The CO2CRC Otway Project

Presenter
Dr Mark Bunch

Cooperative Research Centre
for Greenhouse Gas
Technologies (CO2CRC)

CAGS Summer School
Wuhan, Hubei province, China
3rd November 2010

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China Australia Geological Storage of CO2

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The CO2CRC Otway Project – location & concept
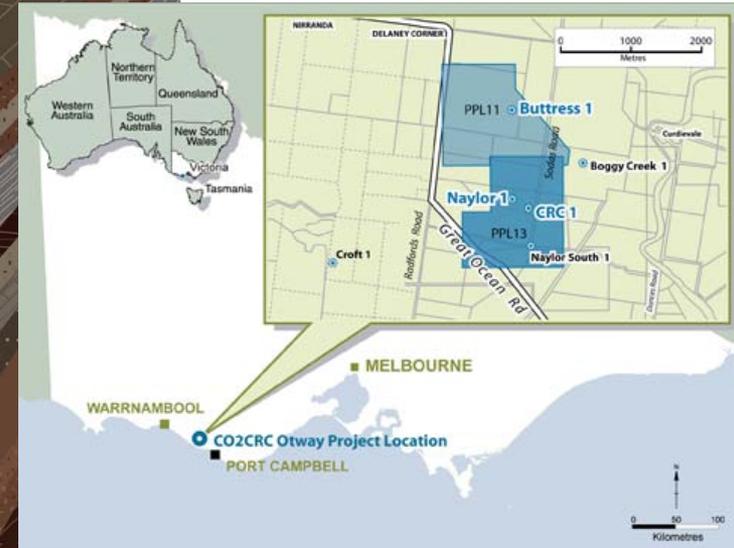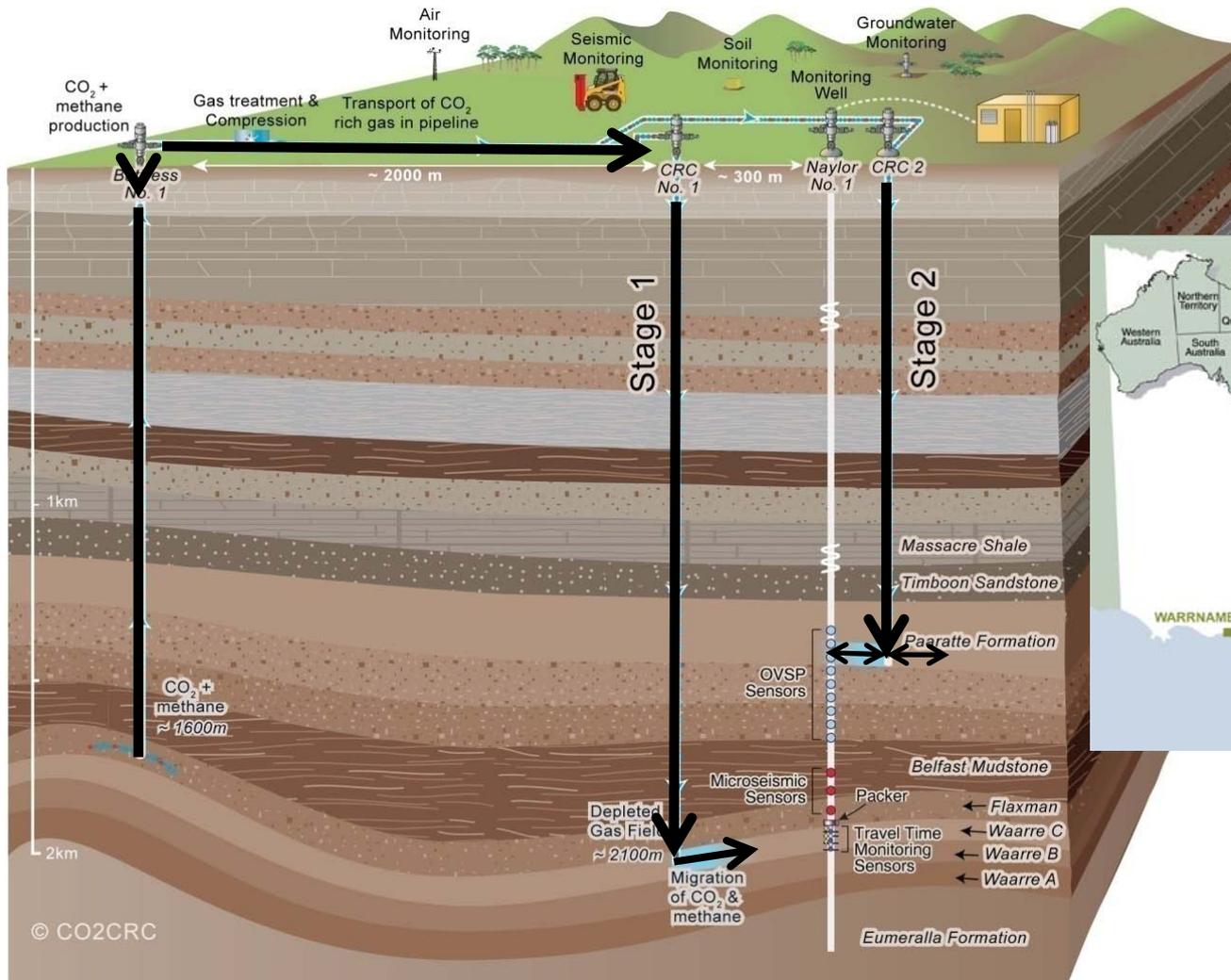
CO2CRC Otway Project facilities
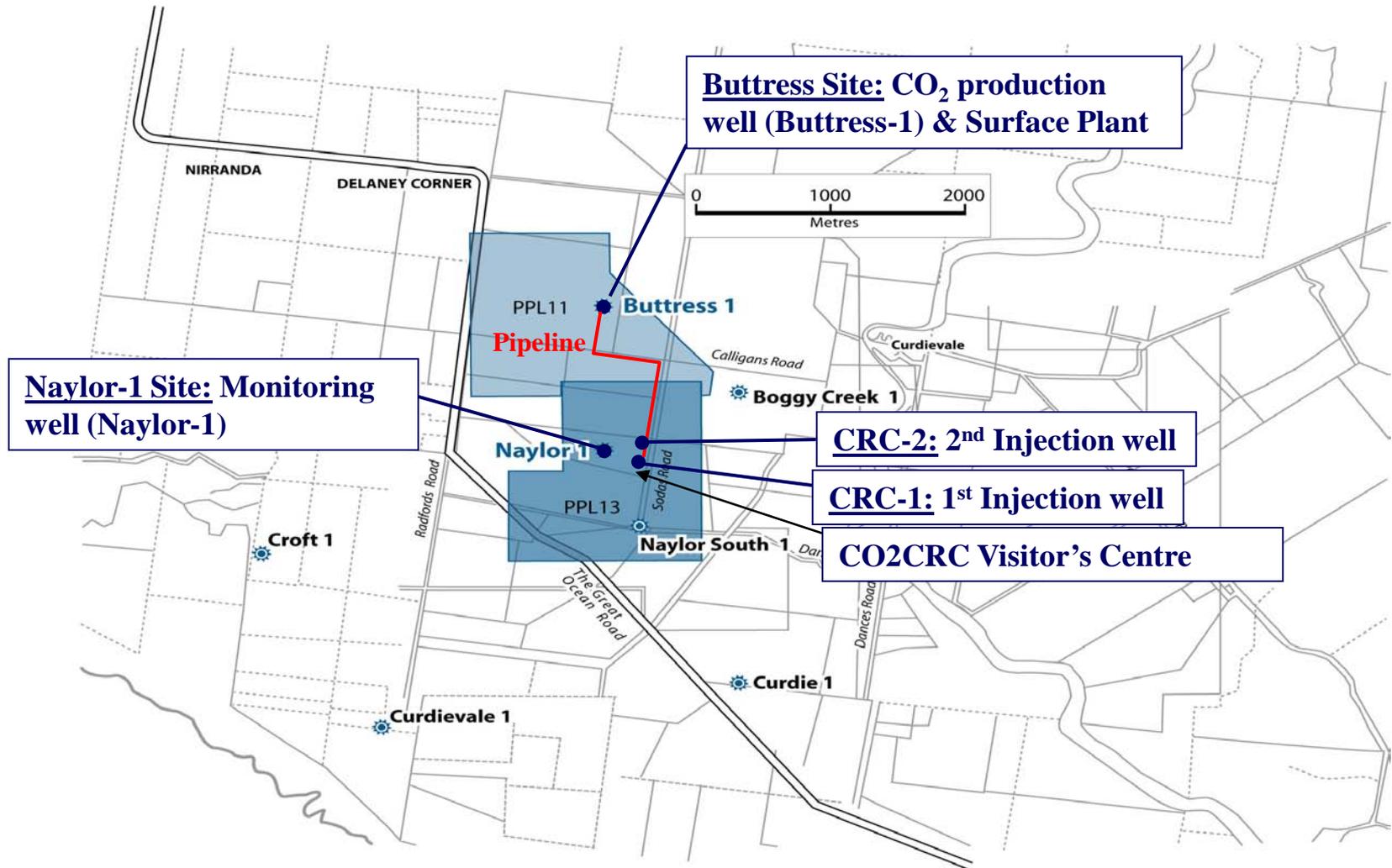
Buttress Site: CO_2 production well (Buttress-1) & Surface Plant

Naylor-1 Site: Monitoring well (Naylor-1)

CRC-2: 2nd Injection well

CRC-1: 1st Injection well

CO2CRC Visitor's Centre

Pipeline

NIRRANDA
DELANEY CORNER
PPL11
Buttress 1
Curdievale
Calligans Road
Boggy Creek 1
Naylor 1
Radfords Road
PPL13
Soda Road
Croft 1
Naylor South 1
The Great Ocean Road
Dances Road
Curdie 1
Curdievale 1

0   1000   2000
Metres

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3D layered Earth model
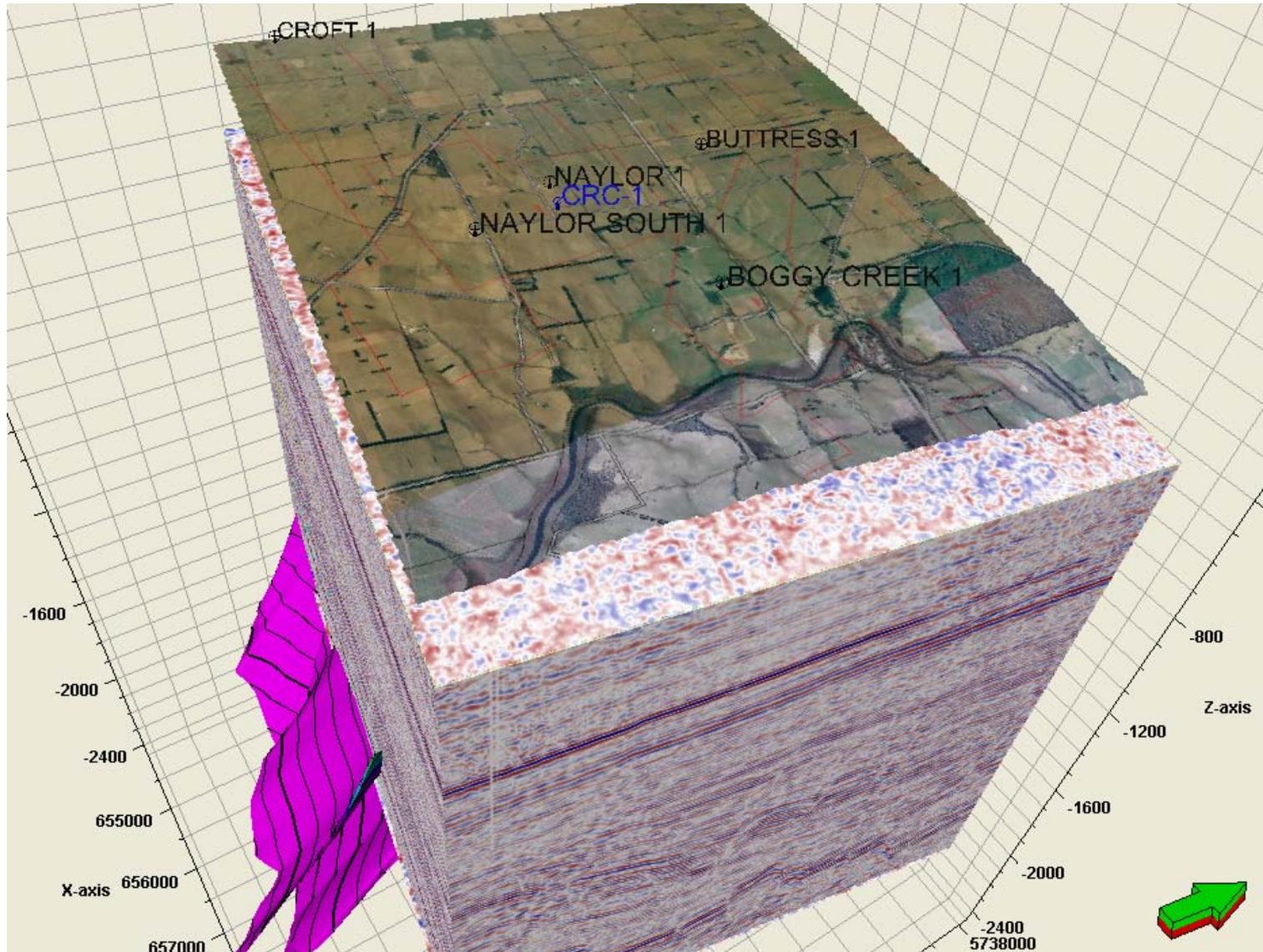
CO2CRC Otway Project: geological model
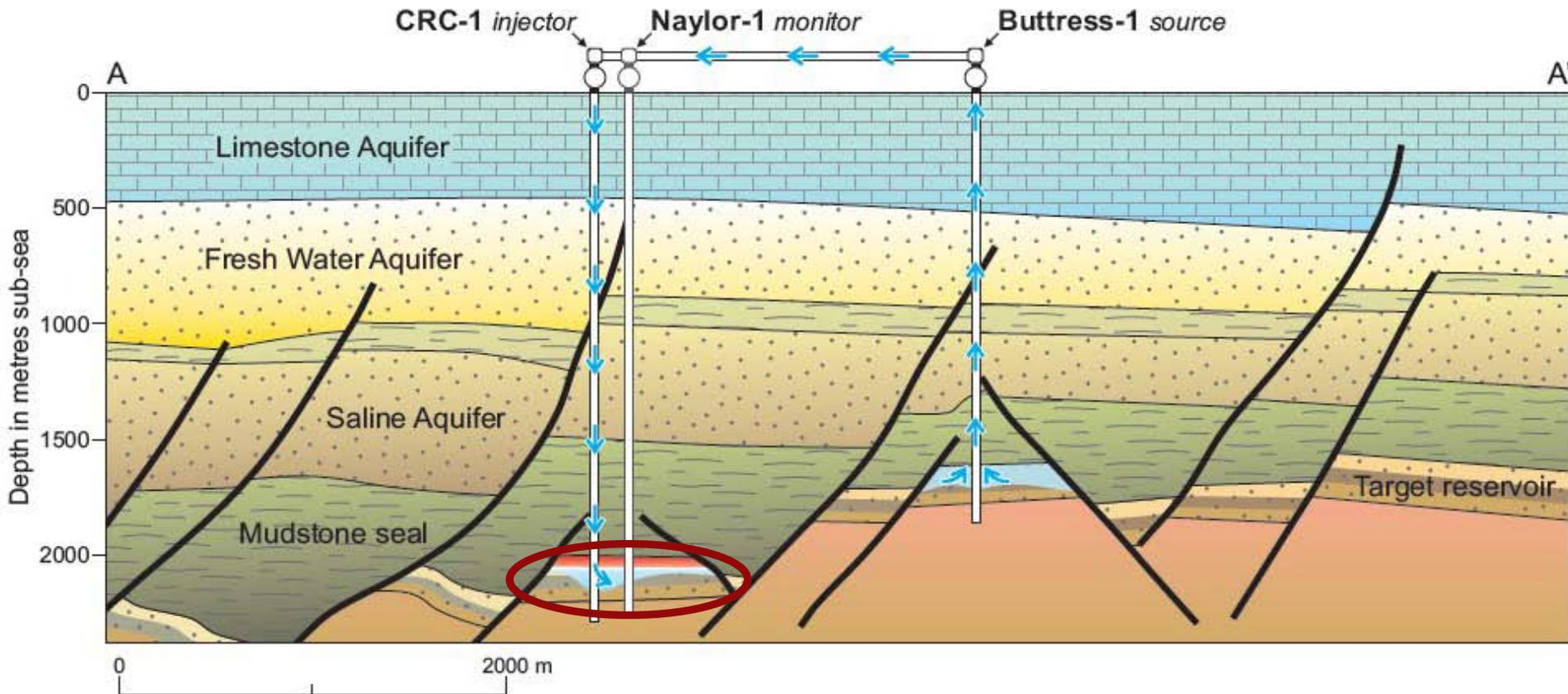
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Onshore drilling rigs

