Field demonstration of CO_2 storage in the CO2CRC Otway Project

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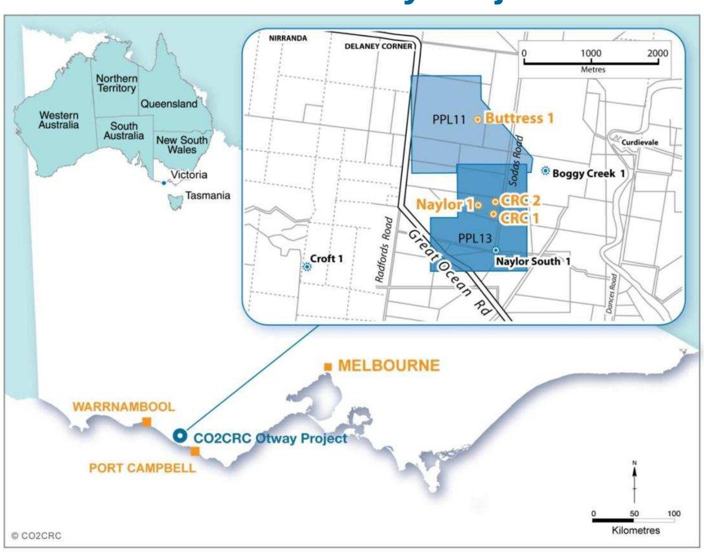
China-Australia Geological Storage of CO_2
Workshop, May 2014

Location of CO2CRC Otway Project



Stages of the project: past and future

Completed

- **Stage 1: March 2008 to September 2009 – injection of 65,400 tonnes of CO_2-rich gas into depleted gas field.**
- **Stage 2B Residual saturation and dissolution test: June 2011 to September 2011 – single well injection of 150 tonnes of CO_2 into saline aquifer**

Proposed

- **Stage 2C Seismic detection test– injection of 15,000 tonnes of CO_2-rich gas into saline aquifer; buried geophone array**
- **Stage 3: Test of reservoir-level monitoring e.g. above zone geophysical detection**

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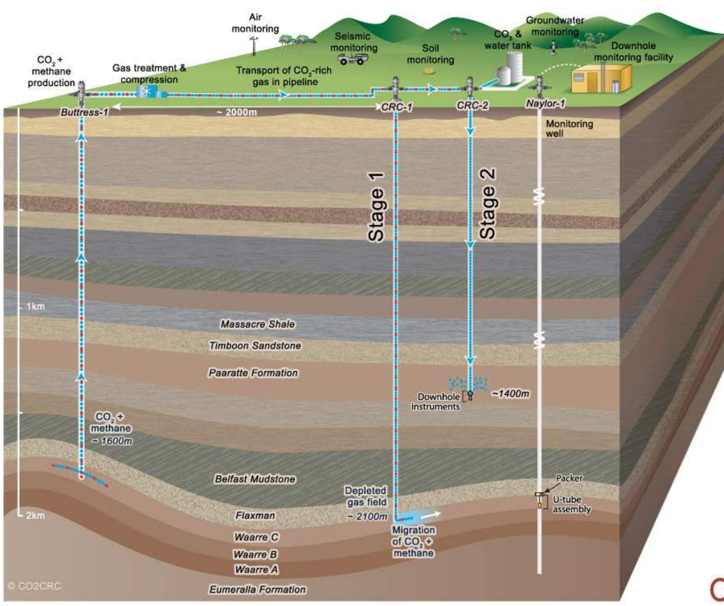
CO2CRC Otway Project - Schematic



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CO2CRC Otway Project aerial view

Key achievements of Stage 1

- **Obtained approvals and support for the project**
  - Assisted in developing a regulatory regime
  - Resolved long-term liability issues
- **Safely injected 65,400 tonnes of CO_2-rich gas**
- **Verified science of CO_2 storage in depleted gas field**
  - Performed extensive pre-injection modeling of site
  - Showed agreement of predictions with reservoir-level monitoring
- **Directly measured the storage efficiency**
- **Confirmed storage integrity**
  - Verified no detectable leakage in overlying formation or surface

