

# Lessons Learnt from Monitoring at the Weyburn and Aquistore Projects

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Mobile, Alabama*

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IEAGHG  
WEYBURN-MIDALE  
CO<sub>2</sub> MONITORING  
AND STORAGE PROJECT

# Petroleum Technology Research Centre

☐ *Non-Profit Research & Development*

☐ *Collaborative partnership with Industry, Government and Research Organizations*

☐ *Committed to reducing environmental impacts of oil production*

☐ STEPS (EOR Centre of Excellence)

☐ *Research associated with CO<sub>2</sub> management*

☐ IEAGHG Weyburn –Midale CO<sub>2</sub> Monitoring & Storage Project

☐ Aquistore



# IEAGHG Weyburn-Midale CO<sub>2</sub> Monitoring & Storage Project (WMP) 2000 to 2012



Commercial EOR operations in Weyburn and Midale oilfields utilise anthropogenic CO<sub>2</sub>



Over 20Mt of CO<sub>2</sub> injected and stored since 2000

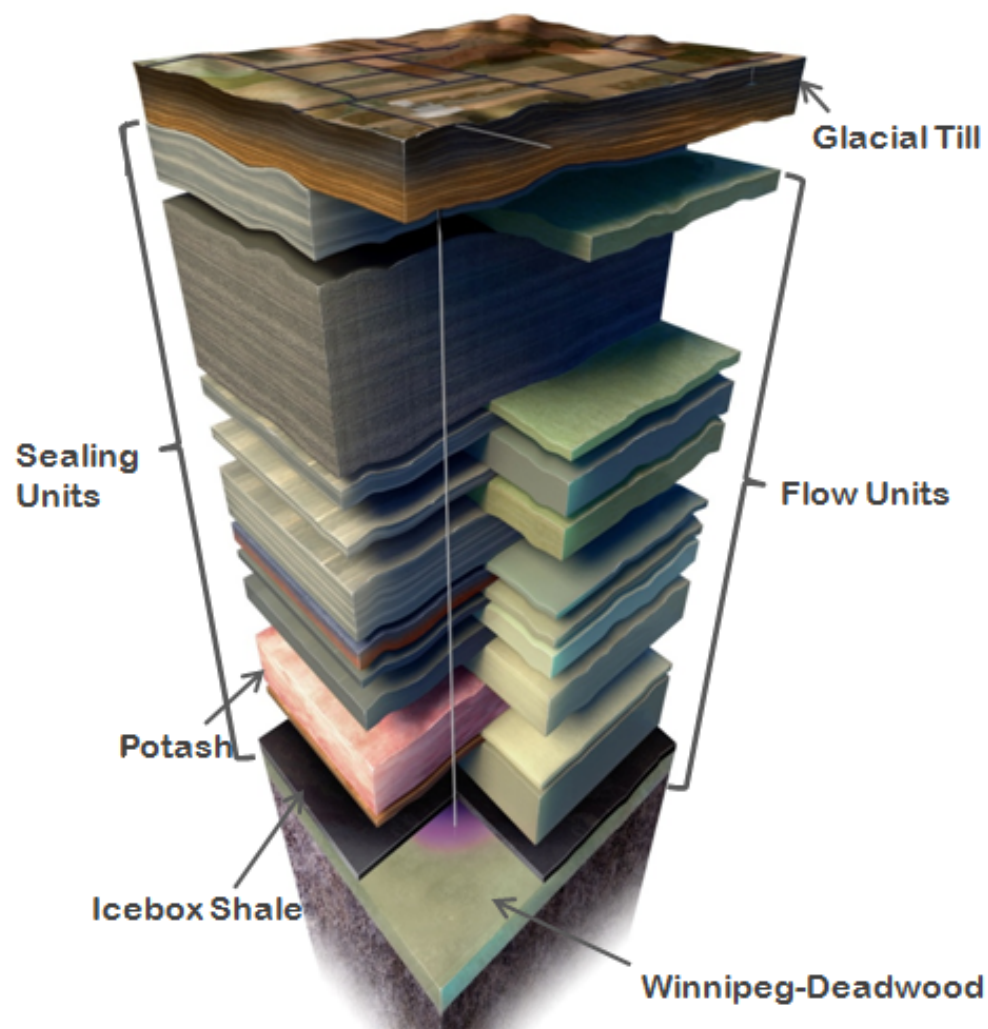


WMP has used these sites to study technical aspects of CO<sub>2</sub> geological storage



# Aquistore

Saskatchewan's  
Deep Saline  
CO<sub>2</sub> Storage  
Research Project



# WMP Best Practice Manual

## The BPM provides:

A record of significant lessons learnt for assessment and validation of storage site suitability and performance; and,  
Technical guidance on site characterization, modelling, monitoring, and risk management