CRC-1 Well (Mar 07)

42.9 M Core
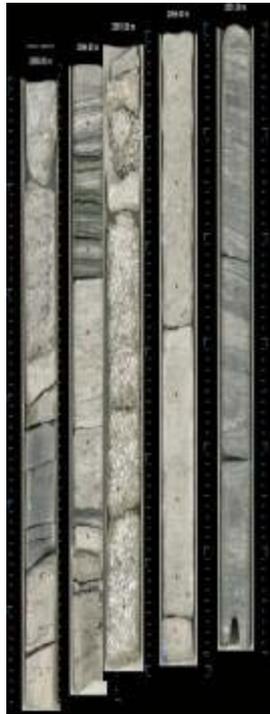
Full Suite of Logs

- Gamma ray, neutron, density, resistivity and caliper log
- NMR
- ECS (elemental capture spectroscopy)
- FMI (image log)
- Sonic Scanner
- Formation tester
- 3D VSP
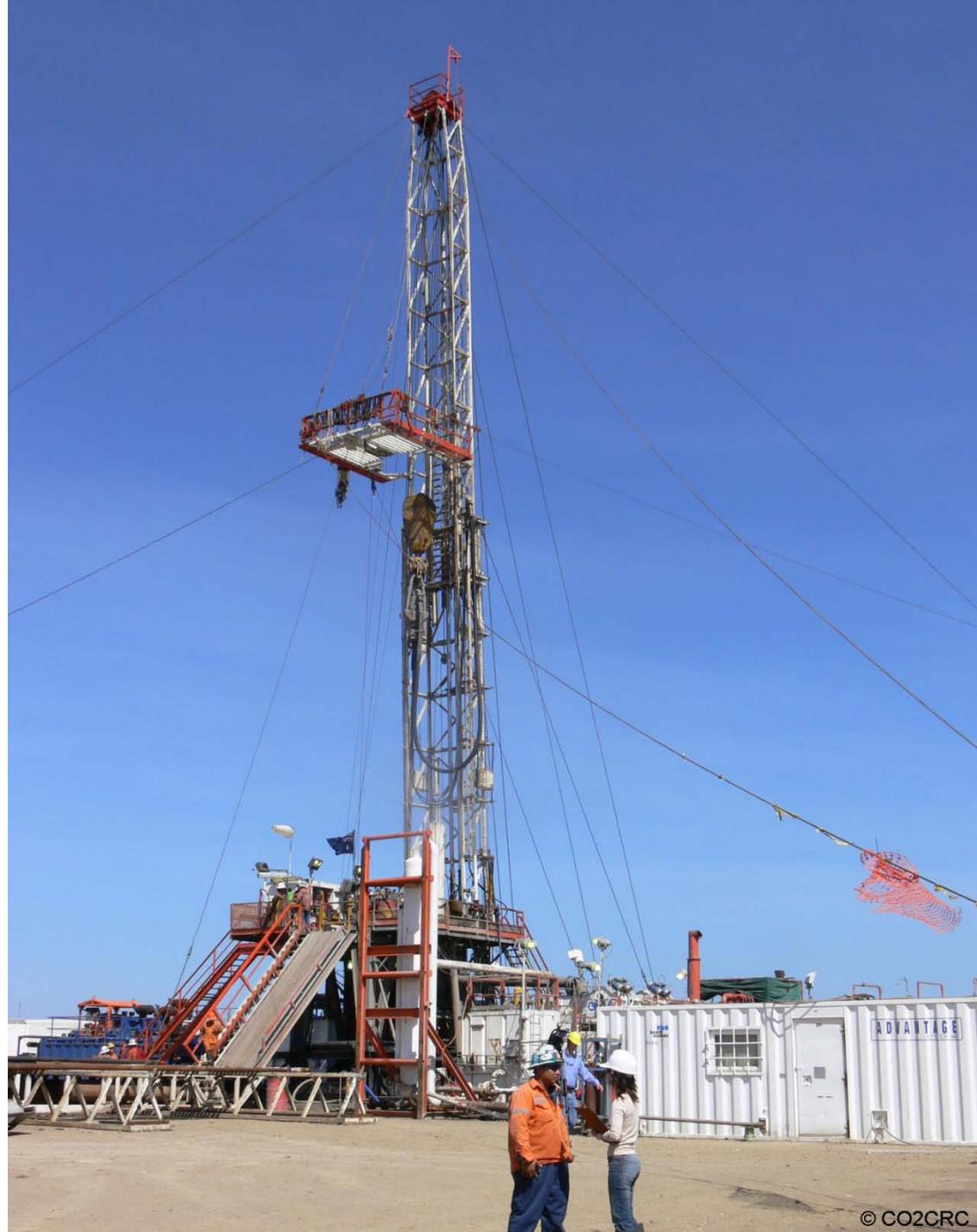
SEDIMENTARY STRUCTURES

Highly bioturbated medium sandstone with irregular wavy mud laminations.

5 cm

Stacked channel deposit grading from gravel dominated rippled beds with scour marks at the base, to medium sandstone.

5 cm

Very poorly sorted, weakly bedded, gravel dominated conglomerate. Kaolinite and siderite coating grains.

5 cm
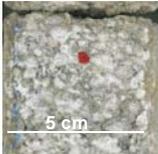
Abandoned channel fill. Mud drapes and thick wavy nonparallel lamina, covering pebbles sand and silt.

5 cm
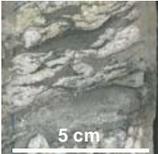
Ripples and mud draped beds disturbed by intense bioturbation, burrows filled with silty sand.

5 cm
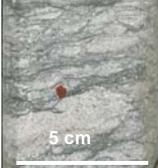
Fluvial heterolithic sandstone with medium bedded carbonaceous to muddy laminea and mud drapes.

5 cm

Core

m	GR	FACIES	POROSITY	PERMEABILITY
			0 30	0.01 10D

Offshore mud

2052.5

Transgressive sand

2055

Amalgamated channels

2057.5

2060 — Abandoned chan. fill

Gravel dominated Fluvial channels

2062.5

Abandoned chan.fill

2065

Wave re-worked Fluvial channels

2067.5

2070

Tidal fluvial

2072.5

2075

Tidal fluvial

2077.5

Abandoned channel fill

2080

Tidal? fluvial
Inferred

2082.5

● Core plug poro/perm
➤ Profile permeability

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Naylor-1
Monitoring well

CRC-1
injection well

Facies

	tidal fluvial
	wave re-worked
	gravel dominated
	amalgamated channels
	transgressive sand
	offshore mud
	Abandoned channel fill

Site characterisation process

- Build detailed reservoir model using current state of the art modelling packages

- History match with actual production data to validate model.

- Predict future trend.
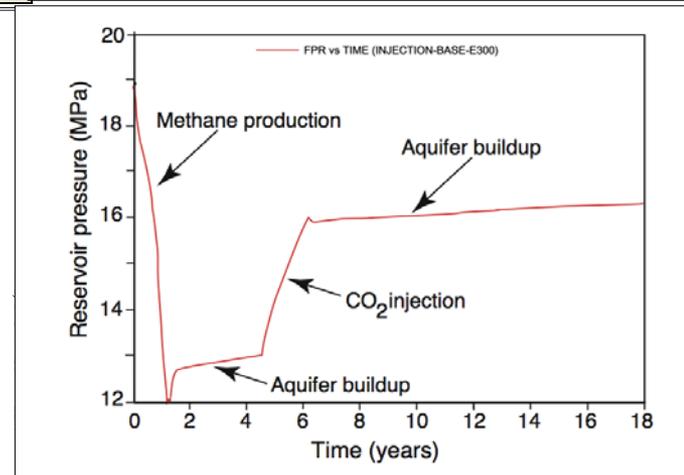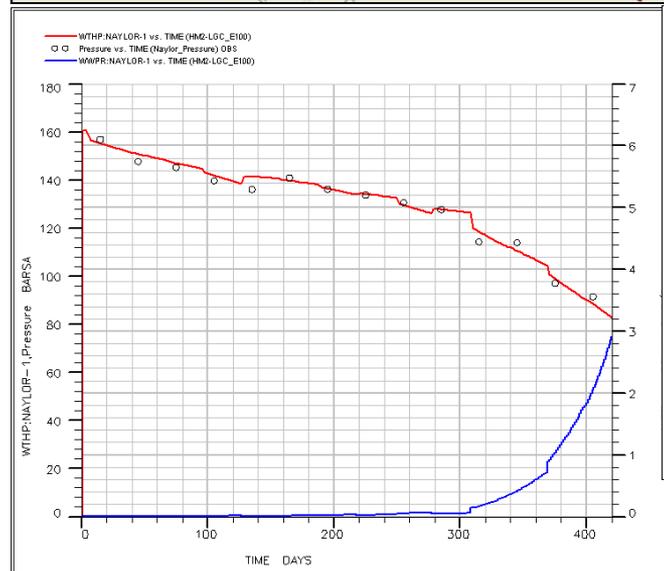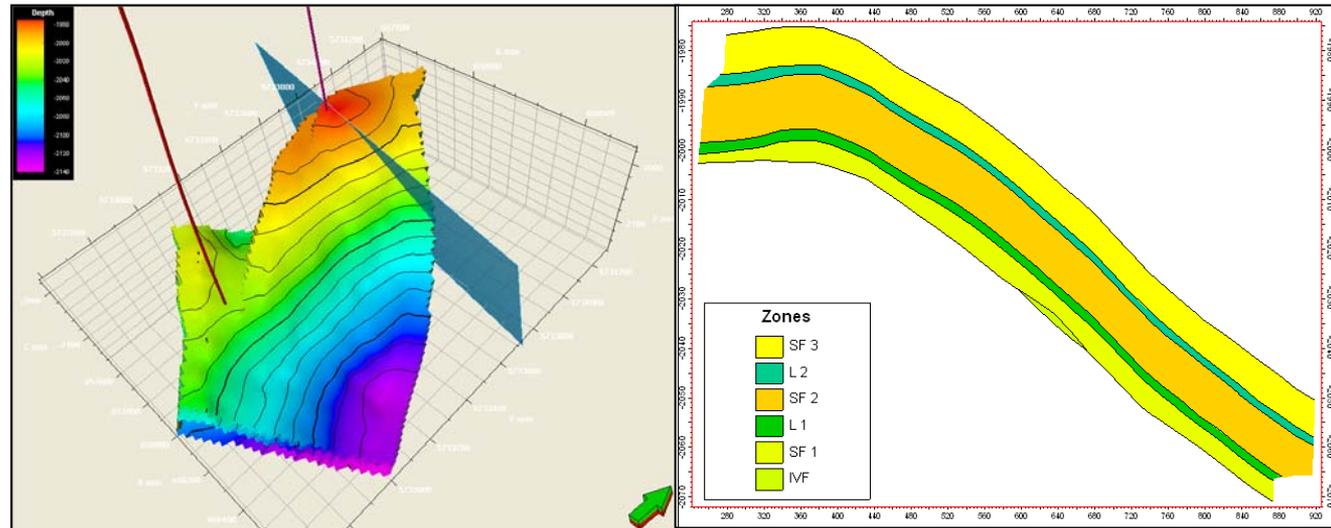
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Conceptual model

