GEO-SEQ

LBNL's Consolidated Sequestration Research Program (CSRP)

Project Number FWP ESD09-056

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U.S. Department of Energy

National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Developing the Technologies and
Infrastructure for CCS

August 20-22, 2013

Presentation Outline

- Benefits and Goals of GEO-SEQ
- Technical Status
  - Otway Project (CO2CRC)
  - In Salah (BP, Sonatrach and Statoil)
  - Ketzin Project (GFZ, Potsdam)
  - Aquistore (PTRC)
- Accomplishments and Summary

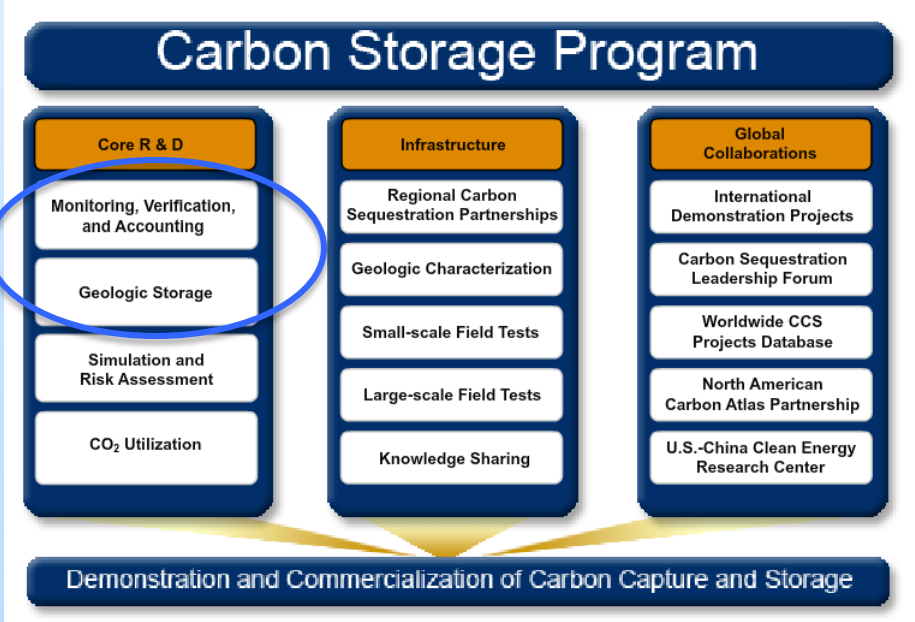
Benefit to the Program

- Program goals being addressed:
  - Develop and validate technologies to ensure 99 percent storage permanence.
  - Develop technologies to improve reservoir storage efficiency while ensuring containment effectiveness
- This research addresses these goals through active collaborations with significant international demonstration programs. Research is varied and includes:
    - **Storage Process Monitoring**
    - **Deployment and testing of new monitoring strategies, technologies and tools**

Benefit to the Program

- DOE and the carbon sequestration community will benefit from:
  - a close working relationship with numerous domestic and foreign industrial and academic teams
  - interactions with and assistance given to DOE infrastructure programs
  - publications and presentations made available to all parties interested in removing barriers to commercial-scale geologic carbon sequestration.

Core R&D:
MVA and Geologic Storage



Project Overview: Goals

- Improve understanding of storage processes and monitoring through leveraging international research opportunities
  - Improve estimates of storage capacity and sweep efficiency
  - Develop new monitoring tools and technologies to achieve 99% storage confirmation
- Integrate research with Task 3.0 Fundamental Studies
  - Results from Fundamental Studies applied to the field and field observations requiring additional research used to direct future laboratory research

Project Overview: Objectives

- LBNL's Consolidated Sequestration Research Project (CSRP) aims to provides knowledge and lessons learned from performing distinct tasks with common overall goals:
  - Developing the knowledge base to enable commercialization of geologic carbon sequestration (GCS)
  - Identifying and removing barriers to sequestration through targeted research.
  - Understanding processes and developing improved tools
    - improve quantitative interpretation of monitoring data to ensure 99 percent storage permanence.
    - ensure containment effectiveness.

