in-tube U-tube - Completion of engineering design and fabrication of an initial tube-in-tube U-tube. This patent pending technique has never before been tried and relies on close coordination with a manufacturer in coming up with an appropriate
- Subtask 6.2.2 Tube-in-tube U-tube – Deployment and operation at the Ketzin site - This subtask will be successful if we are able to carry out the deployment of a tube-in-tube U-tube and develop protocols for its operation for monitoring shallow groundwater above CO₂ storage reservoirs.

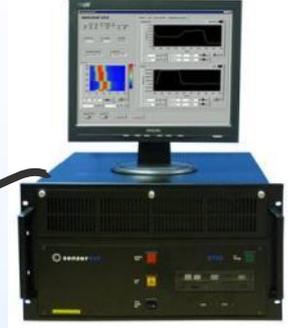
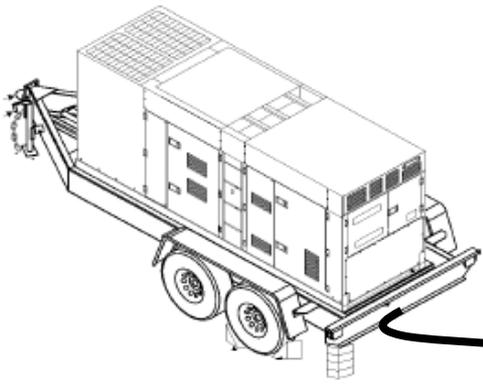
Technical Status

- Heat-pulse testing
 - Theory
 - Evolution of cable deployments
 - Latest innovations in integrated monitoring
- Tube-in-tube U-tube
- Accomplishments
- Summary/Future Plans