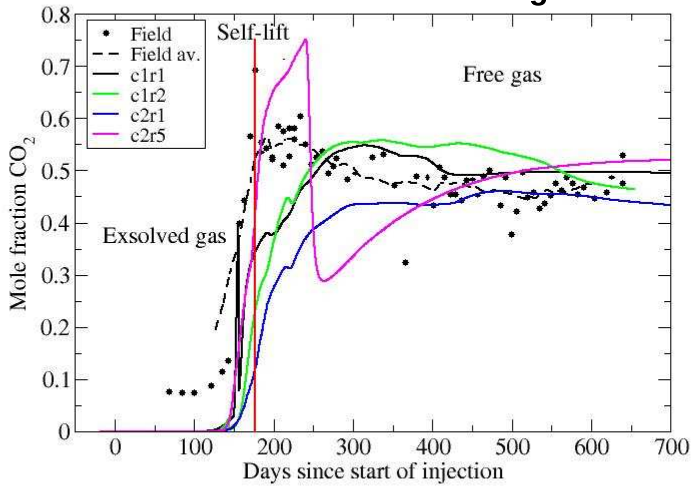
Downhole monitoring in Stage 1

- **Memory gauges in CRC-1 injection well**
  - High accuracy and frequent sampling (every 12 s)
  - Replaced every six months, so data not available until gauge brought back to surface
- **Fluid sampling in Naylor-1 monitoring well**
  - U-tube system with three sampling levels
  - Samples done weekly
  - Challenges in interpreting gas/water samples when brought down to atmospheric pressure

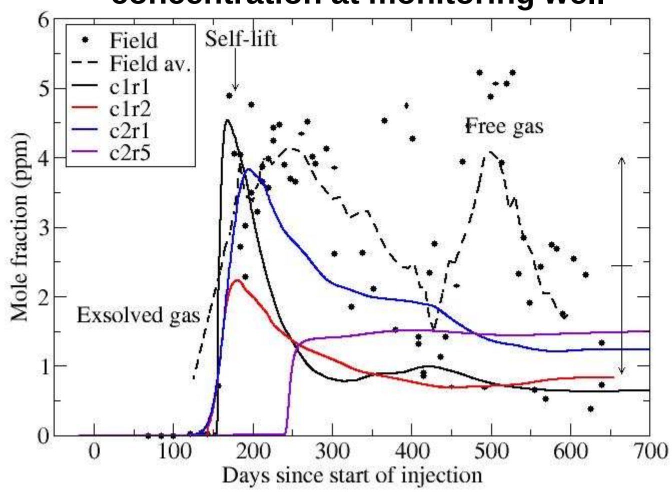
History matching process

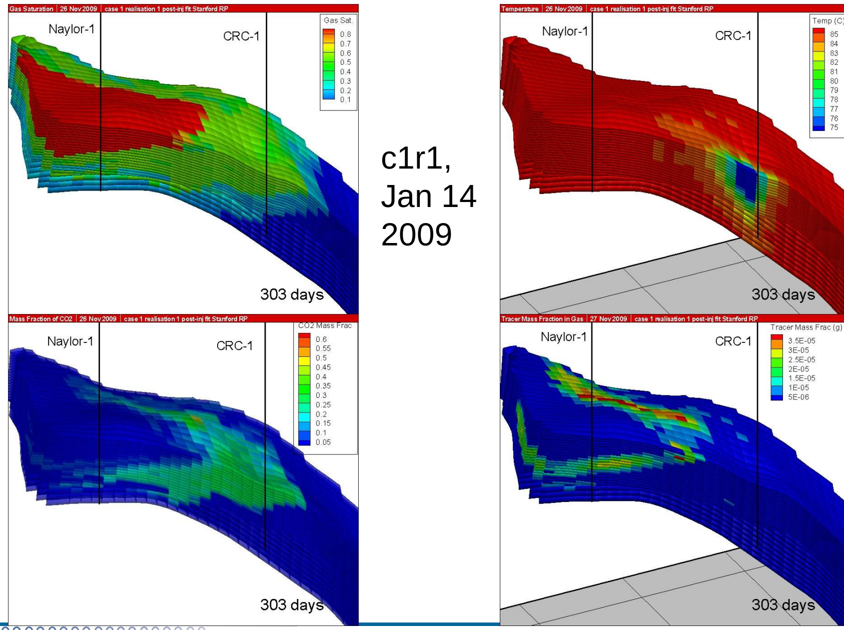
- **Four realisations of the geological model were simulated, and matched to the following data:**
  - Location of GWC before and after production
  - Wellhead pressure during production
  - Downhole pressure gauge data at CRC-1 during injection
- **Predictions were then made for**
  - Gas composition (CO_2 and tracers) at monitoring well
  - Change in GWC over time – 'filling efficiency'
- **See Jenkins et al PNAS (2012) 109(2): E35-E41**

Prediction vs field data for CO_2 concentration at monitoring well



Prediction vs field data for tracer concentration at monitoring well





c1r1,
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2009

What did we learn from Stage 1 reservoir-level monitoring?