Observation well

CO_2 accumulation

CO_2 Injection well
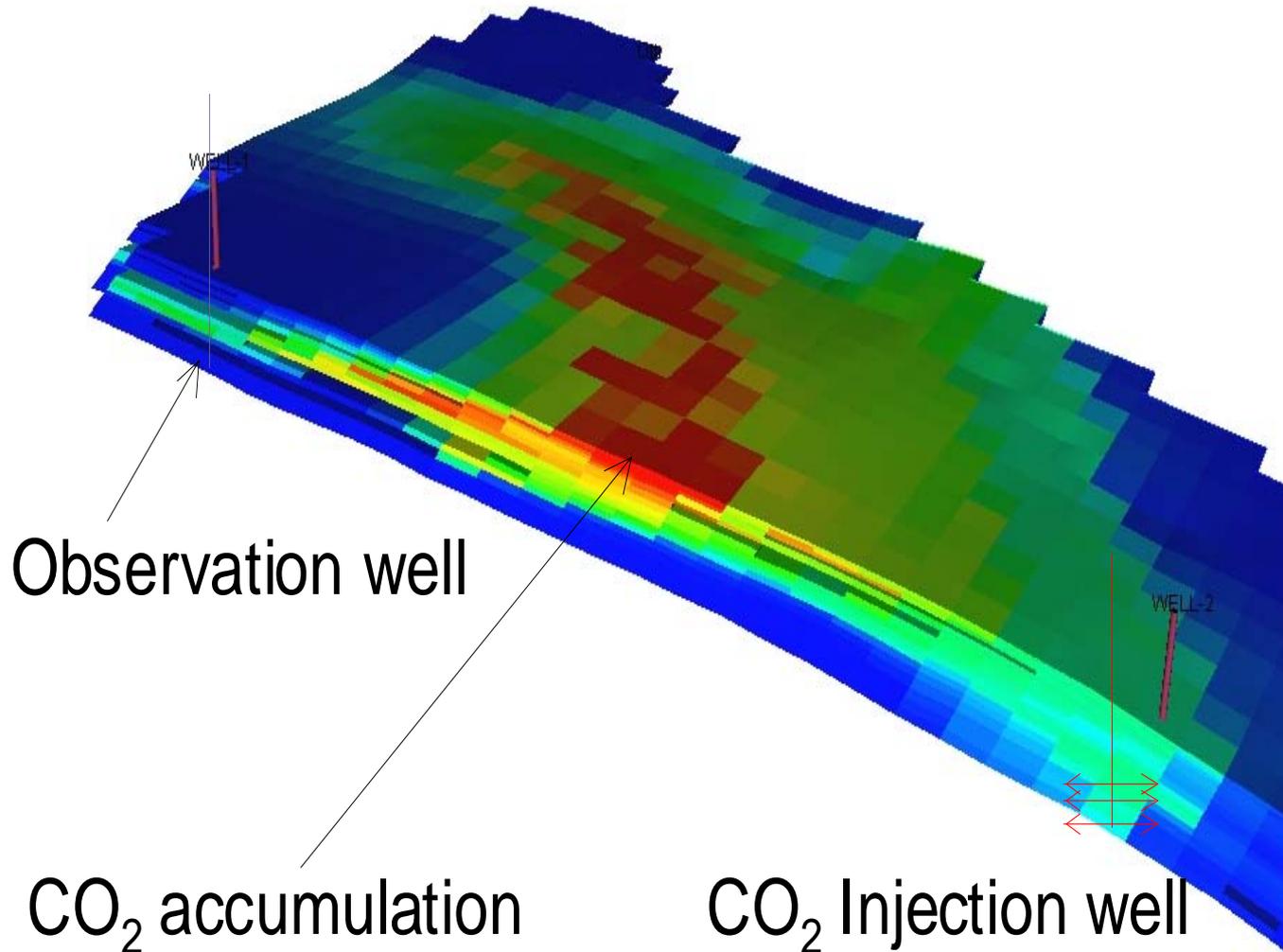
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Monitoring the injected CO_2

ATMOSPHERIC MONITORING — **ATMOSPHERE**

ASSURANCE MONITORING

SOIL GAS SAMPLING — **SURFACE**

HYDROLOGICAL & GROUNDWATER MONITORING — **AQUIFERS**

SEAL

INTEGRITY MONITORING

INJECTED CO_2

GEOCHEMICAL SAMPLING & SEISMIC MONITORING
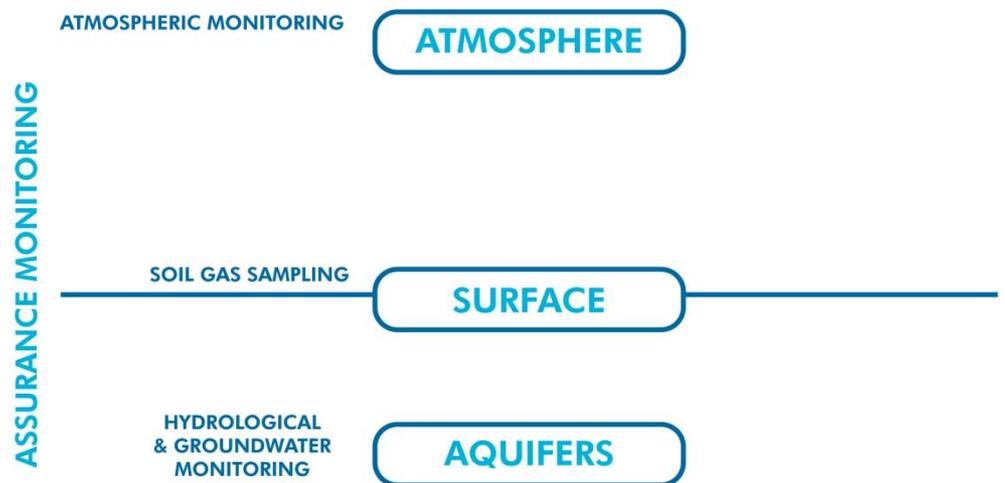
Measuring the atmospheric concentration of CO_2

Measuring the concentration of CO_2 in the soil

Analysing the groundwater

Measuring the temperature and pressure, recording sound waves and detecting chemical changes

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Atmospheric monitoring

Objectives:
To verify that injected CO_2 stays underground; or in the unlikely event of leakage to surface, demonstrate the capacity to detect and quantify surface leakage

baseline wind sector

Images CSIRO, CO2CRC

Otway

Cape Grim baseline
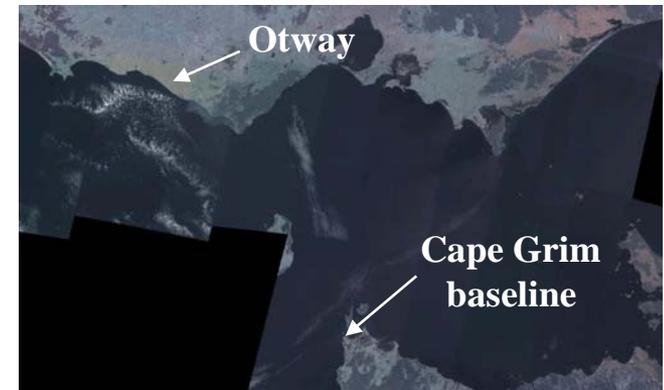
Monitoring using CO_2 concentration alone needs ideal conditions, so other species including CH_4, SF_6, CO and $^{13}CO_2$ are monitored to enhance sensitivity

D. Etheridge et al CSIRO

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Lo-Flo & air monitoring centre

Flux Tower

Towards CRC-1 site

Air Monitoring (Lo Flo & Flux Tower)

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Soil gas monitoring

Objective:
- Establish CO_2 variations within the extended area beyond the CO2CRC tenements
- Determine the likely source of origin
- Differentiate natural from injected CO_2.

Methods:
- The soil gas program extracts air from the unsaturated soil zone above the water table.
- Samples are analysed on site (portable gas chromatograph) and in the laboratory for CO_2, CH_4 and isotopes.

Frequency
- Baseline: Four surveys
- Once a year during and after the injection
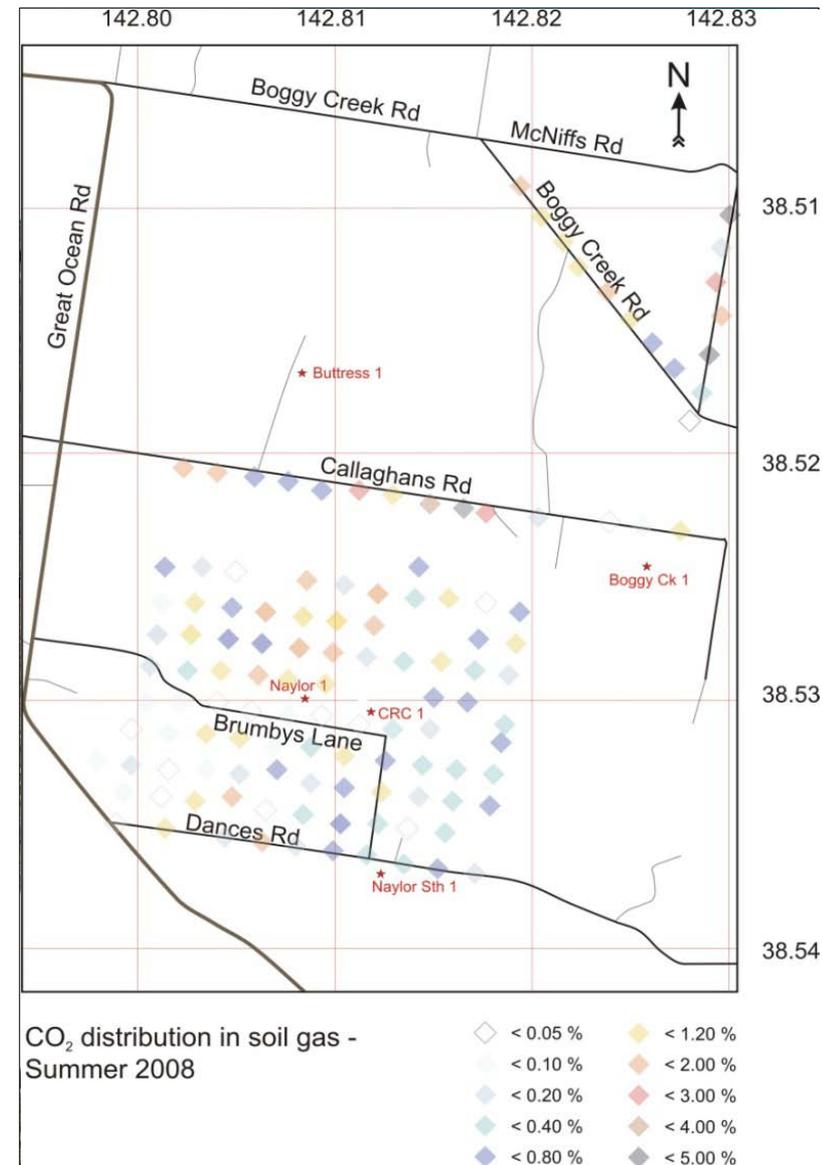
CO_2 distribution in soil gas - Summer 2008

◇ < 0.05 %	◆ < 1.20 %
◇ < 0.10 %	◆ < 2.00 %
◇ < 0.20 %	◆ < 3.00 %
◆ < 0.40 %	◆ < 4.00 %
◆ < 0.80 %	◆ < 5.00 %

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Ground water monitoring

Cap
Cable permanently installed
Steel Cable
Waterlevel
5-10m
Datalogger
Screen

Objective:
- Monitor water levels to determine seasonal variation, flow rate and direction
- Identify any chemical changes associated with possible CO_2 leakage

Methods:
- Dataloggers
- Water chemistry

Aquifers monitored:
- Shallow unconfined Port Campbell Limestone,
- Deep confined Dilwyn aquifer

2007/10/16
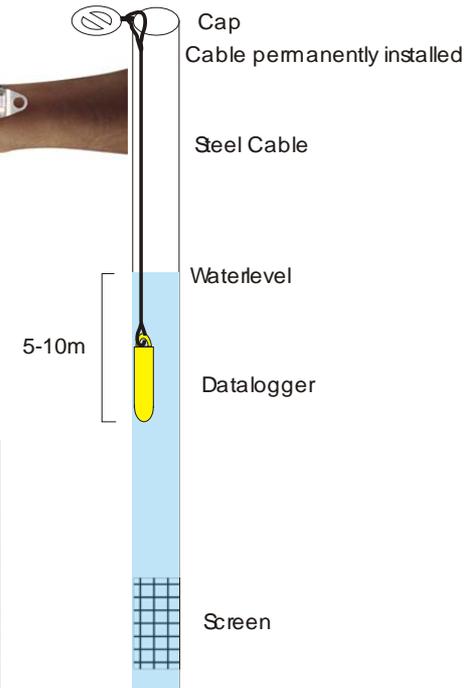
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Example: Wannon Water Bore

Station V

Legend:
- A — pH
- B — EC (μS/cm)
- C — T ($^\circ$C)
- D — Eh (mV)
- f — HCO$_3^-$ (mg/L)