Heat pulse testing

Energy Meter

Fiber-optic DTS

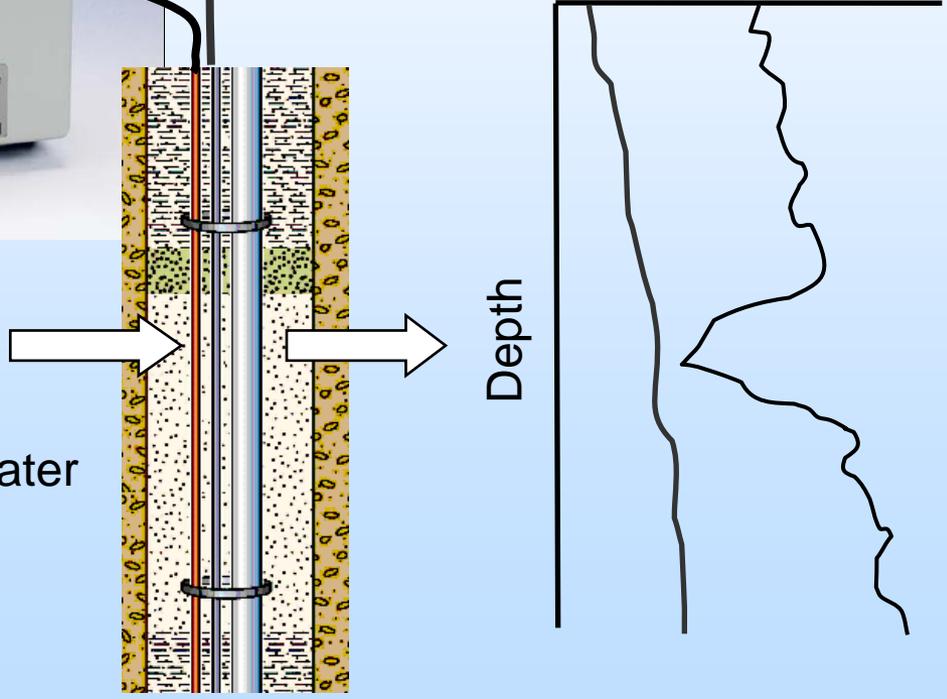


Electrical Generator
Or Grid Power

