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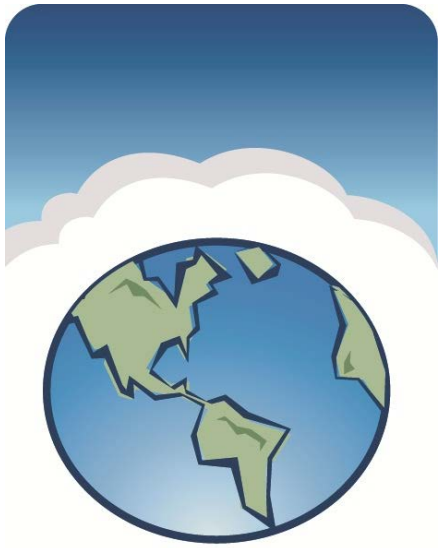
# Weyburn-Midale: Recent Developments and Best Practice Manual

*Neil Wildgust, Chief Project Officer*

*June, 2012*

*IEAGHG Joint Network Meeting, Santa Fe*



IEAGHG
WEYBURN-MIDALE
$CO_2$ MONITORING
AND STORAGE PROJECT

# IEAGHG Weyburn-Midale $CO_2$ Monitoring & Storage Project (WMP) 2000 to 2012

Commercial EOR operations in Weyburn and Midale oilfields utilise anthropogenic $CO_2$

Over 20Mt of $CO_2$ injected and stored since 2000

WMP has used these sites to study technical aspects of $CO_2$ geological storage

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# Best Practice Manual

## Introduction

- Purpose, scope, context, background, …

## Characterization

- Regional geology
- Regional hydrogeology
- Containment characterization
- Geomechanical characterization
- Geochemical characterization

## Performance predictions

- $CO_2$ migration
- Capacity and mass partitioning
- Containment

## Geochemical monitoring

- Groundwater
- Soil gas
- Reservoir fluids
- Reservoir/caprock core

## Geophysical monitoring

- Geophysical char. of rock-fluid system
- Feasibility studies
- Downhole monitoring methods
- 3D seismic methods

## HM and performance validation

- Prediction/measurement comparison
- Revision of Geologic Models

## Well integrity

- Integrity assessment
- Design considerations
- Remediation and conversion
- Abandonment considerations
- Integrity monitoring and field testing

## Risk assessment

## Community outreach

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# Integrated technology portfolio for geologic $CO_2$ storage

Chapter 2
**Site Characterization**

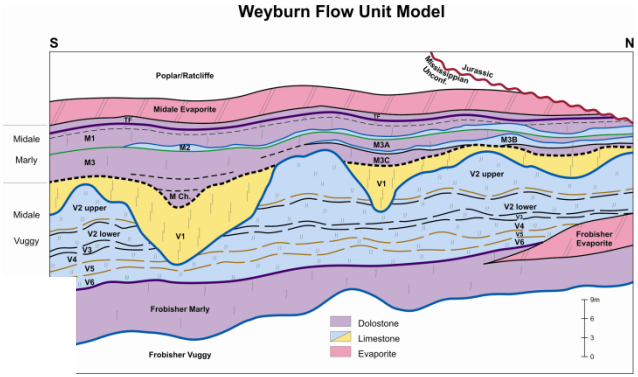
Chapter 3
**Modeling**

Chapters 4-5
**Monitoring**

**define & bdry** | **initial conds**

**predict isolation performance**

**measure isolation performance**




- Demo site feasibility
- ID screening criteria
- Design site char, injection, & monitoring strategies
- Quantify risk (CFC uncertainty)

- Calibrate predictive models
- t-lapse data for iterative site char & modeling refinement
- Demo regulatory compliance
- Crucial for public acceptance

Chapter 6
**History Match**

**compare results: resolve discrepancies & refine CMM capabilities**

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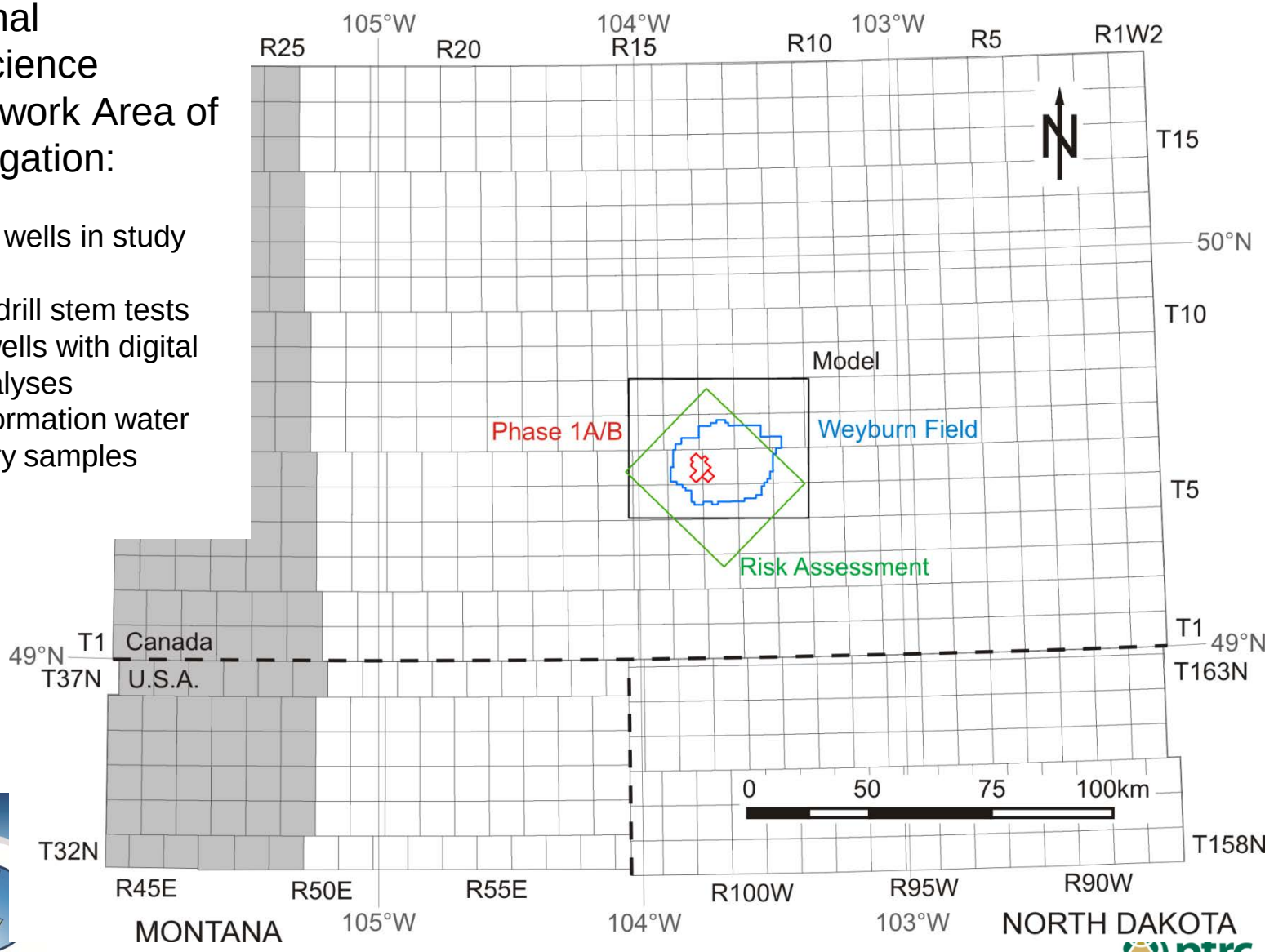
# Staged Study Areas:

Regional GeoScience Framework Area of Investigation:

>30,000 wells in study area
-11,121 drill stem tests
-6,292 wells with digital core analyses
-9,207 formation water chemistry samples