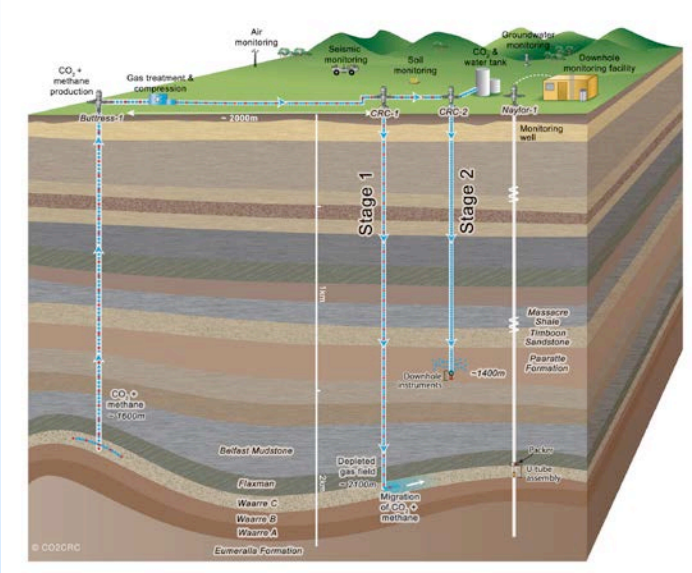
Technical Status

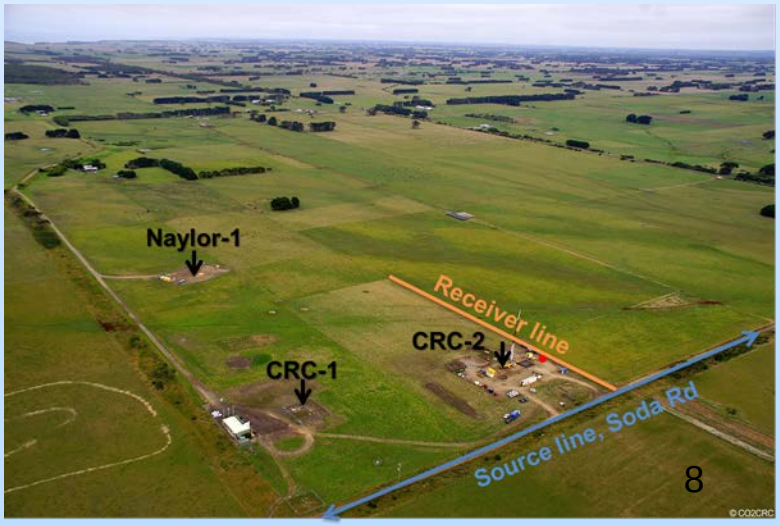
- In FY14 GEO-SEQ focused on collaborations with significant international storage demonstration programs as part of LBNL's Consolidated Storage Research Program (CSRP).

- ***GEO-SEQ Field Project Participation***
  - ***CO2CRC Otway Project (Australia)***
  - ***In Salah Joint Industry Partnership (Algeria)***
  - ***GFZ Ketzin Project (Germany)***
  - ***2.4 Aquistore (Canada)***

CO2CRC Otway Project

- *Field Testing*
  - Upcoming Stage 2b-extension and 2c injection
- *Modeling and Simulation*
  - reservoir modeling to interpret the data collected during Stage 1
  - joint inversion of hydrological and geochemical data from Stage 2.
- *Planning and Coordination*
  - coordinating the numerous research groups, different data sets acquired, and reporting requirements to different government entities





Otway Stage 2b Extension

- Stage 2b Extension
  - investigates the chemical interaction between the CO2 storage rock, CO2, its co-contaminants, formation fluids, and the deep microbial activity

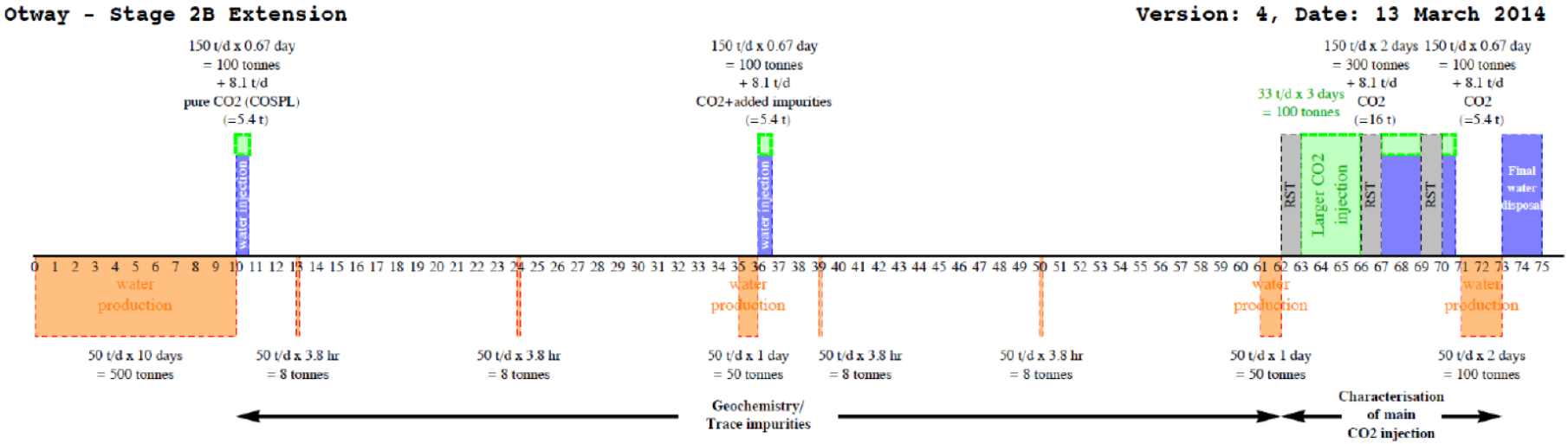
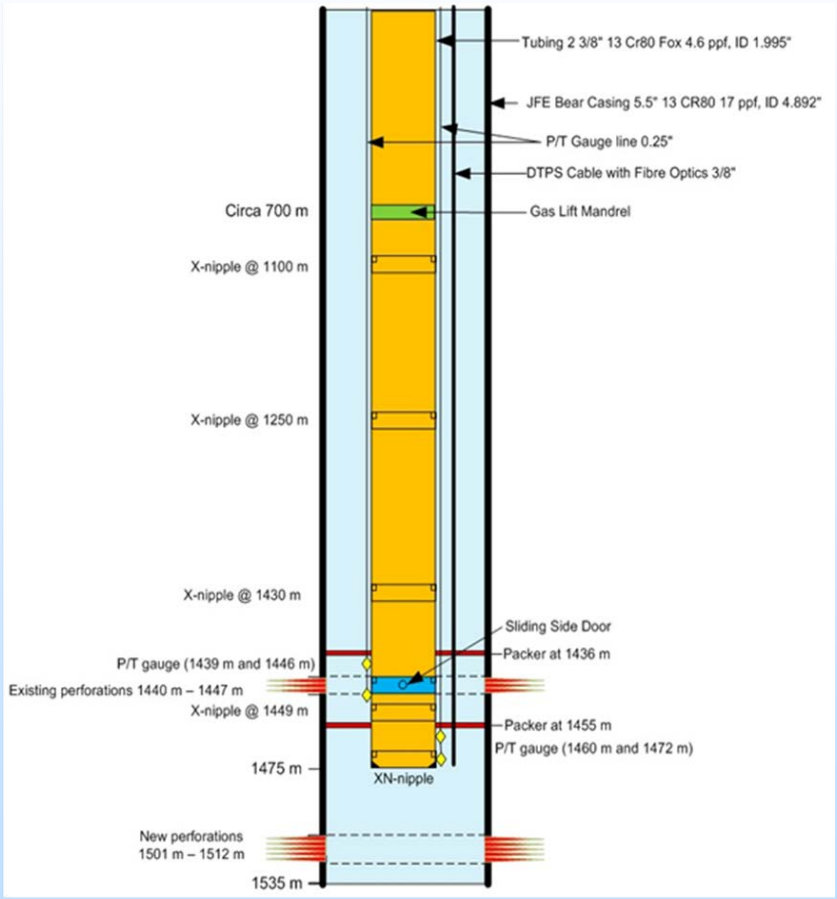