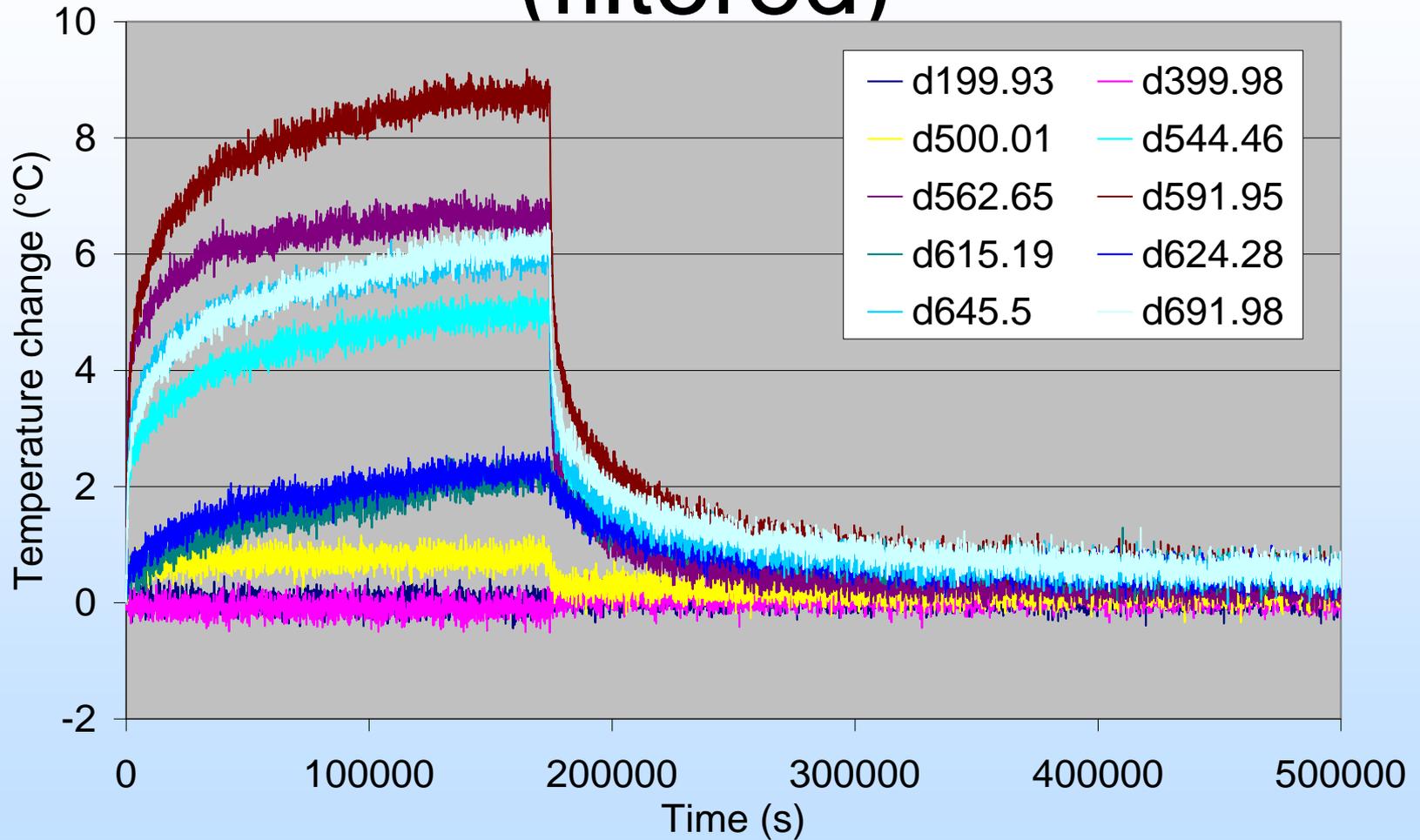
Temperature

Line Source Heater

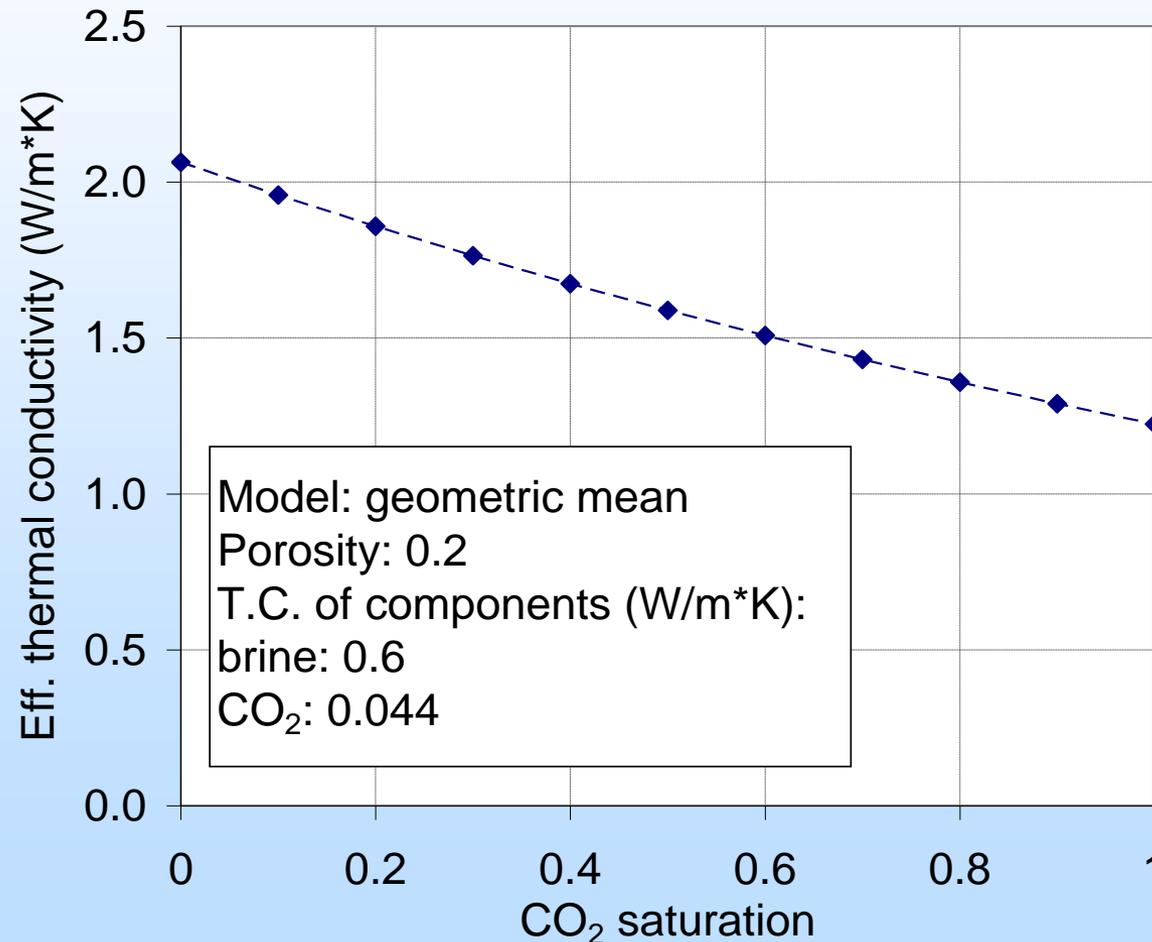
Depth



Measured temperature changes (filtered)