- **Value of downhole P/T gauge in the injection well**
  - aquifer properties
  - well test
  - pressure buildup during injection
- **Value of fluid sampling at the crestal well (Naylor-1)**
  - arrival of injected gas through tracers and gas composition
  - sensitive probe of the models.
  - filling efficiency (56-84% of pore volume produced)

Stage 2B: Residual saturation and dissolution test

- Residual trapping is a key mechanism for the storage of carbon dioxide in saline formations
- The test measures field-scale residual trapping using a single well configuration and six different methods – pressure, temperature, RST logging, noble gas tracers, reactive tracers and a dissolution test.
- The field results enable us to evaluate the effectiveness of each method, and to recommend how such a test could be improved.

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Surface facilities during Stage 2B test

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Stage 2B Downhole monitoring

- **Four permanent pressure/temperature gauges**
  - two above the injection zone and two below
  - Surface readout in real-time (~ 1-5 minute intervals)
  - Useful for making operational decisions about injection
- **Distributed temperature sensor (optical fibre)**
  - Depending on surface equipment, gives temperature profile over the whole well at 1m intervals.
  - Gives information on distribution of injection over completion
- **U-tube system for downhole fluid sampling**

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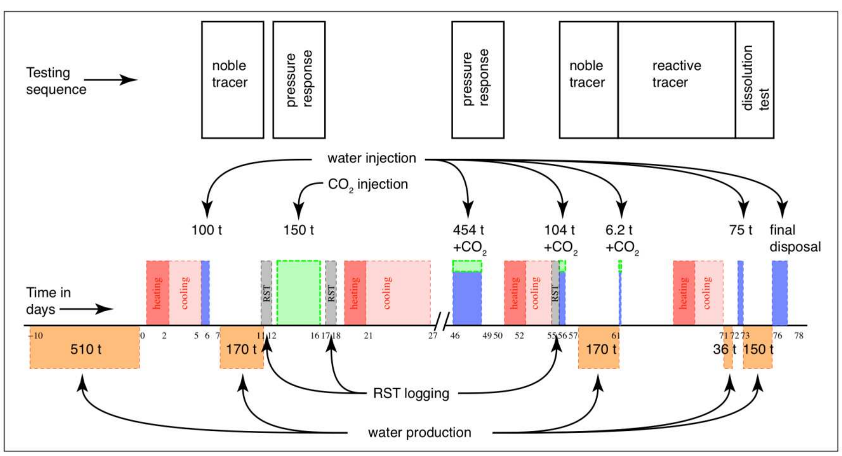
Otway Residual Saturation and Dissolution Test



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What's the range of investigation?

- Pressure: diffusivity κ ≈ 24 m^2/s, range is 10's-100's of metres for a 1 hour test.
- Thermal: diffusivity κ ≈ 1.5 * 10^{-6} m^2/s, range is up to 0.5 m (conduction only, heating test)
- Noble gas tracer: limited to region contacted by injected water, here 10-20m
- Reactive ester tracer: limited to region contacted by injected water, here < 2 m.
- Pulsed Neutron logging (RST): up to 0.5 m.

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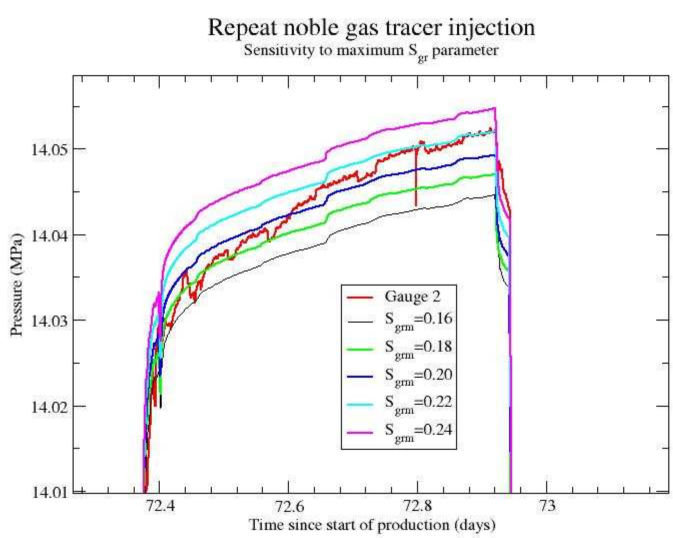

Maximum S_{gr} 18-22%, corresponds to average S_{gr} = 15-19%

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What did we learn from Stage 2B reservoir-level monitoring?