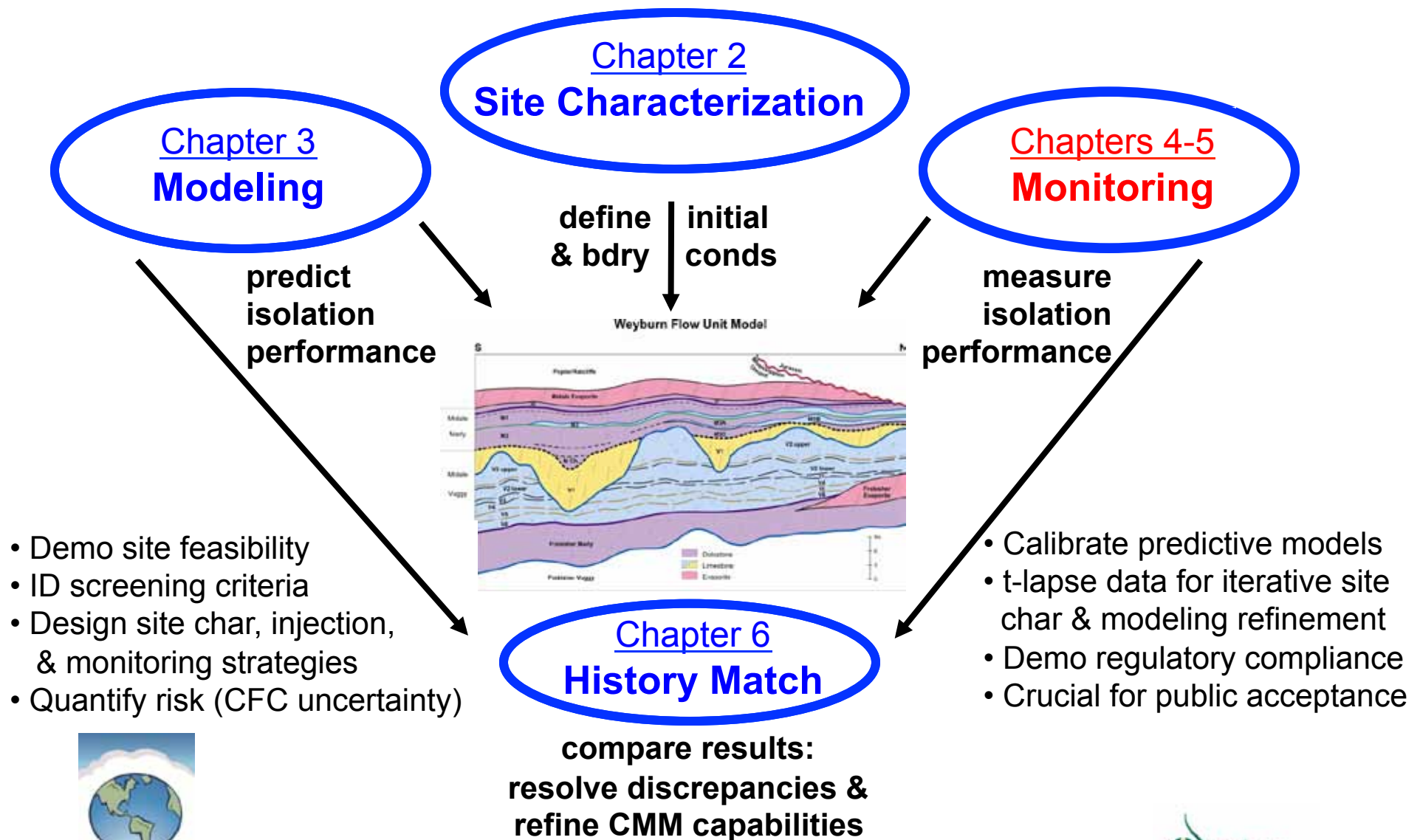
- for CCS projects seeking to validate CO<sub>2</sub> storage, and
- for CO<sub>2</sub>-EOR operators seeking recognition for CO<sub>2</sub> storage

**Intended audience:** Operators, regulators and stakeholders with an interest in the technical basis for, and process by which, safe CO<sub>2</sub> storage can be validated.