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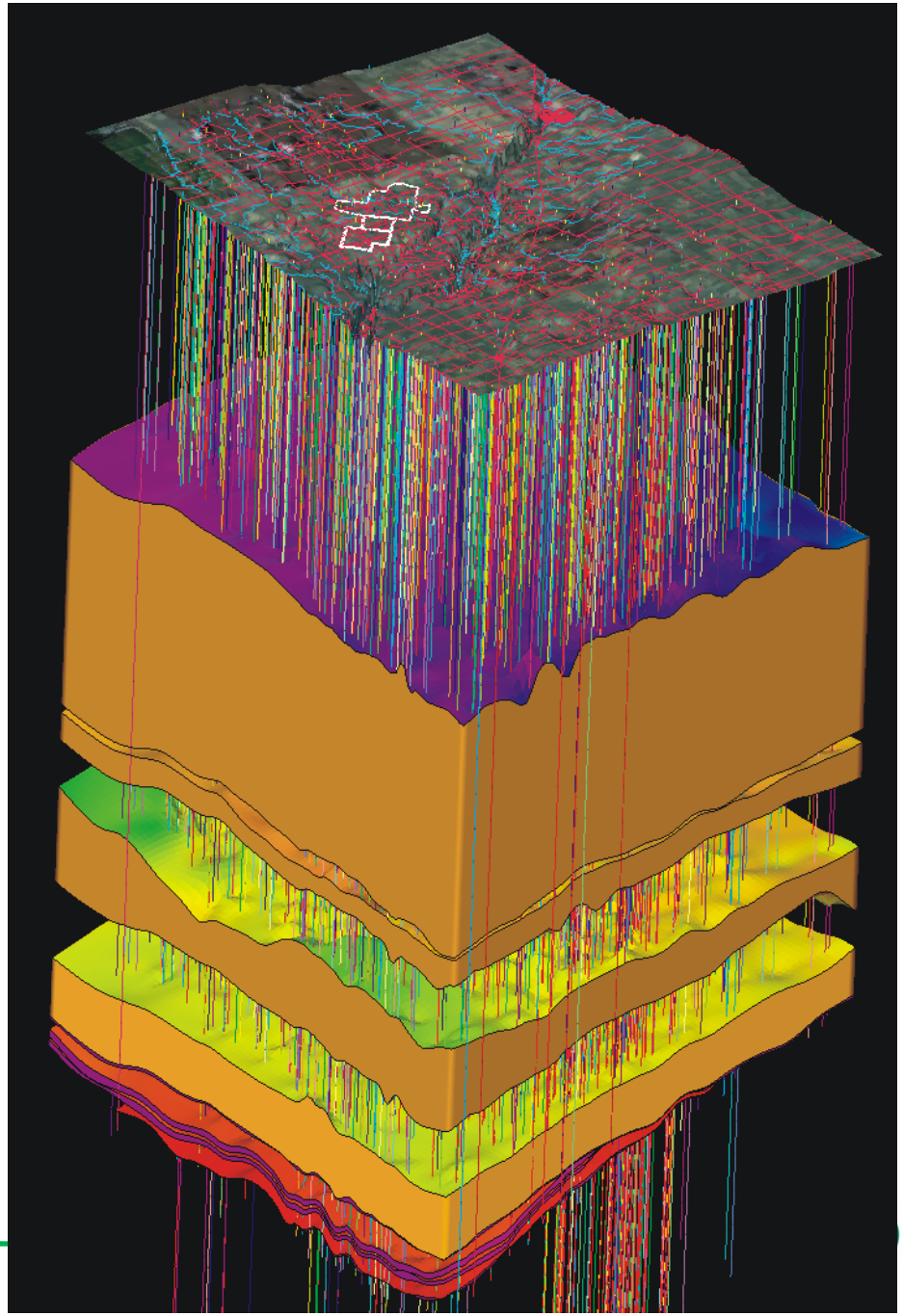
# Revised Model

Was improved with:

1. More detailed aquitard characterization
2. Larger area
3. More accurate subcrop mapping
4. Increased well density (800 in area)



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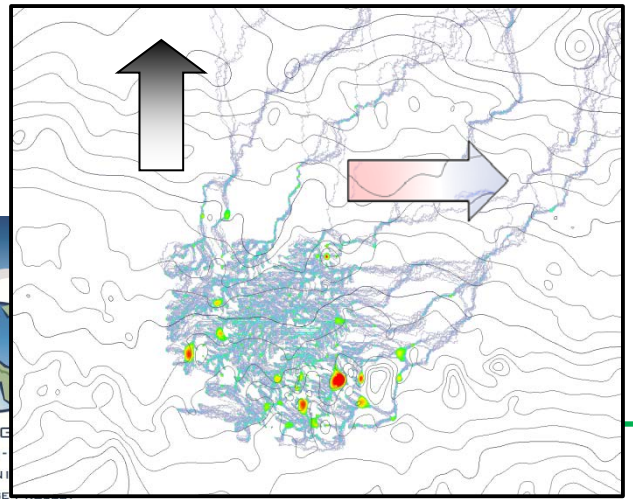
# Migration scenarios (Cavanagh, 2011)

Slightly leaky wells: 1 micron

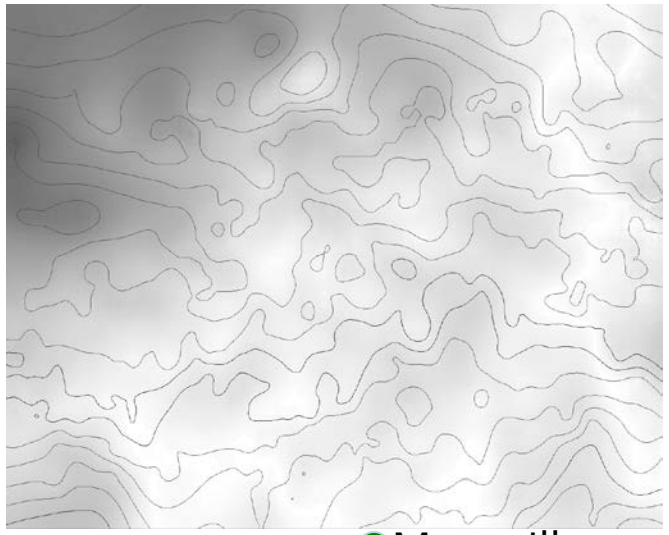
*Containment: Jurassic aquifer*

| | |
|---|---|
| *Newcastle:* | *---* |
| *Mannville:* | *---* |
| *Jurassic:* | *1.4 Mt* |
| *Newcastle* | *---* |
| *Mannville* | *---* |
| *Jurassic* | *20 largest pools, 1.3 Mt* |

