IEAGHG Monitoring Network
Updates from June meeting

Tim Dixon

US DOE Carbon Storage R&D Project Review Meeting

18th August 2015

Pittsburgh

10th Monitoring Network Meeting

Hosts: Lawrence Berkeley National Laboratory

Sponsors: GCEP, CMC, Battelle, Global CCS Institute

10th ï 12th June 2015

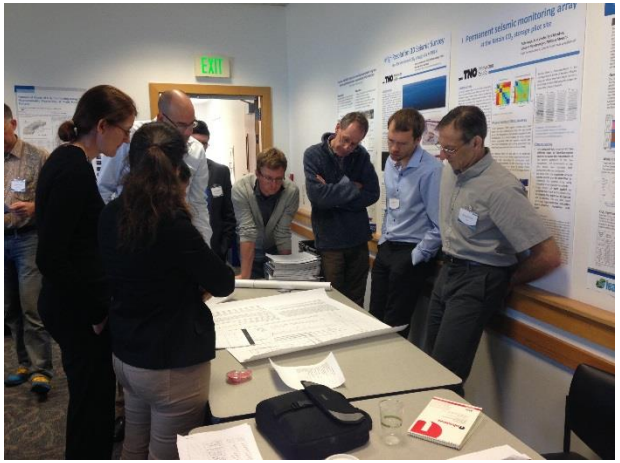
Berkeley, California

www.ieaghg.org

Technical Sessions

- Monitoring for Large-scale projects
- Permit Requirements
- Induced Seismicity
- Shallow Monitoring
- Link Between Geophysical Monitoring Responses and CO_2 in Reservoirs
- Pressure Monitoring and Reservoir Management
- Monitoring Tools ï Shallow
- Monitoring Tools ï Deep
- Update on Demonstration Projects
- Post Closure Monitoring
- Leakage Failure Scenarios ï How to Detect Them (Group work exercise)


EXIT
IEAGHG 10th Monitoring Network Meeting Berkeley, California June 10-12, 2015
WELCOME!
RAMSA

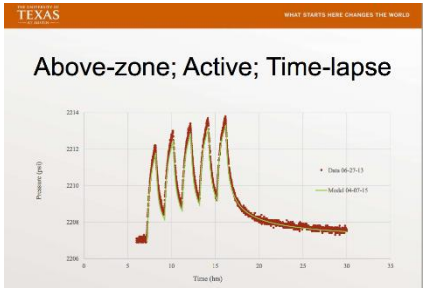

EXIT

Panel

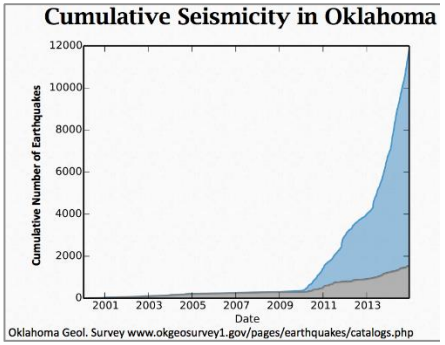
- Tom Daley, LBNL — tmdaley@lbl.gov
- Katherine Romanak, BEG University of Texas at Austin — katherine.romanak@beg.utexas.edu
- Don Lawton, CMC, Canada — lawton@ucalgary.ca
- Owain Tucker, Shell, UK — O.Tucker@shell.com

Technology R&D For Deep Monitoring and Geophysics

- **Pressure monitoring: High use and potential but challenges remain**
  - **Optimize leakage detection**
  - **Active testing vs passive monitoring**
  - **Permanent deployments above reservoirs**
    - **Need for deep monitoring wells**
- **Induced seismicity: How can we devise a monitoring strategy for safe operation?**
  - **Use of microseisimcity as monitoring tool**
  - **Example protocols for I.S. from geothermal development**
- **4D surface seismic: continued advances**
  - **e.g. Sleipner, Snohvit**