- The pressure test has a large range of investigation, but wellbore storage and near-well effects complicate interpretation. S_{gr} = 15-19%
- DTS data gives information about distribution of injection over the completion.
- Noble gas tracers give good estimate of residual, but are complicated to sample and analyze. S_{gr} = 11-20%
- Pulsed neutron logging has a shallow depth of investigation ~ 0.5m. S_{gr} = 18-23%

Proposed Stage 2C Seismic Detection Test

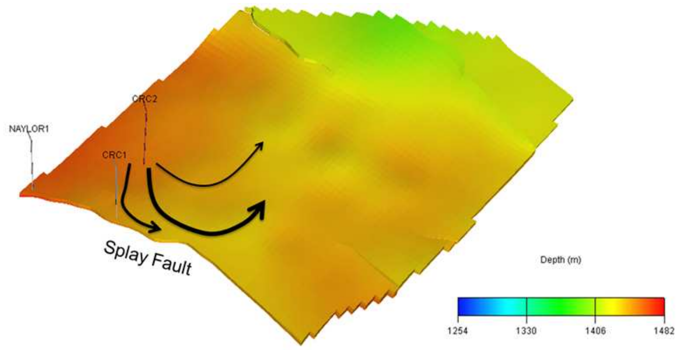
Objectives:

- Detect injected CO_2-rich gas using time-lapse seismic (TLS) – understand seismic detection limits
- Observe plume development using TLS
- Verify plume stabilization using TLS – understand trapping in saline formations

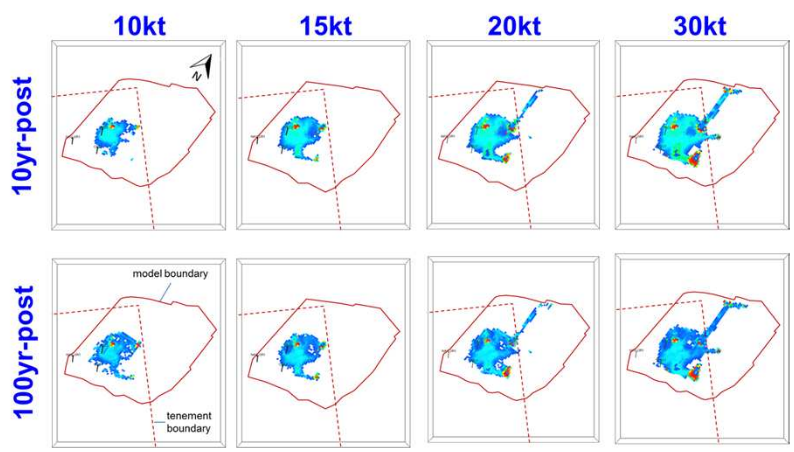
Design:

- 15,000 tonne injection in saline aquifer at 1500 m depth
- Buried array of geophones (1 km^2) to reduce noise
- Simulated multiple scenarios for plume development
- Performed forward modeling of seismic signal

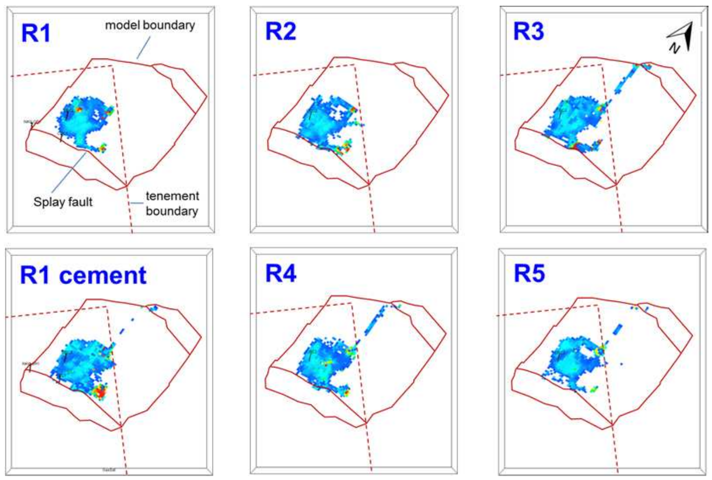
Topography of top surface in reservoir interval



Plume predictions varying amount of CO_2



Plume predictions for geological realizations



100 yr post-injection

Timeline for Stage 2 Seismic Detection Test

- **Make final investment decision by Dec 2014**
- **Install buried array of geophones Q1 2015**
- **Inject CO_2-rich gas Q4 2015 – Q2 2016**
- **Repeat seismic surveys Q2 2016 – Q2 2018**

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CO2CRC Participants

Supporting Partners: The Global CCS Institute | The University of Queensland | Process Group | Lawrence Berkeley National Laboratory
CANSYD Australia | Government of South Australia | Charles Darwin University | Simon Fraser University