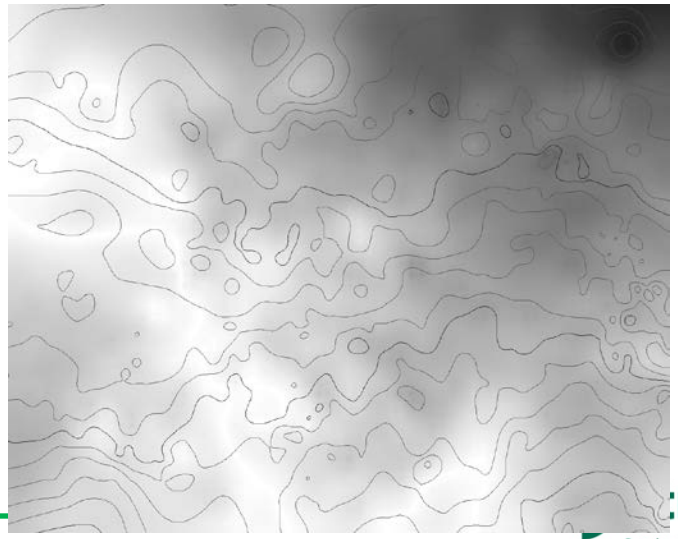
- Jurassic: small pools, migrates NE



Newcastle

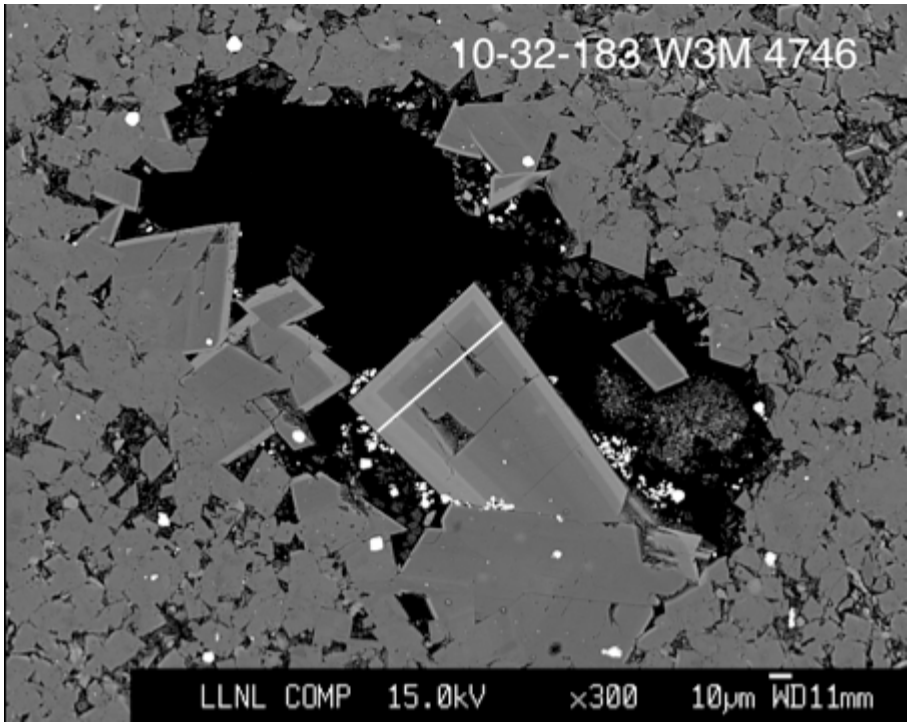


Mannville



Permedia Group

# Natural Analogue Study

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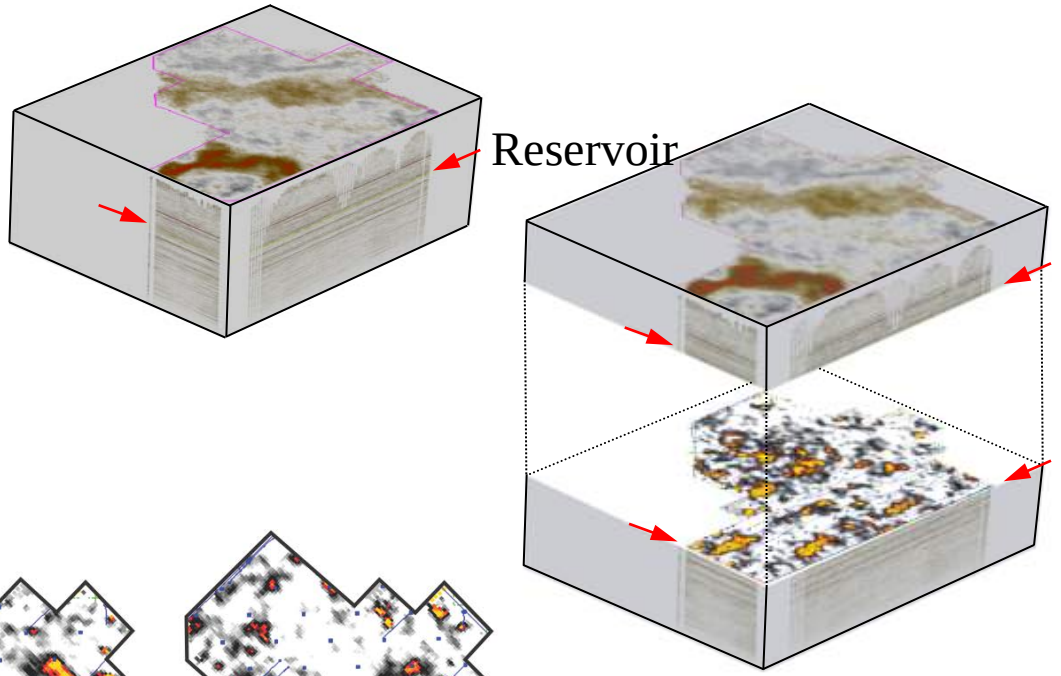
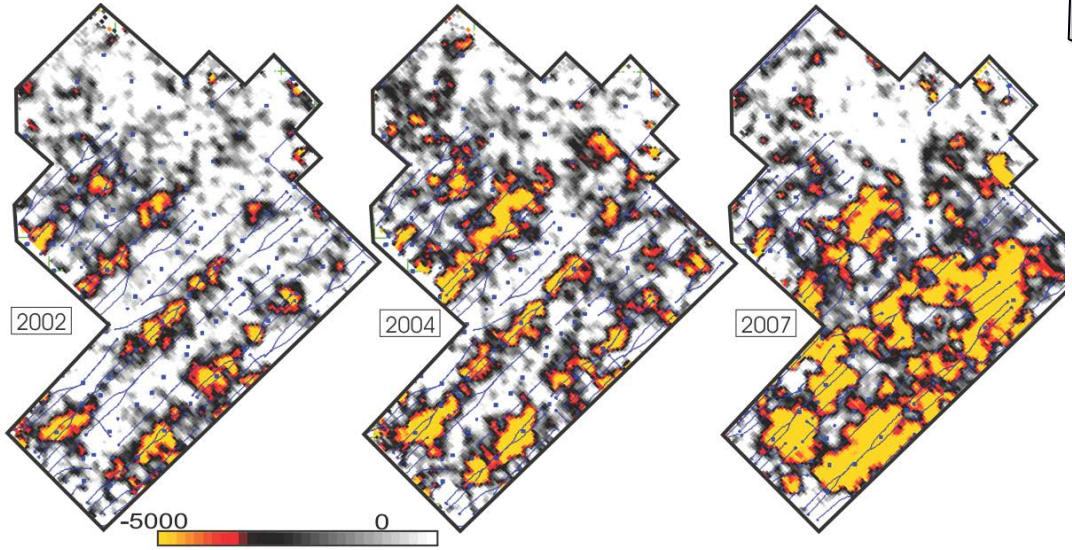
# 3D Time-Lapse Seismic: $CO_2$ Distribution

*Monitoring regional subsurface distribution of $CO_2$:*

- *Verifying storage conformance*
- *A primary input for updating reservoir models*
- *Optimal resolving capability*
- *Sensitive to low $CO_2$ saturations*
- *Data repeatability is fundamental*

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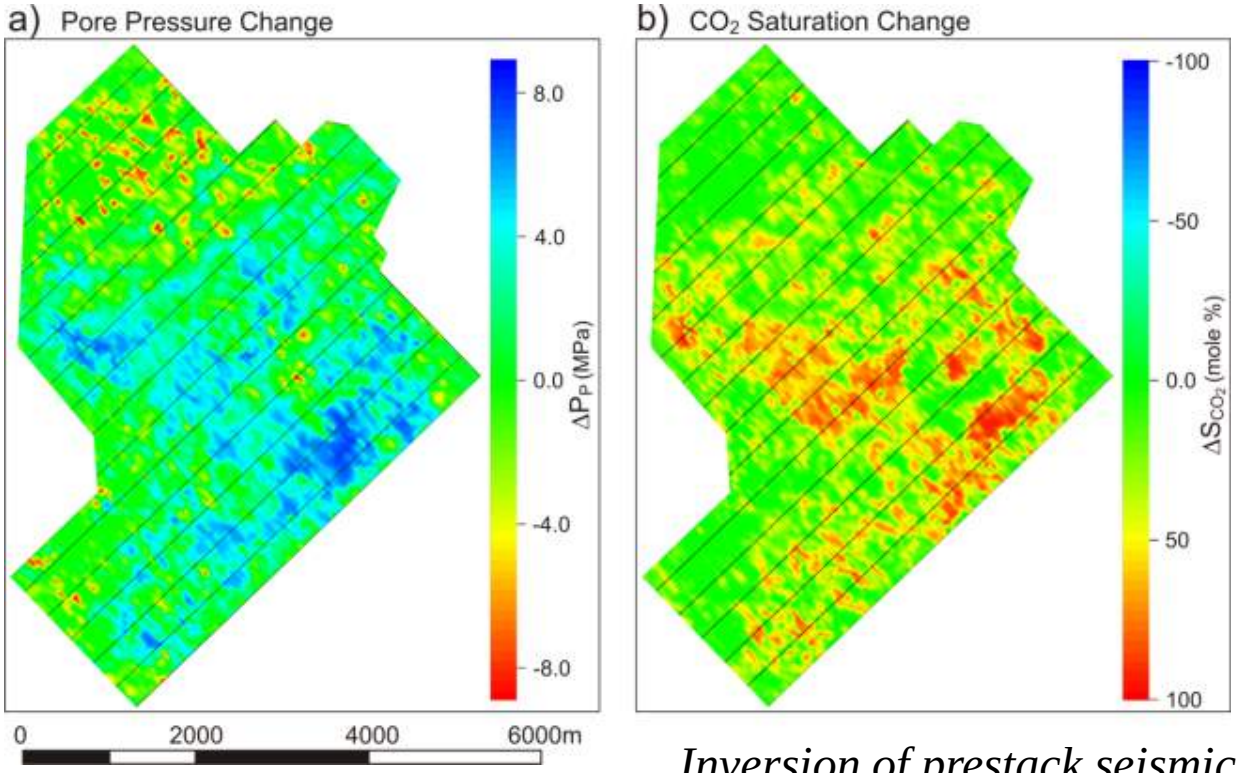
# 3D Time-Lapse Seismic: Pressure vs. $CO_2$ Saturation




*Inversion of prestack seismic data:*

- *Semi-quantitative $CO_2$ saturation and P changes*
- *Results are model-based*
- *Characterization of reservoir rock physics is essential*
- *Monitoring survey design is important as "long offset" data are required*