CO_2 injection
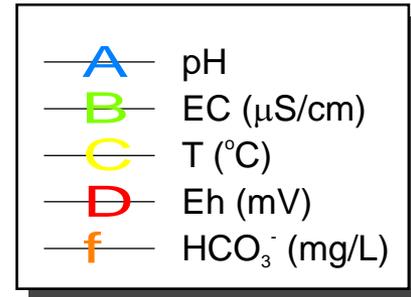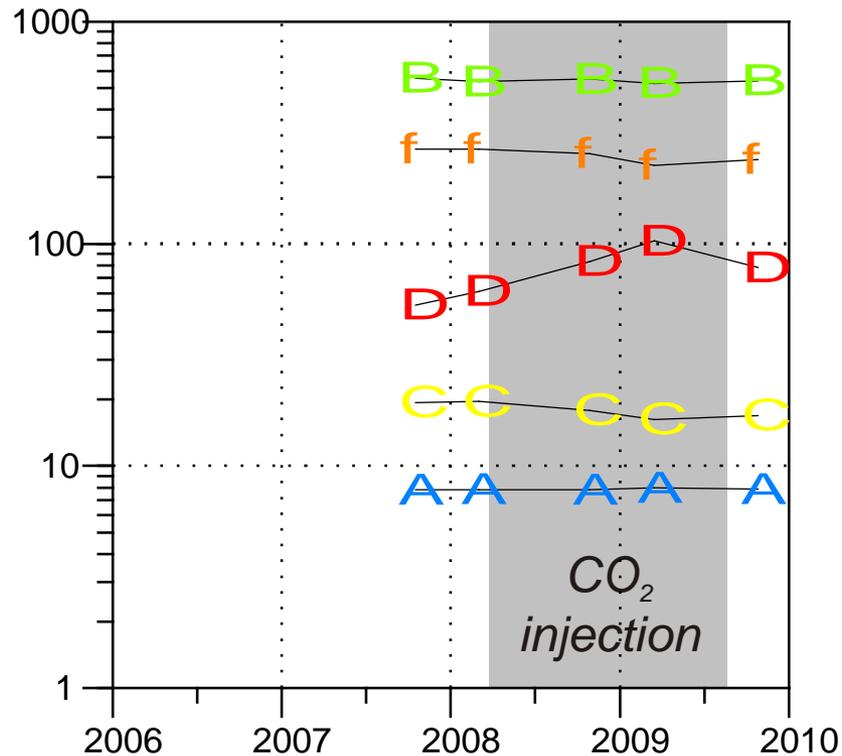
Dilwyn Formation
TD 826 m
SWL ~13.6 m

Downhole geochemical monitoring
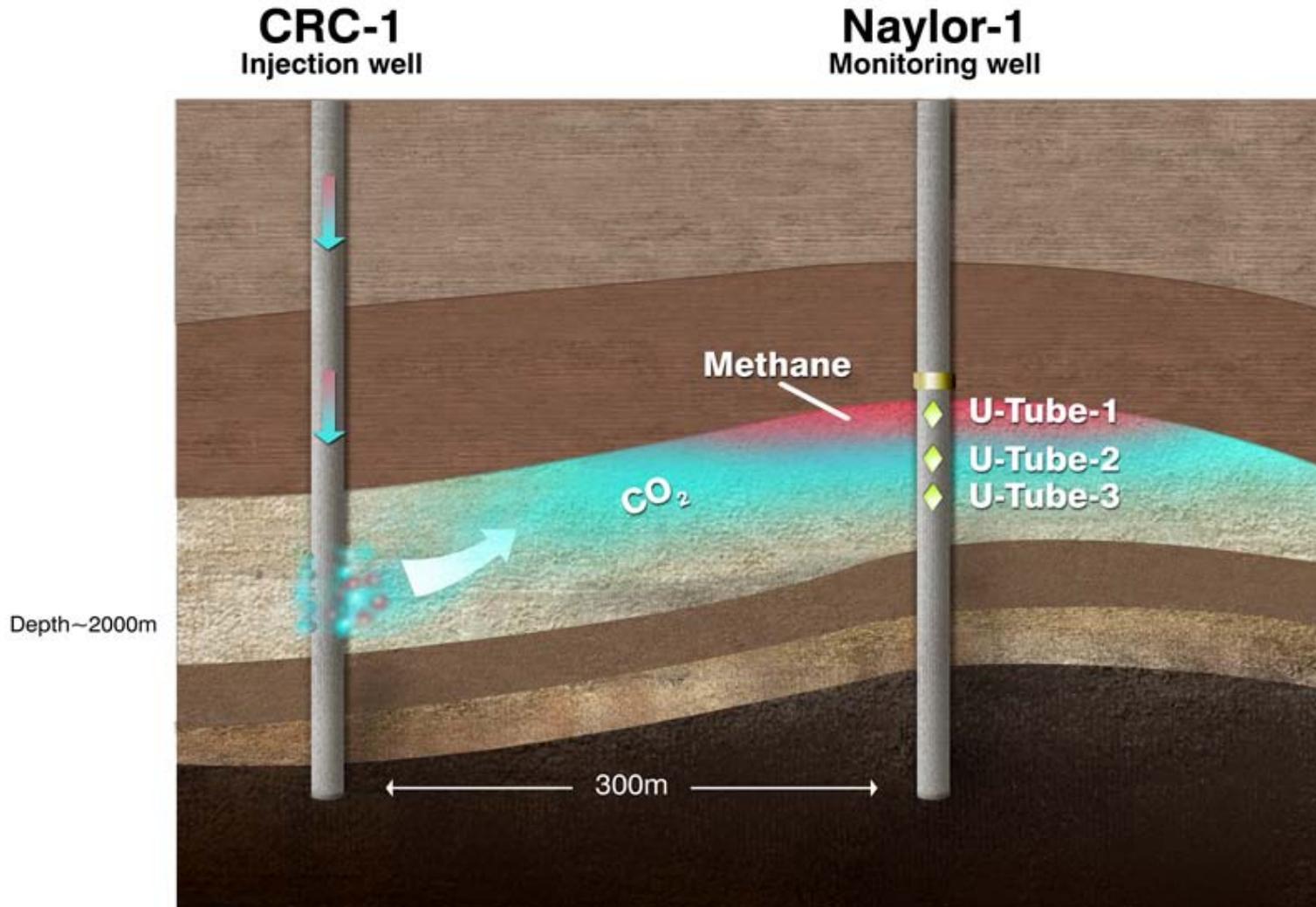
Downhole monitoring

Image, CO2CRC

- Fluid sampling

- Use of tracers

- Temperature and pressure

Depth markers:
- 1420 m
- 1500 m
- 1700 m
- 1850 m
- 2000 m
- 2025 m
- 2055 m

Legend:
- Geophone with clamp
- 3c Geophone with clamp
- Hydrophone
- U-tube Inlet

- Drive leg
- Sample leg
- N_2 inflation line for packer
- Tee connector - "T"
- Check value
- Packer
- Connector
- Filter

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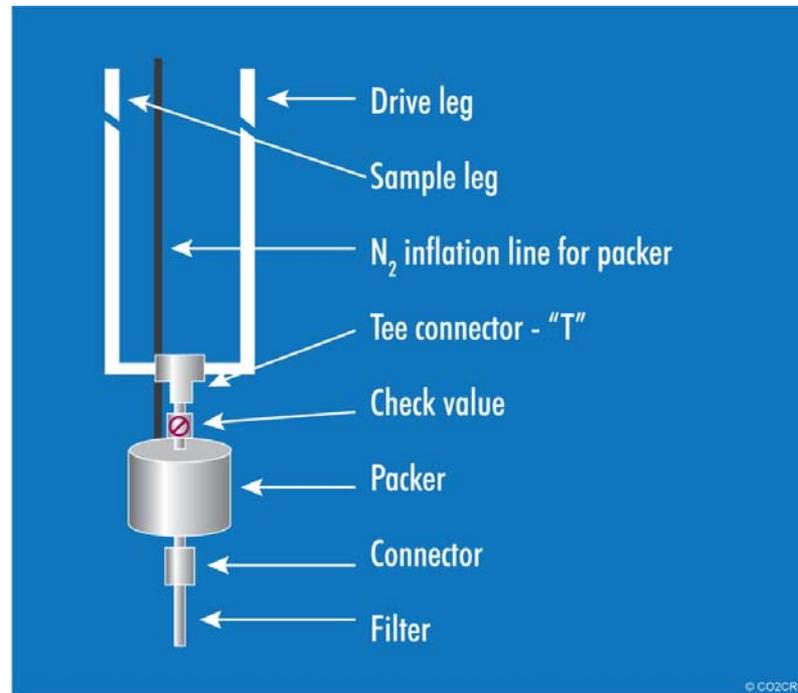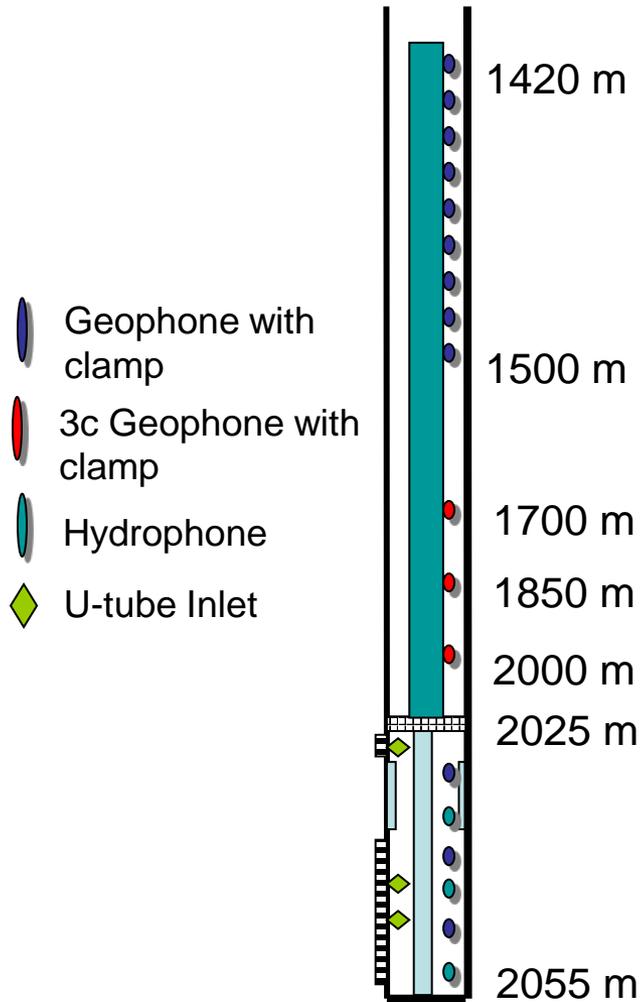
What should the data tell us?
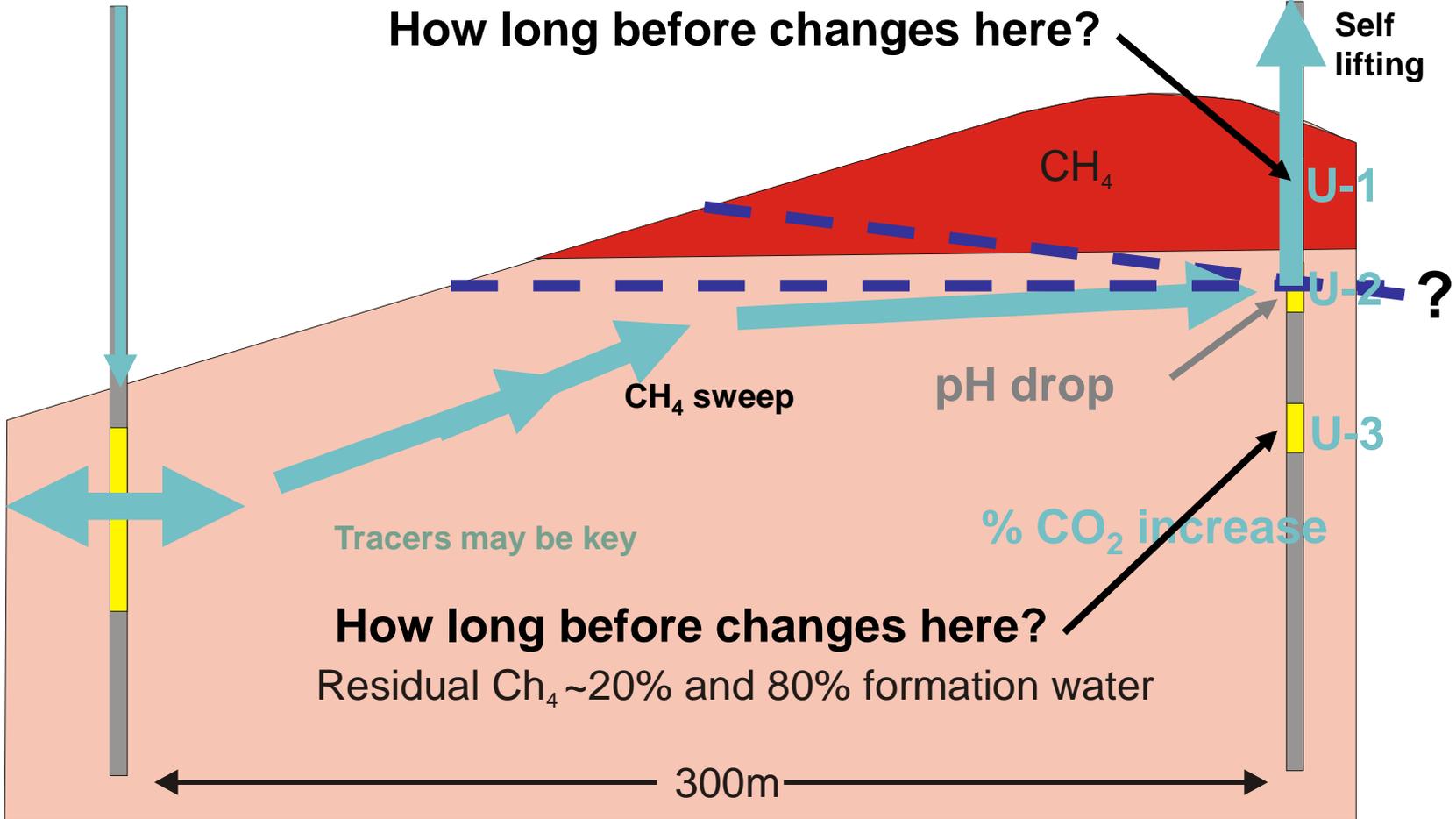
CO₂ concentration time series from Naylor-1
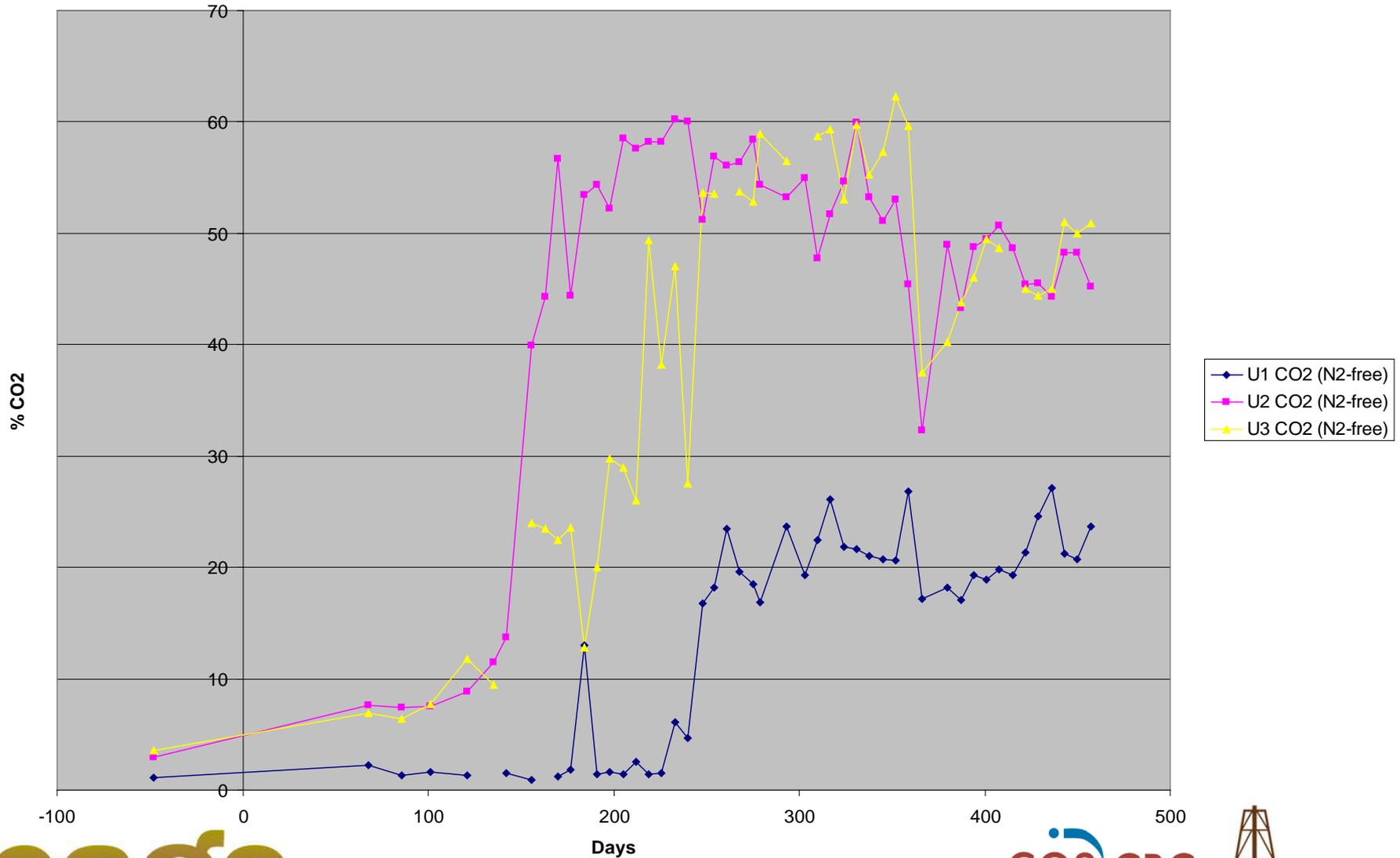
3D surface seismic monitoring