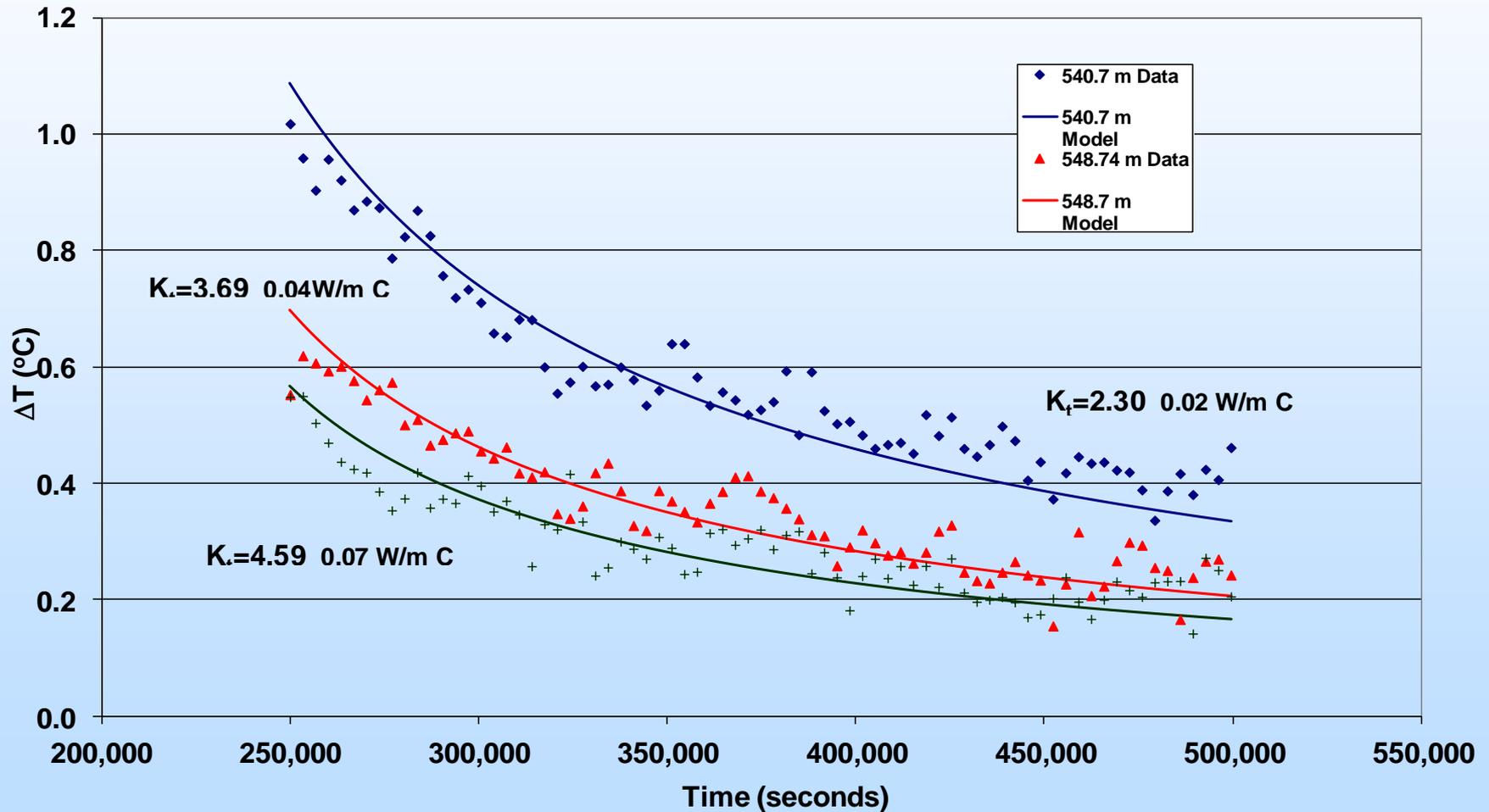


Thermal Conductivity relationship with CO₂ Saturation

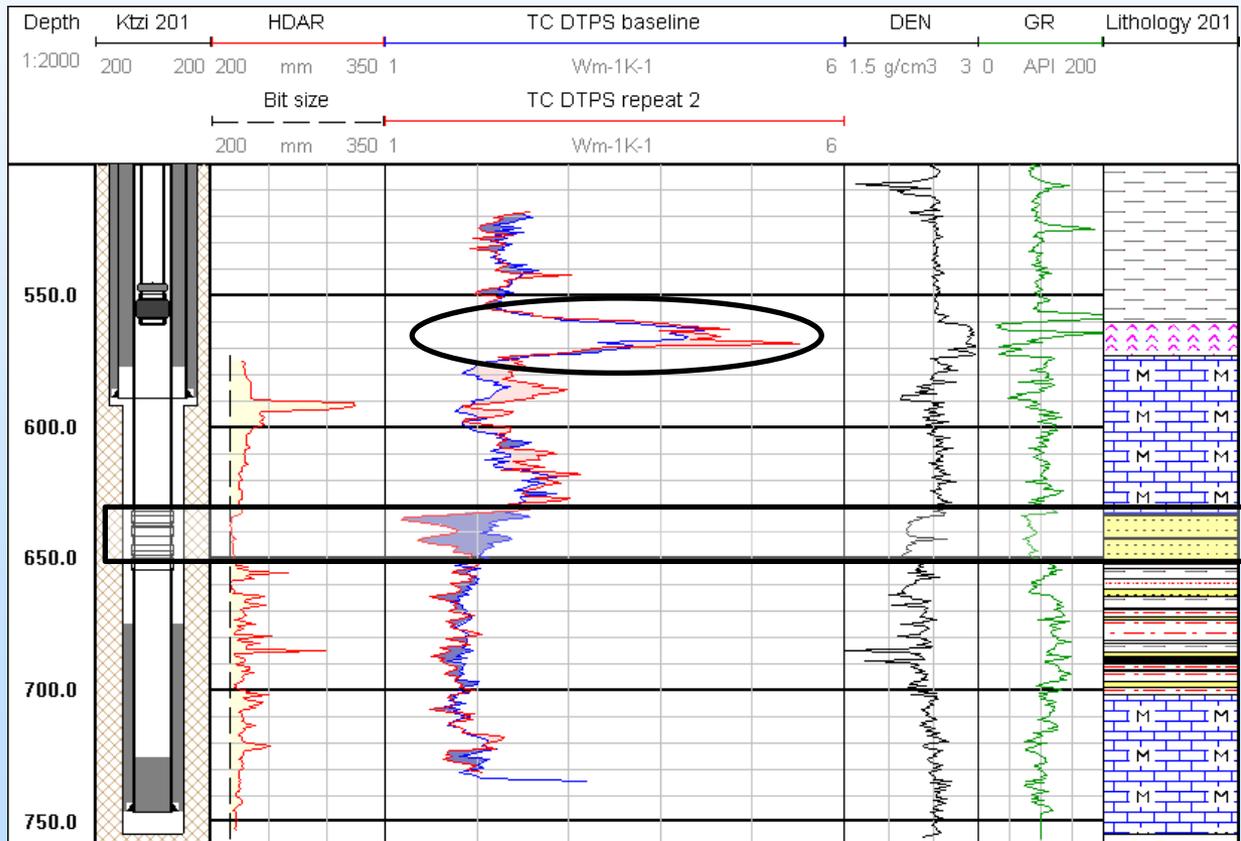


About 40%
reduction of
effective t.c.
by replacing
brine by CO₂

Inversion: estimation of thermal conductivity



Thermal conductivity repeat DTPS Ktzi201 (after start of CO2 injection)



Good overall fit to baseline results (e.g. K2 marker horizon).

Distinct zone with decrease in thermal conductivity: main zone of CO2 injection.

No clear indications for CO2 below „main“ injection interval.

Initial deployment: Separate heater and fiber-optic lines



Improvements to the heat-pulse sensor... several initial failures working with plastic jacketed cables



Pressure testing of polyurethane
jacketed cables in pack-offs