Hosseini, 2015

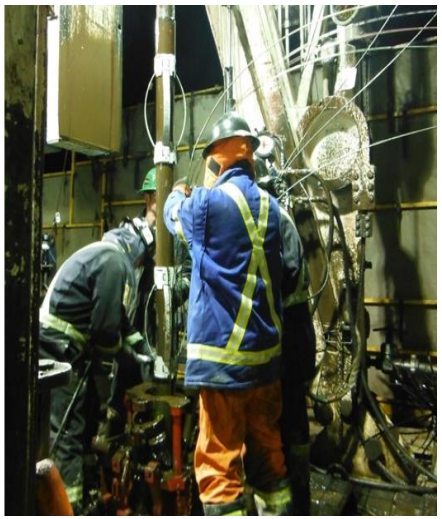


Holland, 2015

Technology R&D For Deep Monitoring and Geophysics

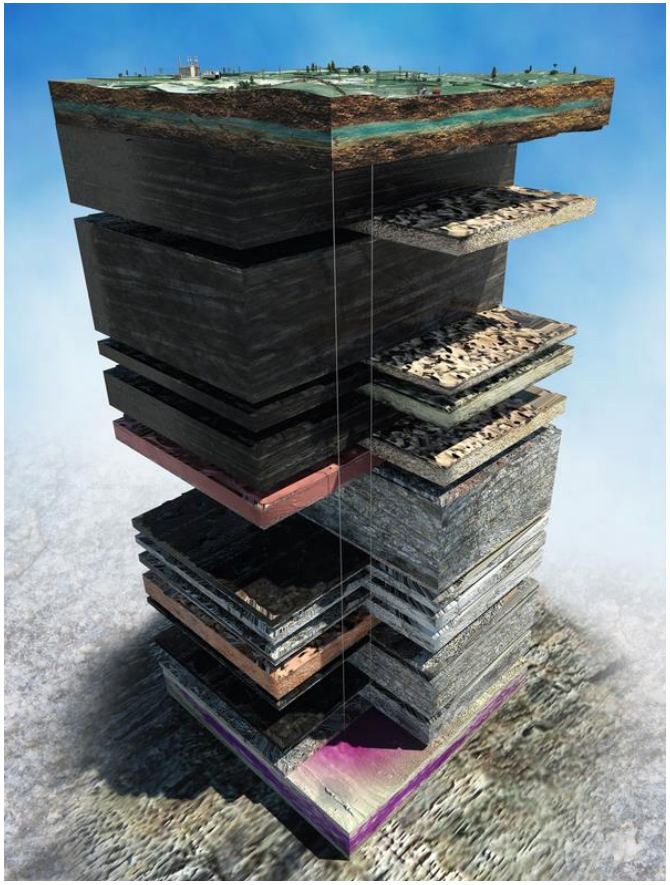
- **Distributed Acoustic Sensing (DAS) – fibre optic seismic: great potential**
  - **Various field deployments are likely precursors of improvements in seismic imaging**
  - **Continuous monitoring potential**
    - **Coupling permanent sensors with permanent sources**
  - **Aquistore: integrated DAS vertical seismic profile (VSP) with surface seismic**
    - **Notable: Injection begins, with first data!**
  - **RITE: testing fibre strain sensing at small scale borehole test**