Figure 2.1.1. *Test sequence for the Otway Stage 2b extension test incorporating both fluid injections and production.*

Otway Project Stage 2C Monitoring Test

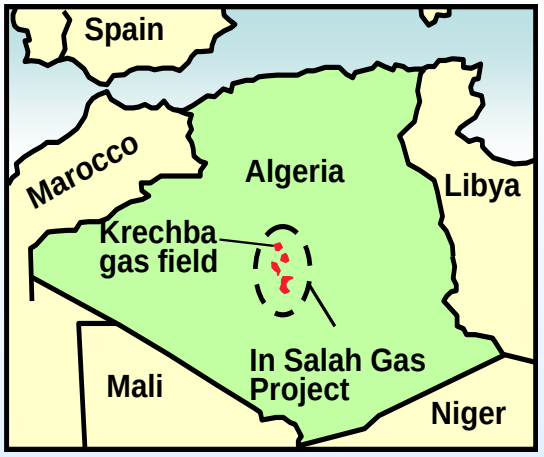
- Stage 2c – inject 10,000 T
- monitor using a permanent buried geophone network
- New technologies brought by LBNL
  - Surface CASSM rotary source
  - FO DAS surface and well-based monitoring
- LBNL aids engineering of CRC-2 recompletion for Stage 2c
  - two-zone completion, with in-line valves that can be used for selecting the testing interval.
- Adding quartz pressure and temperature gauges for independently monitoring the top and bottom of each test interval.
- New integrated hybrid fiber-optic design for heat-pulse monitoring,
- designed for operation with high voltage DC power as opposed to the three-phase AC used with the earlier design.

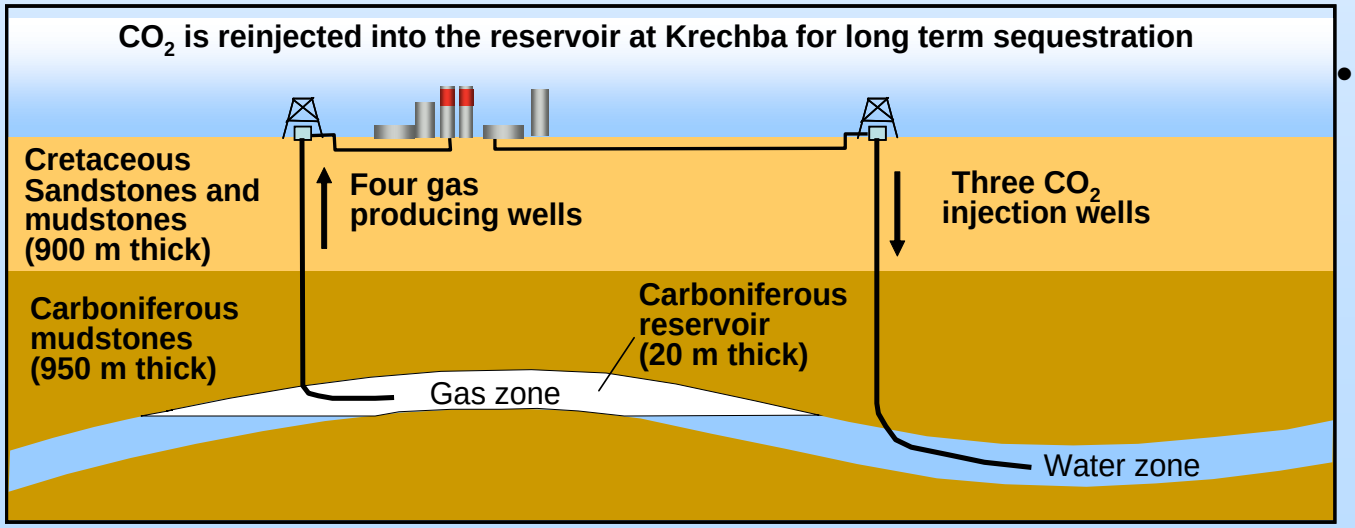
CRC-2 Well Completion



In Salah Subtasks

1. Simulation of Large Scale Deformation and Stress Changes via Coupled Modeling
2. Inverse Modeling
3. Analysis of Ground Surface Deformations from InSAR
4. Fracture Based Seismic Analysis





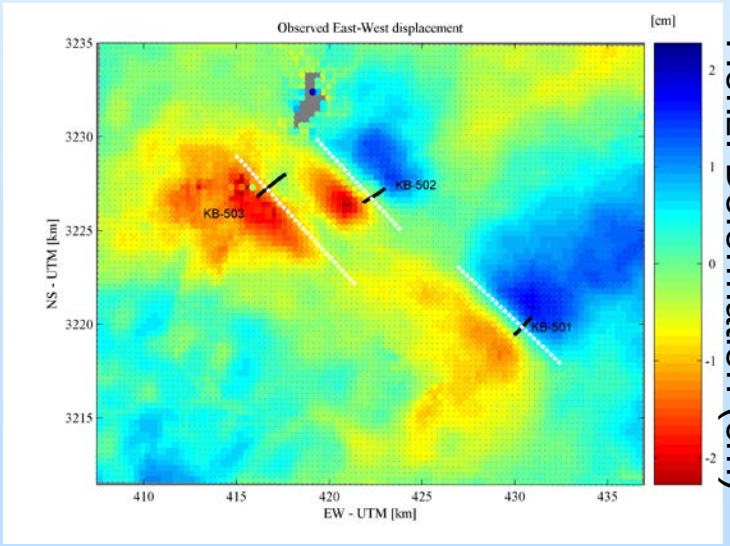
In Salah JIP Update:

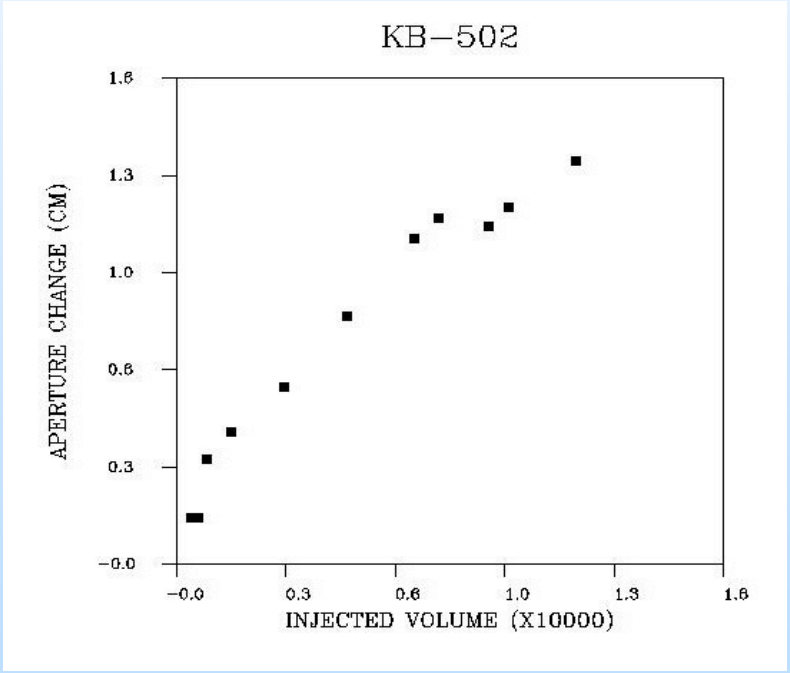
- Continued suspension of CO_2 injection
- Integration of existing monitoring/modeling data (InSAR and seismic) indicate containment of CO_2 within the base of caprock

Analysis of Surface Deformation from InSAR

- Analysis of Surface Deformation from InSAR
  - Fracture aperture change with injection volume