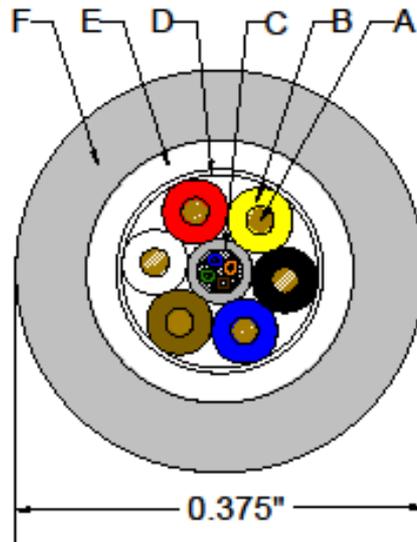
Unacceptable results for
pressure control!

Low mechanical pull strength achieved using Kevlar reinforcements



New hybrid fiber-optic cable design

SIX 20 AWG CONDUCTORS & FOUR FIBER FIMT STAINLESS STEEL TUBE



Components

- A: 6 x 20 AWG 7/28 Tin Coated Copper; O.D.: 0.96 mm (0.037") Nominal
- B: Colored T-01 (FEP); O.D.: 1.73 mm (0.068") Nominal;
- C: 316L FIMT containing gel and 2 x 50/125 & 2 x SM HT Acrylate Coated Fibers; O.D.: 1.8 mm
- D: PTFE Tape (0.003" Thickness) Wrap over Cabled Core
- E: White P-06; O.D.: 7.75 mm (0.305") Nominal
- F: 316L Stainless Steel Tube; Wall Thickness: 0.89 mm (0.035"); O.D.: 9.53 mm (0.375") Nominal

Incorporates:

- DTS
- DAS
- Heat-pulse (3-phase AC heating)