Casing Deployment
Of Fiber Optic Lines

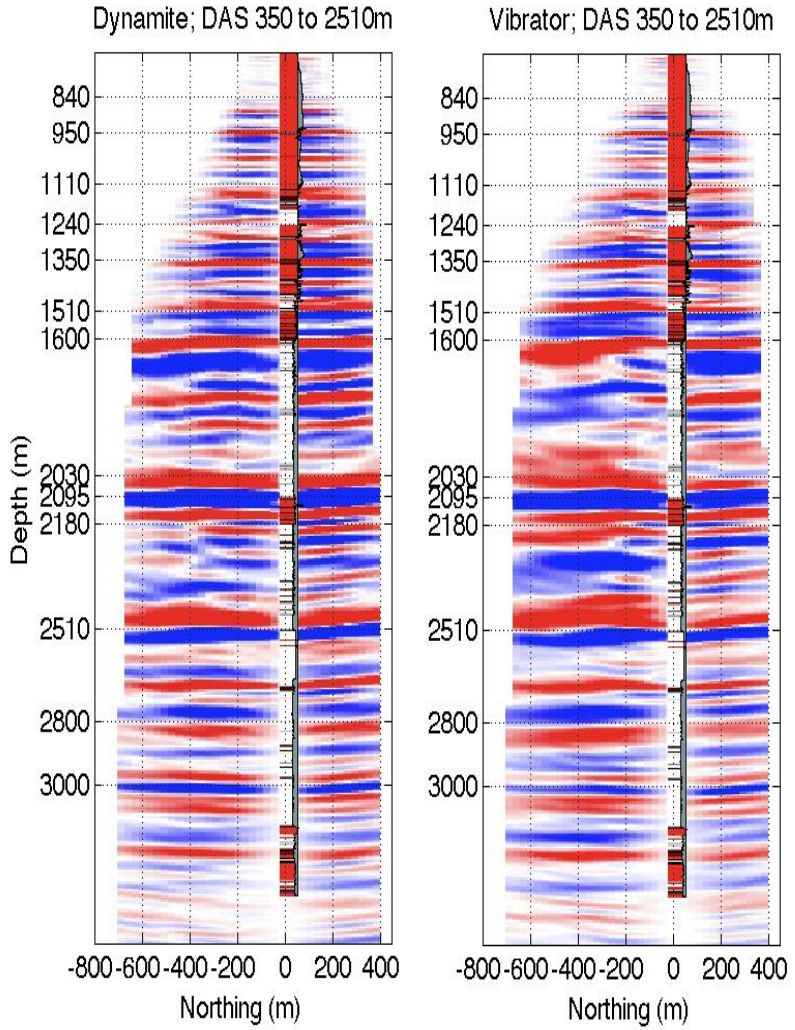


Technology R&D For Deep Monitoring and Geophysics

Example DAS VSP Images at Aquistore



Å **~2700 m of Fibre Cable**



Shallow Monitoring

- ñShallow monitoring: how much do we need and how can we do it?ò
- Panel discussion with practitioners giving their experience in
  - soil gas,
  - marine,
  - groundwater
  - atmosphere
- Four short presentations on the ability and practicality of surface monitoring techniques to detect, attribute and quantify CO_2 followed by open discussion.

Overarching Issues

- How much do we need?
  - How big of a leak is important to find?
  - Are we sending mixed messages about leakage?
  - Risk of false alarms
- How can we do it?
  - Viability of using baseline is questioned*
  - Emerging techniques are creating a paradigm shift
    - No need for extended baseline measurements only one-time characterization
    - Targeted response to stakeholder concerns, environmental assessment, or quantification.
    - Faster, easier, less expensive, more accurate

Additional Points

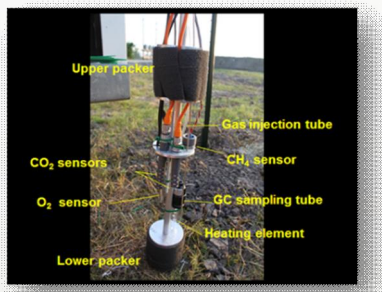
Marine

- Leakage detection is easier offshore than onshore
  - acoustic methods can locate bubble streams
- Attribution and environmental variability challenges are similar to onshore.

Shallow Groundwater

- Leakage detection using geochemistry in groundwater wells will be difficult.
  - Attenuation of signal
  - Dense well-spacing required

