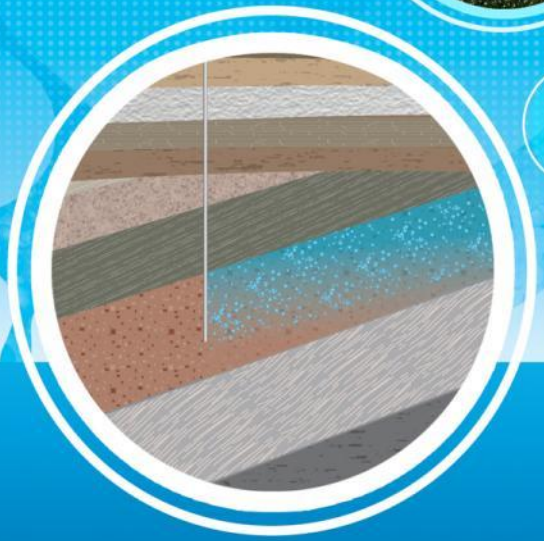
CO2CRC Otway Project



Presenter

Dr Peter J Cook, Chief Executive

(on behalf of the Otway Team)

Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)

Presenting to
DoE Regional Partnerships meeting,
Pittsburgh, October 2010

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CO2CRC

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TOTAL

State Government Victoria Department of Primary Industries

Government of Western Australia
Department of Mines and Petroleum

xstrata coal

CRC AUSTRALIA

Established & supported under the Australian Government's Cooperative Research Centres Program

CO2CRC

CO2CRC OTWAY PROJECT

Particular thanks to...

Lawrence Berkeley National Laboratory

for its outstanding research contribution to the Otway Project

US Department of Energy

for ongoing support of the Otway Project

and

Carbon Sequestration Leadership Forum

for its endorsement of the Otway Project

Researchers involved in the CO2CRC Otway project

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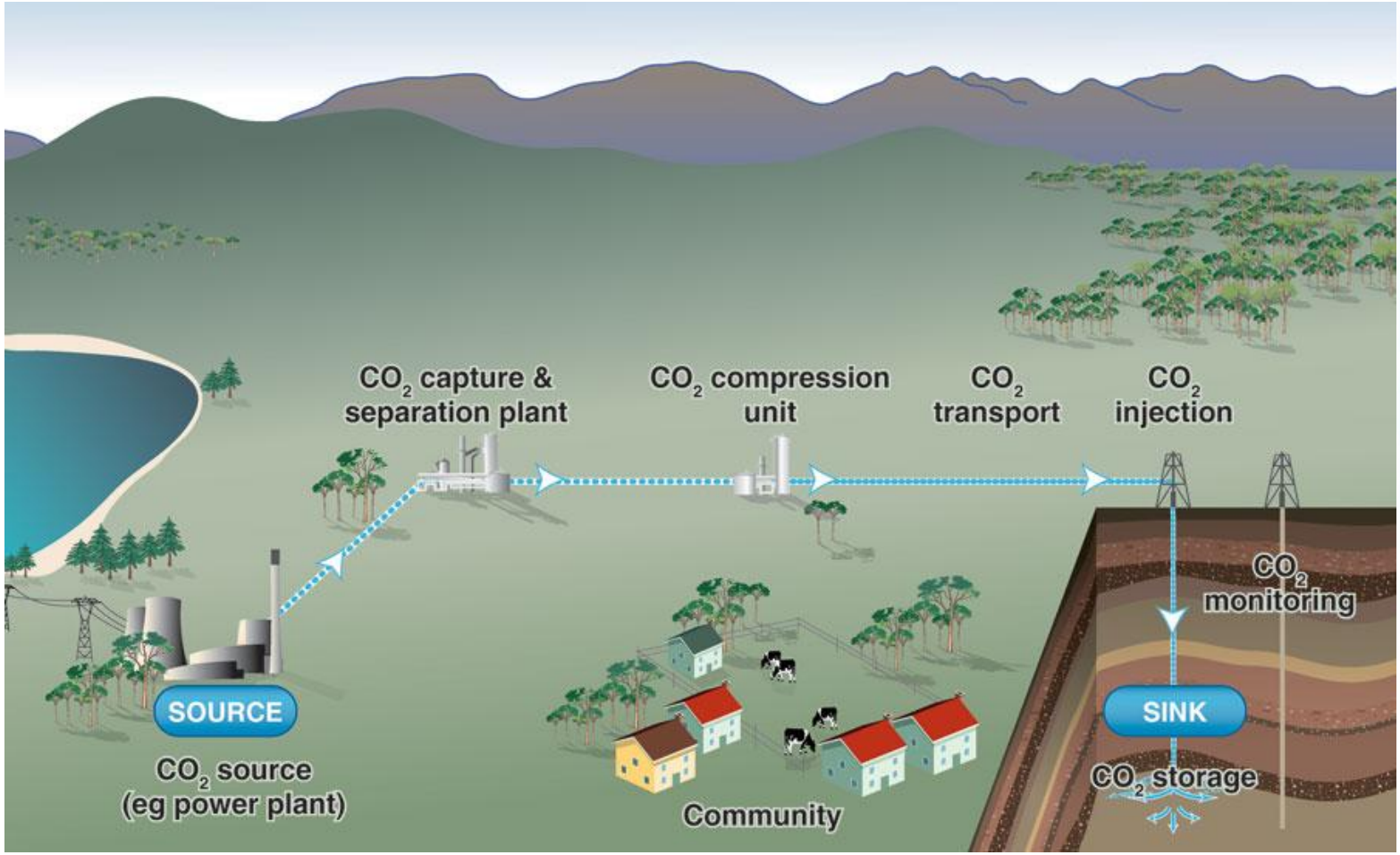
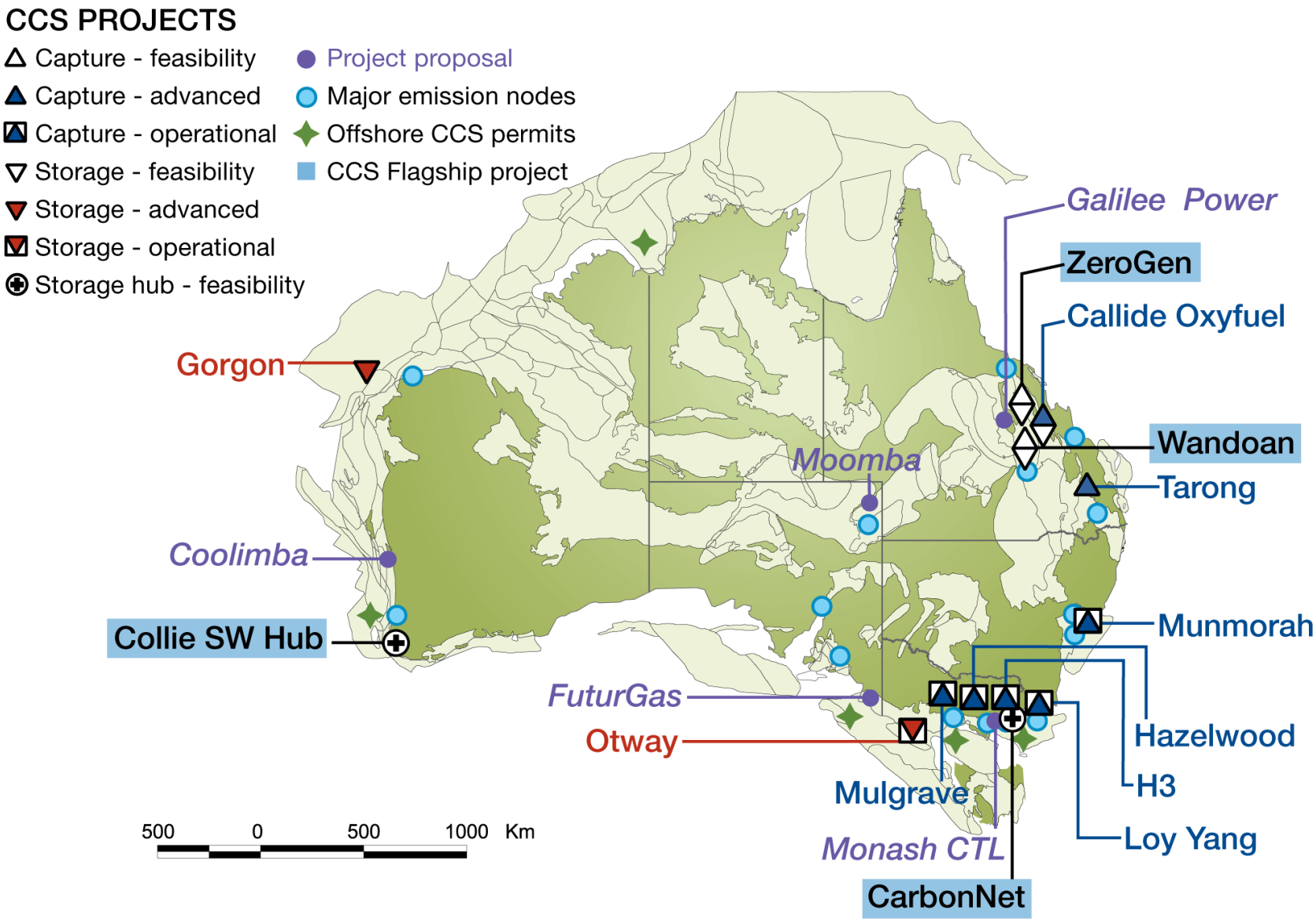
Peter Cook
Tess Dance
Tom Daley
Kevin Dodds
Patrice De Caritat
Jonathan Ennis-King
David Etheridge
Barry Freifeld
Allison Hortle
Charles Jenkins
Anton Kepic
Dirk Kirste
And many others…….

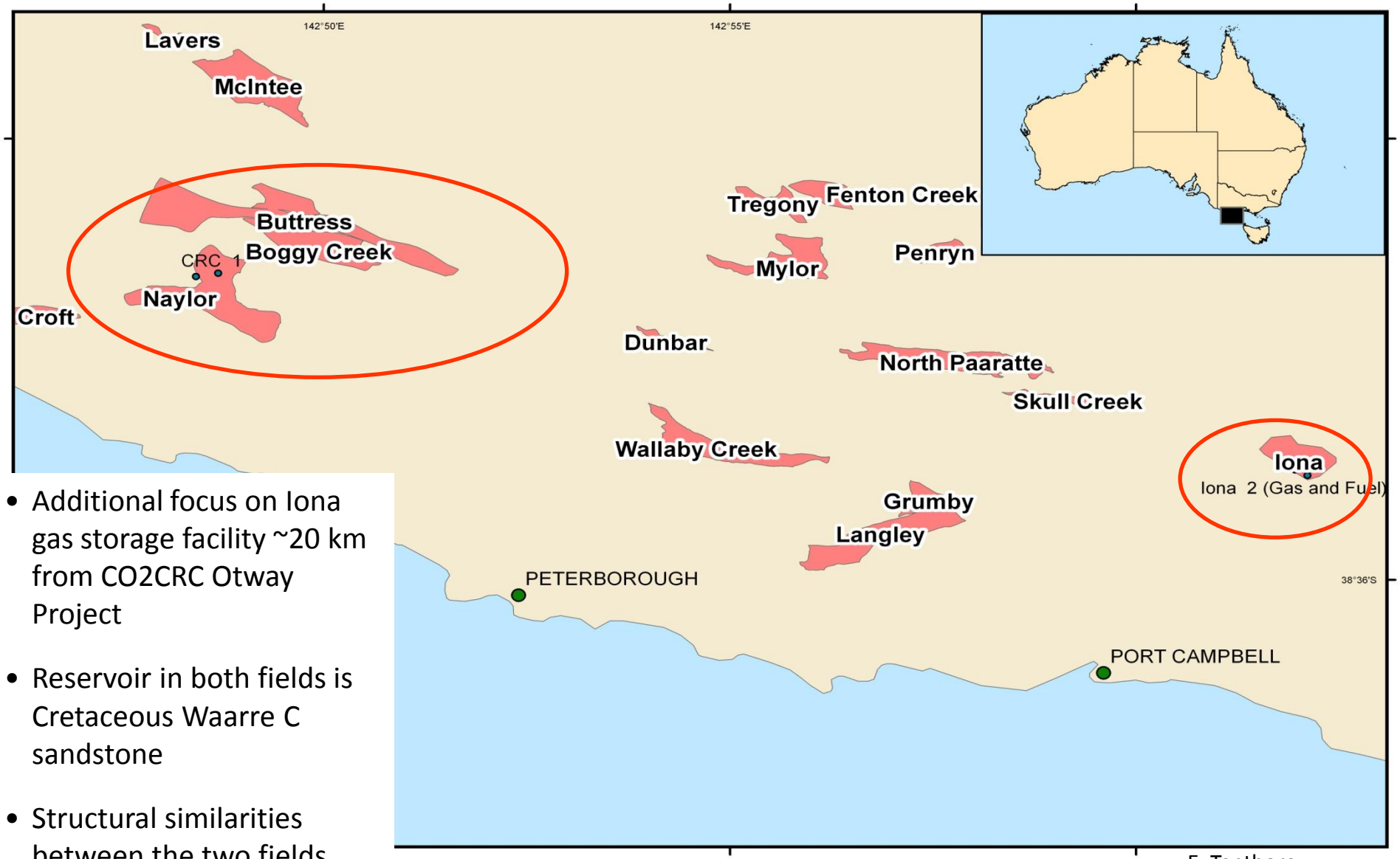
Zoe Loh
Lincoln Paterson
Roman Pevzner
Ernie Perkins
Ulrike Schacht
Sandeep Sharma
Don Sherlock
Valeriya Shulakova
Anthony Siggins
Linda Stalker
Eric Tenthory
Jim Underschultz
Milovan Urosevic
Josh Q Xu
Max Watson

CCS


CO_2 capture & separation plant
CO_2 compression unit
CO_2 transport
CO_2 injection
CO_2 monitoring
SOURCE
CO_2 source (eg power plant)
Community
SINK
CO_2 storage


CCS PROJECTS
Capture - feasibility
Capture - advanced
Capture - operational
Storage - feasibility
Storage - advanced
Storage - operational
Storage hub - feasibility
Project proposal
Major emission nodes
Offshore CCS permits
CCS Flagship project
Galilee Power
ZeroGen
Callide Oxyfuel
Gorgon
Wandoan
Moomba
Tarong
Coolimba
Collie SW Hub
Munmorah
FuturGas
Otway
Hazelwood
H3
Mulgrave
Loy Yang
Monash CTL
CarbonNet
500 0 500 1000 Km