InSAR Horizontal component deformation

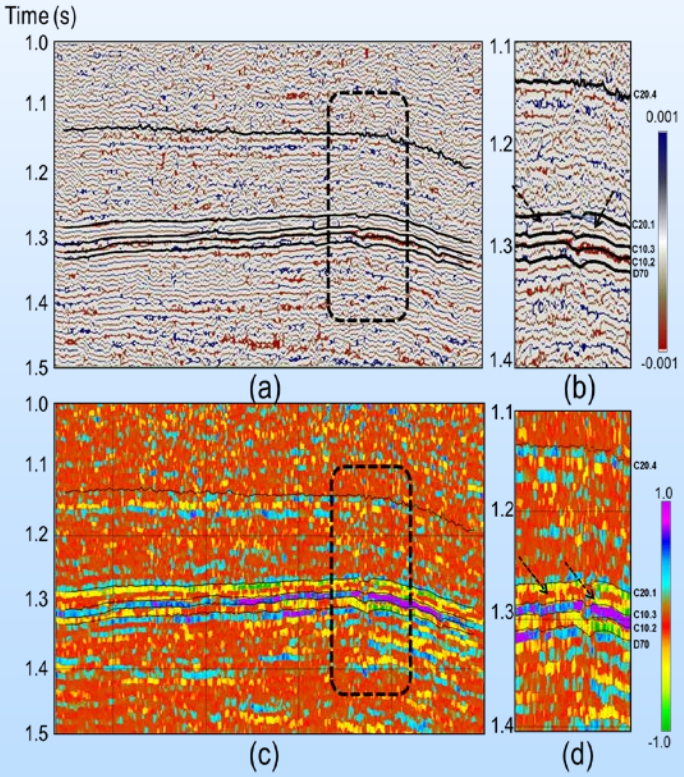


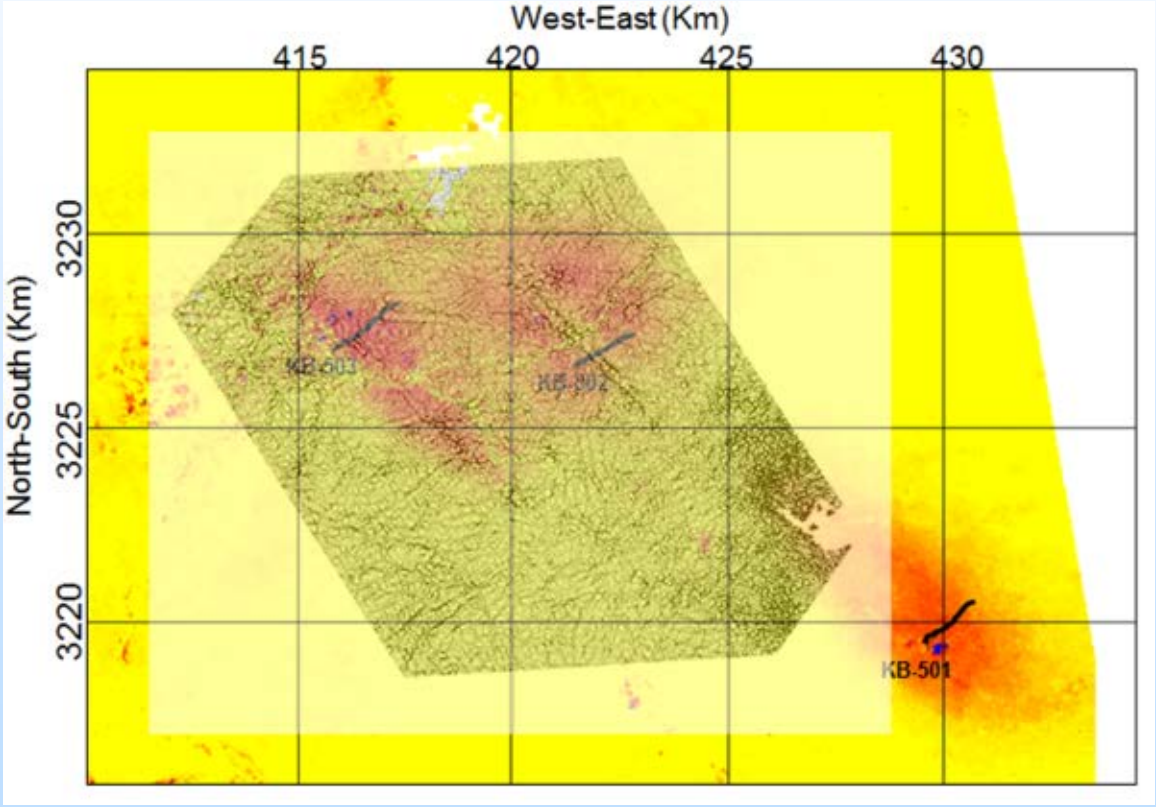


Don Vasco (LBNL)

Fracture Based Seismic Analysis

- Improved imaging of base caprock reflectors with thin bed inversion
- Attribute analysis indicates fracture zone (max curvature and ant tracking)
  - With B. Harbert, Univ Pitt



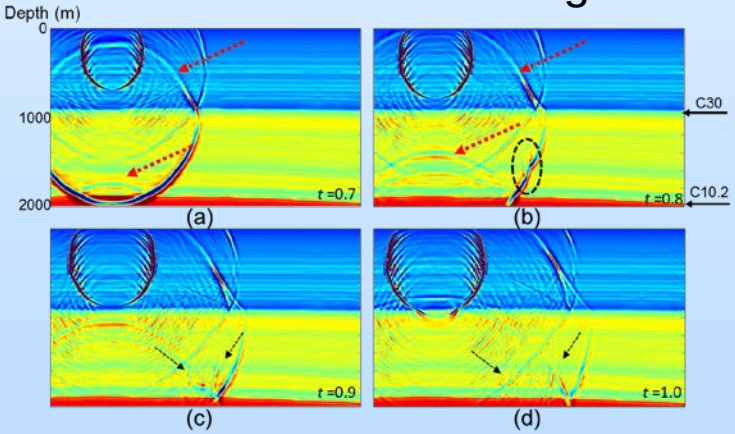


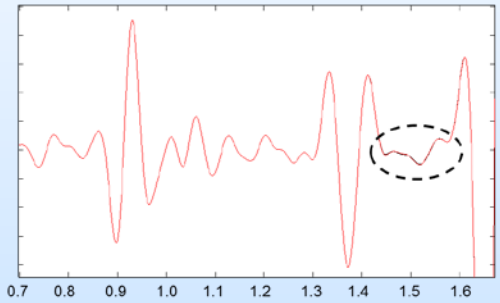
Fracture Based Seismic Analysis

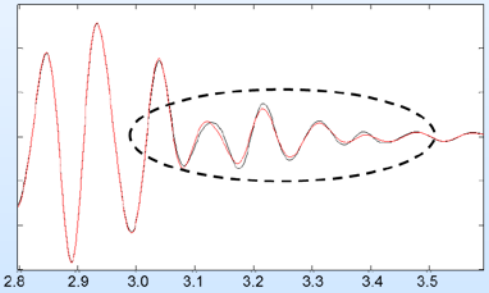
Modeling using geomechanical fracture properties

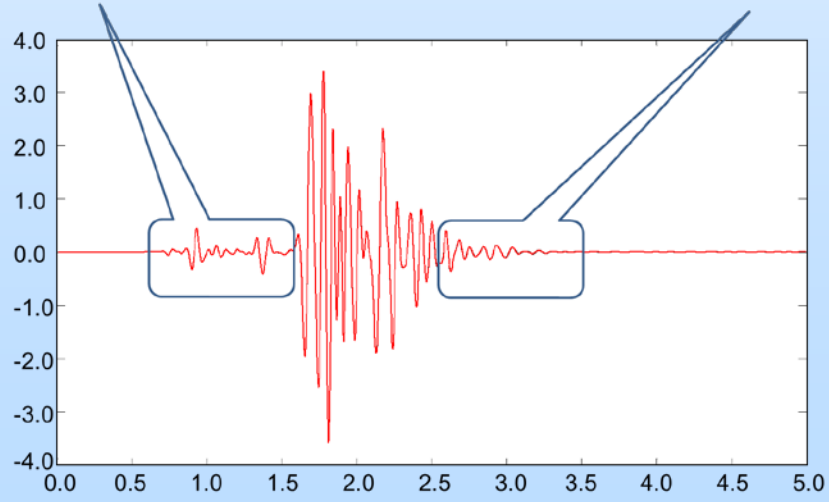
- Red seismogram is with fracture zone and black seismogram is without fracture zone.
- The relative amplitude of diffraction waves and reflection waves is 1/100, indicating that discrete scattered events from a fracture zone with the geomechanical model properties is likely not observable.