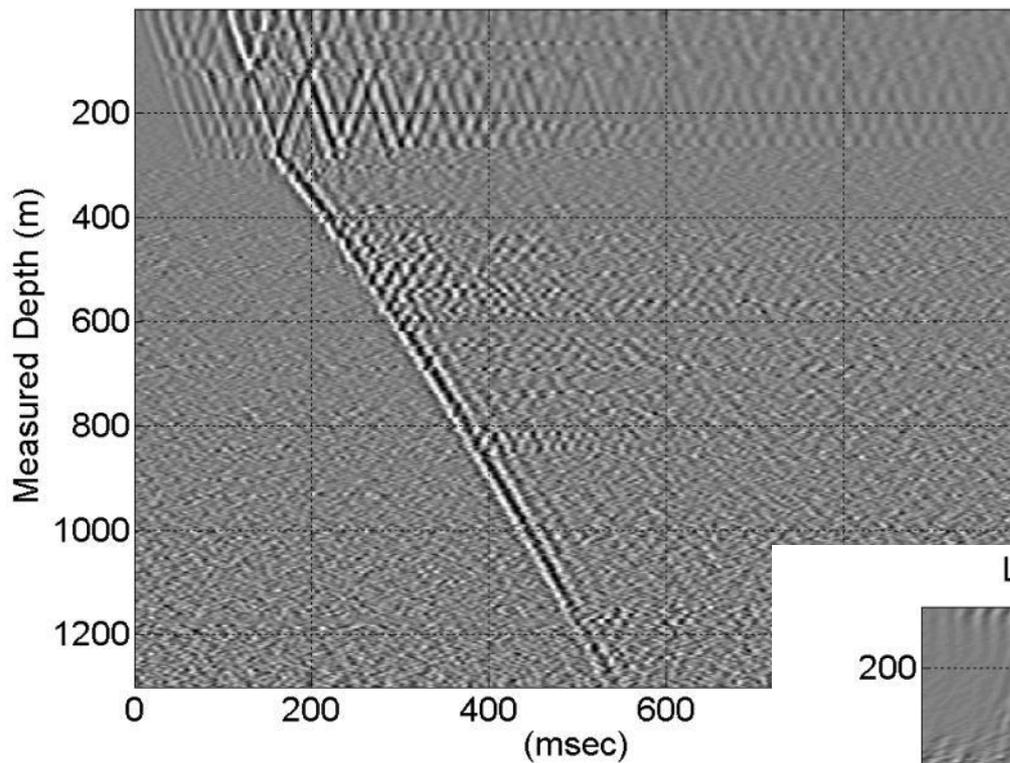
Developed an innovative welded termination to eliminate mechanical seals



Program cross-fertilization: Test of new heat-pulse cable at Raft River Geothermal Program RRG-9 Well, Malta, Idaho



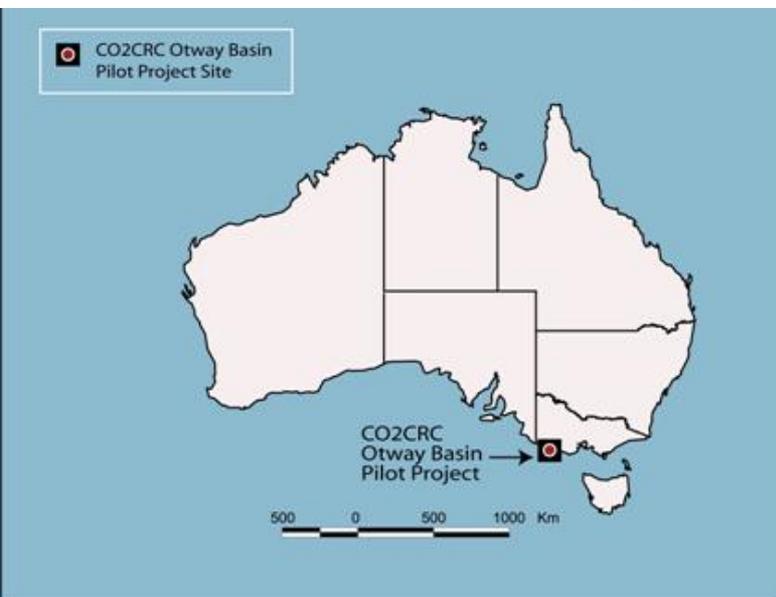
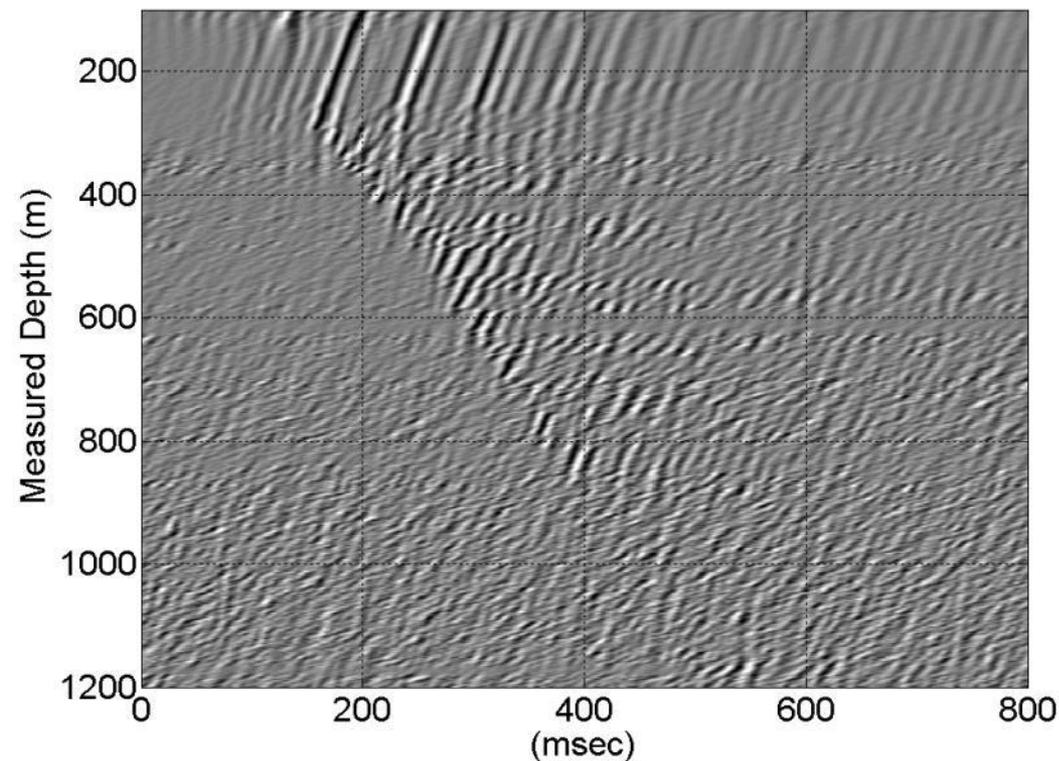
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FO cable modified to permit seismic acquisition