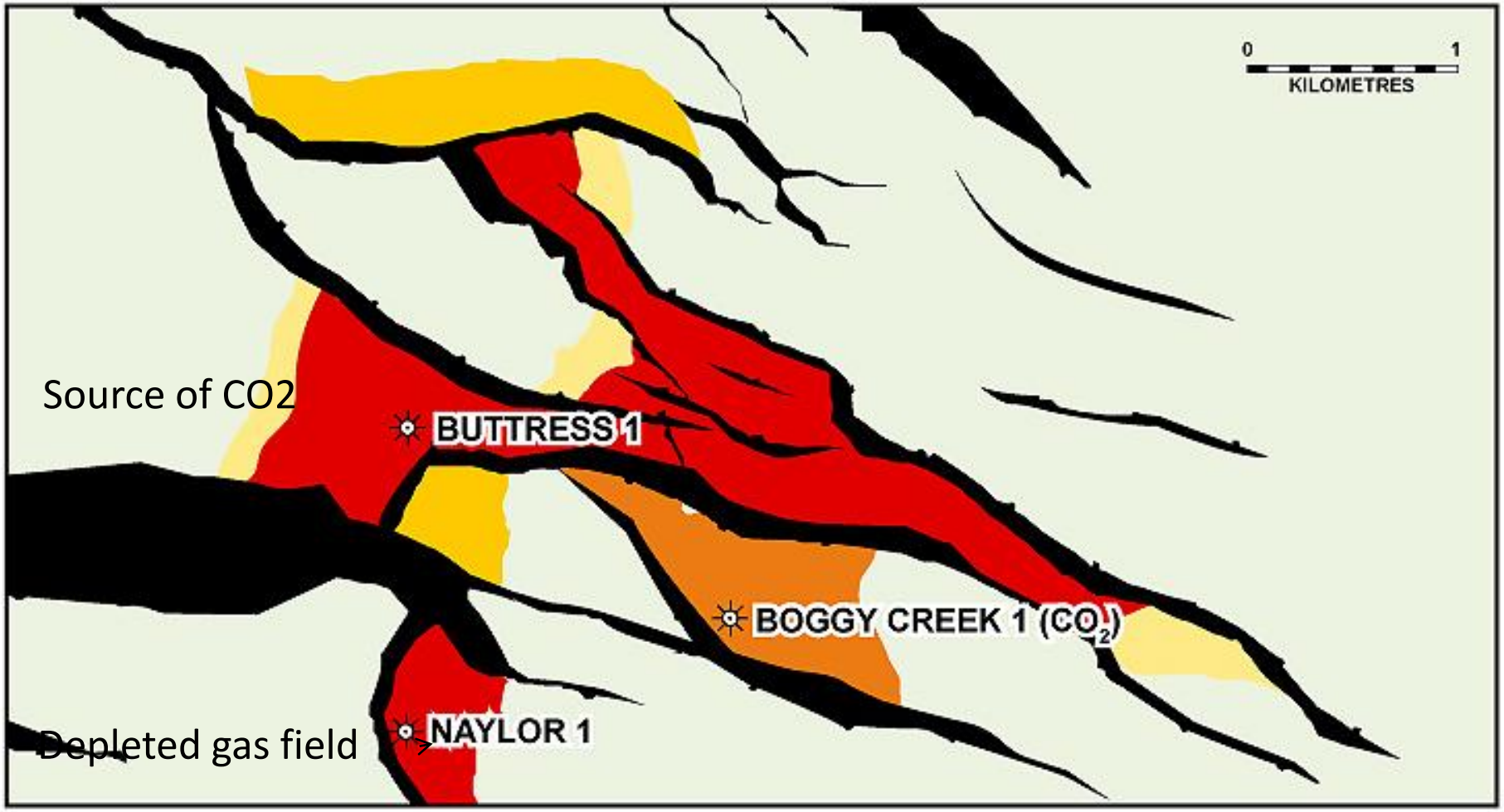
Location of CO2CRC Otway Project



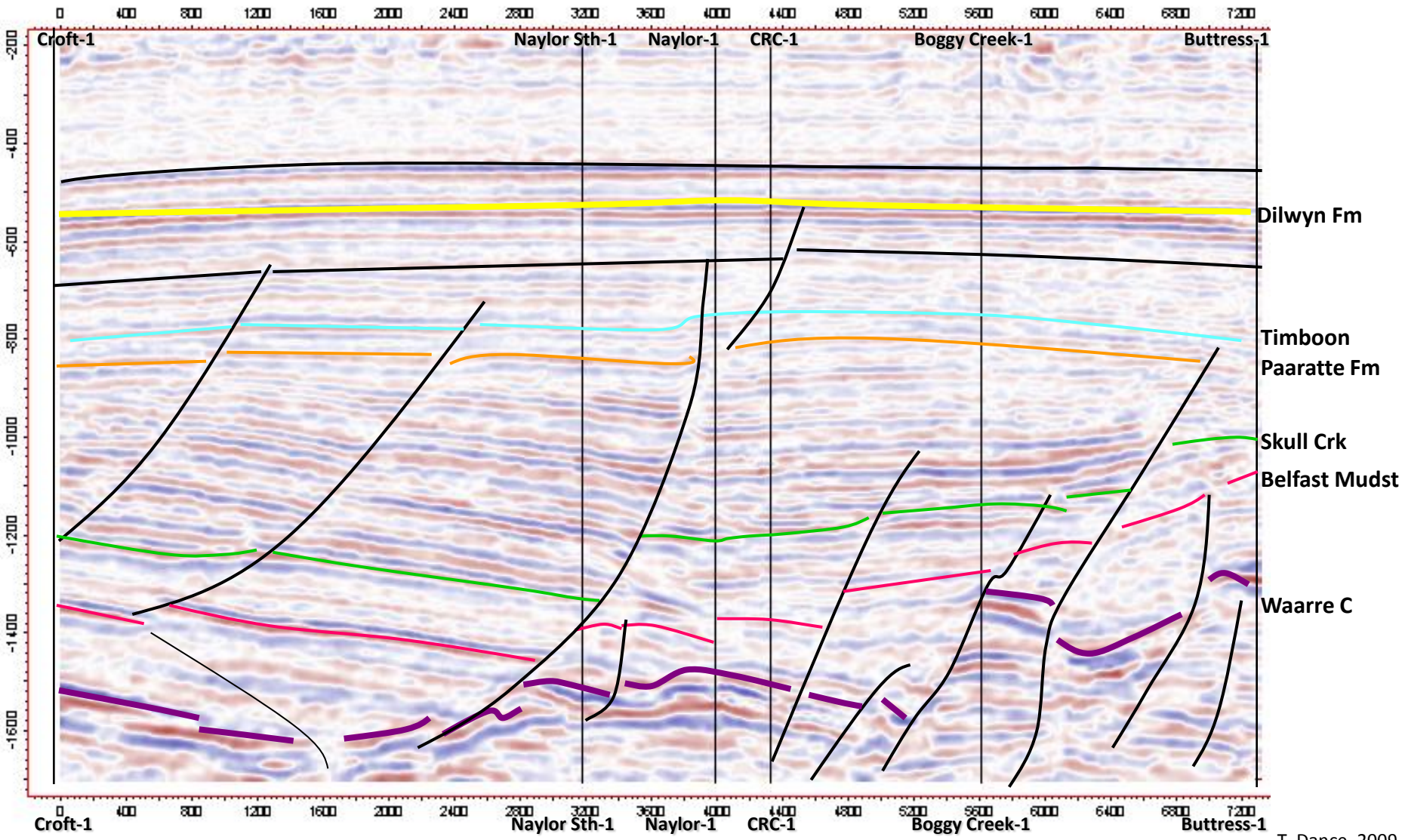
- Additional focus on Iona gas storage facility ~20 km from CO2CRC Otway Project
- Reservoir in both fields is Cretaceous Waarre C sandstone
- Structural similarities between the two fields

E. Tenthorey

Sealing Faults in the vicinity of the CO2CRC Otway Project

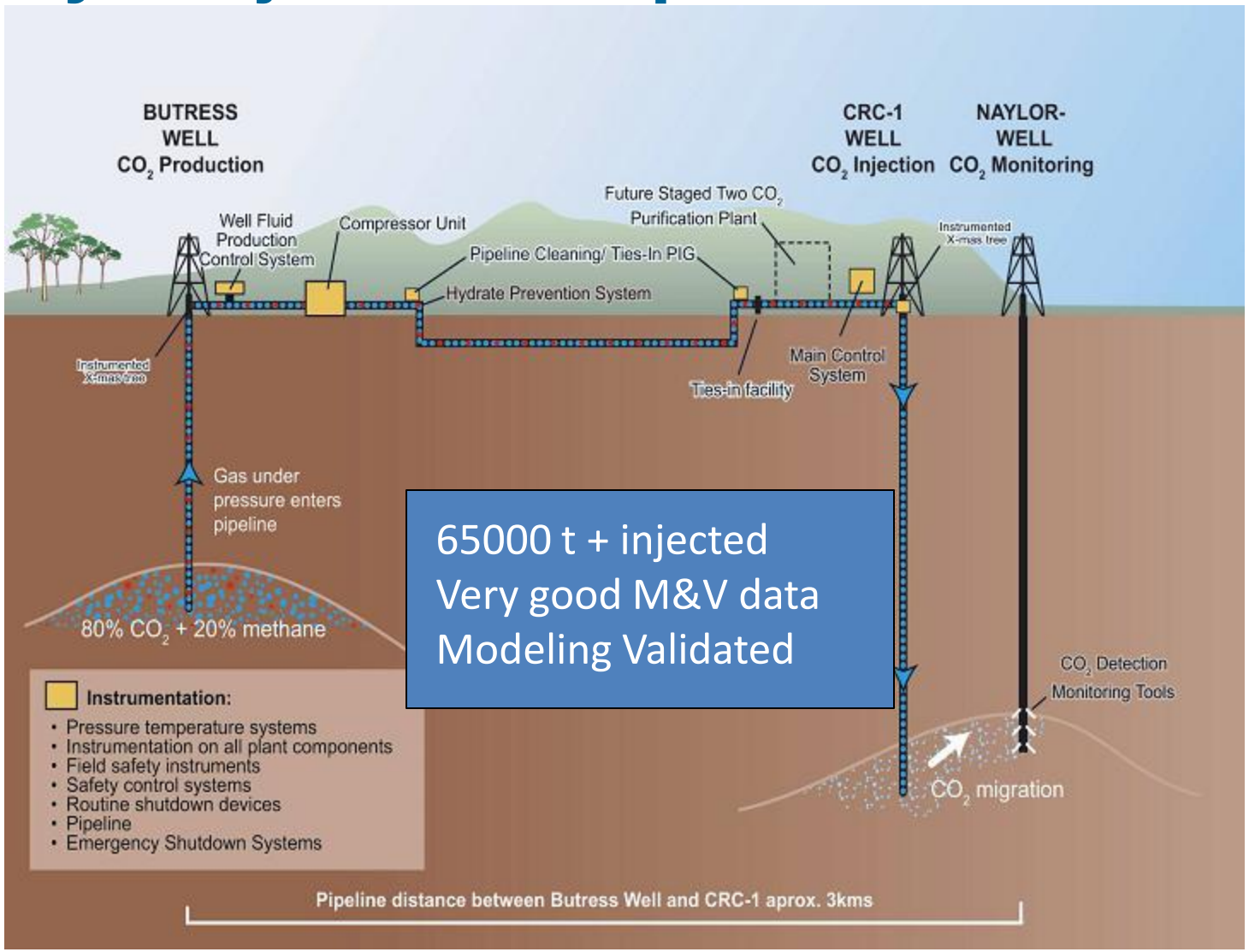


Sub-surface characterisation: seismic interpretation



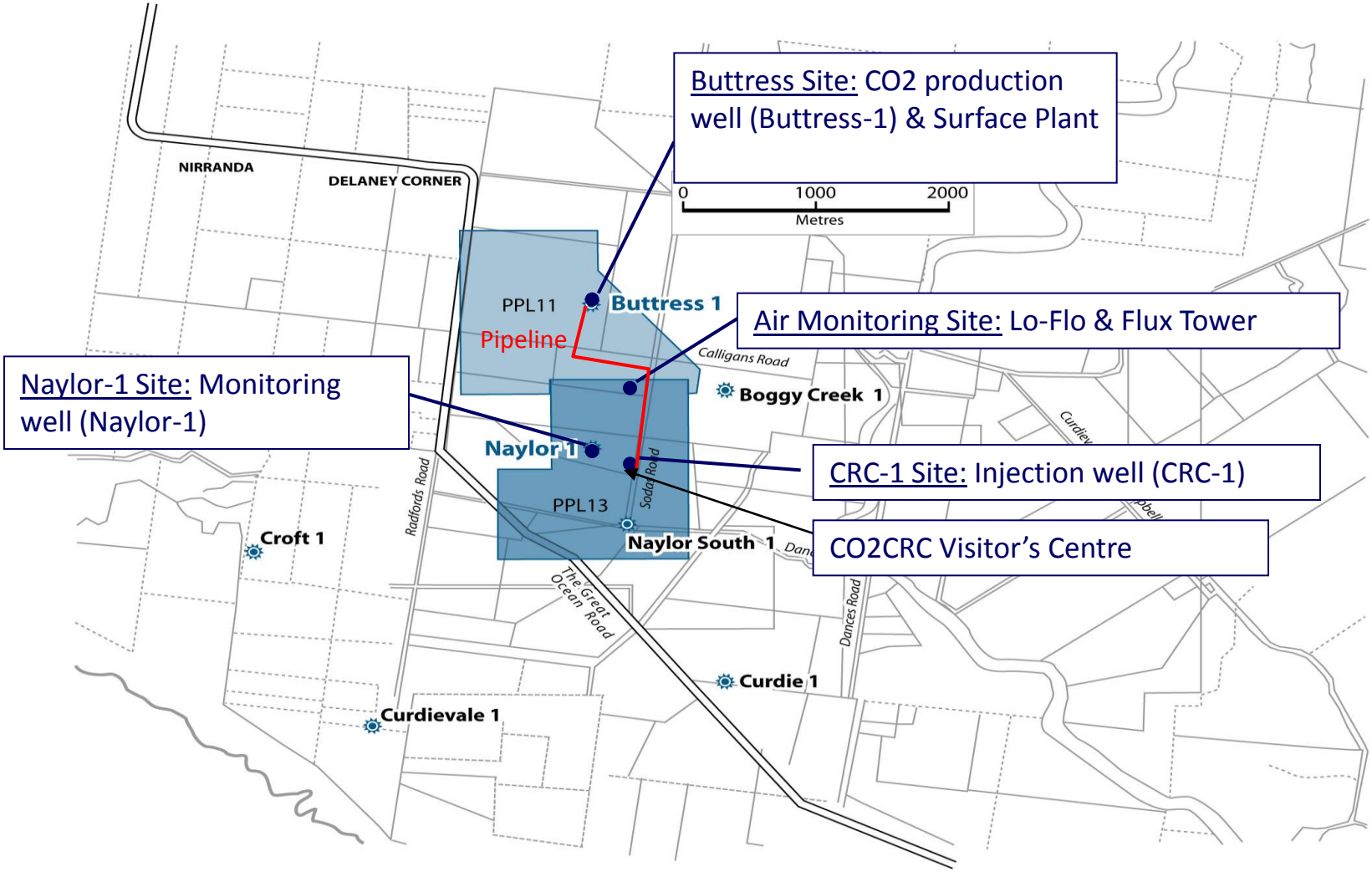
T. Dance, 2009

Otway Project Concept

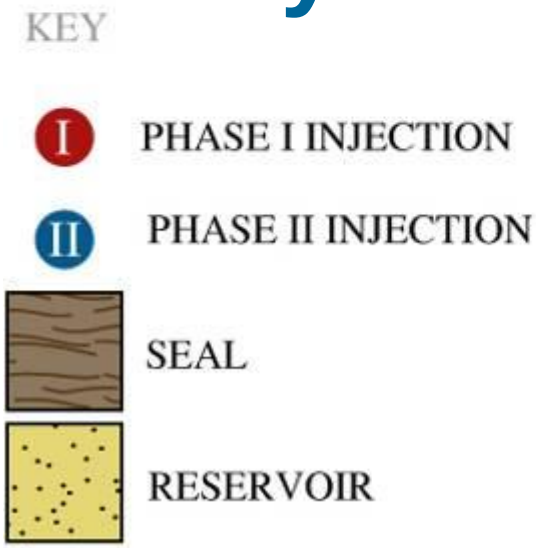


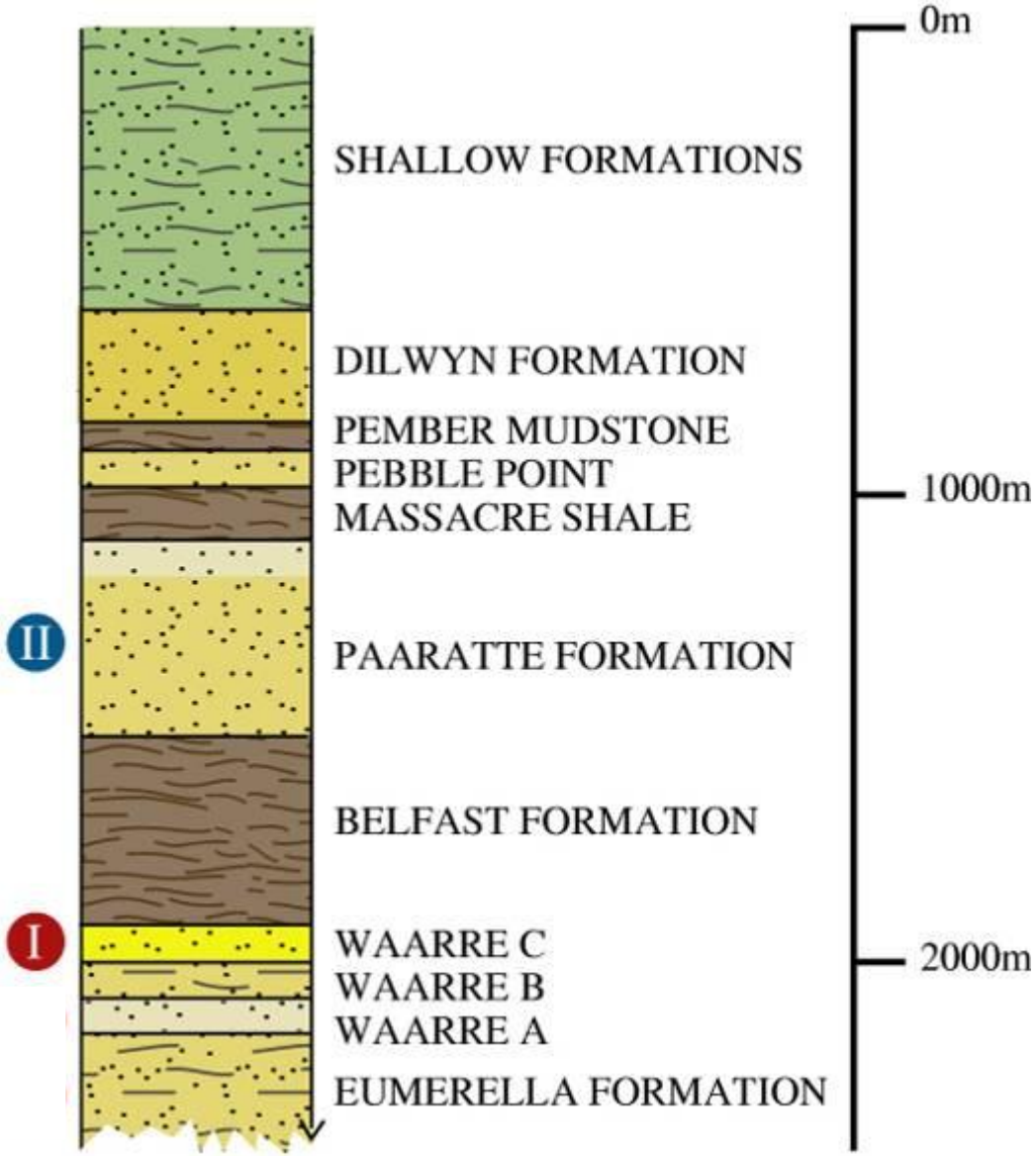
65000 t + injected
Very good M&V data
Modeling Validated