Anisotropic
Finite Difference Modeling





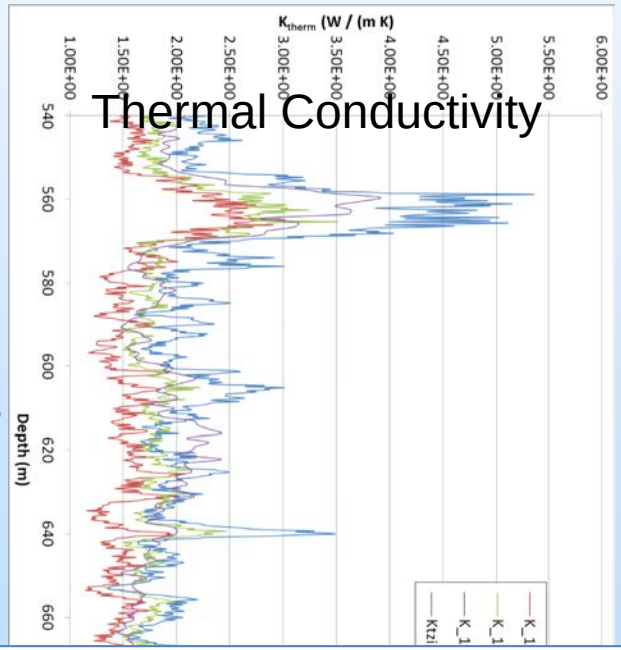




Zhang, et al, submitted IJGCC

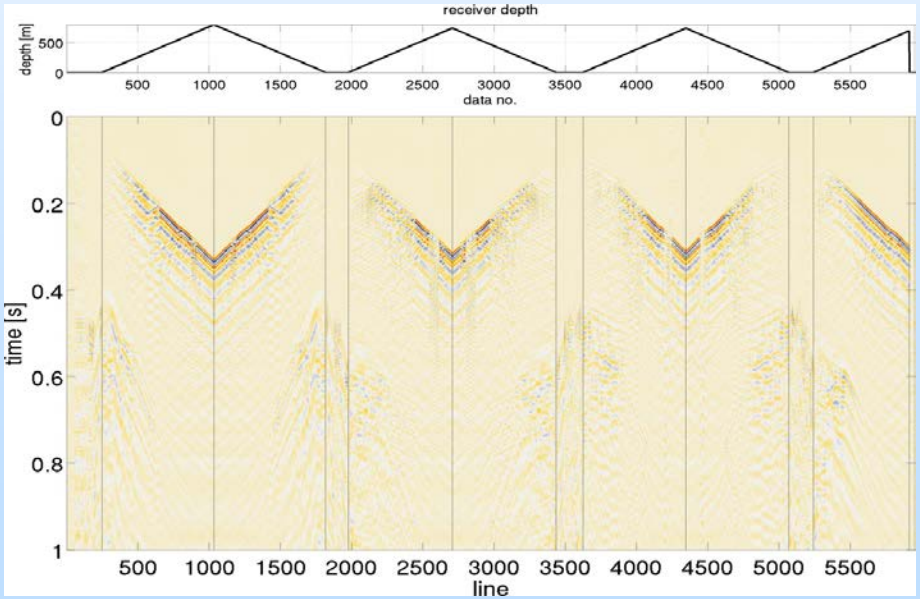
Ketzin Project

- Heat-pulse method used for diagnosing a cement blockage in the Ktzi 203 well, that was subsequently drilled out. (GHGT paper submitted).
- Negotiating a data sharing agreement with the GFZ for use of the DAS data acquired during the second DAS survey for application of virtual source crosswell.
- Ketzin site to be planning for closure in 2015.



Estimated effective thermal conductivity for the four Ktzi203 heat-pulse tests conducted in 2013