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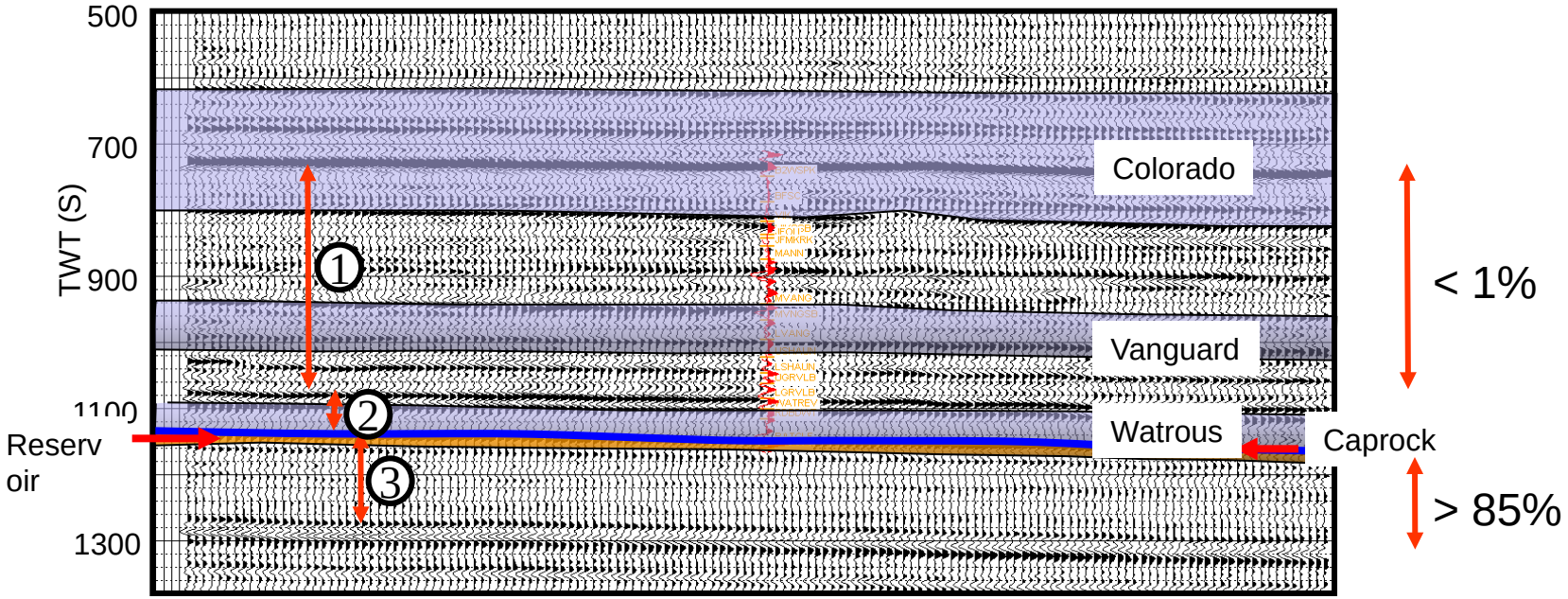
# 3D Time-Lapse Seismic: Containment




*Interval travel-time changes:*

- *Semi-quantitative apportionment of $CO_2$ within various layers of the storage complex*
- *Results are model-based*
- *Characterization of reservoir rock physics is essential*
- *Data repeatability is essential*

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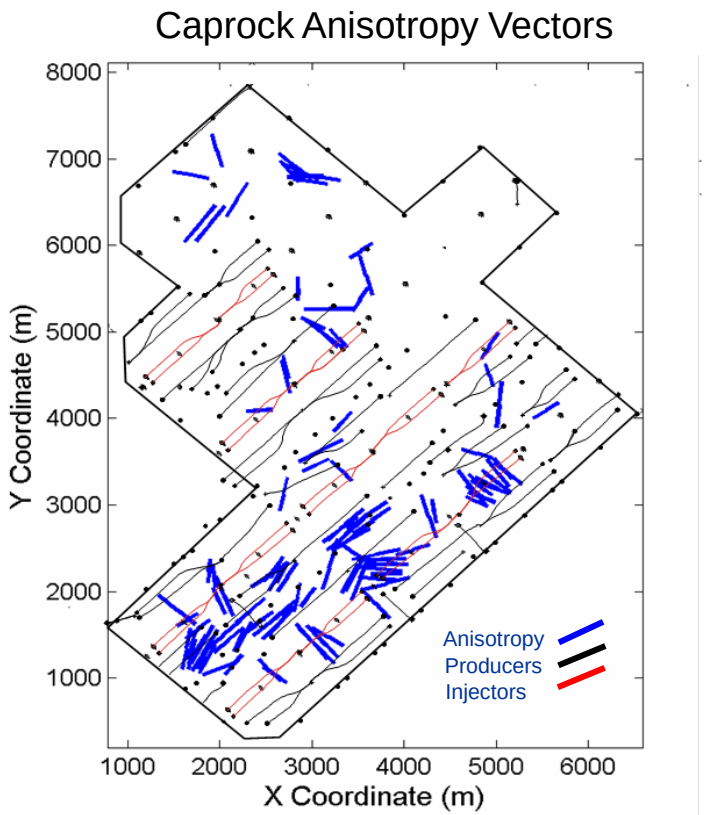
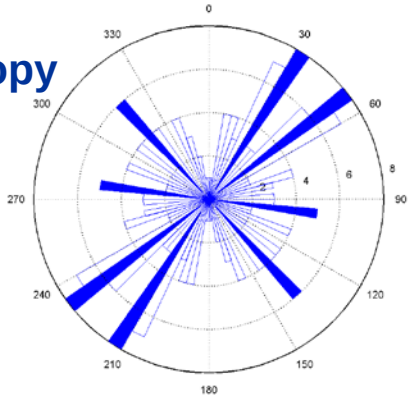
# Seal Integrity: Fracture Mapping

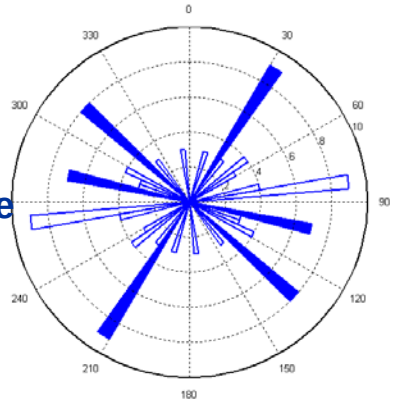



**Anisotropy vectors**




**Bunge, 2000**

**Reservoir oriented core sample fracture analysis**




*Seismic anisotropy as a proxy for vertical fracturing:*

- *Means of identifying potential fracture zones regionally*
- *Scale of individual fractures and hydraulic conductivity is not resolved*
- *"Fracture zones" may warrant subsequent attention*

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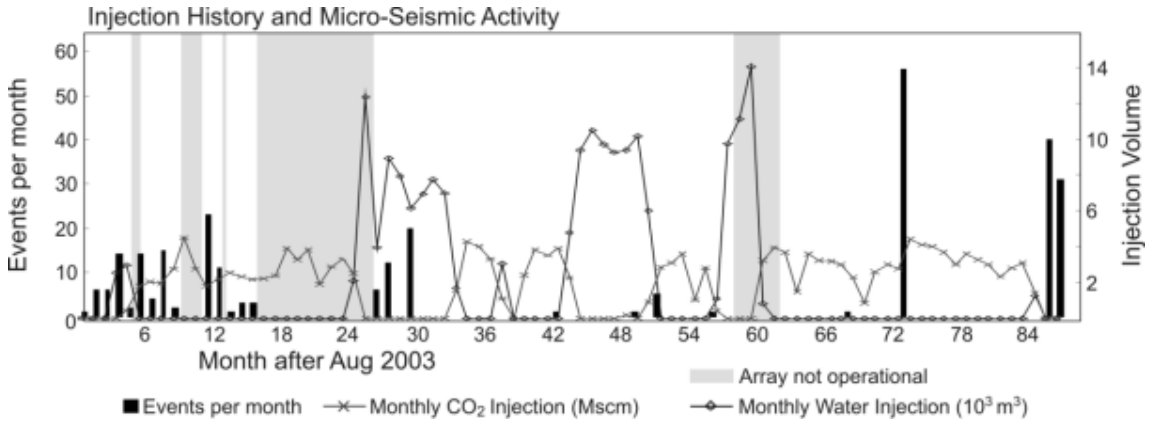
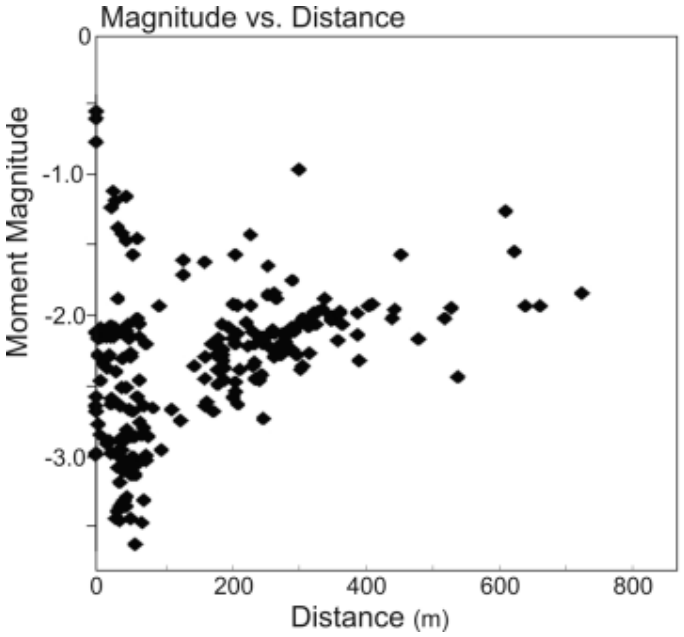
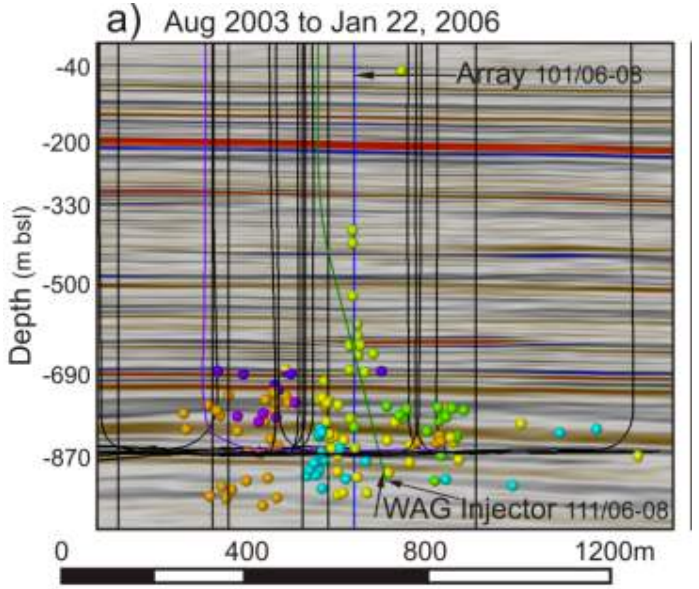
# Passive Seismic Monitoring