Multifunction FO cable installed at Otway Project Field Site – baseline data collected June 2012

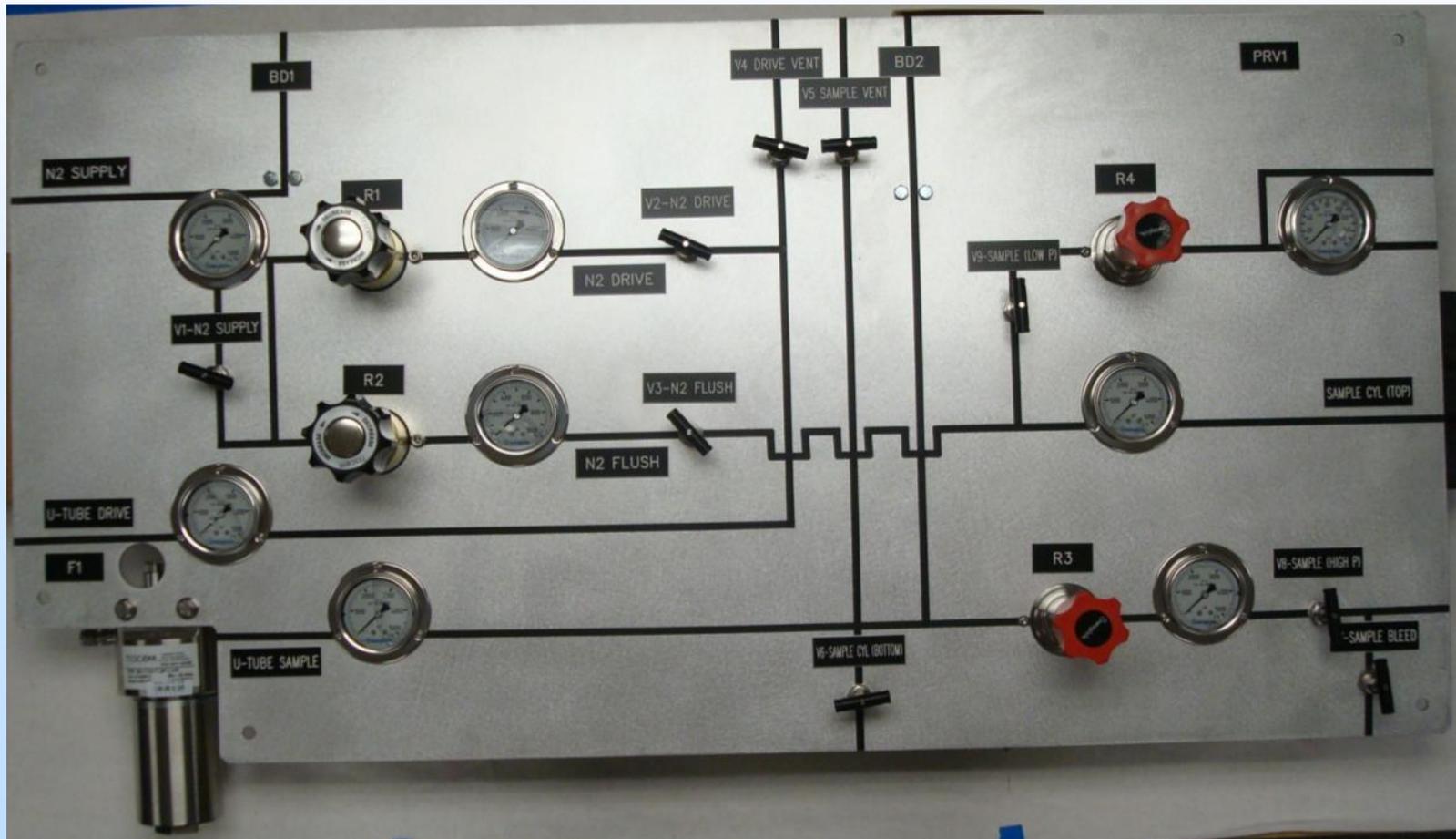
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Tube-in-tube U-tube