CO2CRC Otway Project facilities

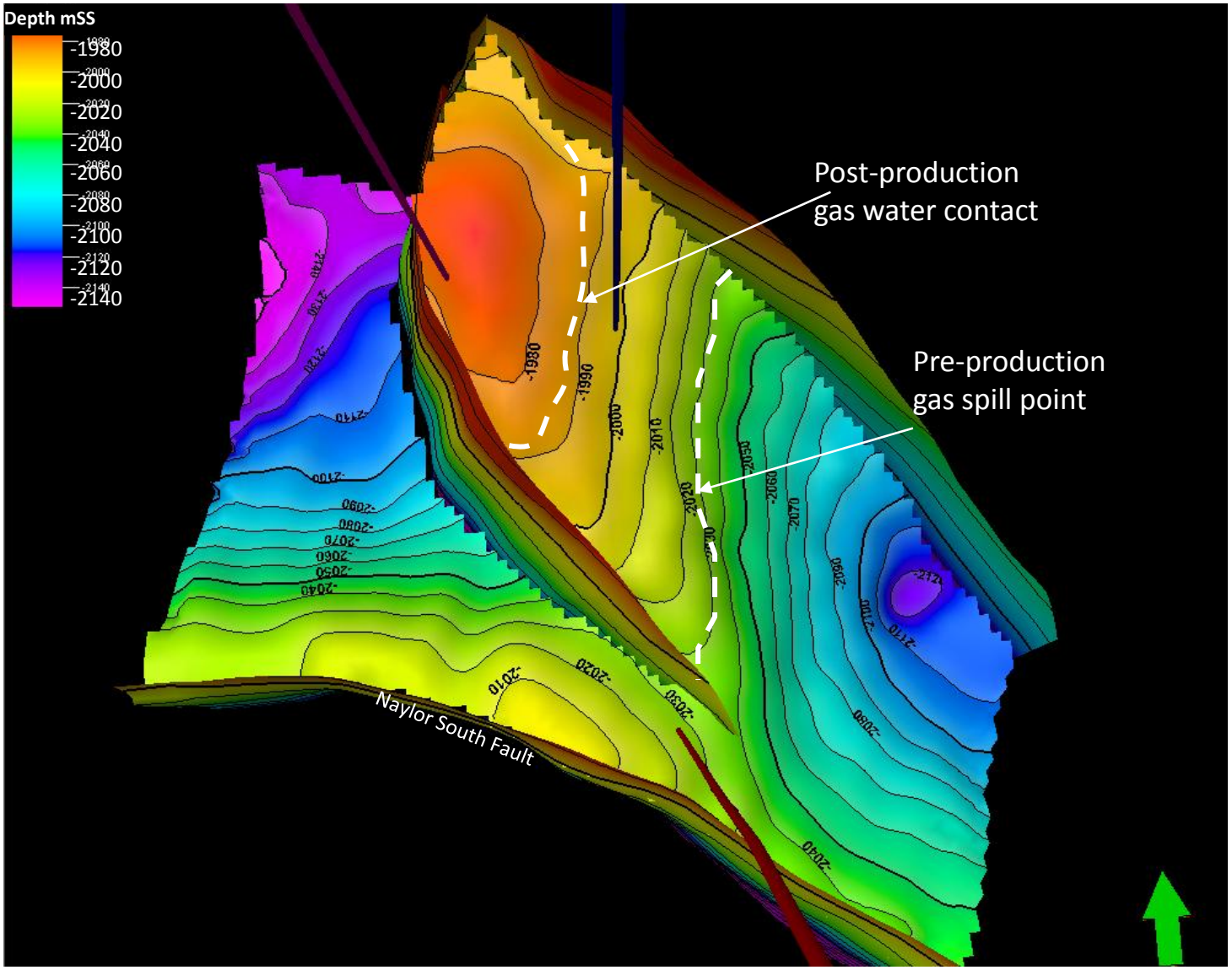


Schematic Stratigraphic Column of Otway Basin



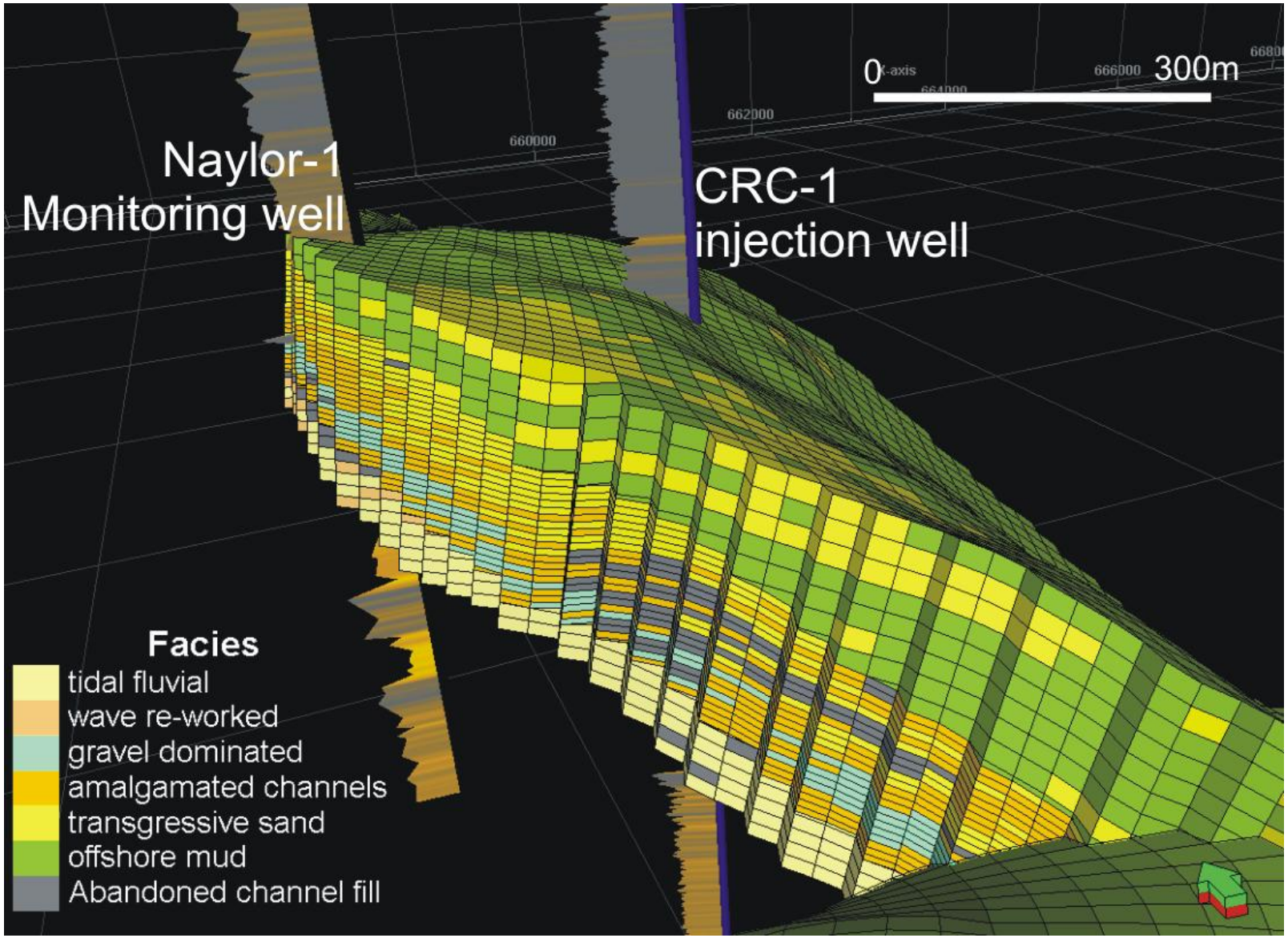


Sub-surface characterisation: structural mapping



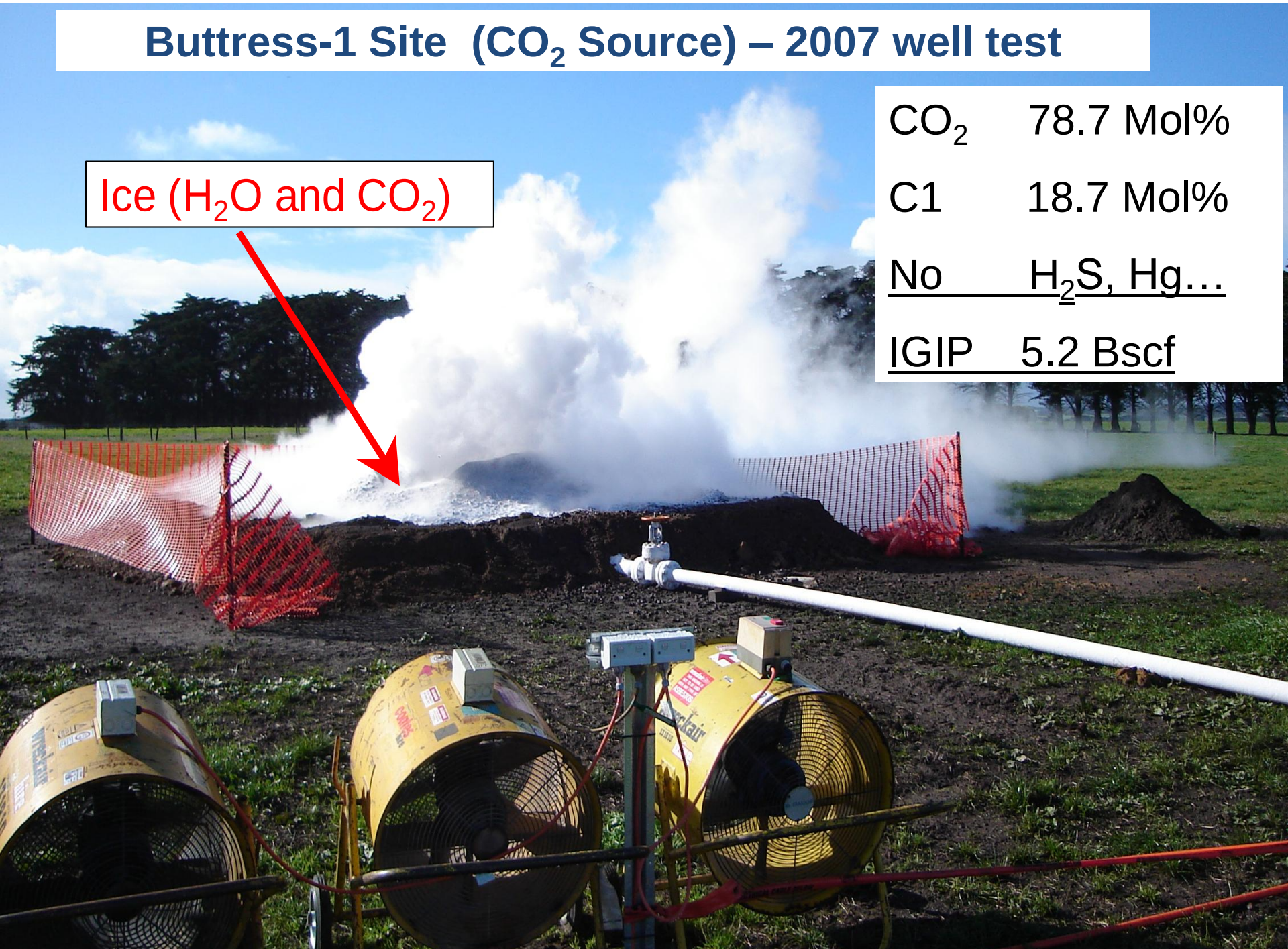
T. Dance, 2008

Sub-surface characterisation: static model



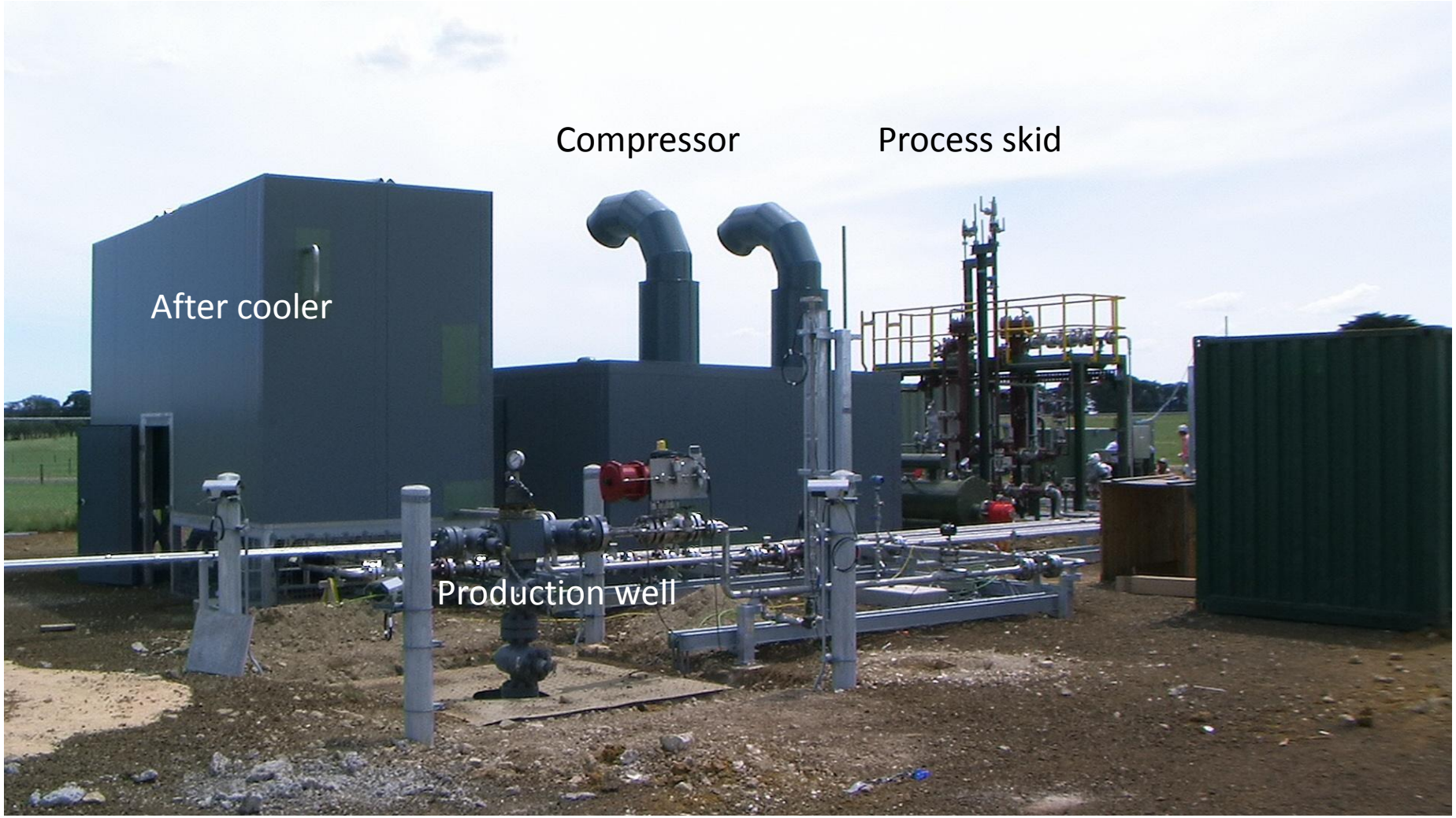
T. Dance

Buttress-1 Site (CO_2 Source) – 2007 well test



CO_2	78.7 Mol%
C1	18.7 Mol%
No	H_2S, Hg…
IGIP	5.2 Bscf

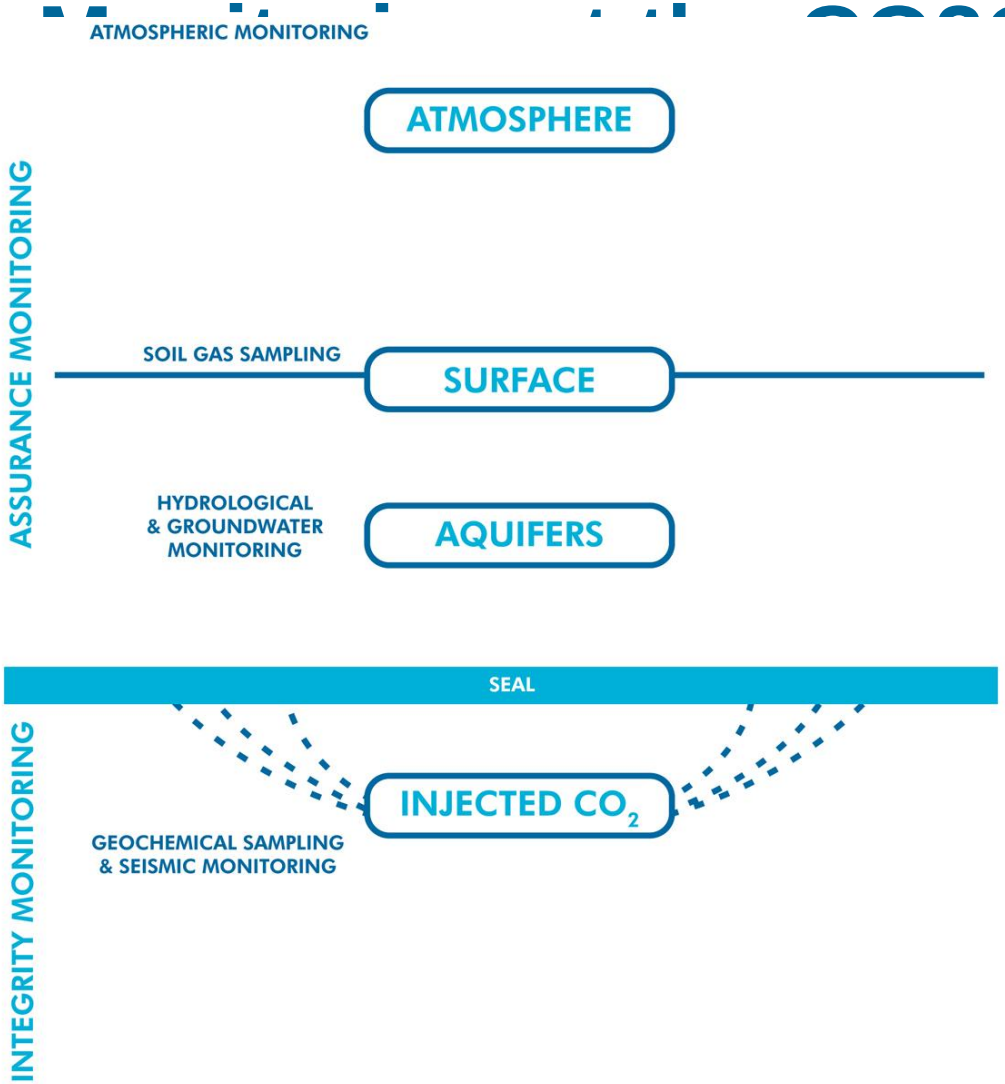
Buttress-1 Site (CO_2 Source) – April, 2009



Transporting the CO_2 by pipeline