*Documentation of time, magnitude and location of seismicity:*

- *Public assurance*
- *Integrity of the sealing units*
- *Injection control*

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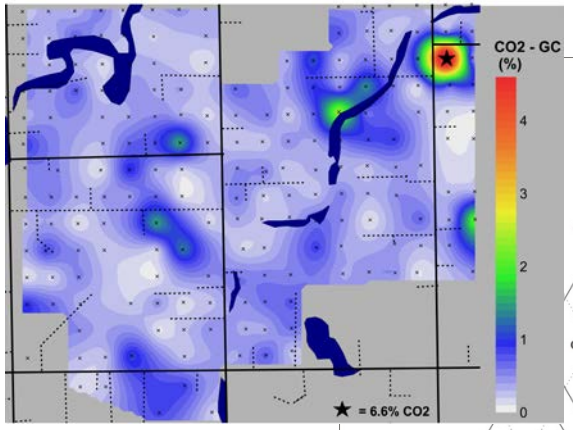
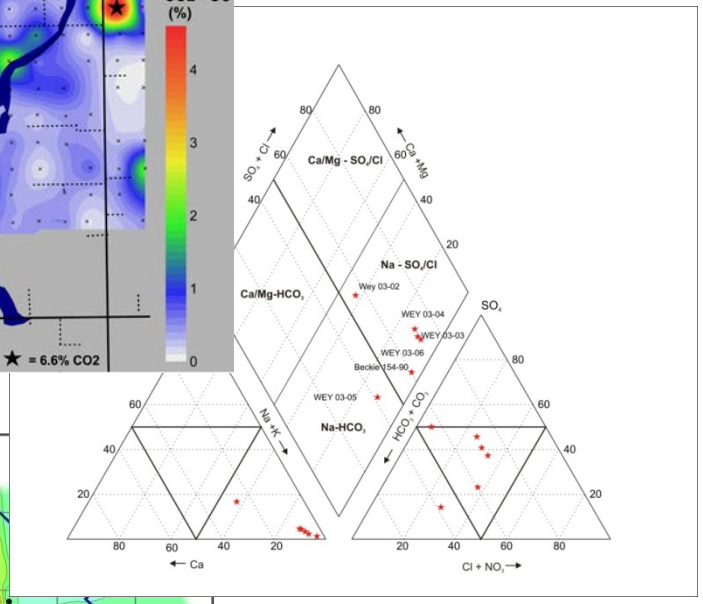
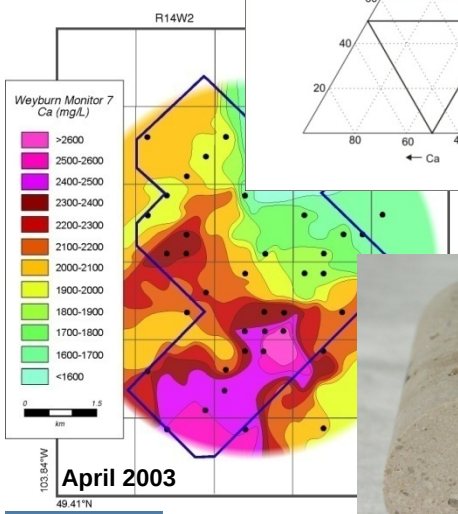
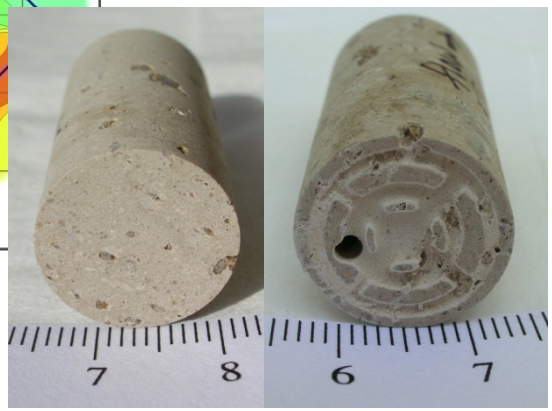
# BPM chapter 4: Geochemical monitoring




**4.1 Summary**

**4.2 Introduction**

- 4.2.1 Context
- 4.2.2 Objectives
- 4.2.3 Components

**4.3 Soil gas**

**4.4 Groundwater**

**4.5 Reservoir fluids**

- 4.5.1 Produced brines & gases
- 4.5.2 Produced hydrocarbons

**4.6 Reservoir/caprock core**

**4.7 Recommendations**

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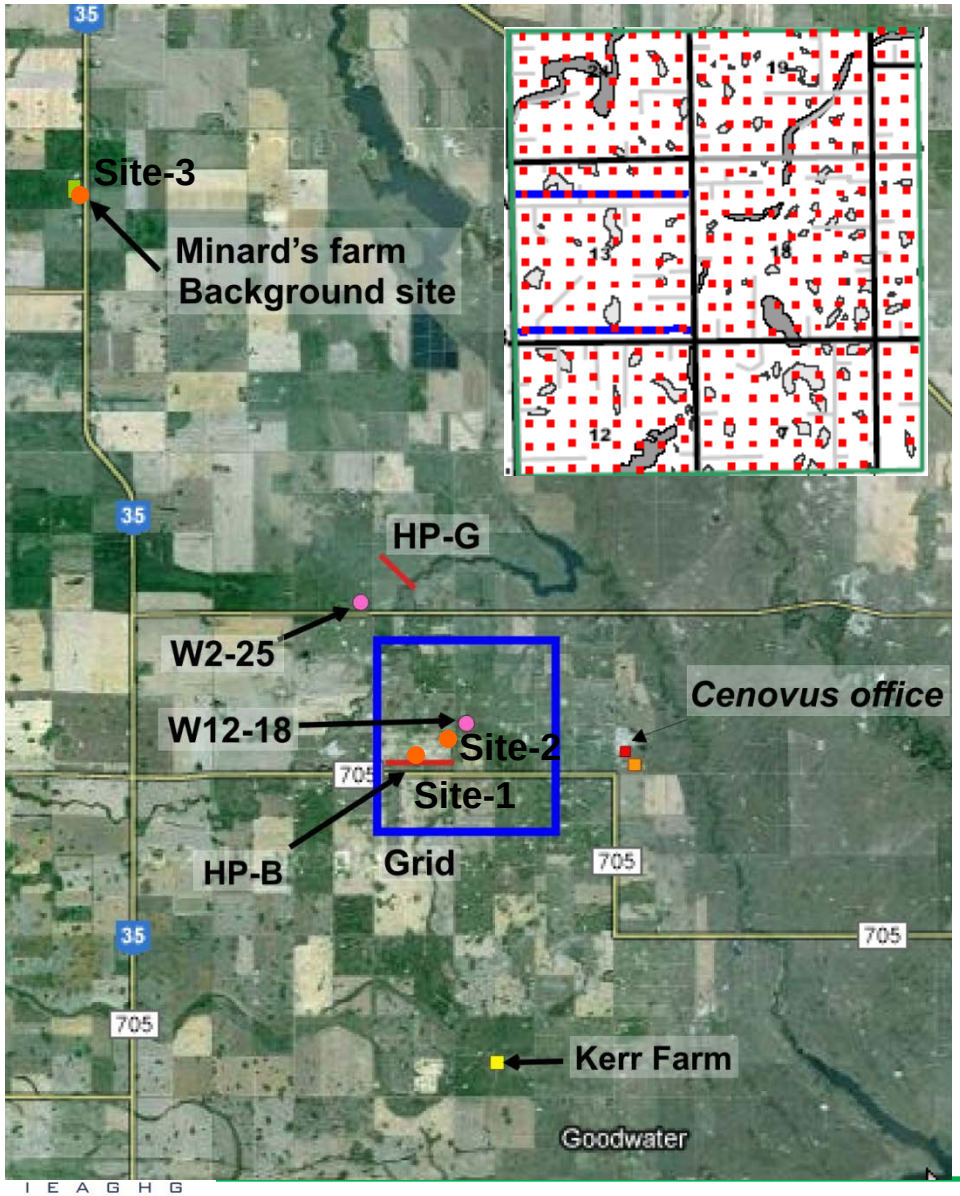
# Soil gas monitoring: Overview




## Research Providers

- ✓ Dave Jones et al. (BGS)
- ✓ Dave Risk et al. (StFX)