Objective: to map the migration path of CO_2 plume from injector to producer

Methods: 4D or time-lapse surveys

Repeatability of surveys before, during and after the CO_2 injection is very important for every aspect of acquisition (source and receivers positioning; source signal; hardware; time of year; processing)
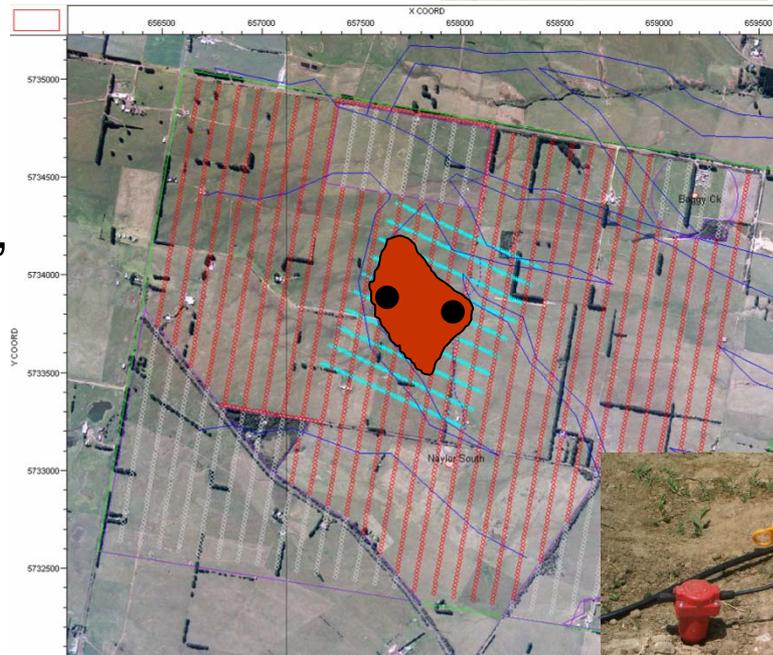
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Xline 81 – Is this change real/significant?
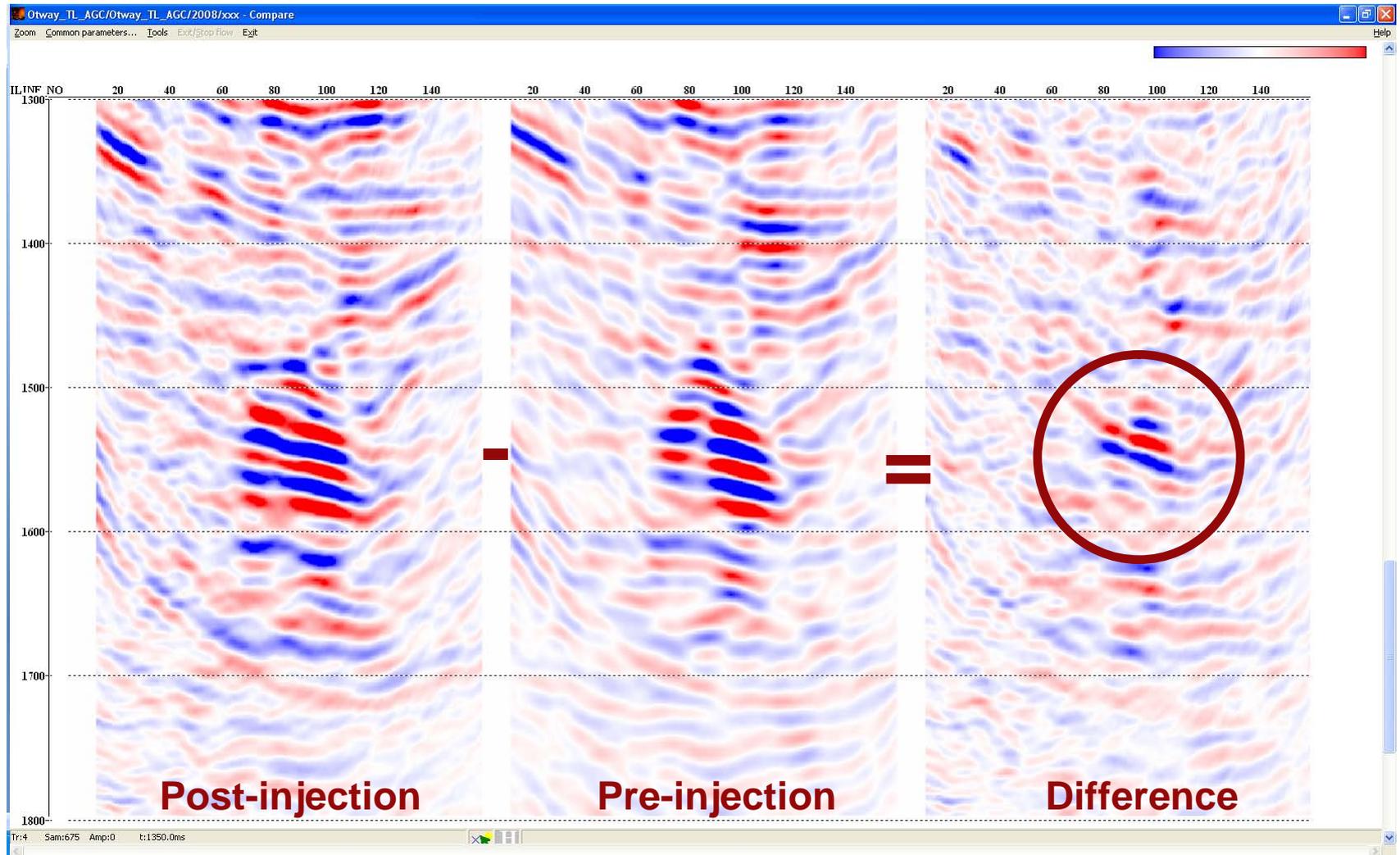
Post-injection   –   Pre-injection   =   Difference

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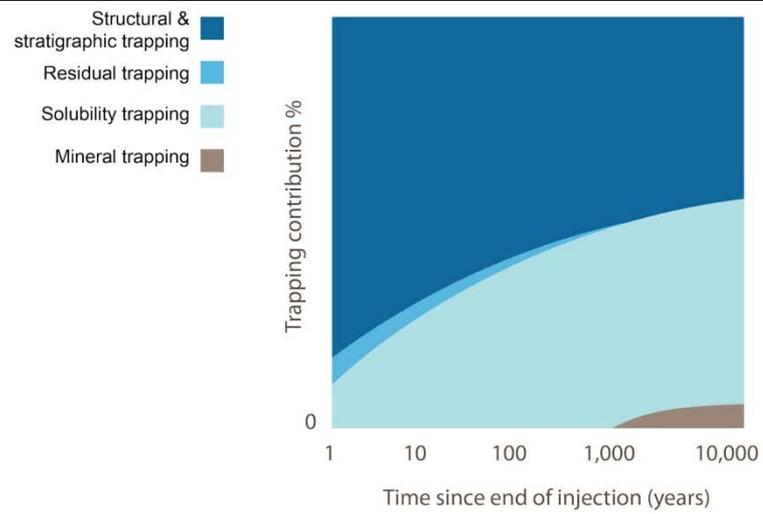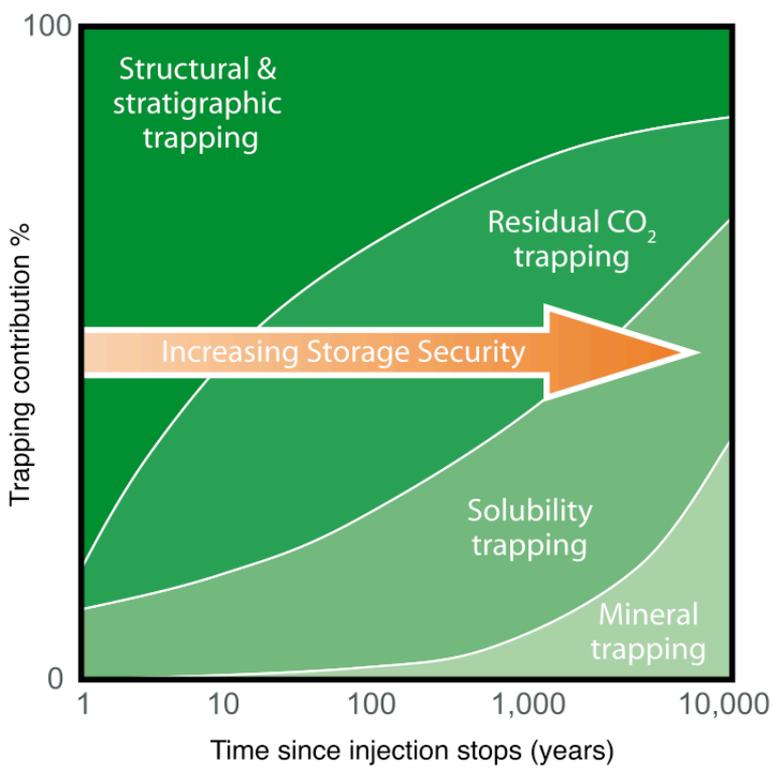
Otway Project: stage 1

Structural trapping dominates

Increasing Storage Security

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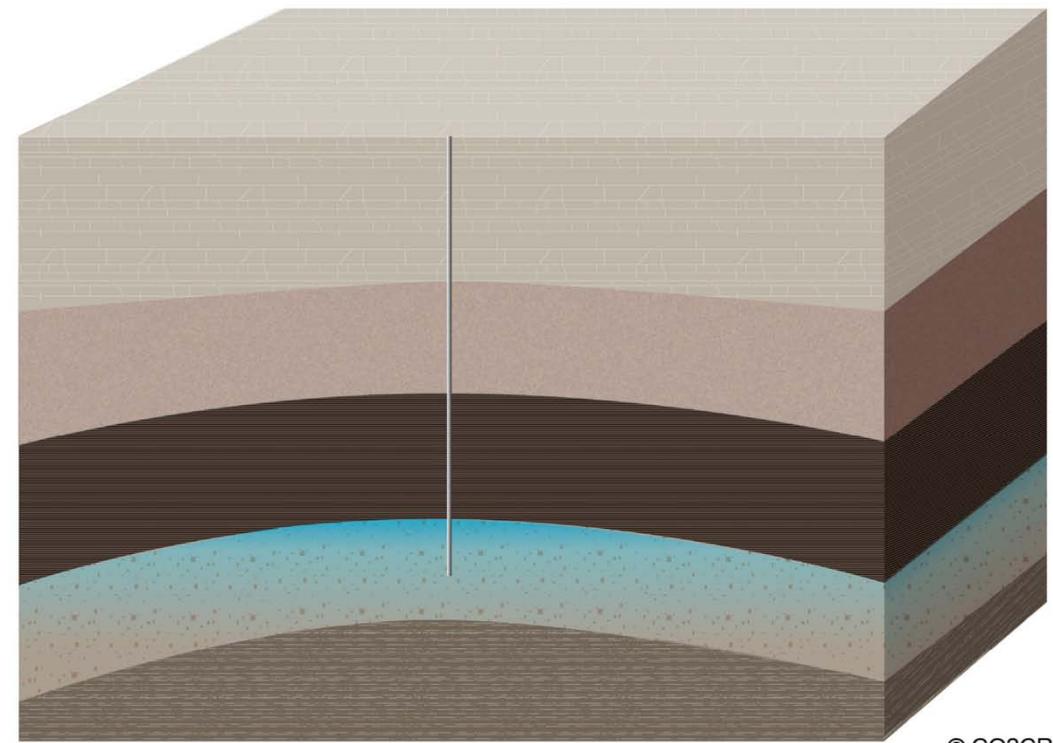
Otway Project: stage 2