Naylor-1 Site (Monitoring Well)

way site



"Well Test"

Once Per Year

Twice Per Year

No Tracers

Fortnightly
(under review)

Atmospheric monitoring

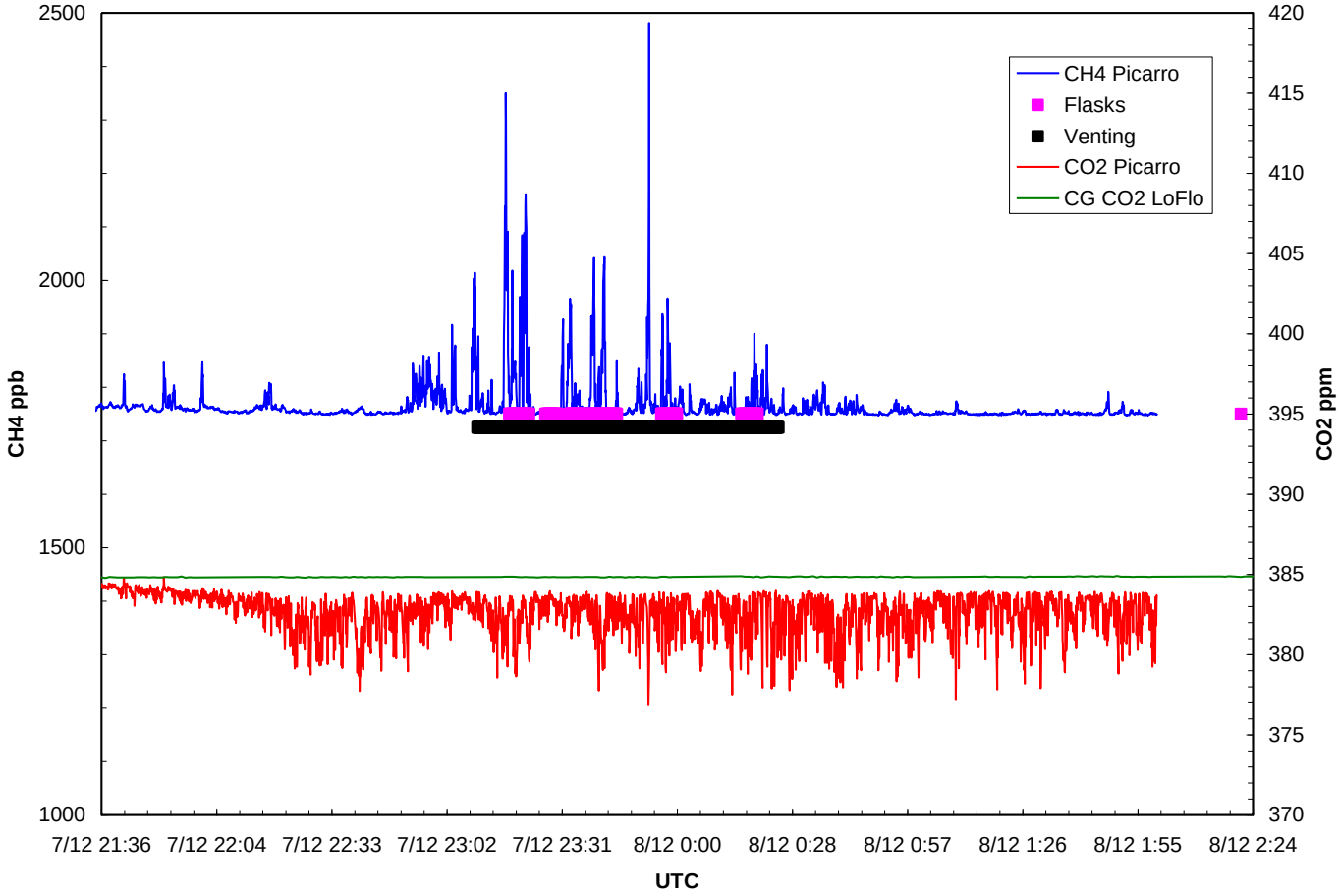
Atmospheric module

Flux station

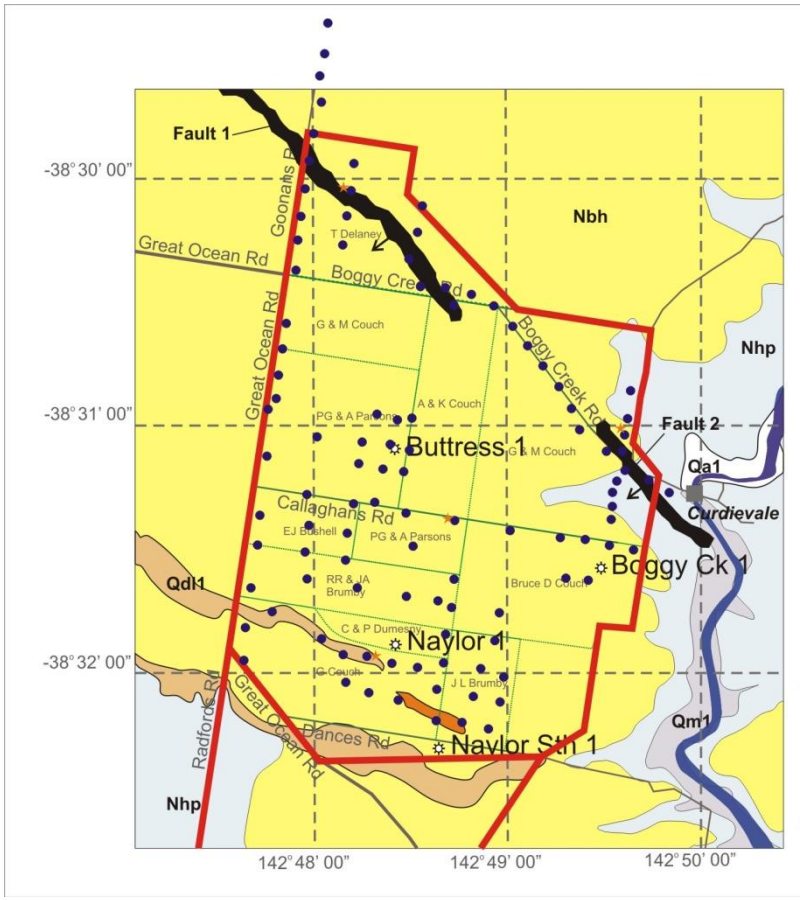
D. Etheridge et al., CSIRO

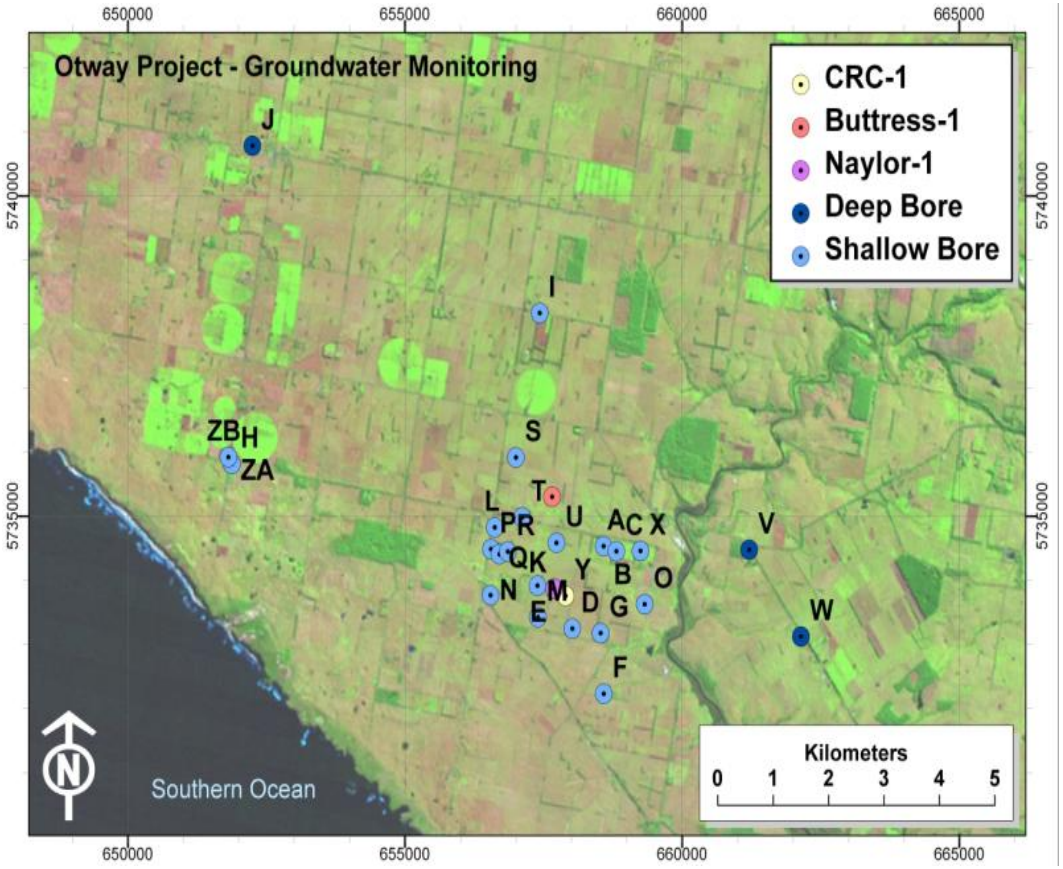
- Monitoring began late 2006
- Existing CO_2 sources characterised
- No evidence of emissions from CO_2 storage to date
- Monitoring using CO_2 concentration alone needs ideal conditions, so other species including CH_4,SF_6, CO and $^{13}CO_2$ are monitored to enhance sensitivity