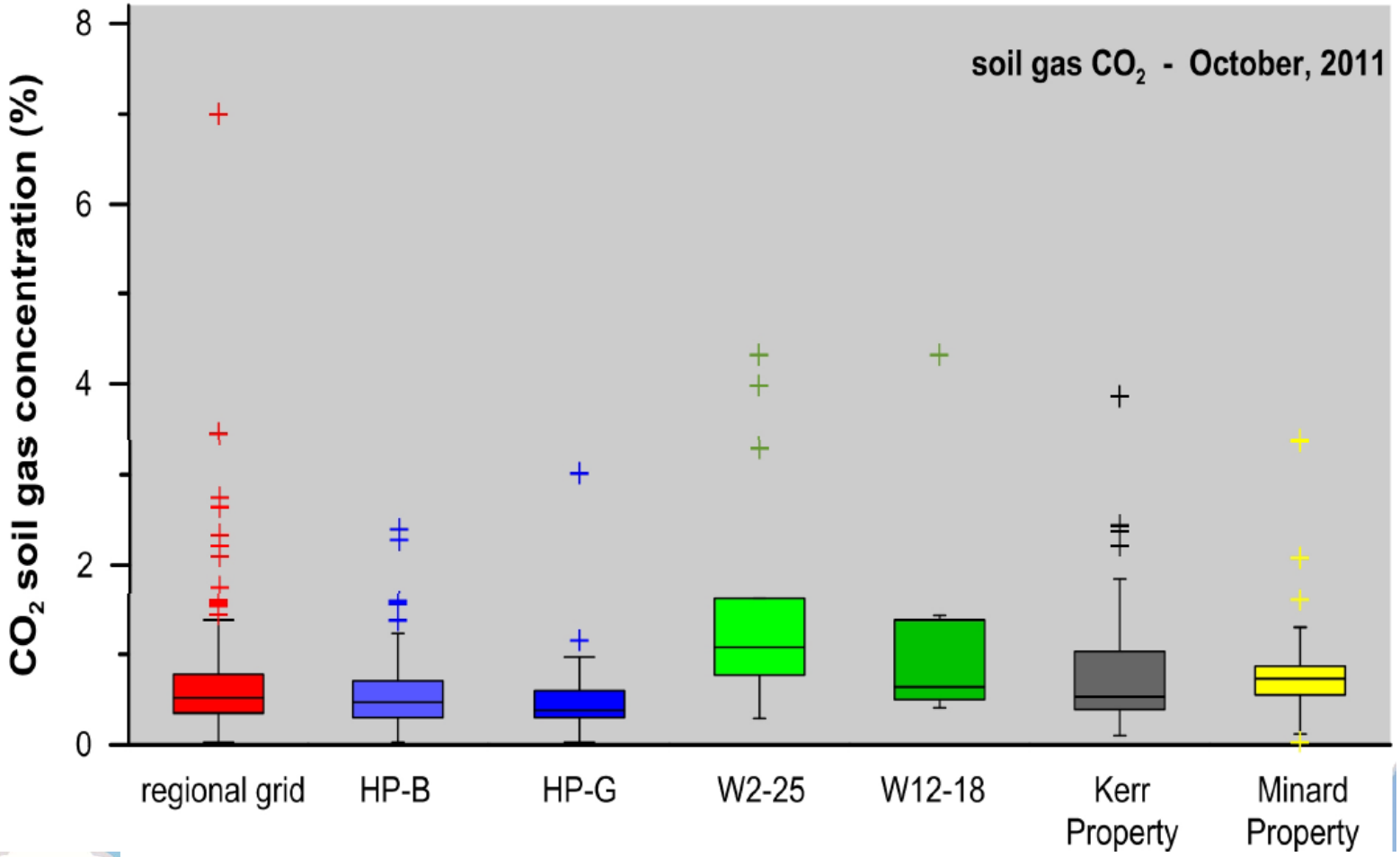
## Measurements

- ✓ $CO_2$, $O_2$, $N_2$ conc.
- ✓ $CH_4$, $C_2H_6$, $C_2H_4$ conc.
- ✓ Rn, He conc.
- ✓ $CO_2$ flux
- ✓ C isotopes

## Methods

- ✓ Single-depth (BGS), depth-profile (StFX) $CO_2$
- ✓ $CO_2$ flux (BGS)
- ✓ Continuous $CO_2$ (BGS), $CO_2$ flux (StFX)
- ✓ $\delta^{13}CO_2$, $^{14}CO_2$

# Soil Gas Monitoring Data

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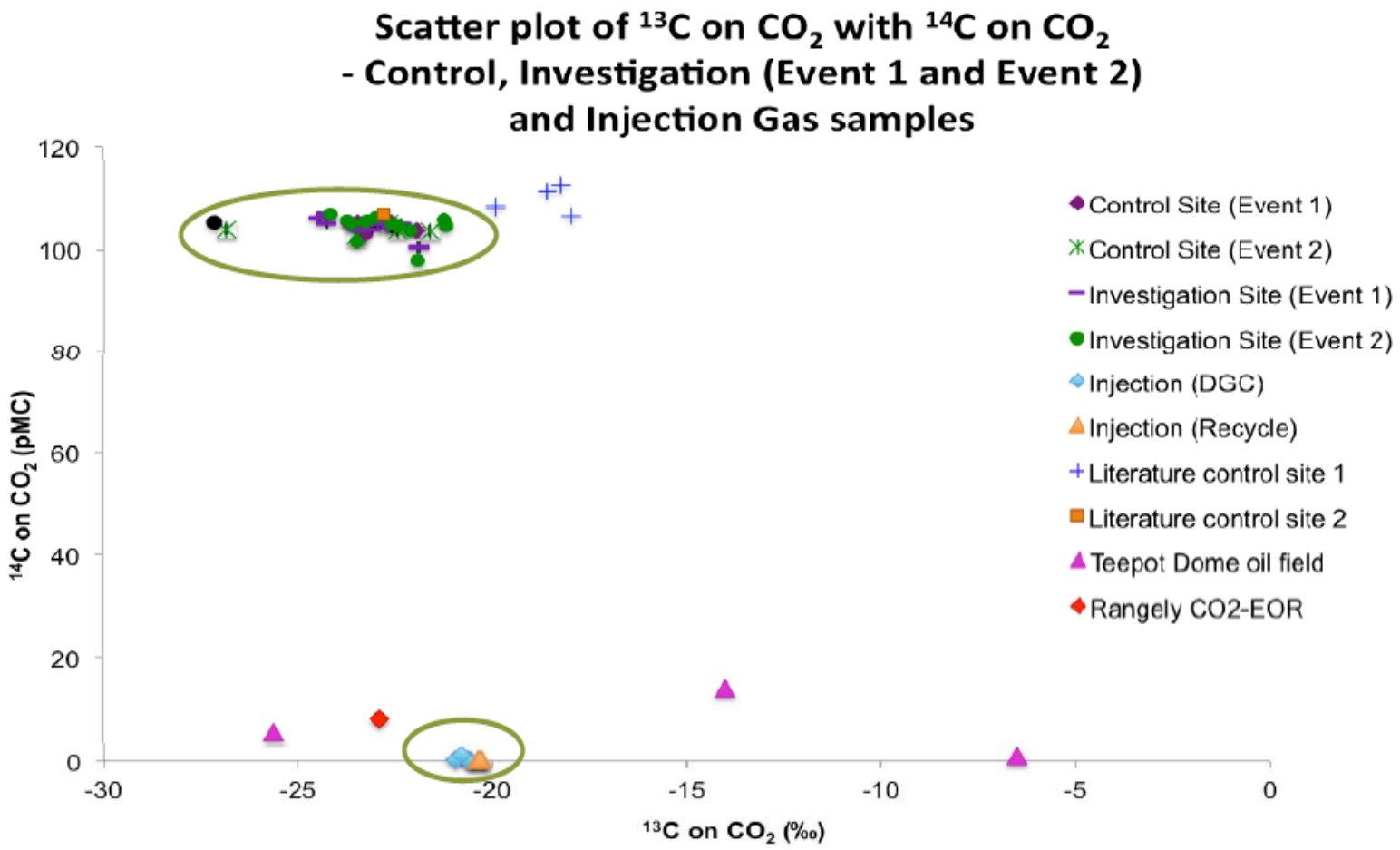
# Carbon Isotopes