- Patent pending technology
 - Simplifies installation
 - Reduces risks during completion
- Initial deployment in CRC-2 Otway Project Stage 2b
- Current and future planned deployments
 - Citronelle Dome
 - Kansas Wellington Field
 - Big Sky

U-tube control system now available through commercial vendor



Accomplishments to Date

- Deployed a heat-pulse sensor as part of the CO2SINK project that was used to identify where CO2 was entering the formation
- Engineered the heat-pulse sensor design and integrated it with a Distributed Acoustic Sensor
- Developed a tube-in-tube U-tube in preparation for the above-zone monitoring well (but it was not deployed at Ketzin)

Summary

– Key Findings

- The heat-pulse sensor can provide information on CO₂ saturation around the wellbore
- The heat-pulse sensor and tube-in-tube U-tube geochemical sampler have progressed to a commercial state of readiness (TRL9)
- Acoustic monitoring has been added to the heat-pulse cable

– Lessons Learned

- Thermal fluctuations cause by producing or injecting fluid make interpretation of heat-pulse data difficult
- Stainless steel coiled encapsulated tubing is highly preferred in comparison to plastic jacketed cables

Future Plans

- An integrated monitoring cable containing a hybrid fiber-optic heat-pulse sensor along with an acoustic fiber will be deployed in Ktzi203 in 2012.

Appendix

Organization Chart

- Barry Freifeld, PI & Hydrogeologist
- Rohit Salve, Hydrogeologist

Ketzin Collaboration

	FY10		FY11		FY12	
FY10 & 11 Subtask 1. Distributed Thermal Perturbation Studies	■	■	■	■	■	■
FY10 Subtask 2. Ketzin core petrophysical measurements	■	■				
FY11 Subtask 2. Development of a tube-in-tube U-tube for geochemical sampling	■	■	■	■	■	■
FY12 Subtask 1. Development of instrumentation and methodology for above zone monitoring					■	■
FY12 Subtask 2. Commercialization of tube-in-tube U-tube and DTSP technology					■	■
Milestones						
FY10 Q2 12 Month Assessment of DTSP Data and Analysis FY10 Q4 CO2SINK DTSP results and comparison with other data sets						
FY11 Q2 Design and engineering of a capillary injection line DTSP device FY11 Q4 Design and engineering of the tube-in-tube U-tube for shallow groundwater sampling						
FY12 Q2 Complete engineering design and safety documentation for 3-phase high voltage DTSP heating system FY12 Q4 Final design of a commercial U-tube sampling system with SOPs for application to both shallow groundwater and deep well multi-phase operation						

Conference Presentations

- Henninges, J.; Baumann, G.; Freifeld, B. M. (2011): Near-wellbore characterization of CO₂ migration at Ketzin using PNG and DTS measurements. IEAGHG 7th Monitoring Network Meeting (Potsdam 2011, Germany).
- [Freifeld, B. M.](#); [Daley, T. M.](#); [Howorka, S. D.](#); [Henninges, J.](#); [Underschultz, J.](#); [Sharma, S.](#) (2009): Recent advances in well-based monitoring of CO₂ sequestration. Energy Procedia, 1, 1, 2277-2284.