Residual trapping dominates

Legend:
- Structural & stratigraphic trapping
- Residual trapping
- Solubility trapping
- Mineral trapping

Trapping contribution %

Time after injection stops (years)

> 800m
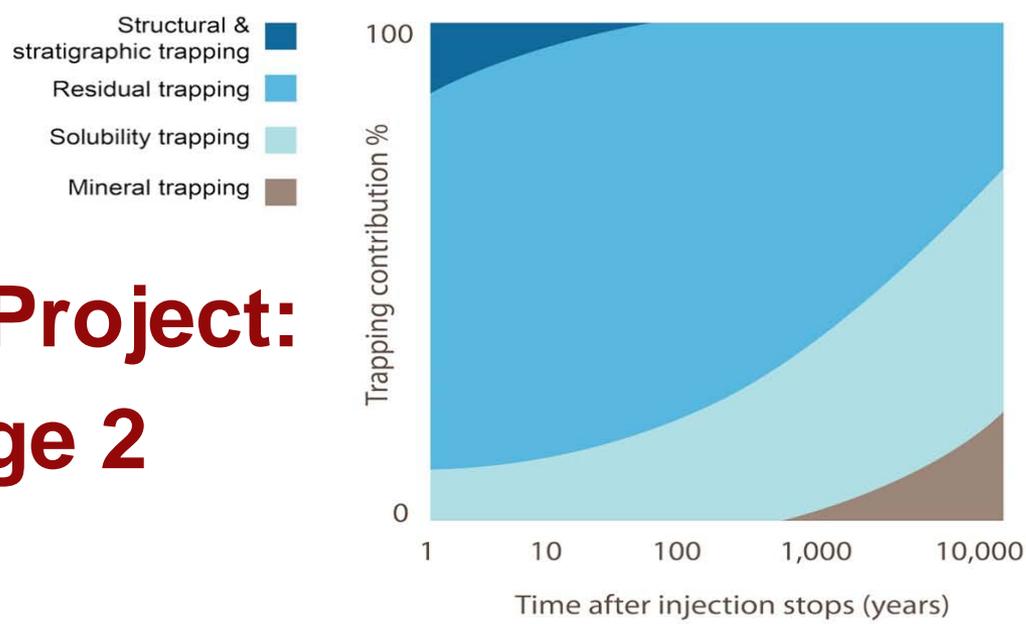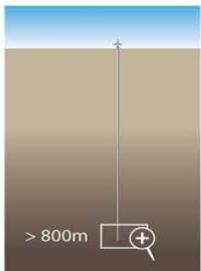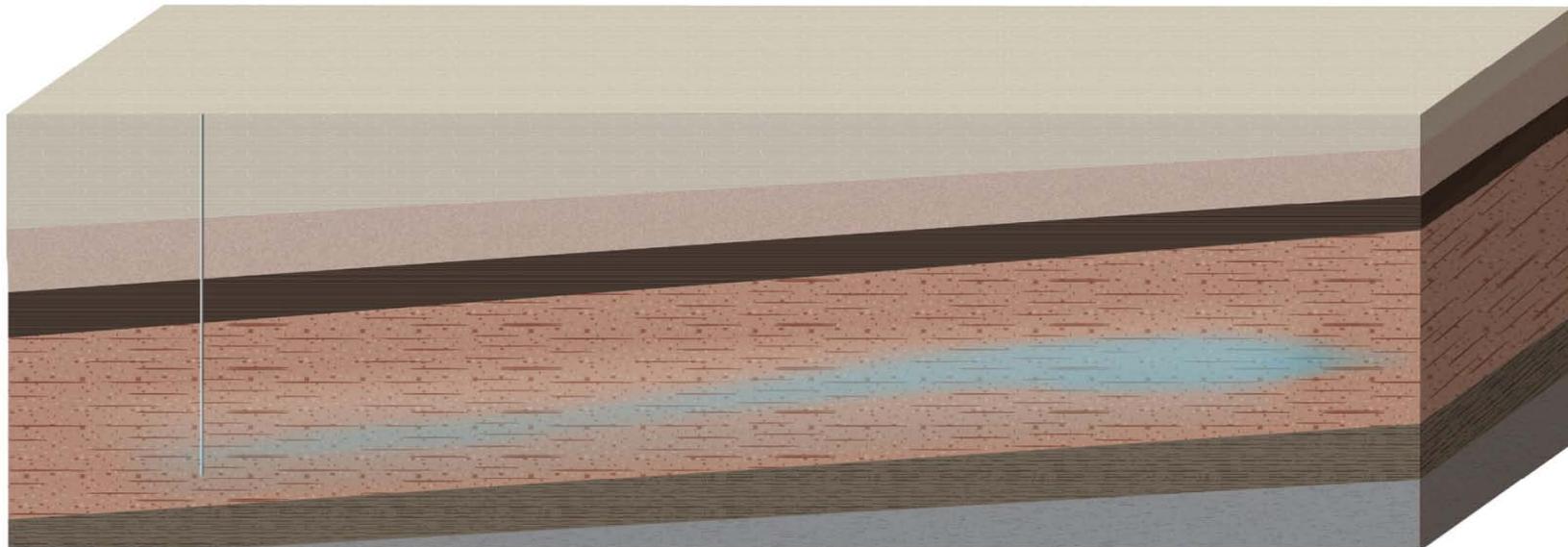
Kilometres to tens of kilometres

© CO2CRC

Residual capillary trapping
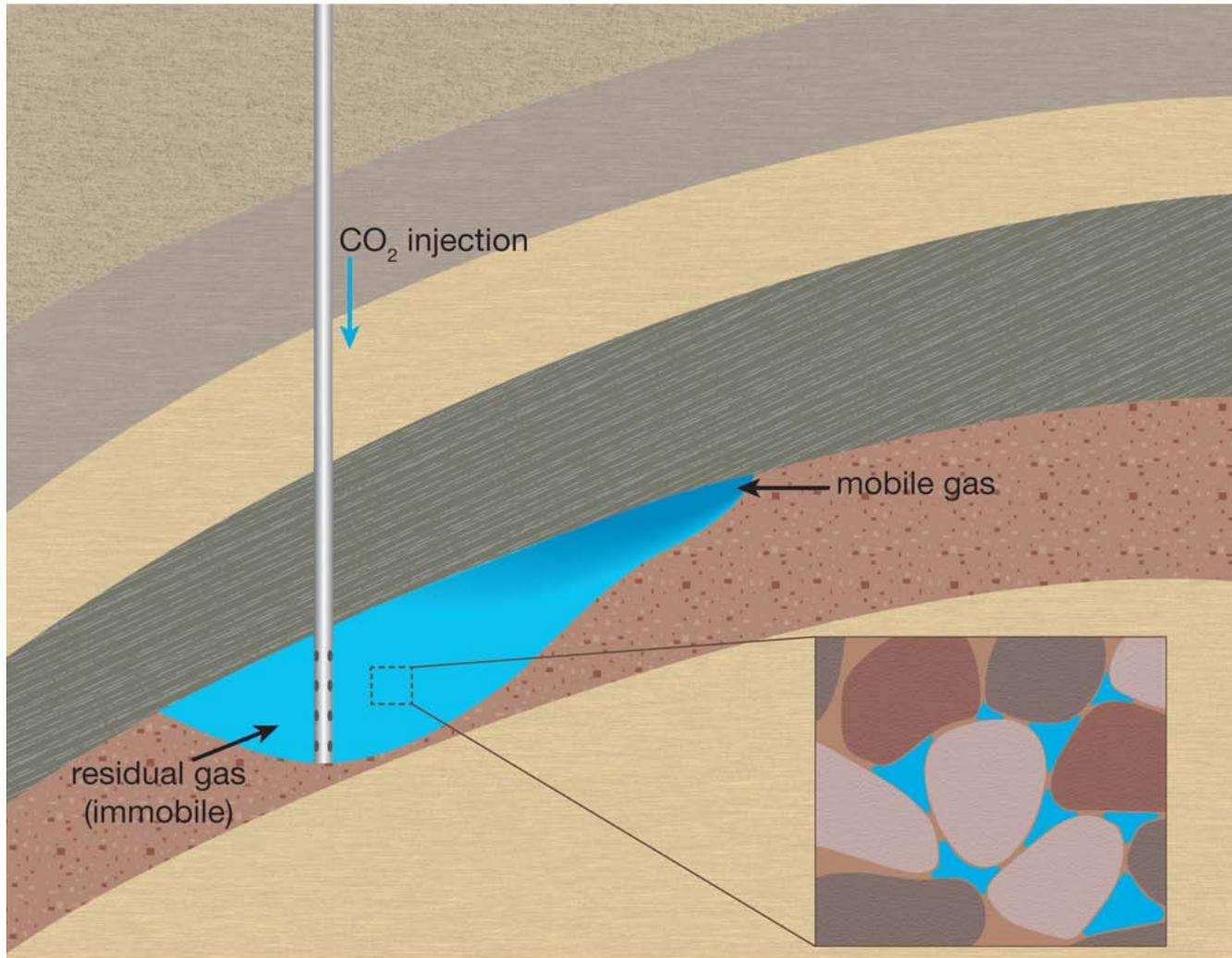
Residual CO_2 is left behind because of snap-off as the plume migrates upward.
[After Juanes *et al.* (2006) Water Resour. Res.]

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Residual CO₂ Saturation
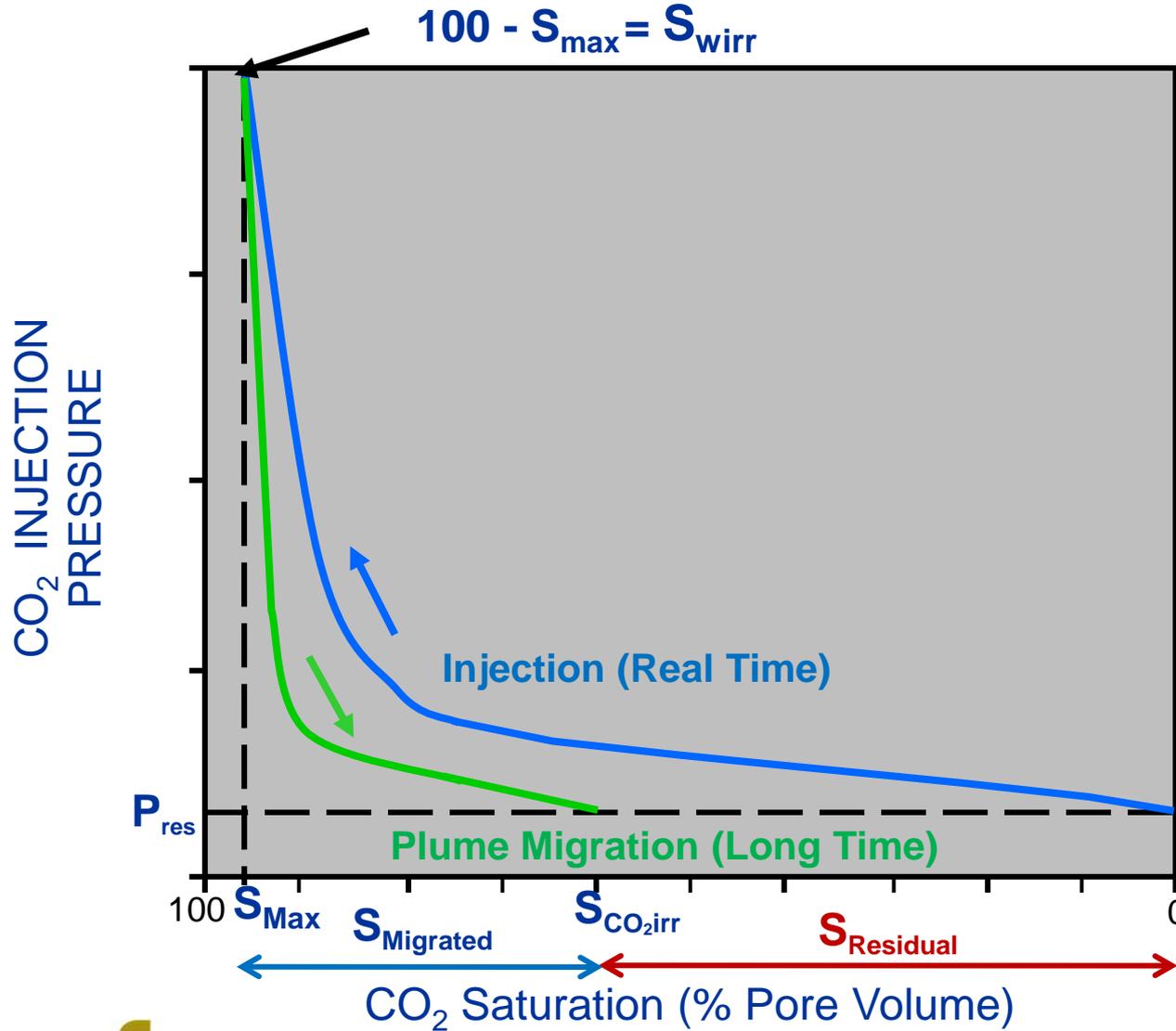
Residual saturation/capillary trapping

- CO_2 can be effectively immobilized by residual trapping - also known as capillary trapping - a process resulting from capillary snap-off of isolated CO_2 bubbles.