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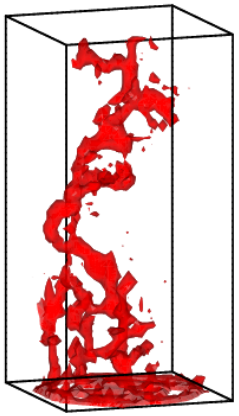
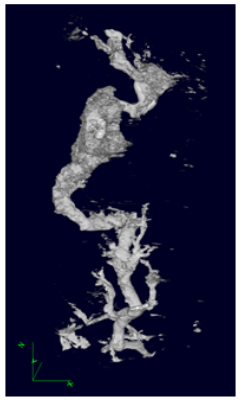
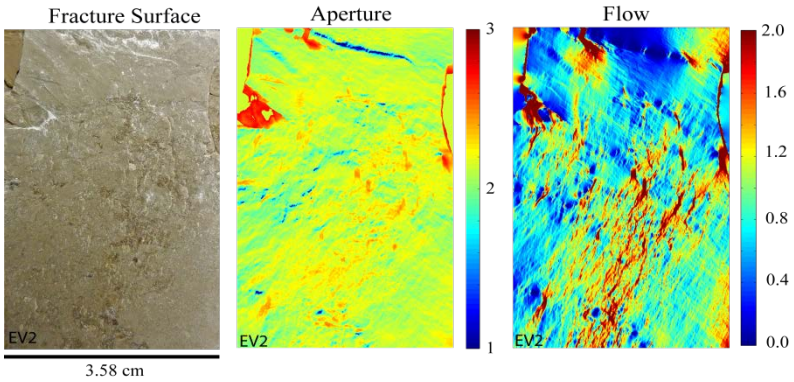
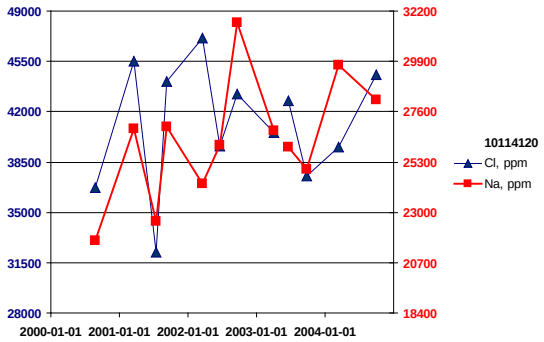
# Chapter 6: History matching & performance validation








## 6.1 Summary

## 6.2 Introduction

- 6.2.1 Context
- 6.2.2 Objectives

## 6.3 Prediction/measurement comparison

- 6.3.1 Core-flood experiments
- 6.3.2 Fracture-flow experiments
- 6.3.3 Field-scale brine chemistry

## 6.4 Revision of geological models

- 6.4.1 Fracture flow
- 6.4.2 Reservoir transport properties
- 6.4.3 Reservoir mineralogy

## 6.5 Recommendations

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# Well Integrity: Field Testing Program

**Modified coring tool:**
**→ Direct confirmation of cement**

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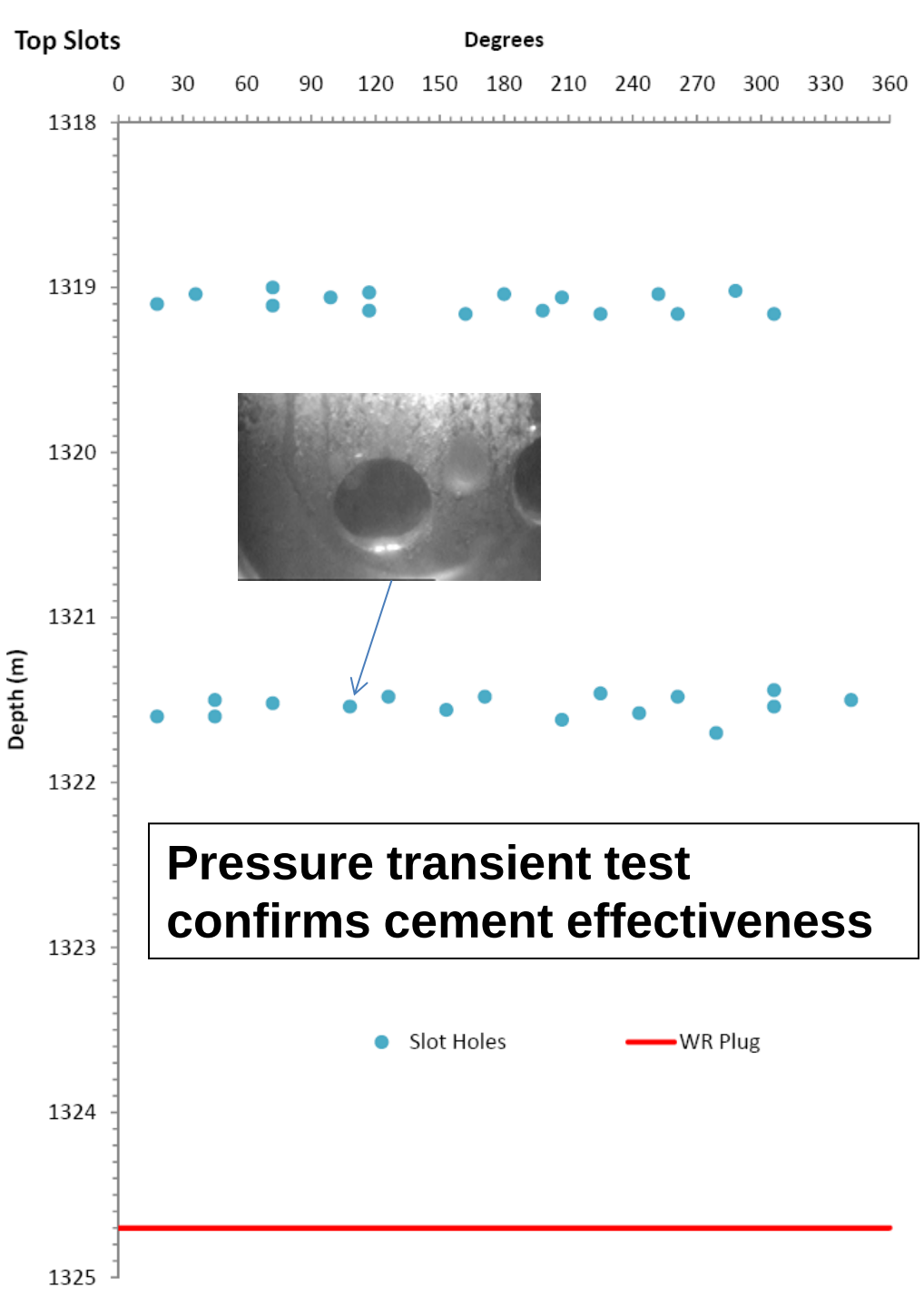
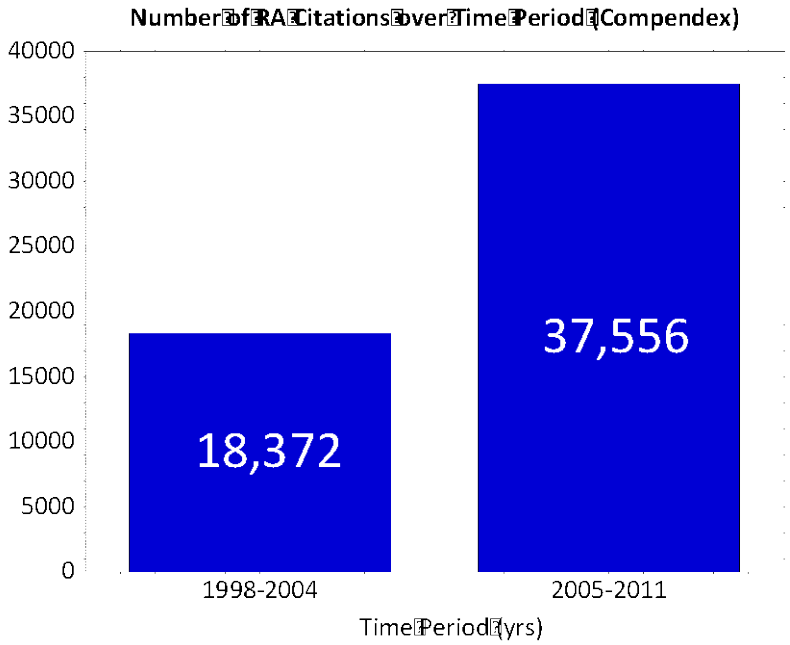
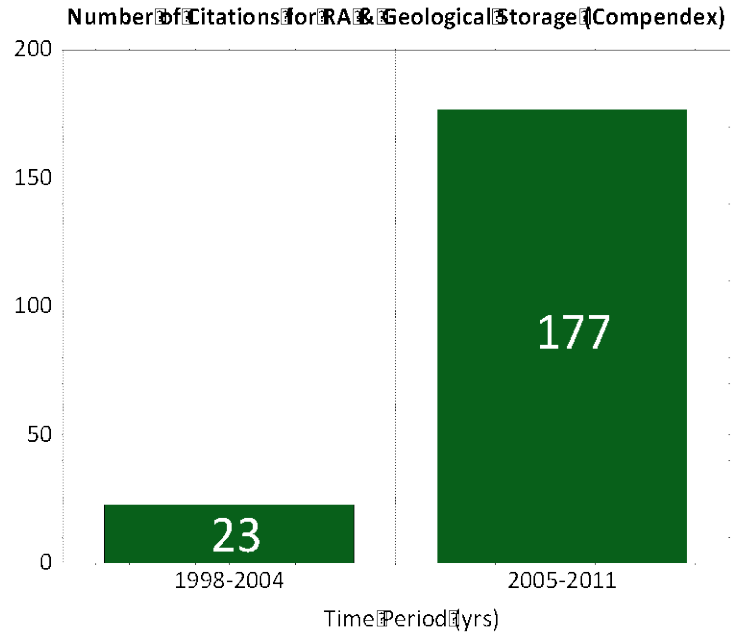