Simultaneous Fiber Optic VSP in 4 Wells

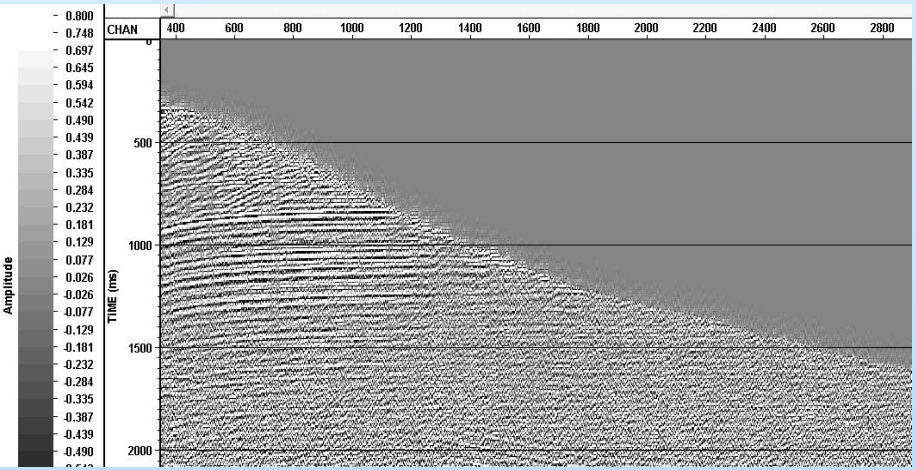


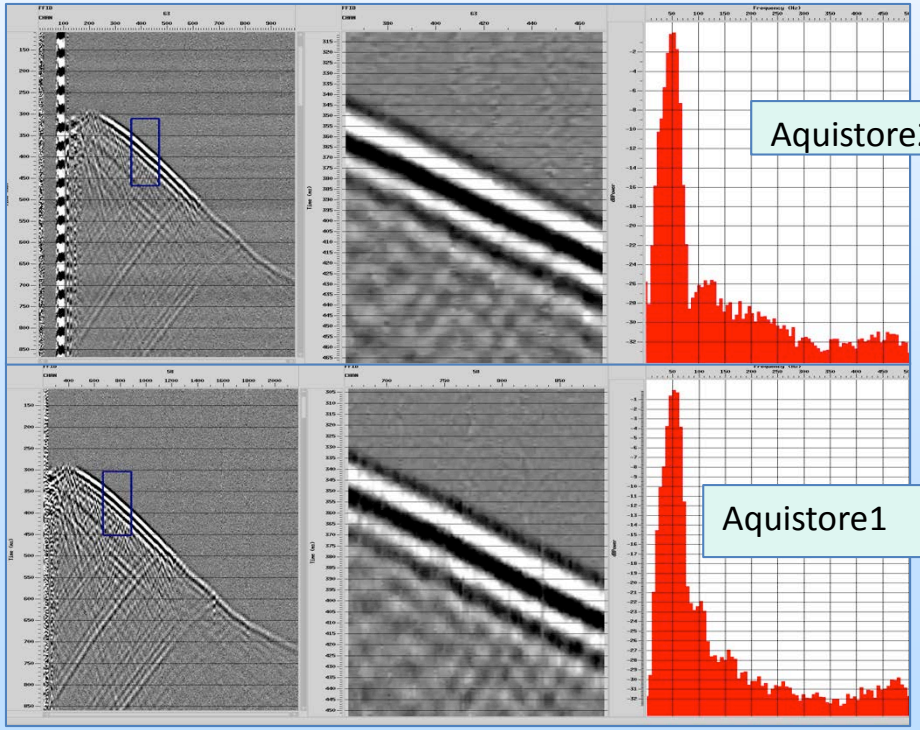
Courtesy GFZ

PTRC Aquistore Project: DAS Vertical Seismic Profile

- Assist design/installation of fiber
- Behind Casing Fiber, cemented, 2.7 km
- Initial recording May 2013, Repeat baseline Nov 2013
- Source: 1 kg explosive shot

Upgoing reflectivity from DAS VSP at Aquistore for shot #71, a 279 m source offset.