Atmospheric monitoring –Naylor release



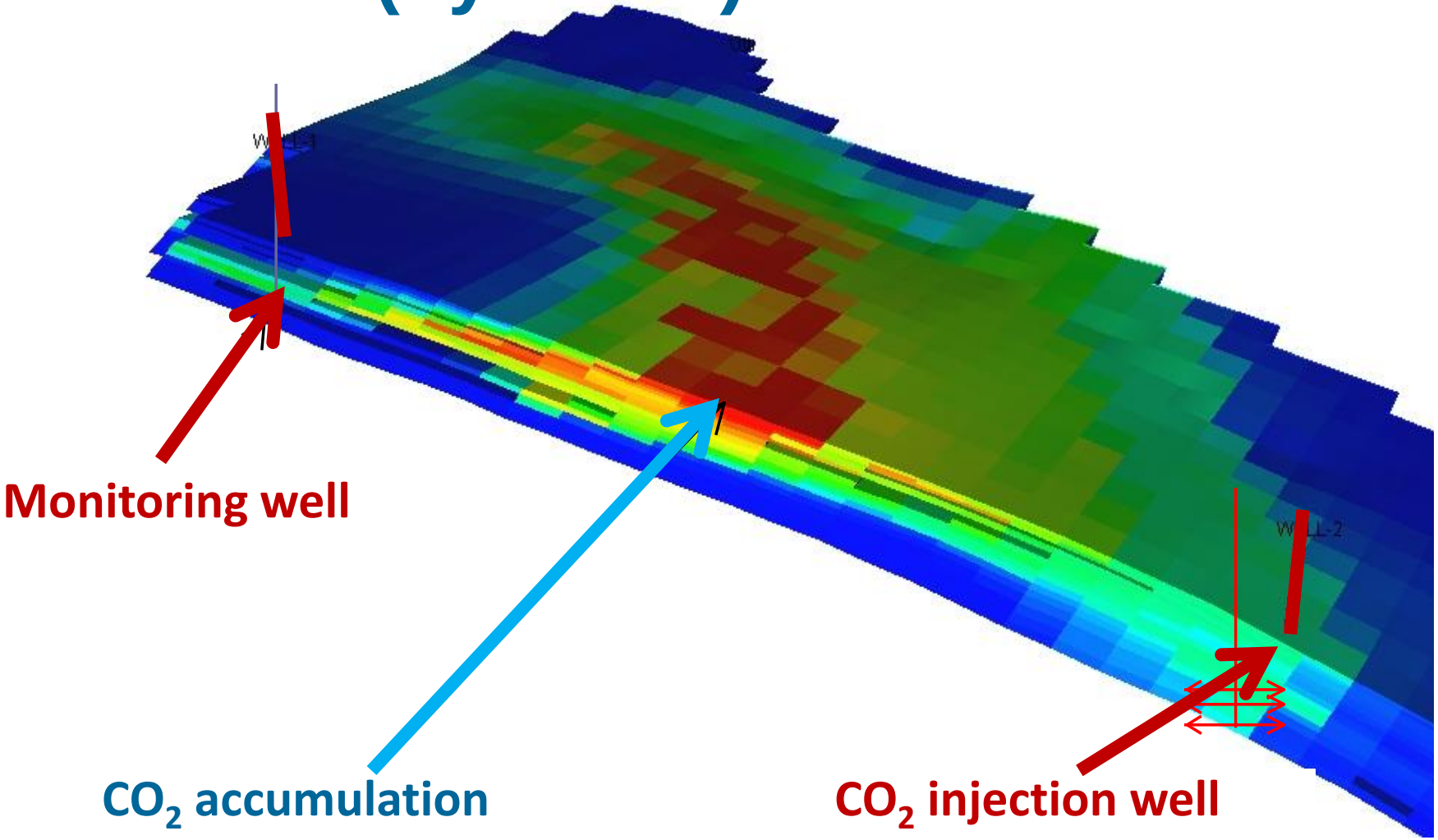
Soil Gas and Water Sampling





J. Underschultz &A. Hortle, 2008

Sub-surface characterisation: reservoir (dynamic) model

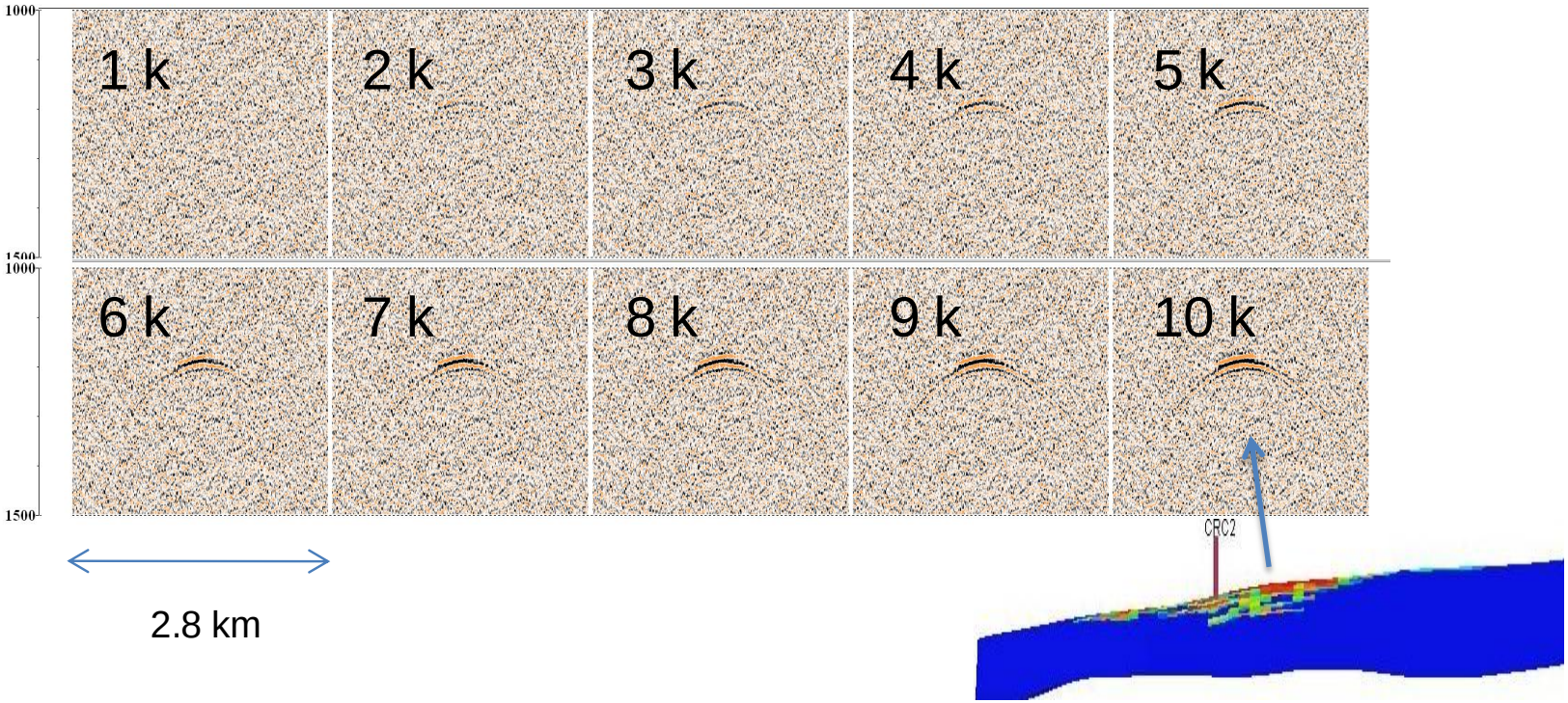


J. Ennis-King

Operational Challenges

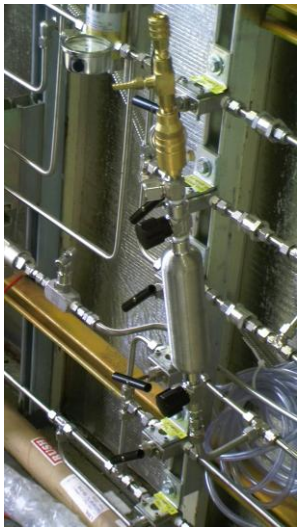
- Boggy ground, windy, rain
- Electric fences – everywhere!
- Noise from local activities
- Access issues: Dairy farms, paddocks, fences

2D sensitivity modelling of a CO_2 "leak" into the Paaratte saline formation - model from reservoir simulation



The CO_2 quantities shown in thousand tonnes. CO_2 occupies thin layer, with small areal extent (less then Fresnel radius) - diffracted energy is roughly proportional to CO_2 volume; 30% of background noise added to synthetic