- This mechanism does not rely on impermeable cap rock to contain the CO_2.

- Efficient residual trapping in dipping aquifers may allow CO_2 storage where there is not structural closure.

- It is also important to CO_2 migration in general as it reduces the volume of the CO_2 plume.

- Thus it is important to measure and verify the amount of residual trapping in CO_2 storage.

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Paaratte (saline) Formation is subhorizontal
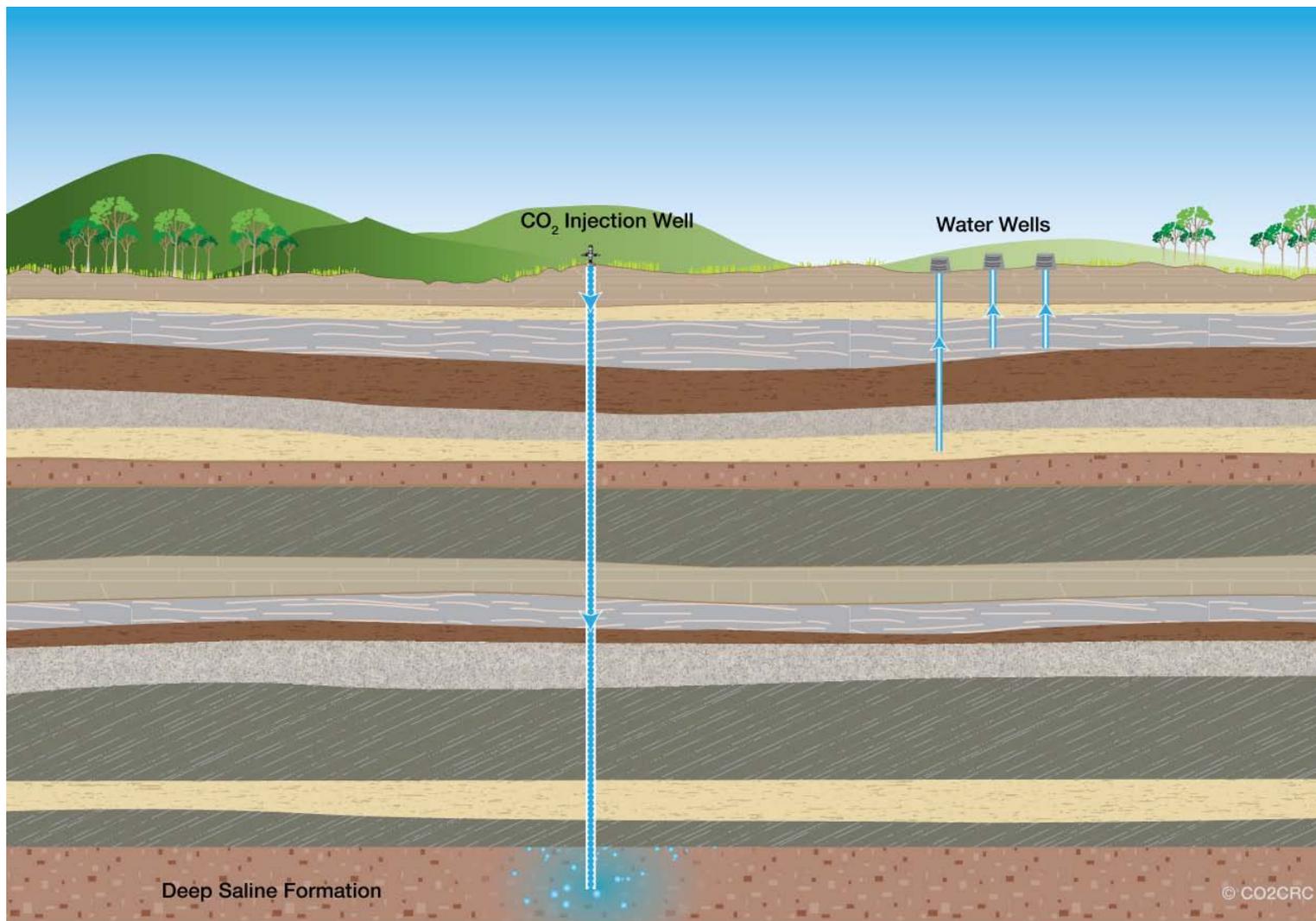
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Original research objectives/method

- Huff and puff/push pull (300 T)

- Core experiments tied to field observations

- Then larger scale injection of up to 10K T

- Repeat logging and 4D seismic monitoring to track plume migration/dissolution

Residual CO_2

Free CO2
Residual CO2
Brine

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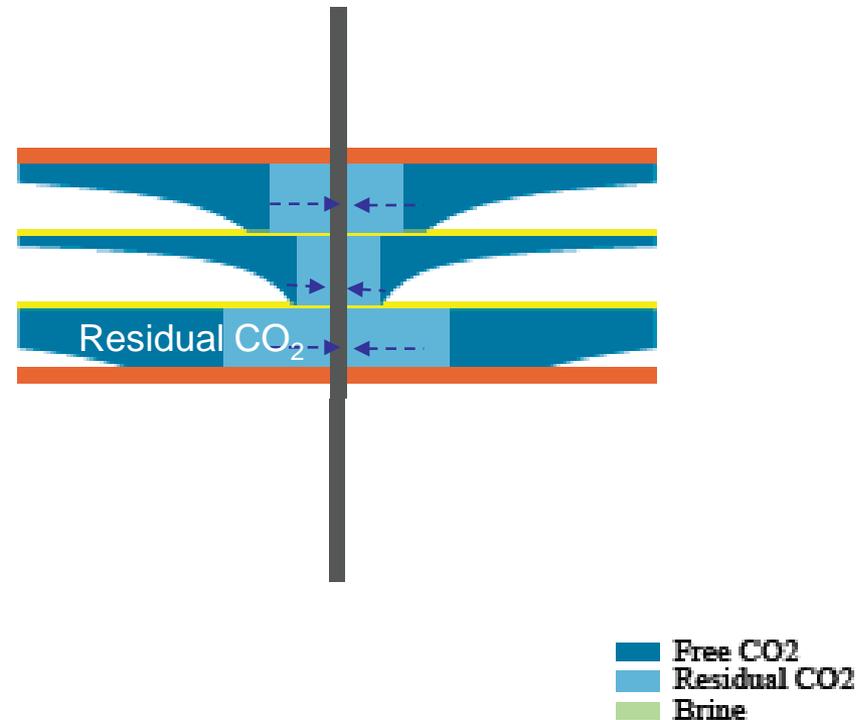
Zone 1 Sequence stratigraphy

Potential for reservoir development
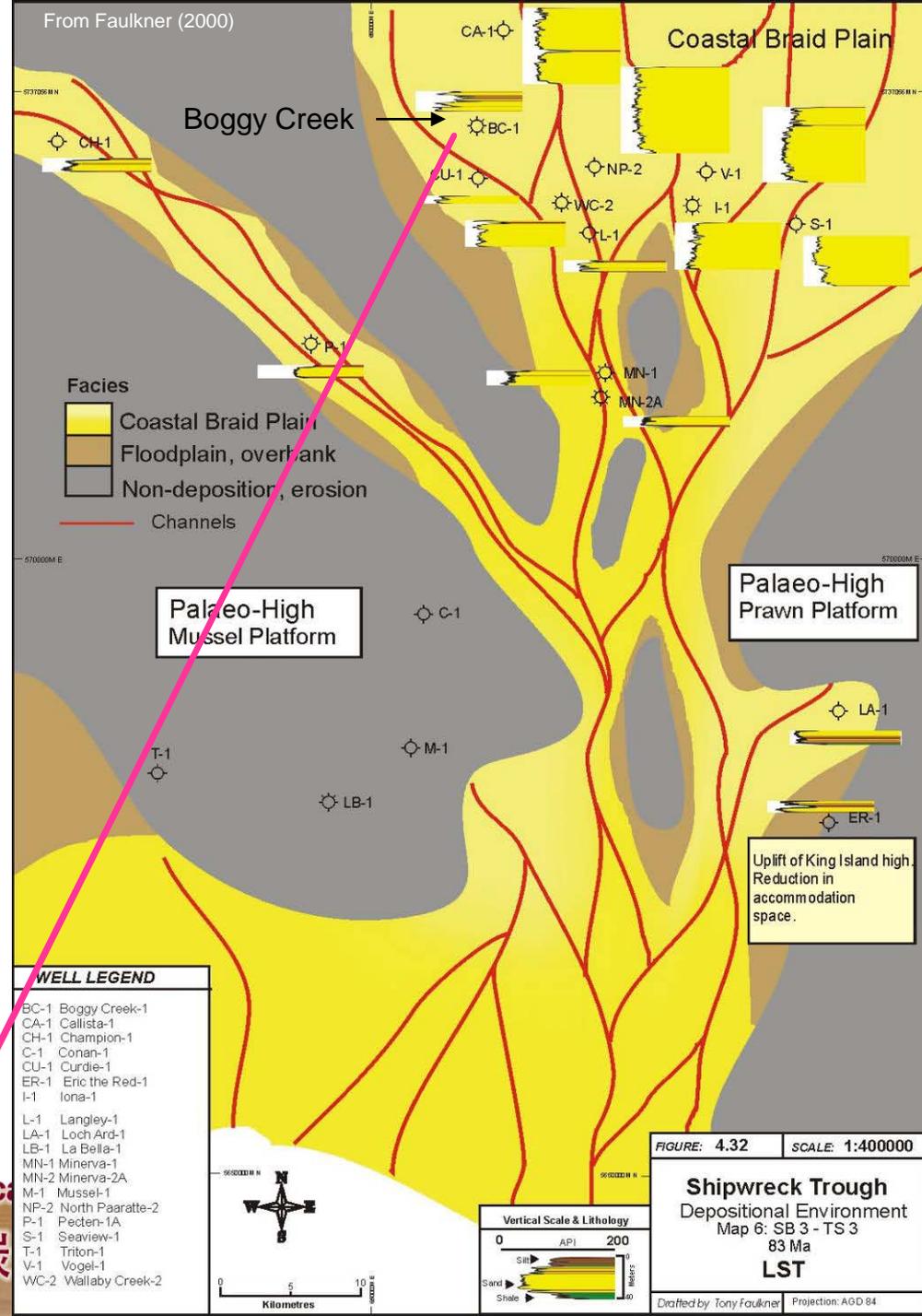
specific zone
of interest

From Faulkner (2000)

Coastal Braid Plain

Boggy Creek

Facies
- Coastal Braid Plain
- Floodplain, overbank
- Non-deposition, erosion
- Channels

Palaeo-High
Mussel Platform

Palaeo-High
Prawn Platform

Uplift of King Island high. Reduction in accommodation space.

WELL LEGEND

BC-1 Boggy Creek-1
CA-1 Callista-1
CH-1 Champion-1
C-1   Conan-1
CU-1 Curdie-1
ER-1 Eric the Red-1
I-1   Iona-1
L-1   Langley-1
LA-1 Loch Ard-1
LB-1 La Bella-1
MN-1 Minerva-1
MN-2 Minerva-2A
M-1   Mussel-1
NP-2 North Paaratte-2
P-1   Pecten-1A
S-1   Seaview-1
T-1   Triton-1
V-1   Vogel-1
WC-2 Wallaby Creek-2

FIGURE: 4.32   SCALE: 1:400000

Shipwreck Trough
Depositional Environment
Map 6: SB 3 - TS 3
83 Ma
LST

Drafted by: Tony Faulkner   Projection: AGD 84

Vertical Scale & Lithology

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Zone 2 Sequence stratigraphy

Potential for seal development

From Faulkner (2000)

Tidal Flats

Tidal Flats

Boggy Creek

Nearshore Marine

Palaeo-High
Prawn Platform

Palaeo High
Mussel Platform

Possible Tidal
Ravinement

Marine

WELL LEGEND

BC-1   Boggy Creek-1
CA-1   Callista-1
CH-1   Champion-1
C-1   Conan-1
CU-1   Curdie-1
ER-1   Eric the Red-1
I-1   Iona-1

L-1   Langley-1
LA-1   Loch Ard-1
LB-1   La Bella-1
MN-1   Minerva-1
MN-2   Minerva-2A
M-1   Mussel-1
NP-2   North Paaratte-2
P-1   Pecten-1A
S-1   Seaview-1
T-1   Triton-1
V-1   Vogel-1
WC-2   Wallaby Creek-2

Facies

Tidal flats, lagoons

Nearshore marine

Open Marine

Non-deposition, erosion

Channels

| FIGURE: | 4.35 | SCALE: | 1:400000 |

Shipwreck Trough
Depositional Environment
Map 7: TS 3- MFS 3
83- 80 Ma
TST

Drafted by Tony Faulkner   Projection: AGD 84

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CRC-2 drilling, coring, logging