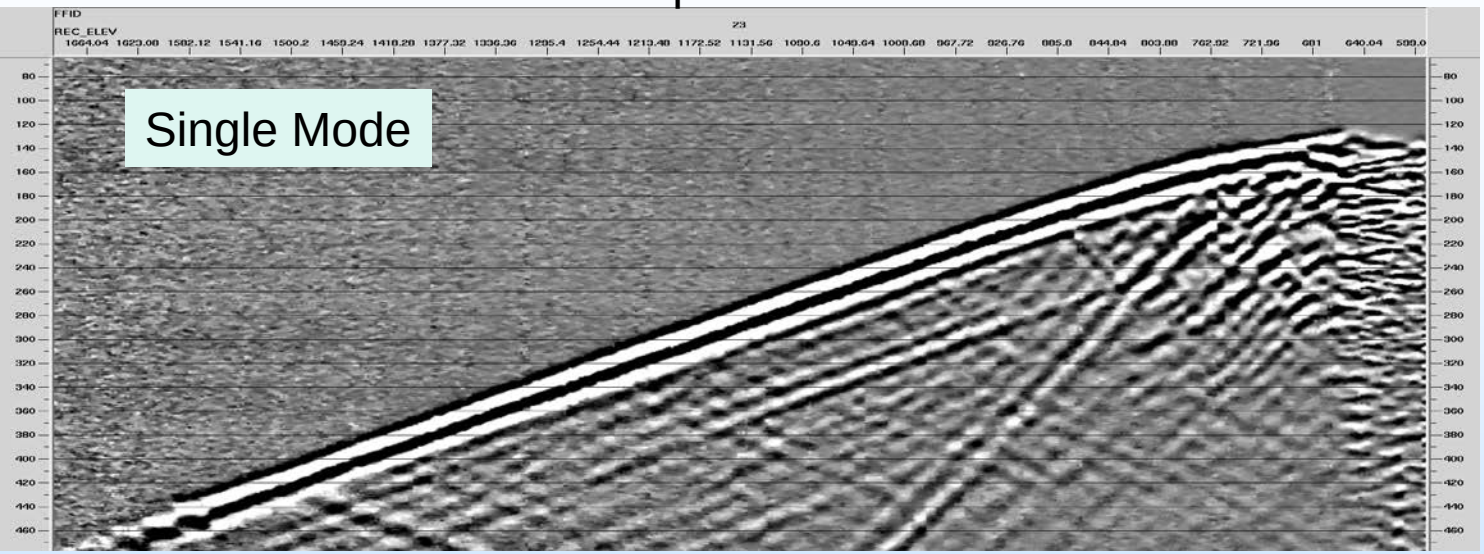


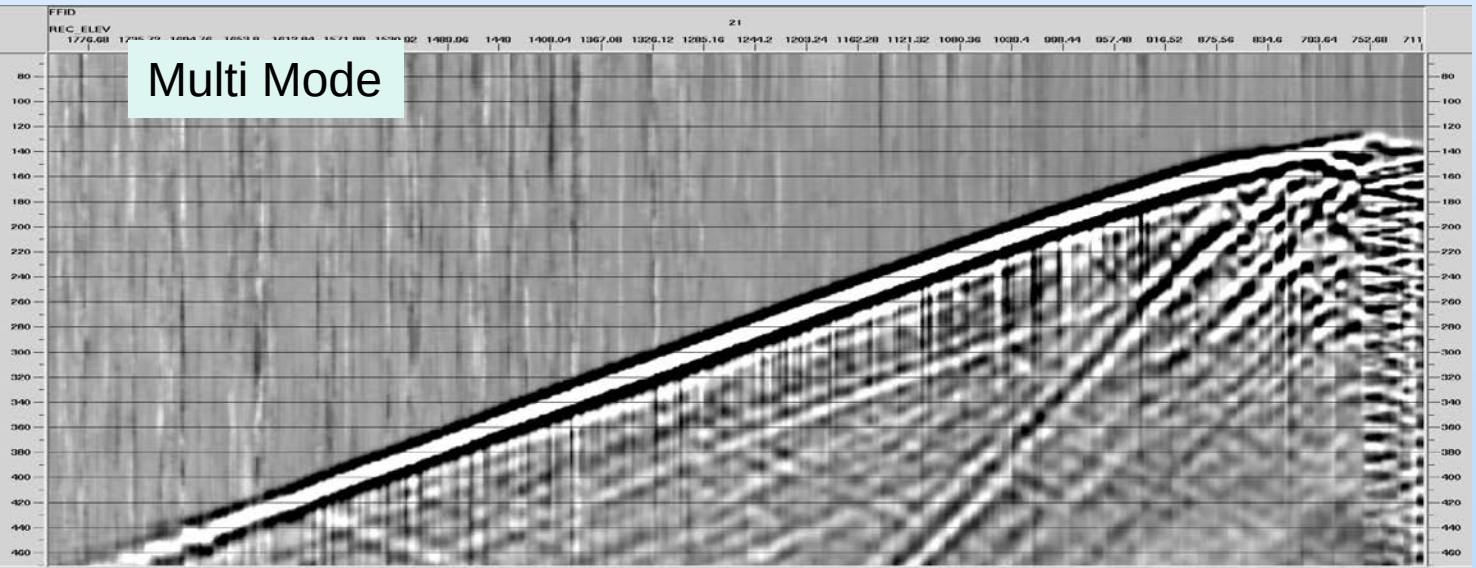


DAS repeatability May/Nov 2013

Aquistore: Comparison of Single-mode and Multi-mode Fiber DAS VSP

Depth





Time

Previous to this test, only single mode fiber was used for DAS

Accomplishments to Date

- Otway Project
  - Stage 2b Extension design (with CO2CRC).
  - Fiber-optic surface cable deployment design completed
- In Salah JIP
  - Geomechanical modeling expanded to the two other injection well (KB-501, KB-503).
  - Inverse modeling to investigate injectivity and effects of multiphase flow properties and temperature on the injection and geomechanics
  - Using fracture properties estimated from geomechanical modeling, forward modeld 3D seismic data with fracture zone: diffractions from fracture 1/100 of reflection amplitude
- Ketzin Project
  - Heat pulse estimated of thermal conductivity
  - Designed virtual source application of multiwell DAS fiber seismic data
- Aquistore
  - Analysis of repeat survey indicates good repeatability
  - Reflections from DAS are good
  - Both Single mode and Multi mode fibers used for DAS VSP

Summary

- Key Findings
  - Collaboration with international field tests adds important knowledge and experience.
  - Fiber optic DAS and DTS recording important monitoring tools ready for field scale deployment
- Lessons Learned
  - No silver bullet for monitoring technology. A multiple methods approach is required to provide a comprehensive picture
- Future Plans
  - GEO-SEQ completed, finish current analysis for InSalah and Ketzin in FY15
  - Seek new international collaboration

Appendix

– These slides will not be discussed during the presentation, but are mandatory

Organization Chart

- GEO-SEQ is one of LBNL's Consolidated Sequestration Research Program Tasks lead by Barry Freifeld
- Closely linked to Fundamental Studies lead by Tom Daley
- GEO-SEQ has four subtasks with principal investigators (PI)
    - Otway Project PI: Barry Freifeld
        - Participants: Tom Daley, Yingqi Zhang, John Peterson, P. Cook
    - In Salah PI: Jonny Rutqvist
        - Participants: Tom Daley, Don Vasco, Hui-Hai Liu, Antonio Rinaldi
    - Ketzin Project PI: Barry Freifeld
        - Participants: Barry Freifeld, Tom Daley, Michelle Robertson
    - Aquistore Project PI: Tom Daley
        - Participants: Barry Freifeld, Michelle Robertson

Fundamental Studies	Title	Role in Task/Subtask
B. Freifeld	PI and Mechanical Engineer	Lead scientist for Otway Project and Ketzin
T. Daley	PI and Research Scientist	Lead scientist for Aquistore
J. Rutqvist	PI and Research Scientist	Lead scientist for In Salah JIP
M. Robertson	Project Scientist	Coordinator of field projects and oversees geophysical measurement facility support
P. Cook	Scientific Engineering Associate	Mechanical engineering and project support
D. Vasco	Senior Scientist	Data processing and In SAR analysis
H.H. Liu	Research Scientist	Hydrogeologist working on In Salah
A.	Postdoc	Geomechanical specialist working on In Salah

Gantt Chart

- GEO-SEQ Task began with a focus on domestic field programs. Changed to a focus on international collaborations.
- Current planning for FY15 is in progress. Expect to complete work with carryover funding in FY15.

MILESTONE GANTT CHART

	Q1 FY14			Q2 FY14			Q3 FY14			Q4 FY14		
Subtask Description	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**
Task 1 Project Management and Planning												
Task 2 GEO-SEQ												
Subtask 2.1 Otway Project									D			
Subtask 2.2 In Salah Industrial-Scale CO_2 Storage			B									C
Subtask 2.3 Ketzin						A*						
Subtask 2.4 Aquistore			E									
Task 3 Monitoring Instrumentation Development						F			G*			
Task 4 Simulation Studies												H, I

* A & G are AOP Tracked milestone

Bibliography

- Daley, T.M., Freifeld, B., Siggins, T., 2014, Seismic Monitoring at Naylor-1 using High Resolution Travel Time (HRTT) and Offset VSP, In: *Geologically Storing Carbon: Learning from the Otway Project Experience*. (Ed. P J Cook) 408pp. CSIRO Publishing, Melbourne, ISBN: 9781486302307.
- Zhang, R., Vasco, D., Daley, T.M., 2014 (submitted), Characterization of a fracture zone using seismic attributes at the InSalah CO_2 storage project, Interpretation.
- Zhang, R., Vasco, D., Daley, T.M., 2014 (submitted), Characterization of a fracture zone using seismic attributes at the InSalah CO_2 storage project, International Journal of Greenhouse Gas Control.