# Field Testing Program

# RA and Geological Storage of $CO_2$




***104% Increase*** ***670% Increase***

**And for just the final? year of each Phase:**
**2004 – 4 and 2011 – 57**

***1,325% Increase***

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# Process: Geosphere & Biosphere Risk

**Technical Inputs**
- Wellbore integrity research
- Characterisation of reservoir characteristics & transport of $CO_2$
- Seismicity of area
- Characterisation of $CO_2$ reactions in reservoir
- Monitoring techniques & effectiveness

**Geosphere Risk Assessment**

**Outputs**
- $CO_2$ risk events (initiating event & pathway) & ranking
- Mass of $CO_2$ released if event occurs
- Likelihood of each event occurring & releasing $CO_2$

**Stakeholder Engagement**

**Stakeholder Values**

**Building Capacity to Engage**

**Biosphere Risk Assessment**

**Other Technical Inputs**
- Characterisation of aquifers
- Characterisation of surface water
- Characterisation of soils / sediments
- Behaviour of $CO_2$ in soils, sediments, groundwater, surface water
- Receptors in environment
- Toxicology (animal, plant, human)

**Outputs**
- Risks to biosphere assets (ranking & severity)

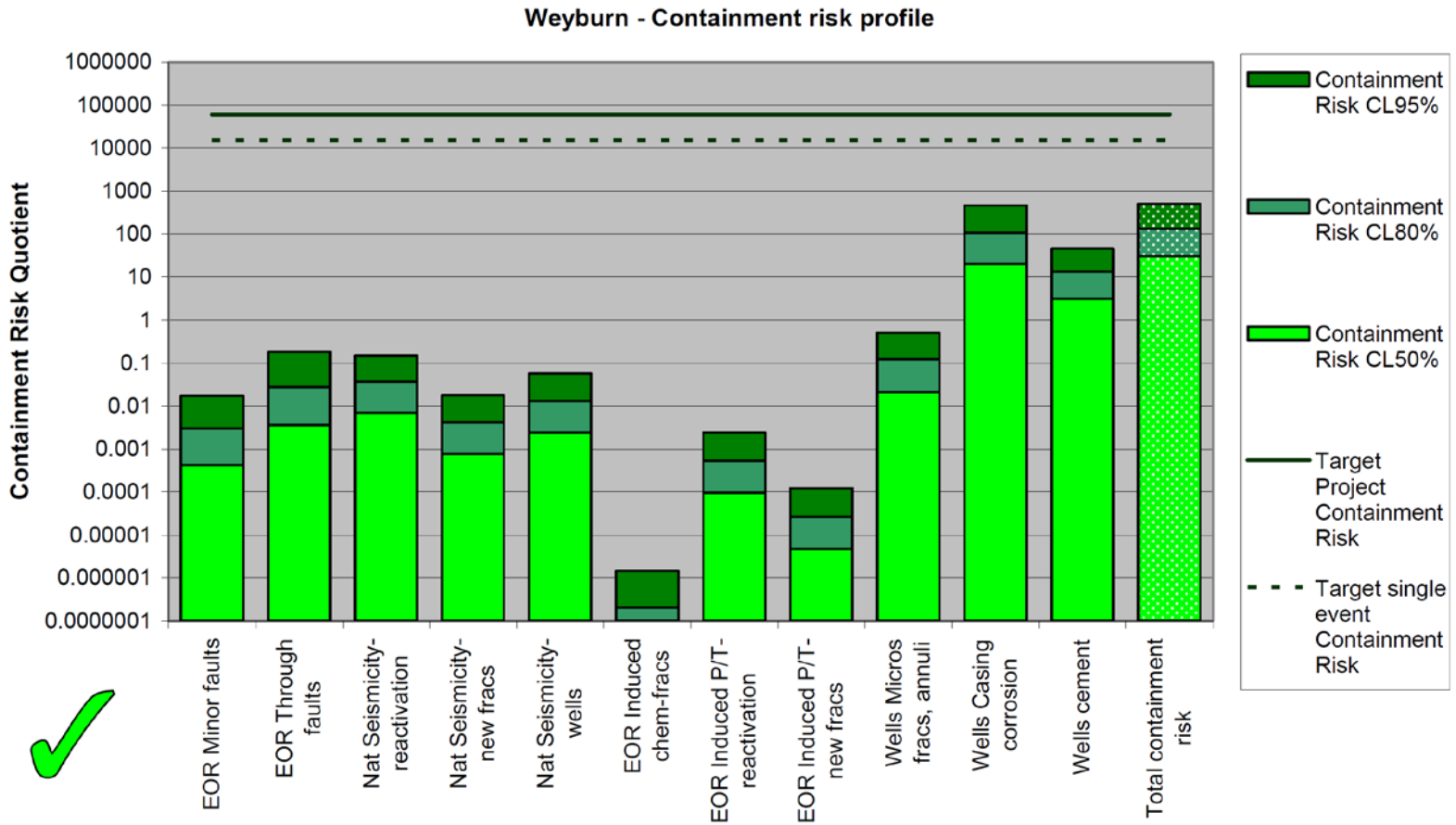
**Acceptability of Risks**

**Mitigation Measures**

# Containment Risk Profile

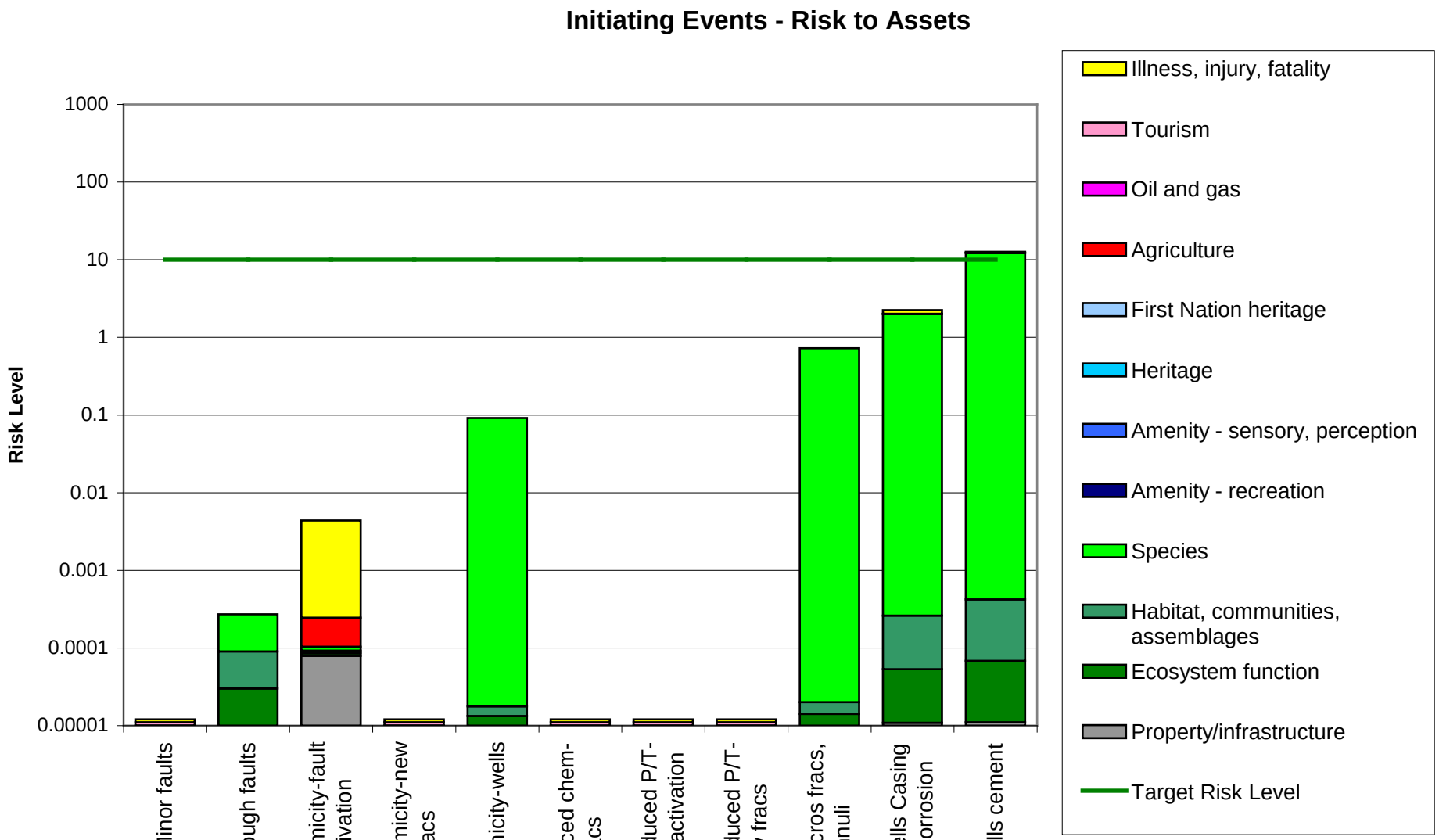
The storage will retain most of the $CO_2$ injected

Containment risk assessment




No further work would be required to demonstrate containment acceptability.

# Identifying Biosphere Assets Most At Risk From Pathways



# Thanks for your attention

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