Sensing Capabilities



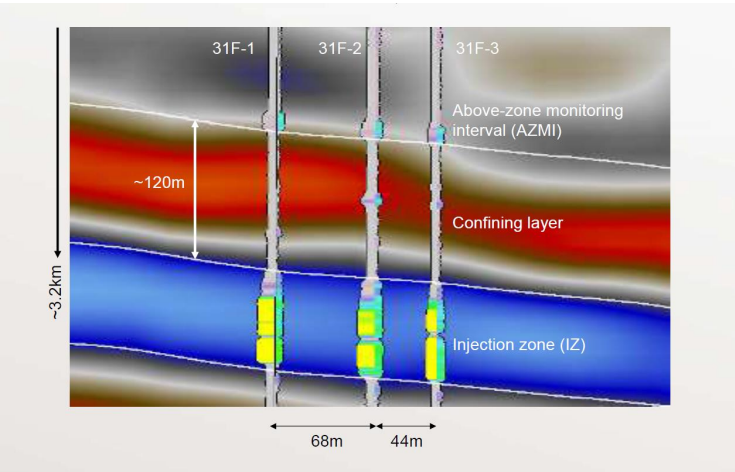
- Need accurate, continuous, real-time smart data collection and simple data reduction

Intermediate depth and overburden monitoring

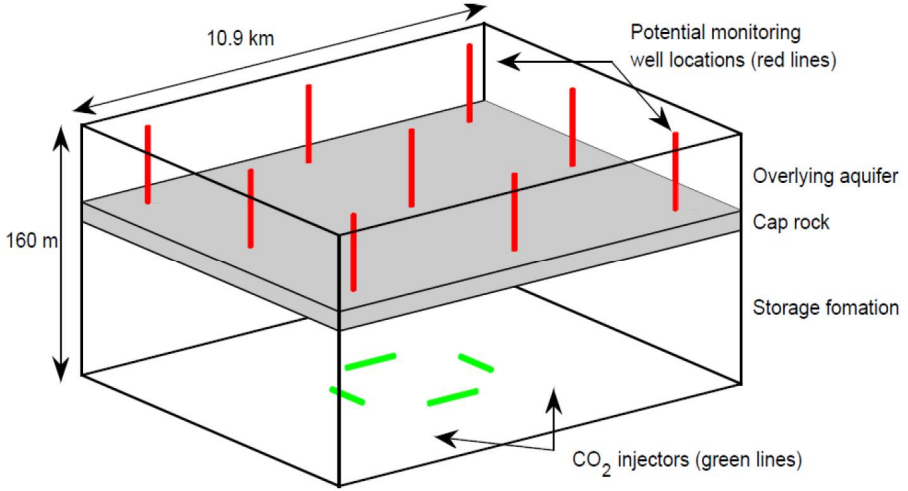
- Controlled CO_2 release experiments into the overburden at various depths.
- Assess CO_2 detection thresholds at these depths across the full range of monitoring technologies.
- Monitor the vertical migration signature of CO_2 through the overburden and impacts on groundwater.
- Understand leakage pathways
- Characterization of full overburden required at baseline.
- Need more geomechanics analyses and models to use monitoring data effectively.
- Pressure monitoring ï work-horse method, opportunity for large areal coverage in above zone monitoring interval.

Intermediate depth and overburden monitoring

Above zone pressure monitoring (Hosseini, 2015)