Downhole fluid sampling

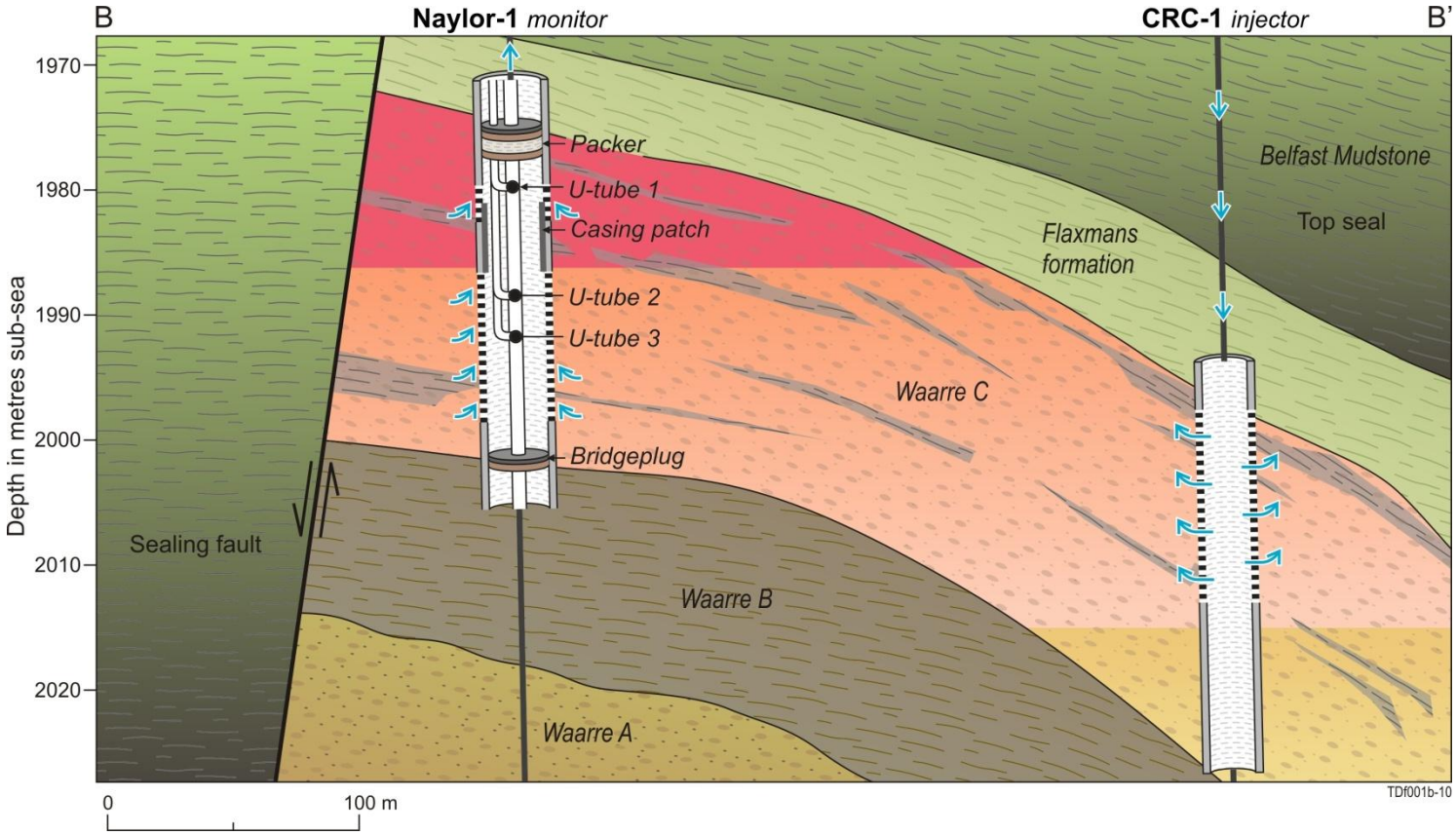


– U-tube surface facility (yellow container) – above

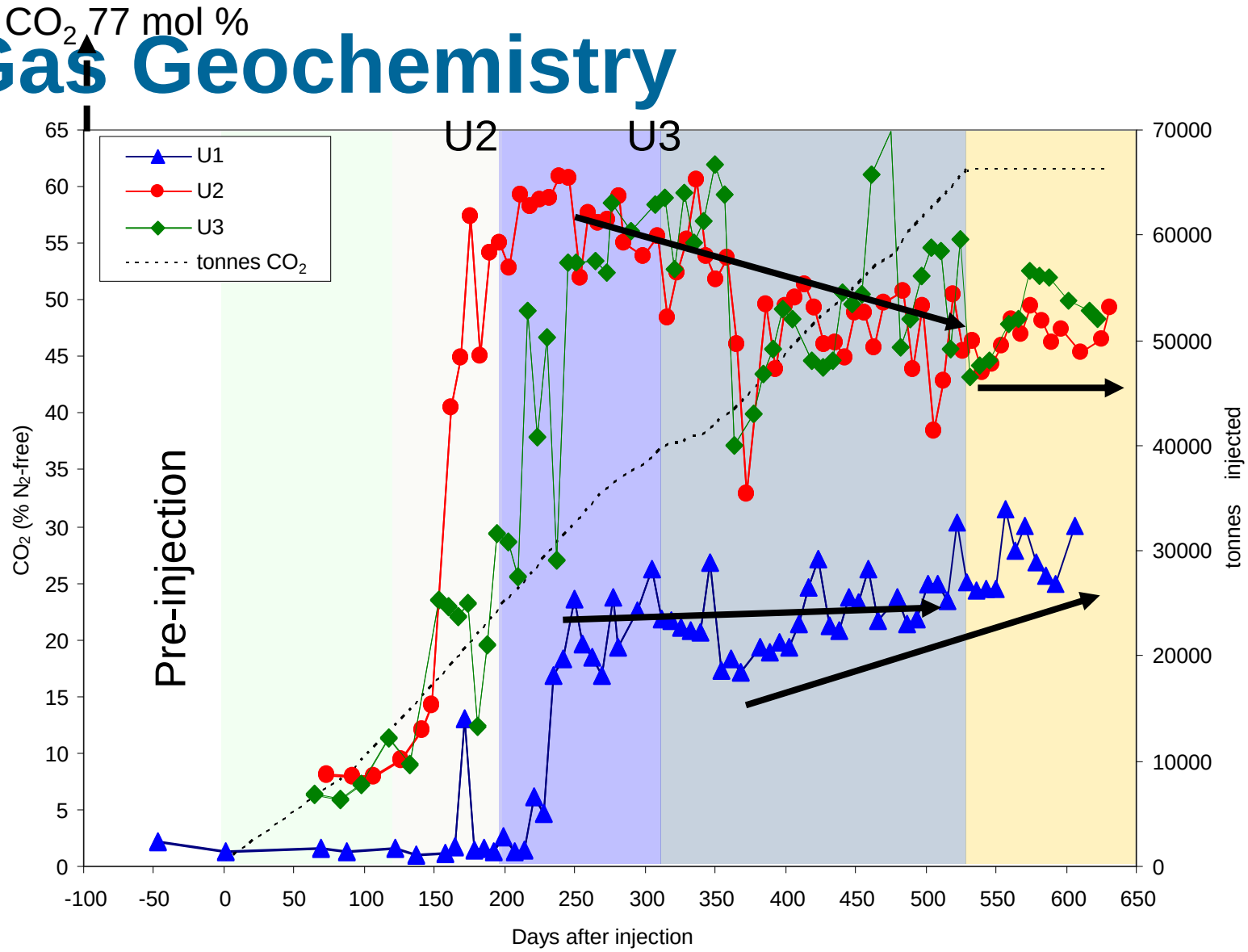
– Isotube sample cylinder – left

- Inside the u -tube surface facility - right

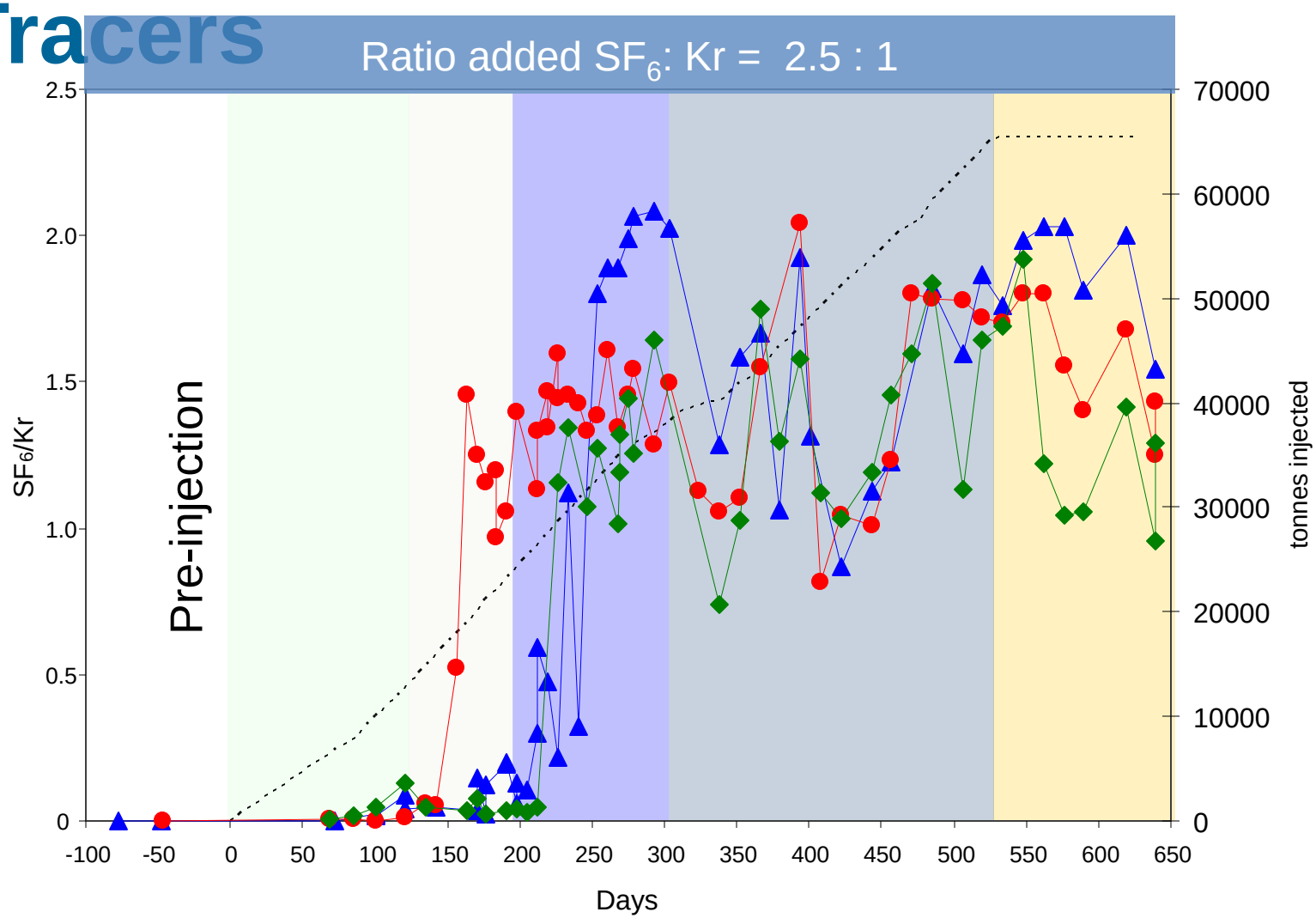
Naylor U-tube system



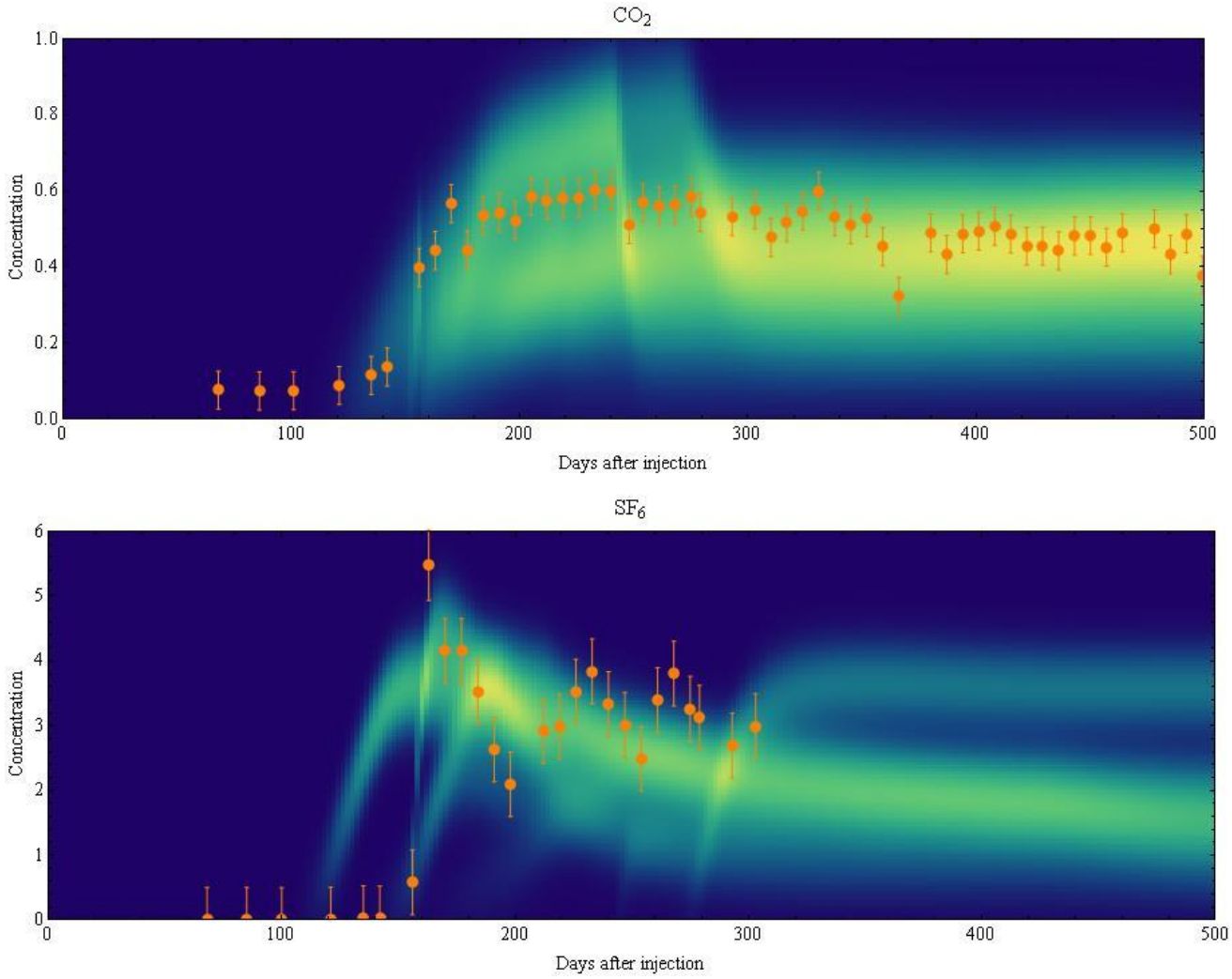
Gas Geochemistry



Tracers


Ratio added SF6: Kr = 2.5 : 1
Pre-injection
SF6/Kr
tonnes injected
Days
2.5
2.0
1.5
1.0
0.5
0
70000
60000
50000
40000
30000
20000
10000
0
-100
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650

Naylor: predictions & data



Summary Stage I

- **Assurance monitoring programme is recording "baseline" before and after injection**
  - A valuable dataset for future M&V design
  - Sustains Otway site for future injections
- **Seismic has verified no significant leakage into sentinel aquifer**
  - Results at Waare-C level are consistent with models
- **U-tube data from Naylor a rich source of information**
  - Consistent with reservoir models, accounting for geological uncertainty

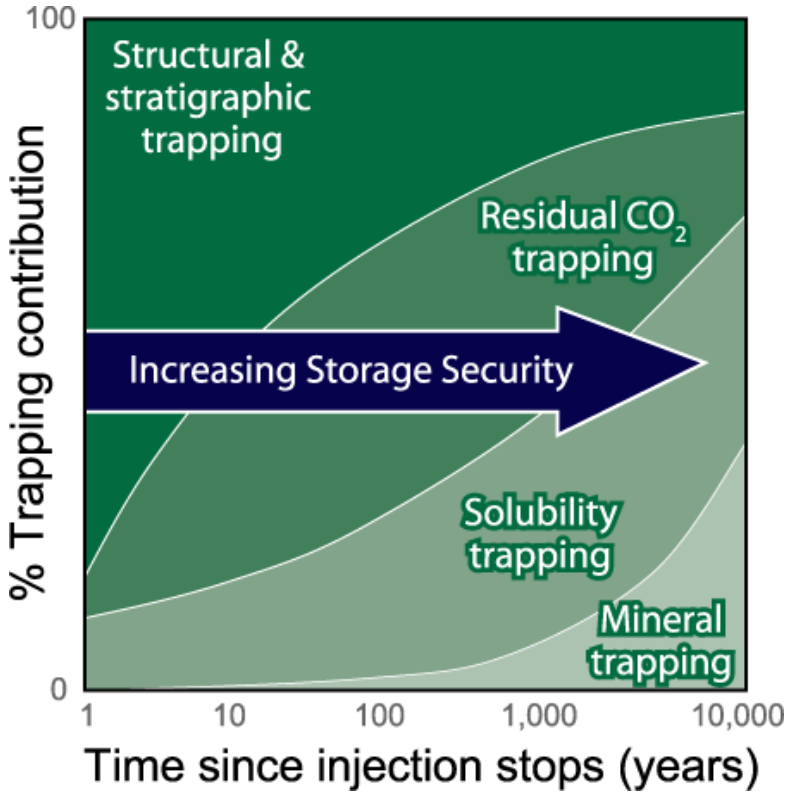
Conclusions

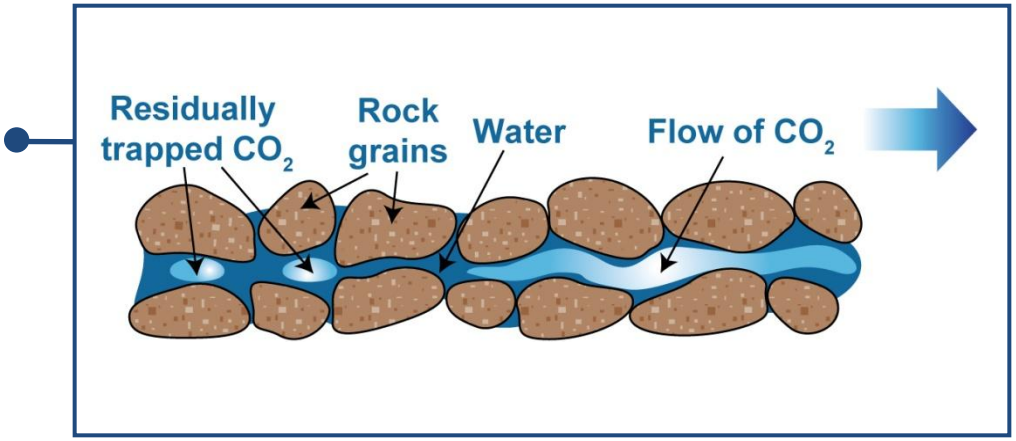
- Successful injection of 65,445 tonnes CO2 into a depleted hydrocarbon reservoir., with no migration out of the reservoir
- “Breakthrough” clearly recorded at the early end of predicted range (4-8 months).
- Successful sampling of ‘in situ’ formation fluids from 2 km depth over extended time with the U-tubes.
- Initial Dynamic Model successfully predicted bulk behaviour.
- Pre-Injection Dynamic Model successfully predicted U-2 and U-3.
- U-1 shows much more mixing than predicted.
- The forecast storage capacity of the reservoir closely matched Naylor U-Tube recordings.