Wireline well logging
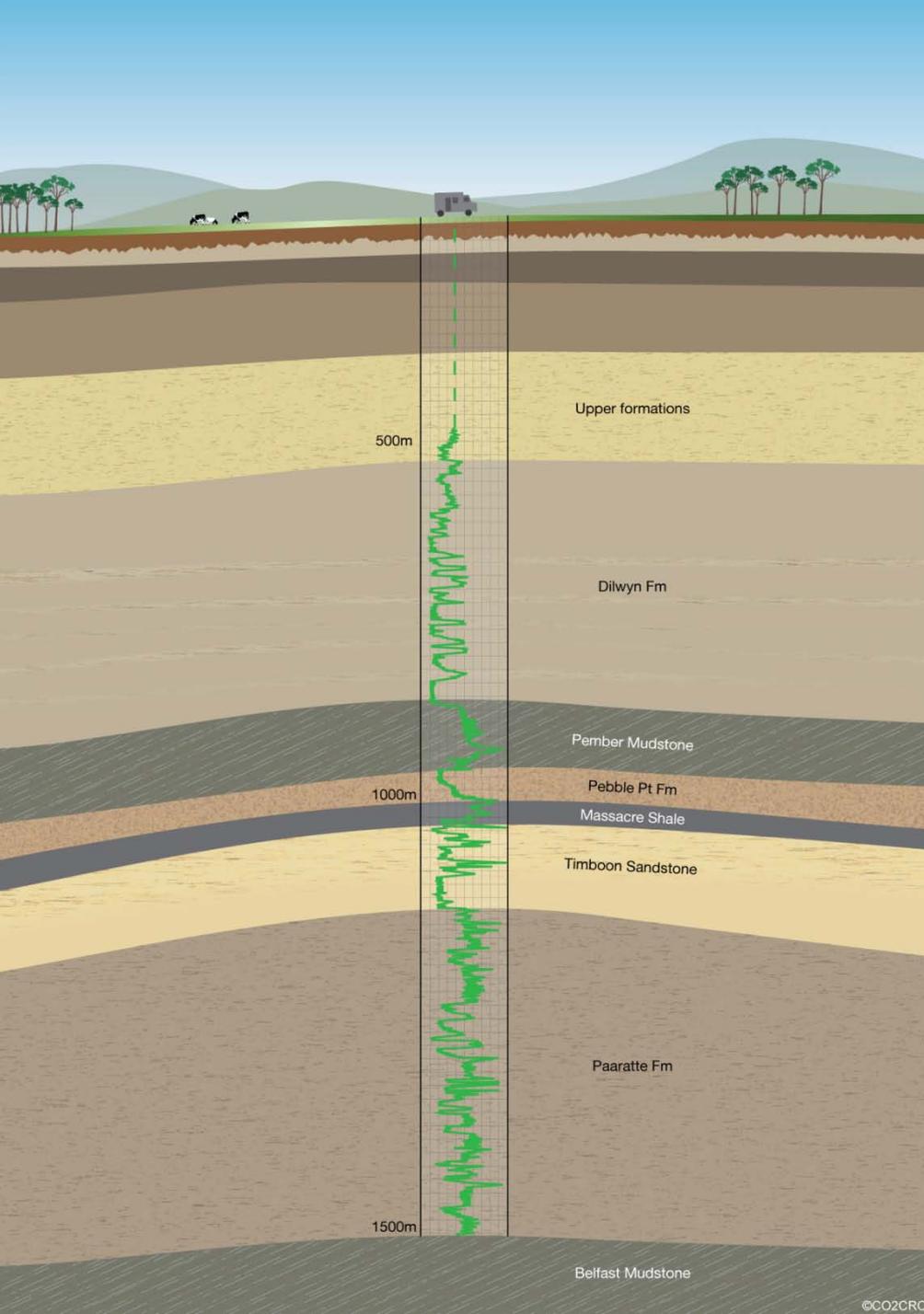
5 runs including:

- GR, SP, density, magnetic resonance, porosity, permeability
- Comprehensive resistivity suite
- Elemental Capture Spectroscopy (ECS)
- Resistivity image log (FMI)
- Formation fluid tests (MDT)
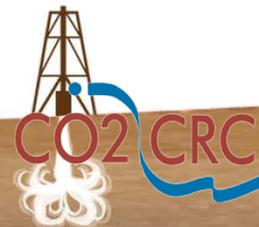
CRC-2 core analysis

CRC-2 core log
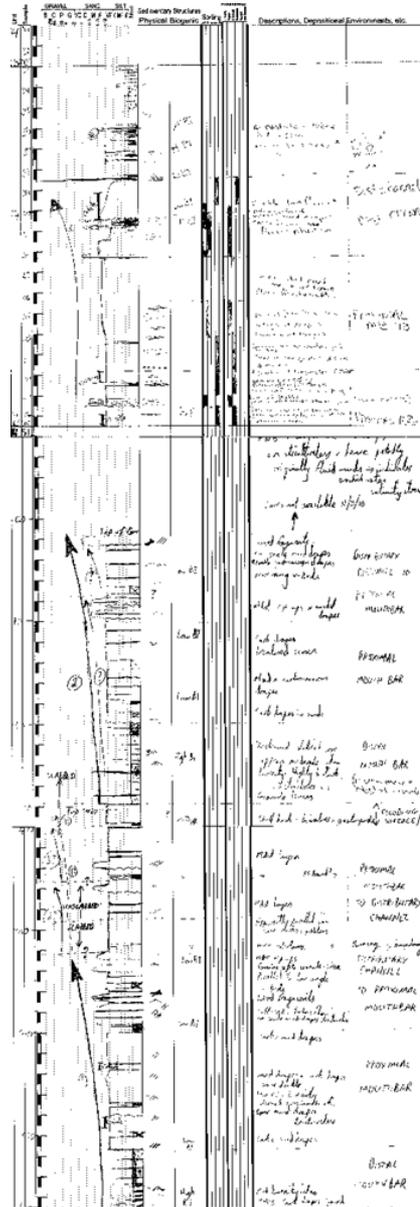
• Reveals a similar sequence stratigraphic framework to the conventional interpretation of well logs across the region

• However, the facies distribution interpreted from core suggests a more proximal location on the delta, where sand deposition was more persistent and transgressions not so influential

• Frequent occurrence of tidal laminae maybe result of tidal amplification within the narrow Shipwreck Trough

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Facies

- Distal mouth bar
- Proximal mouth bar
- Distributary channel
- Cement section
- Delta front

Base case, realisation #1:

Facies model
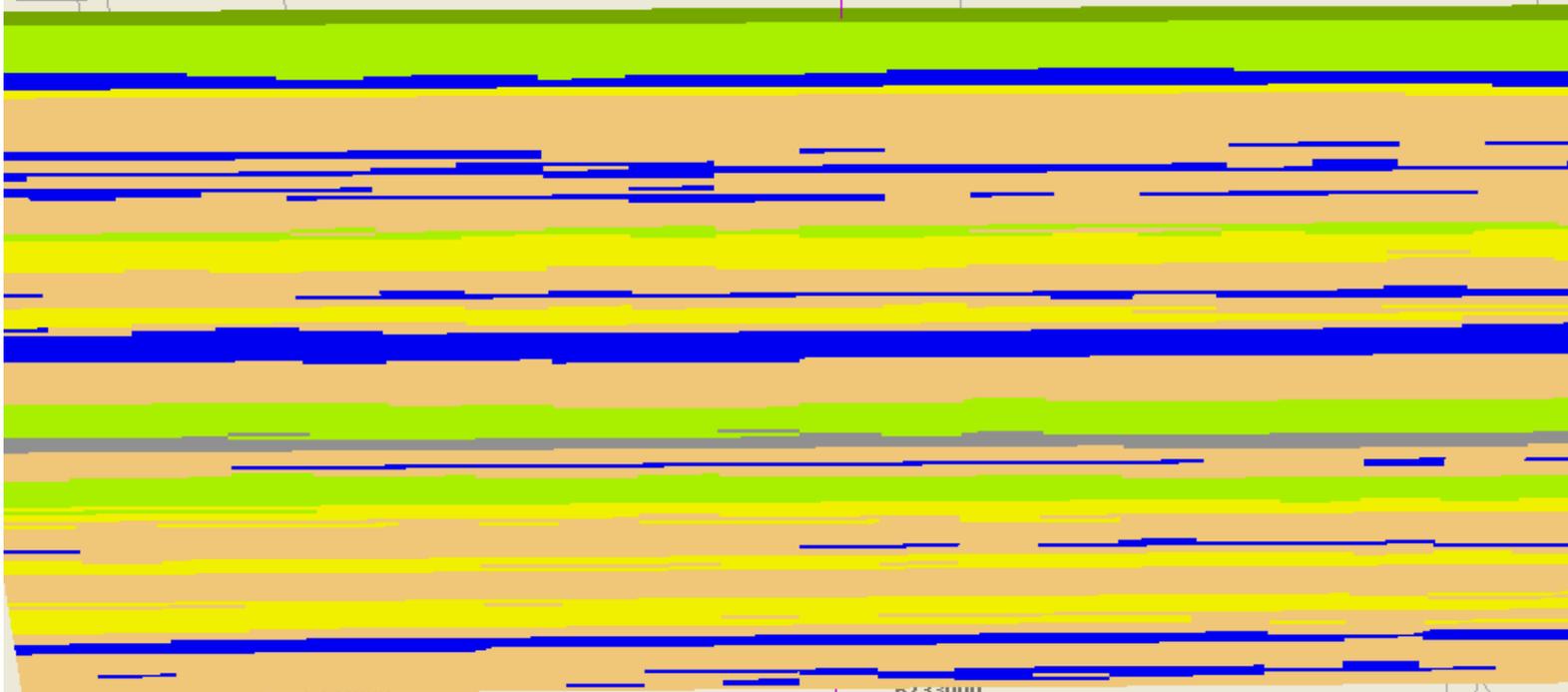
Downhole completion at CRC-2

Residual gas saturation test (Otway Stage 2B)
CRC-2 Well
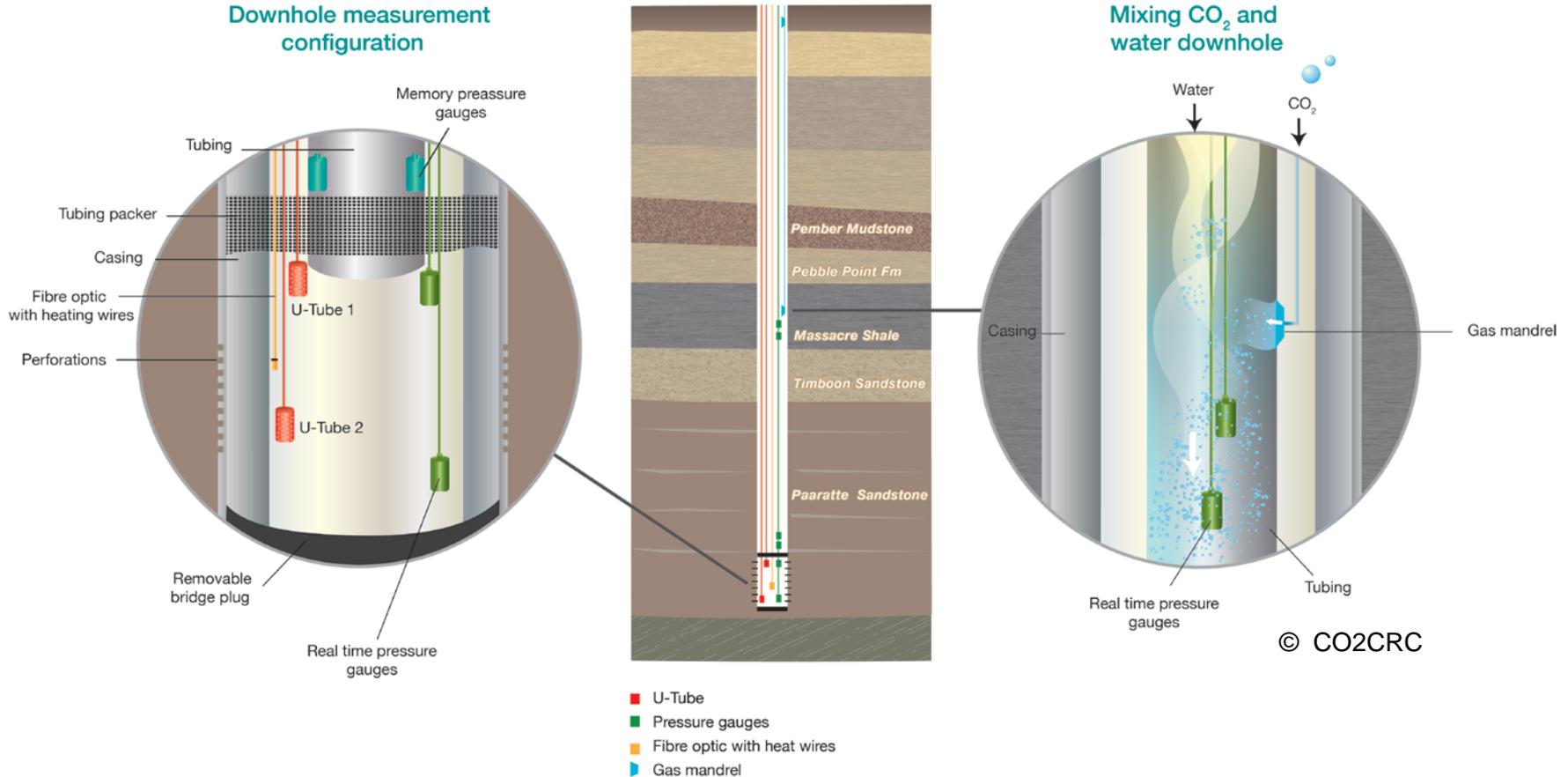
Project Summary

- Injection commenced 2 April 2008; total of approx 65K tonnes carbon dioxide was injected.

- Stage 1 cost A$40M

- Stage 2 may cost A$20M – drilling now complete

- Monitoring & verification a key component

- Learnings include technology, regulation, risk, liability, public interface

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CO2CRC Otway Project milestones

- March 2007: Drilling of CRC-1
- March 18th 2008: Injection commences in CRC-1. Data includes daily injection rates, surface conditions and downhole pressure and temperature gauges, brought up every six months.
- April 4th 2008: First batch of tracers injected: SF_6, CD_4, Kr
- January 2009: Repeat 3D seismic survey.
- January 15th 2009: Second batch of tracer injected.
- August 28th 2009: Injection stops after 65400 tonnes of gas injected (58400 tonnes of CO_2), and well is shut in.
- December 2009: last lot of downhole gauges brought to surface.
- January 2010: Second repeat 3D seismic survey
- Jan/Feb 2010: Drilling of CRC-2 well for stage 2
- **Jan/Feb 2011: Completion of CRC-2**
- **May-June 2011: Stage 2 experimentation at Otway!**

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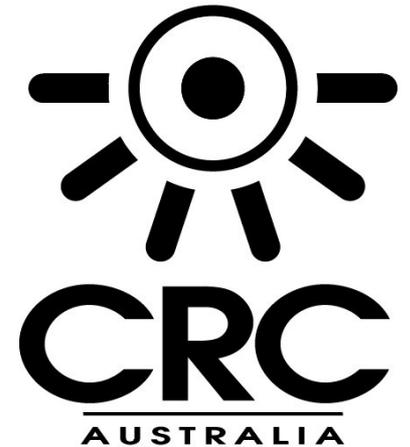
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