Well model for optimum leak detection

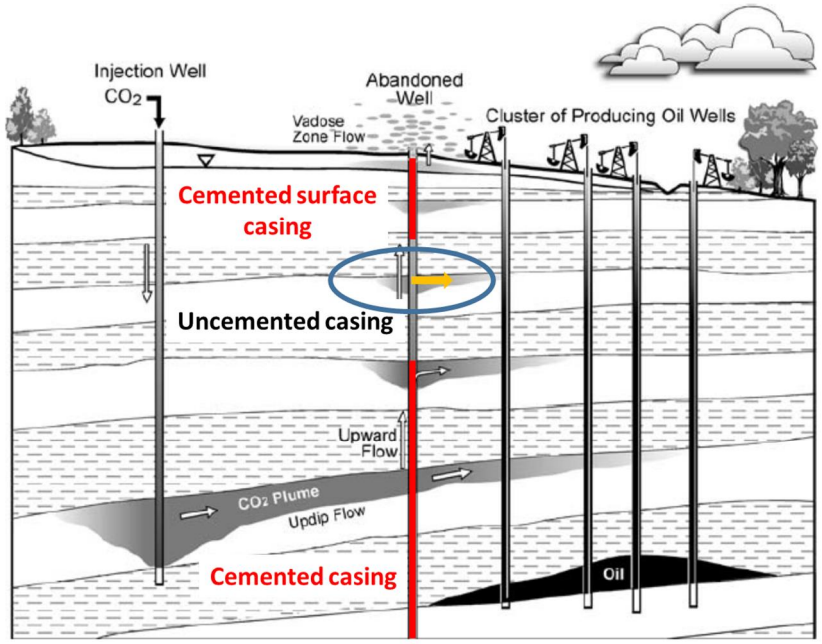


(Cameron, 2015)

- Large areal coverage
- Relatively cheap
- Small pressure changes detectable
- Detect small leaks over time

Intermediate depth and overburden monitoring

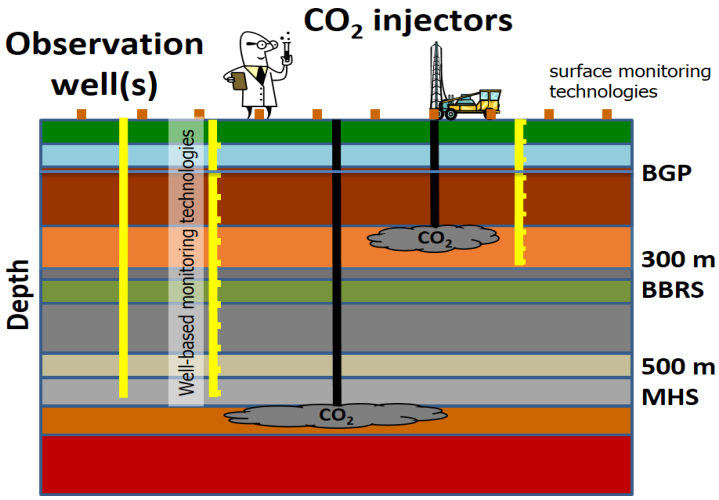
Legacy well integrity/casing failure



After Celia et al., 2004

Legacy wells most likely CO_2 leakage pathway, particularly in depleted oil and gas reservoirs

CaMI test field site, Alberta Canada



Cap rock

Reservoir

300 m

LARGE SCALE COMMERCIAL PROJECTS

Requirements from monitoring

Dr Owain Tucker
Global Deployment Lead CCS

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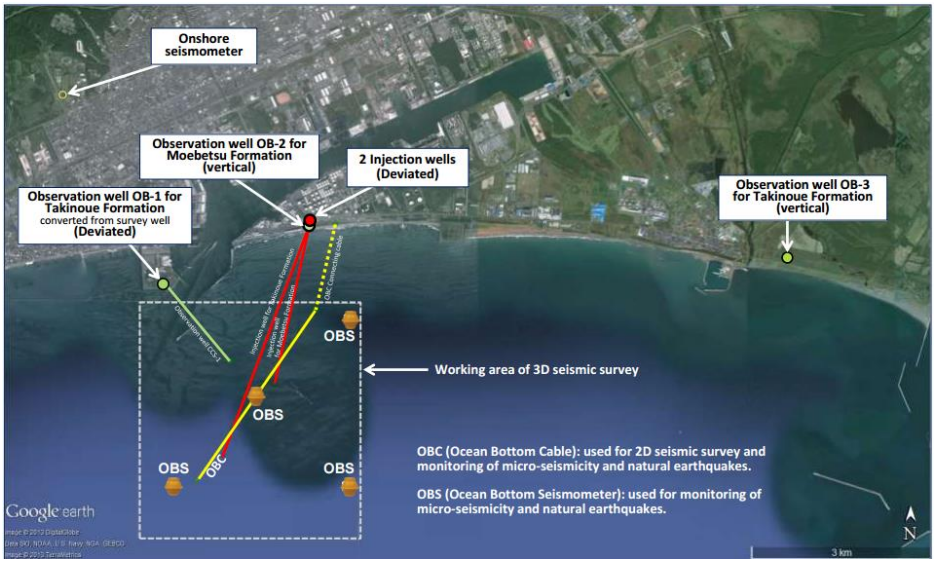
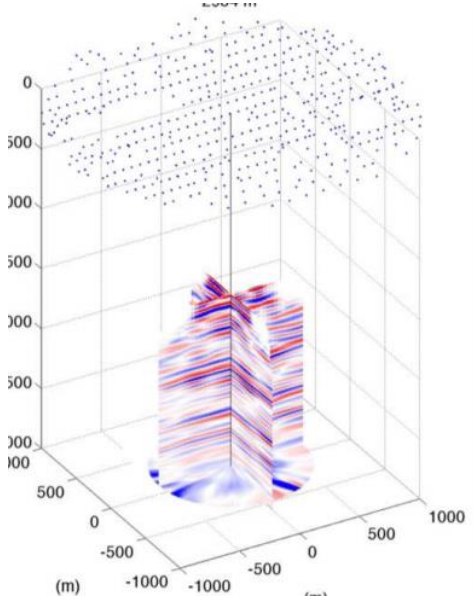
OPERATOR PERSPECTIVE FROM MAJOR PROJECTS