CO_2 injection into Paaratte – CO2CRC Otway Project Stage 2

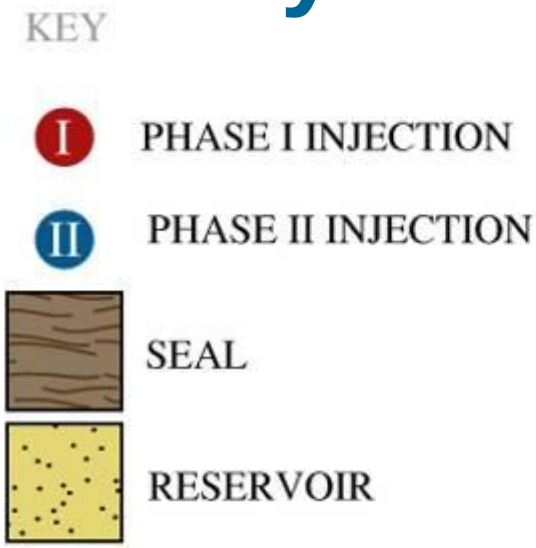
CO2CRC team

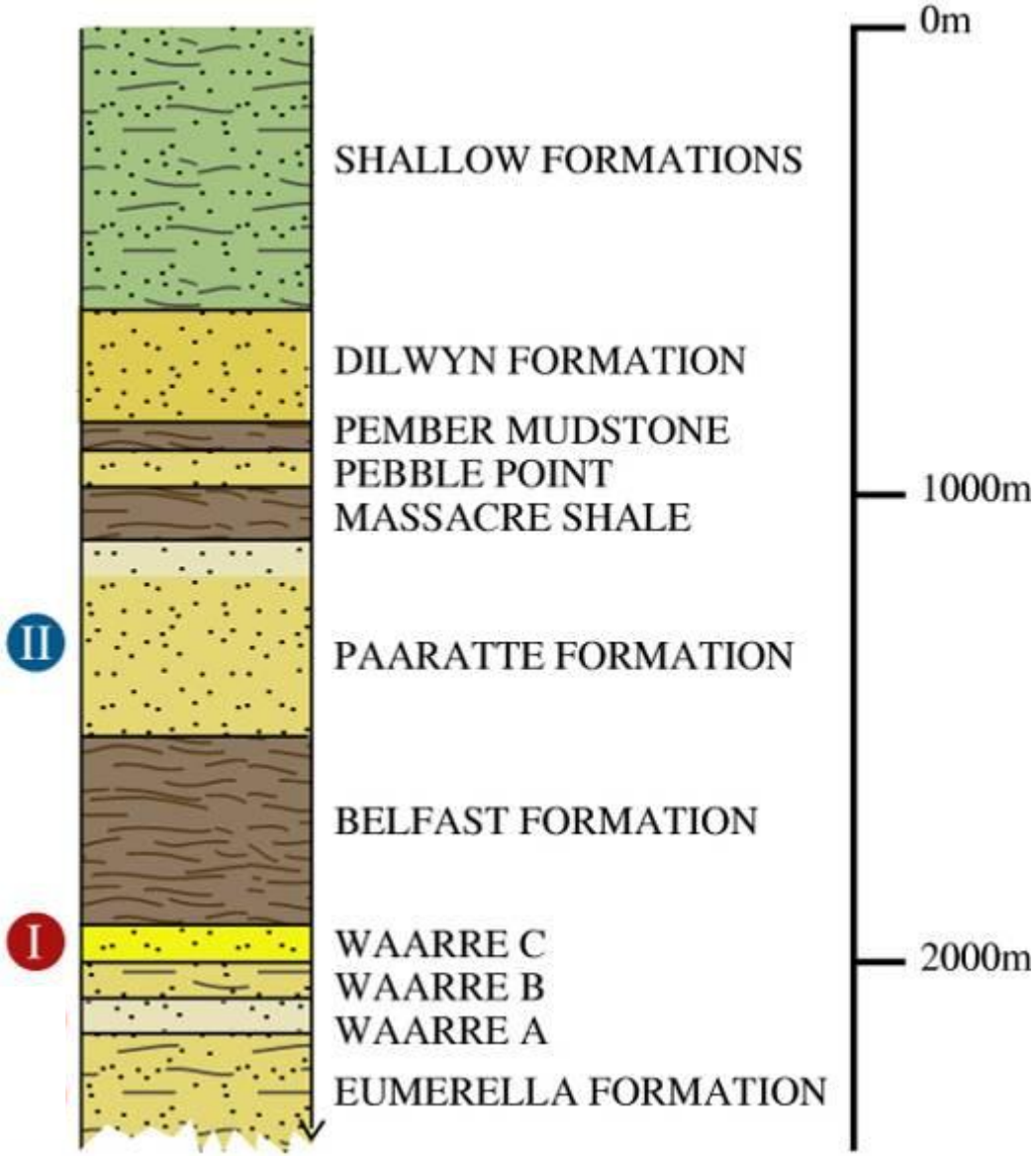
Residual gas trapping of CO_2



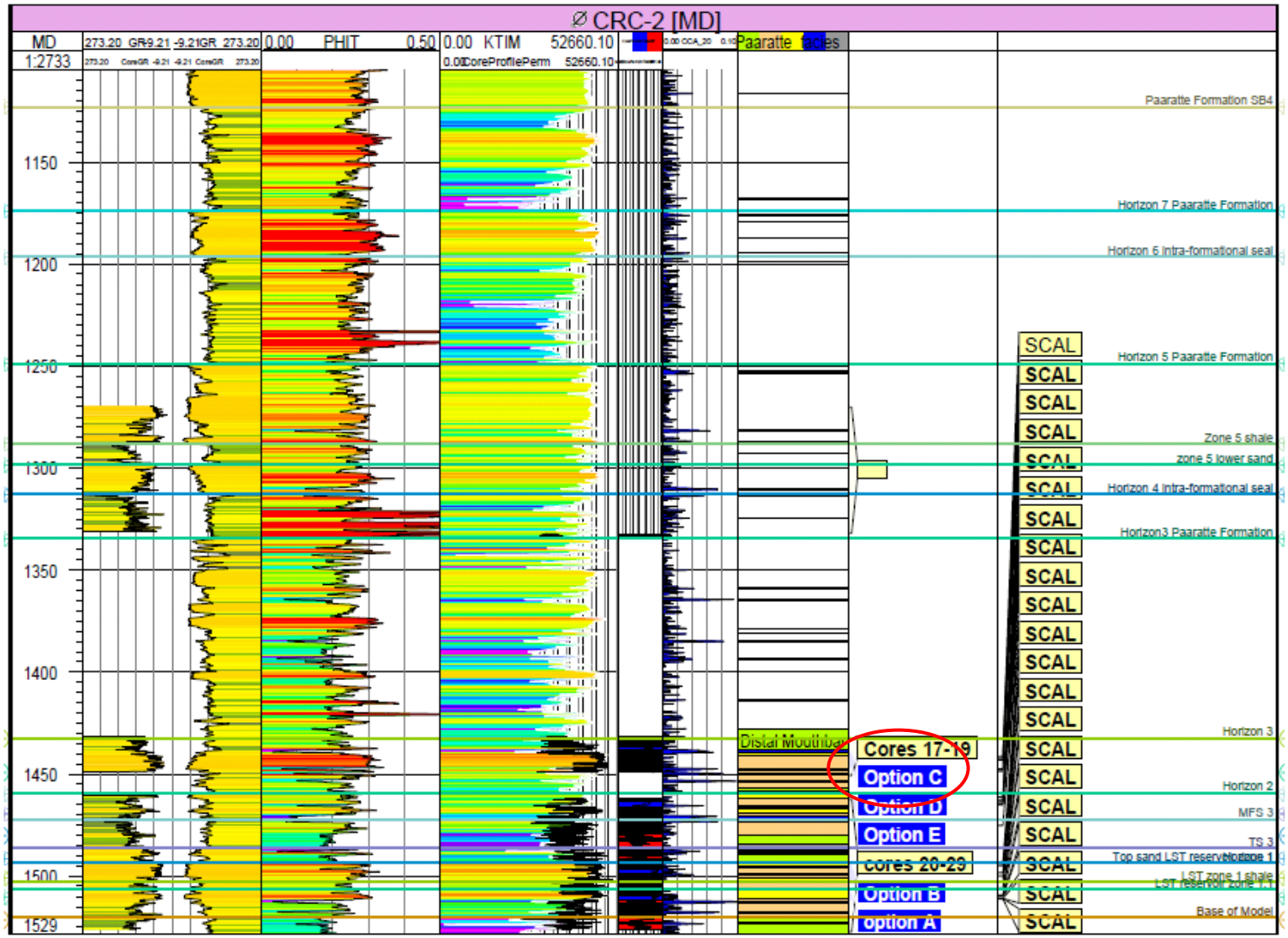


Schematic Stratigraphic Column of Otway Basin

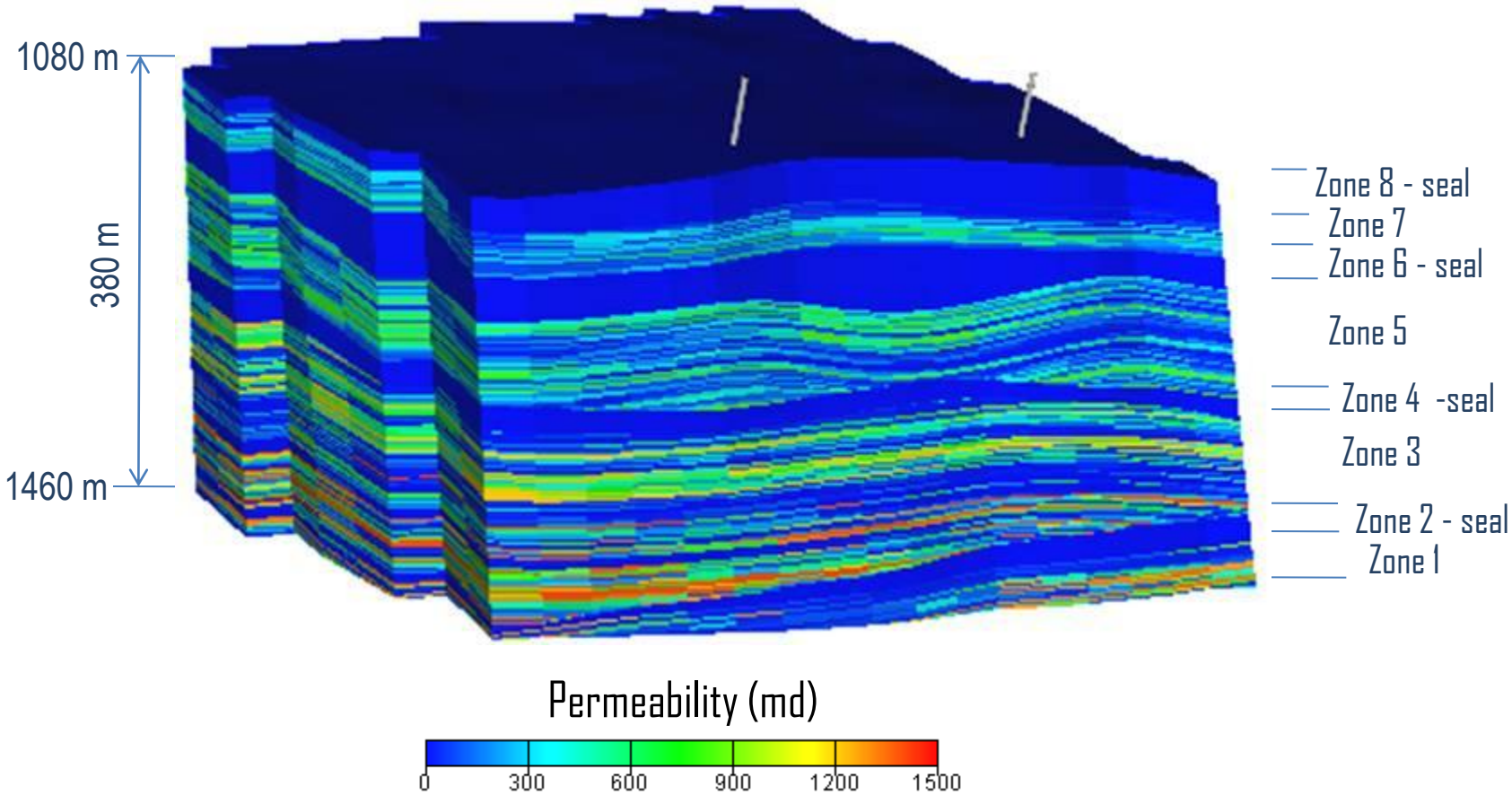




Injection target: lower part of Paaratte Formation

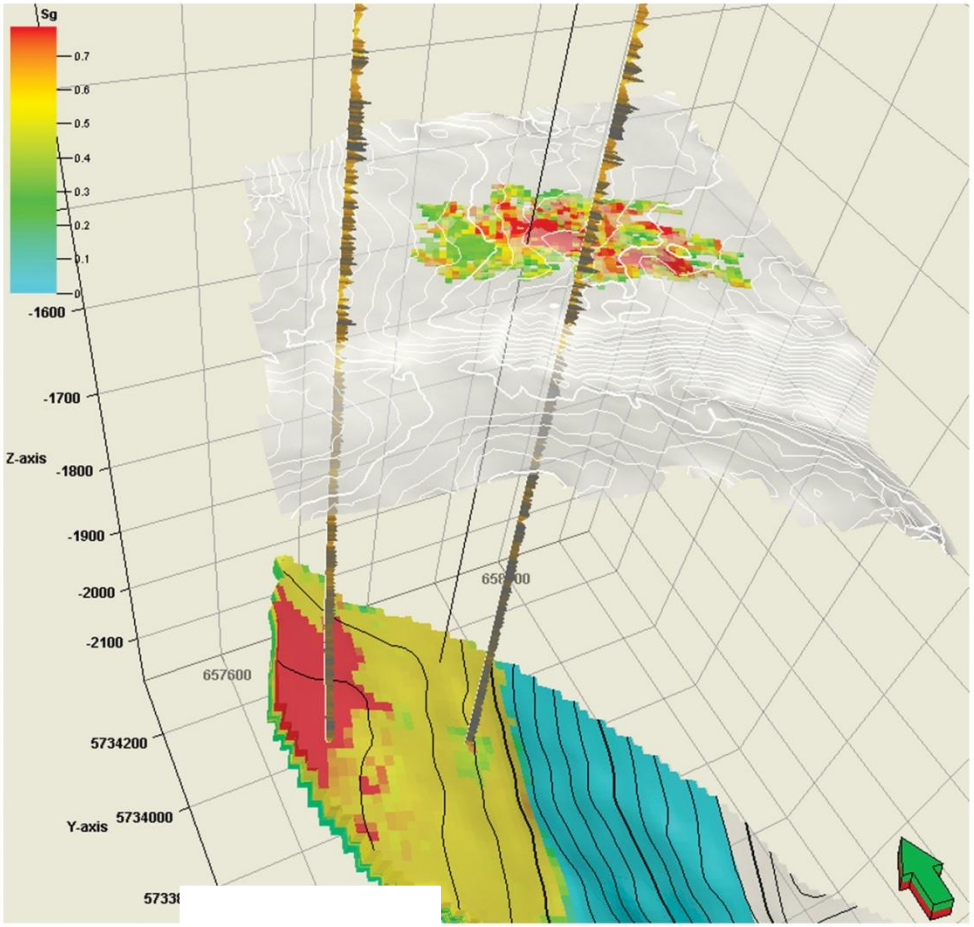


Zones Identified in Paaratte Formation

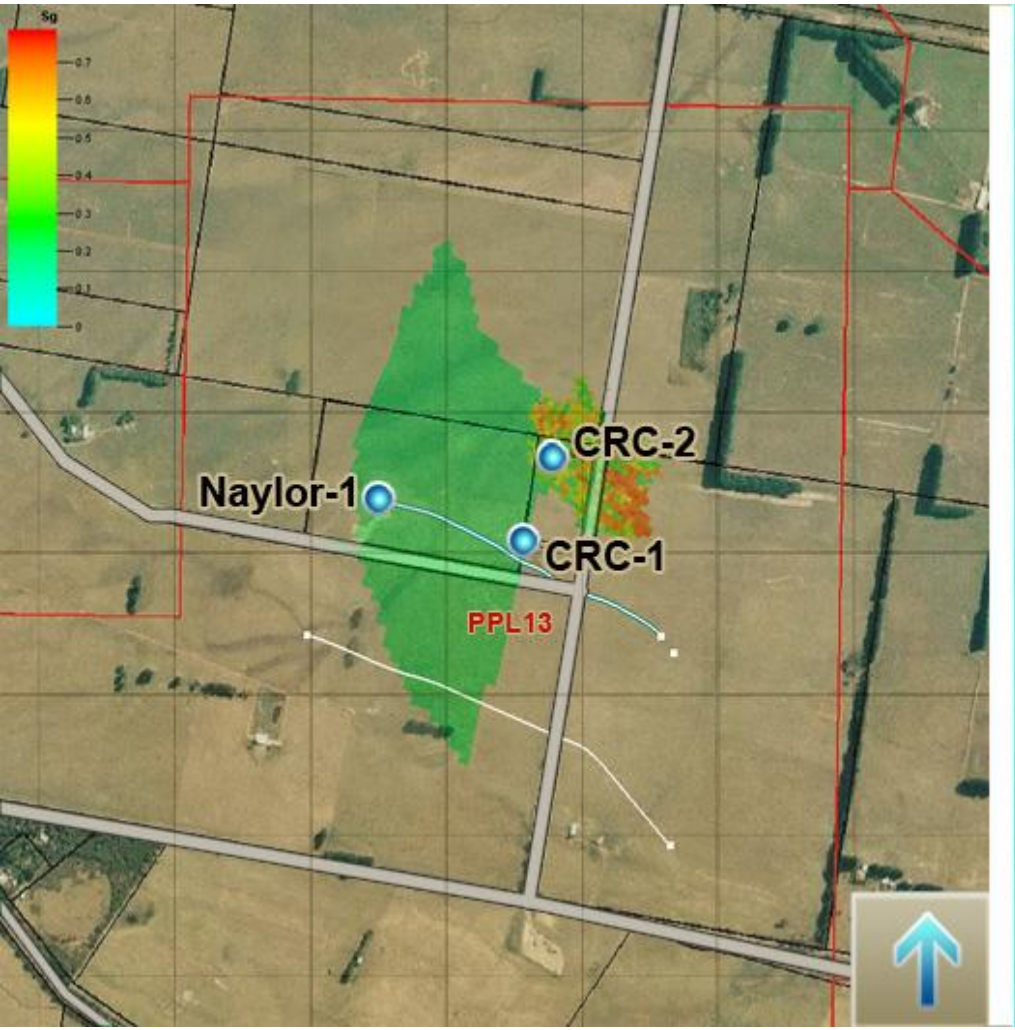


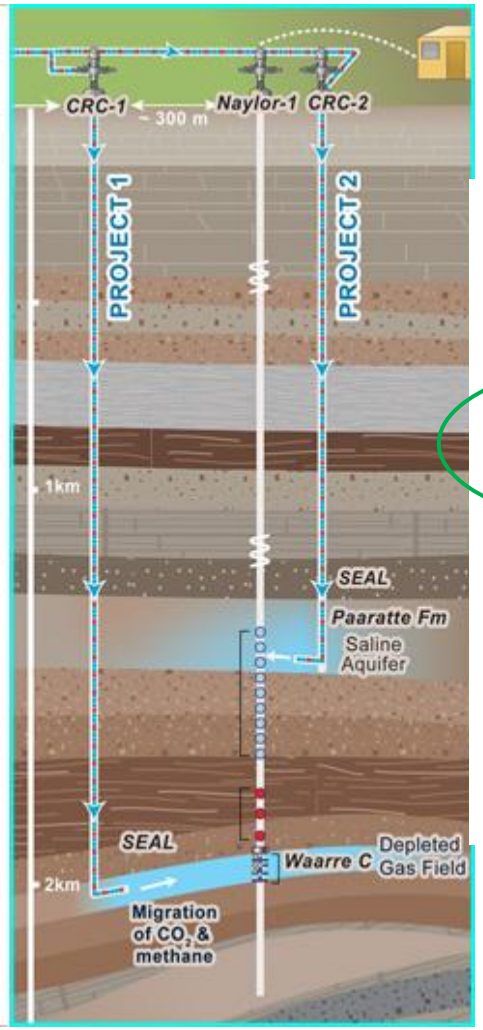
Otway 2C: larger volume injection to test seismic detectability

OTWAY PROJECT STAGE 1 AND STAGE 2



CO2CRC Otway Project 2





2A: Drill CRC-2 well ✓

2B : Residual gas saturation test

2C: Test seismic detection on larger volume injection

CO2CRC

Summary stage 2: Scientific objectives

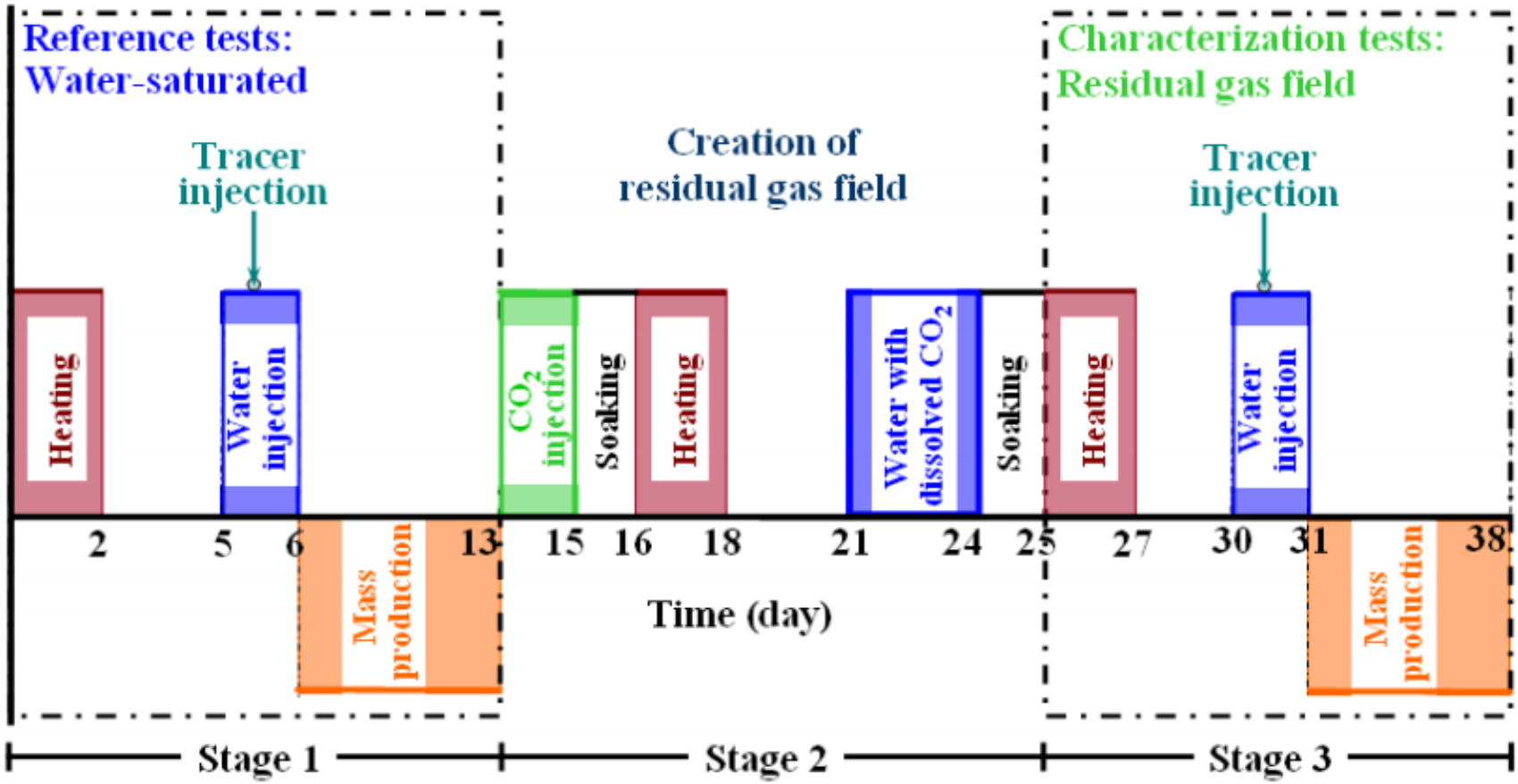
- **Establish residual gas saturation via a single well Huff and Puff test with various measurement methods**
- **Verify numerical simulations/predictions by the field measurements.**
- **Establish distribution of CO_2 within a reservoir from remote measurements.**
- **Use time-lapse seismic anisotropy to verify pore-pressure changes, fluid migration, and saturation.**
- **Develop multi-level injection monitoring system.**

Residual Saturation Test: Adapting the Huff-n-Puff

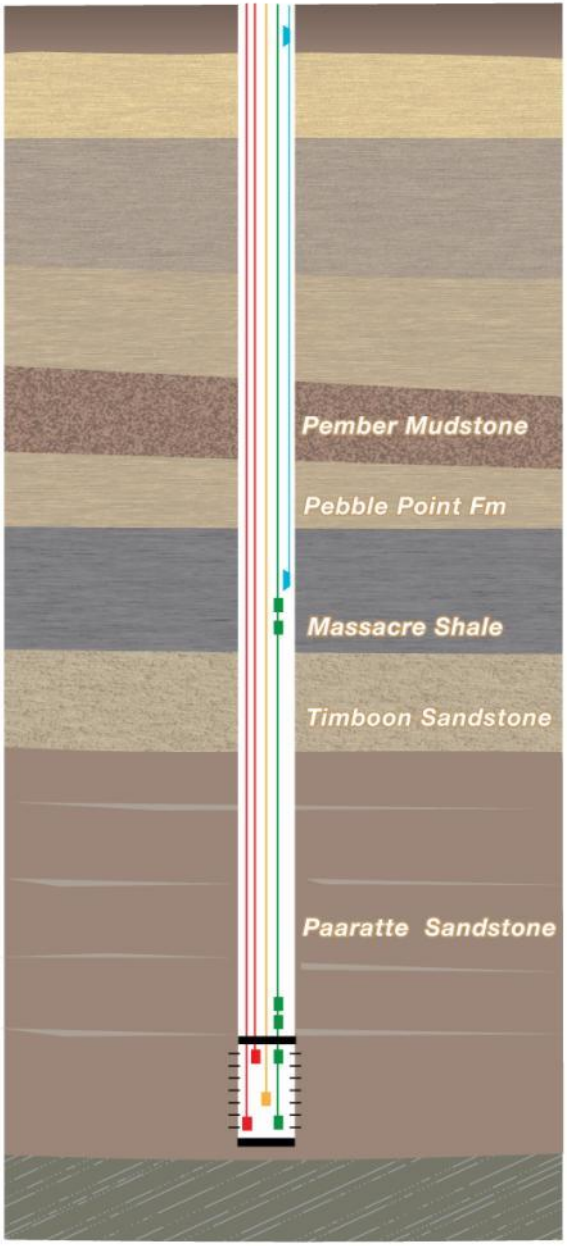
- **Objective: To determine residual CO2 saturation Sgr**
  - The formation anisotropy and relative permeability control the injectivity and migration of the CO_2 plume and physical trapping.
- **Four independent measurement approaches to determining residual trapping:**
  - Thermal logging
  - Tracer partitioning
  - History matching injection and production
  - Pulsed neutron logging
- **Complementary Data**
  - Perform reference test under fully water-saturated conditions
  - Create system at residual gas saturation
  - Repeat reference tests
  - Analyze difference to obtain S_{gr}

Challenges

- **No standard well test available for determination of residual gas saturation (S_{gr})**
- **Simple mass balance approach (difference between injected and produced CO_2) overestimates residual gas trapping**
  - → Need process-based data analysis approach (forward and inverse modeling)
- **Correlation among uncertain parameters**
  - → Use multiple, complementary data to constrain estimates
- **Heterogeneity**
  - → Design a test that is insensitive to geologic heterogeneity

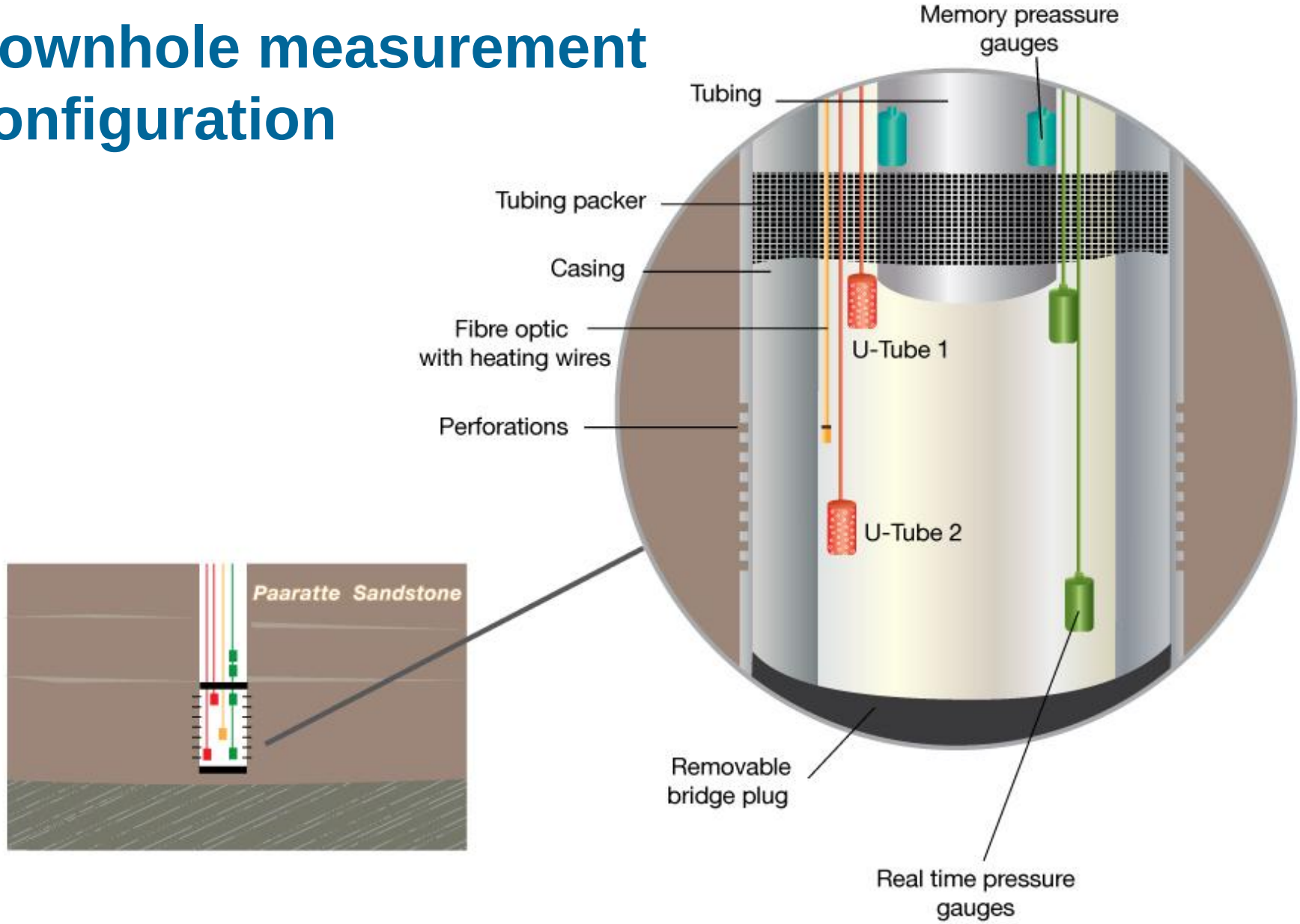

Reference tests:
Water-saturated
Tracer injection
Heating
Water injection
Mass production
Creation of residual gas field
CO_2 injection
Soaking
Heating
Water with dissolved CO_2
Soaking
Characterization tests:
Residual gas field
Heating
Tracer injection
Water injection
Mass production
2
5
6
13
15
16
18
21
24
25
27
30
31
38
Time (day)
Stage 1
Stage 2
Stage 3

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

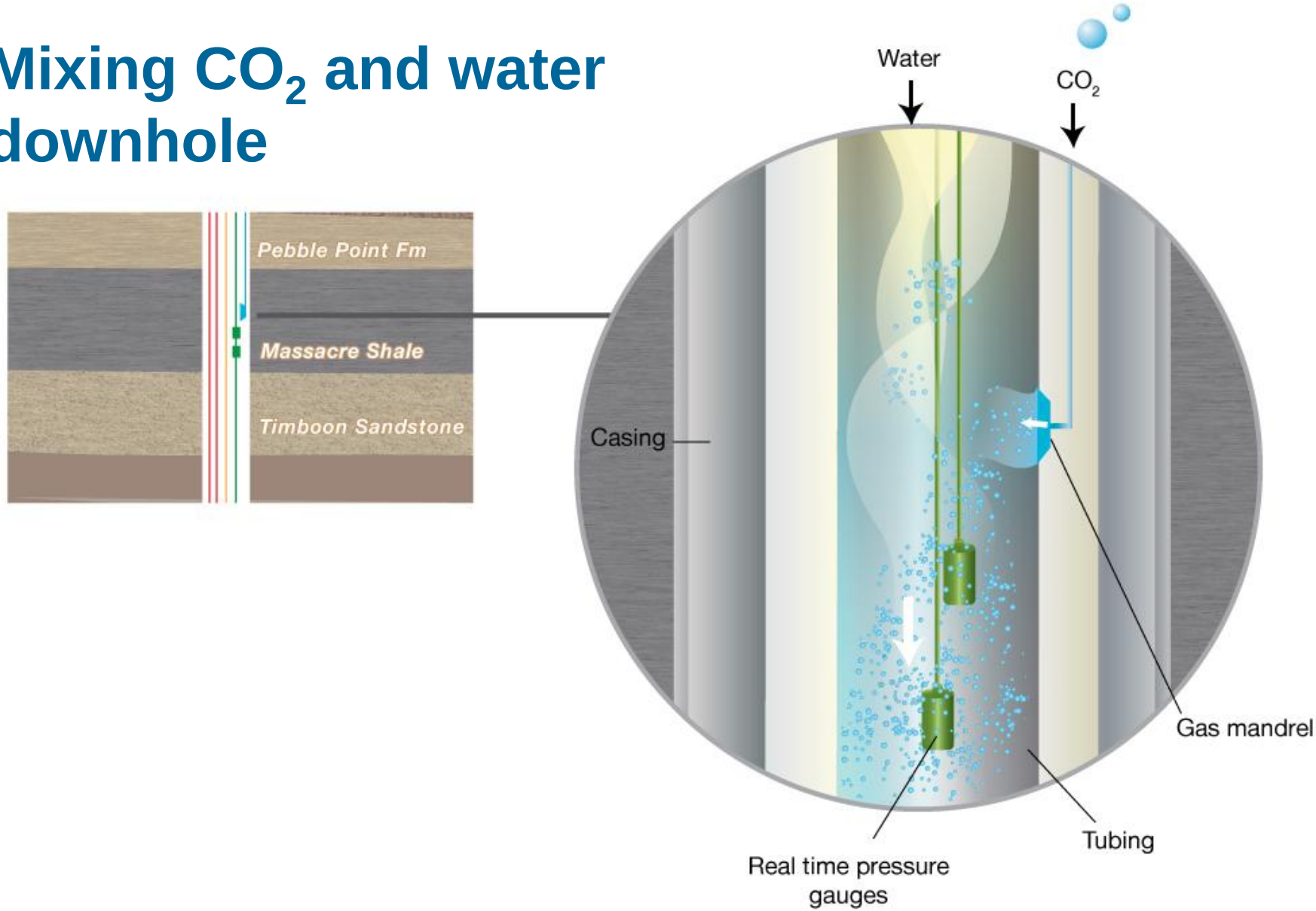


- U-Tube
- Pressure gauges
- Fibre optic with heat wires
- Gas mandrel

Downhole measurement configuration



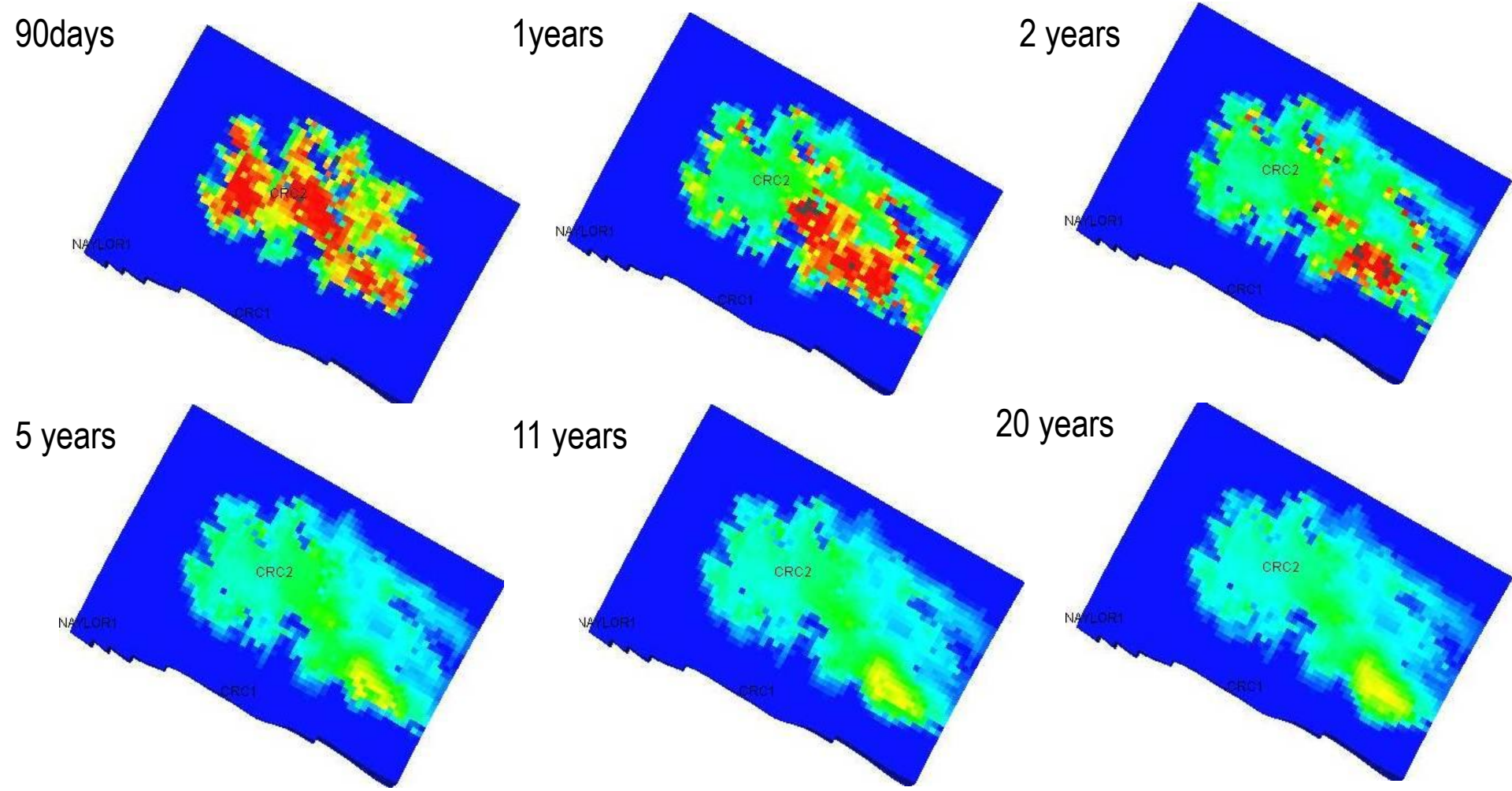
Mixing CO_2 and water downhole



Otway Stage II

- The design combines three measurements – pressure response, thermal response and tracer production – to produce a better estimate of residual saturation.
- The initial design was 'push-pull' i.e. inject CO_2 and then produce it back. The problem is that in the 'pull' stage, formation water dissolves the residual gas, and the pressure response is smaller.
- The current 'push' design uses injection of water pre-saturated with CO_2 to drive the gas saturation down to residual levels.

Larger volume injection –base case 10k tons



CO2CRC Otway Project- Australia's first operational storage project

- Injection commenced 2 April 2008; 65K tonnes injected
- Stage 1 cost A$40M- completed 2010
  Stage 2 cost A$20M- underway
- Monitoring and verification a key component
- U tube gives critical insights into subsurface behaviour of CO2
- Learnings include regulation, risk, liability, technology,
- Interactions with the community very important with seismic work the greatest challenge
- Successful science, ops(HSE) communications, community, politics
- Stage 2 will examine fundamentals of CO2 trapping and subsurface processes

Thank you

Thank you
N
W
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S