- Safely deployable in real world situations; reliable and robust; cost effective
- Minimise impact on stakeholders
- The monitoring will be designed to address risks
  - Support demonstration of absence of leakage
  - Provide evidence for stakeholders that storage site is working as expected
  - Increase the strength of containment barriers ï monitor and act
- Good spatial and temporal coverage is desired; clear detection signals





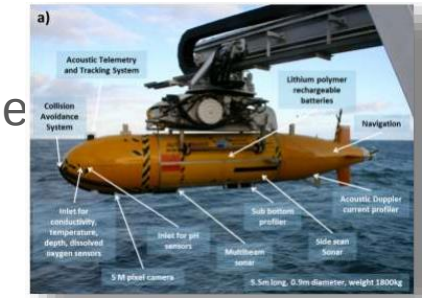
SIGNIFICANT PROGRESS

- Chevron presented experience on bringing all the data together in one system ï integrating subsurface models, micro seismic and InSAR.
- VSP experience on Quest and Aquistore
  - Rapid technology development of fibre based seismic detection
  - Ability to be less intrusive on local stakeholders
  - Better imaging of the subsurface
- Performing focussed risk based monitoring
  - Key to deploying CCS as a cost effective CO_2 reduction technology
  - Discussions and presentations on ï what is the right level of monitoring?
  - Simple techniques like pressure
- What is the correct level of post-closure monitoring?

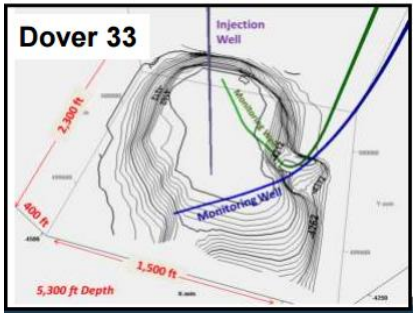
AREAS WHERE FOCUS NEEDS TO BE MAINTAINED

- Understanding microseismicity
  - Water injection experience was presented, but more work needs to be done here (mainly more seismic stations) to characterise the rates and events that cause a risk with water disposal
  - Tomakomai monitoring configuration presented ï this work, combined with InSalah, Decatur, Aquistore and Quest, will provide insight into CO_2 injection microseismicity

- New technologies ï like ambient noise ï have the promise to provide continuous active seismic monitoring without impacting stakeholders
- Significant progress in marine monitoring, but need to continue to characterise the marine ecosystem to the same level as the terrestrial one.



BRINGING STORAGE AND EOR TOGETHER



- Battelle work on Pinnacle reefs, and PCOR work at Bell Creek: monitoring the associated storage that takes place with CO_2-EOR
  - Key work being done in operational sites
  - Scientifically demonstrating the facts that the industry knows ï retention ratios, no leakage, emissions related to recycle etc.

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