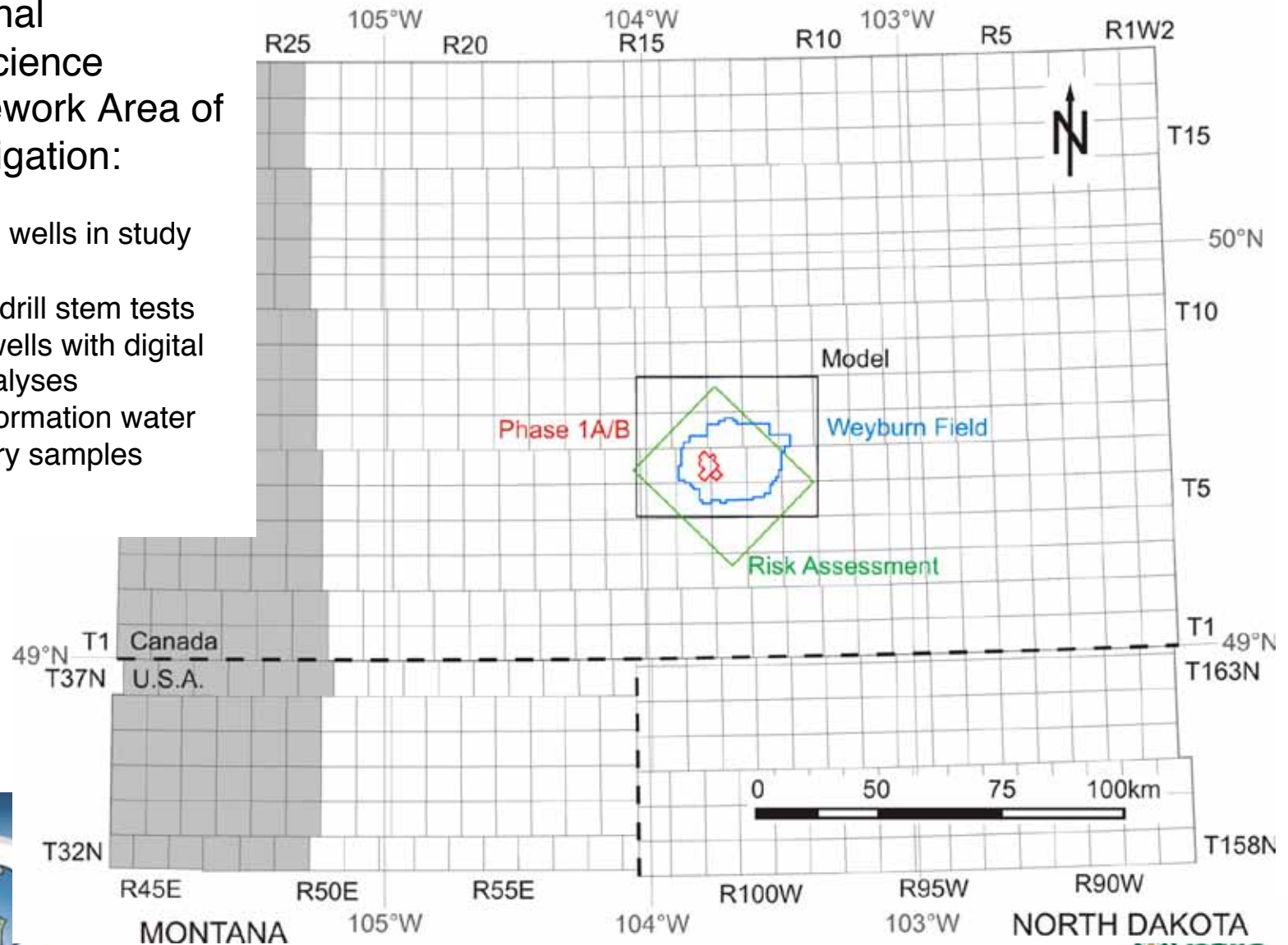
# Integrated technology portfolio for geologic CO<sub>2</sub> storage



# 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



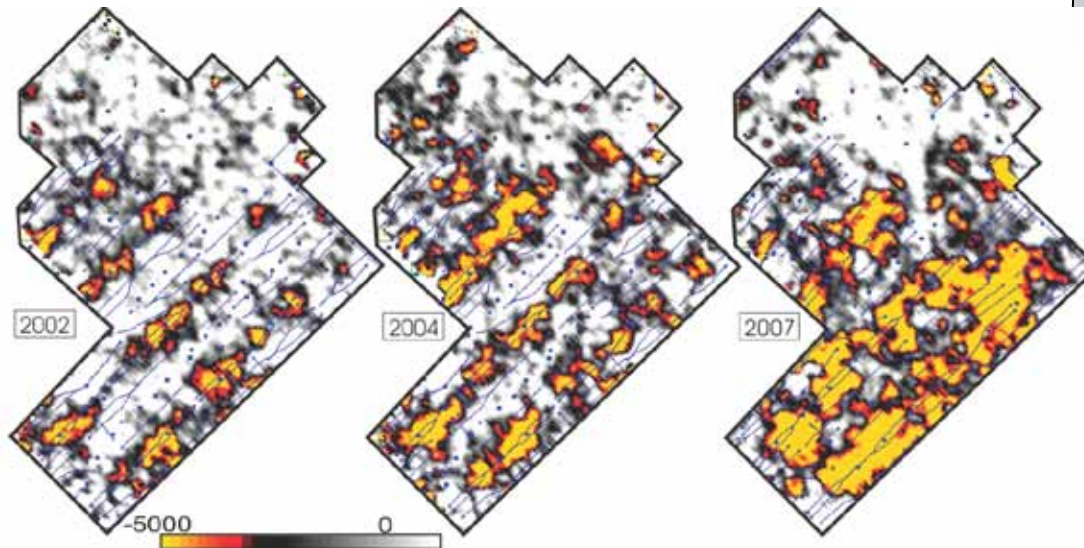
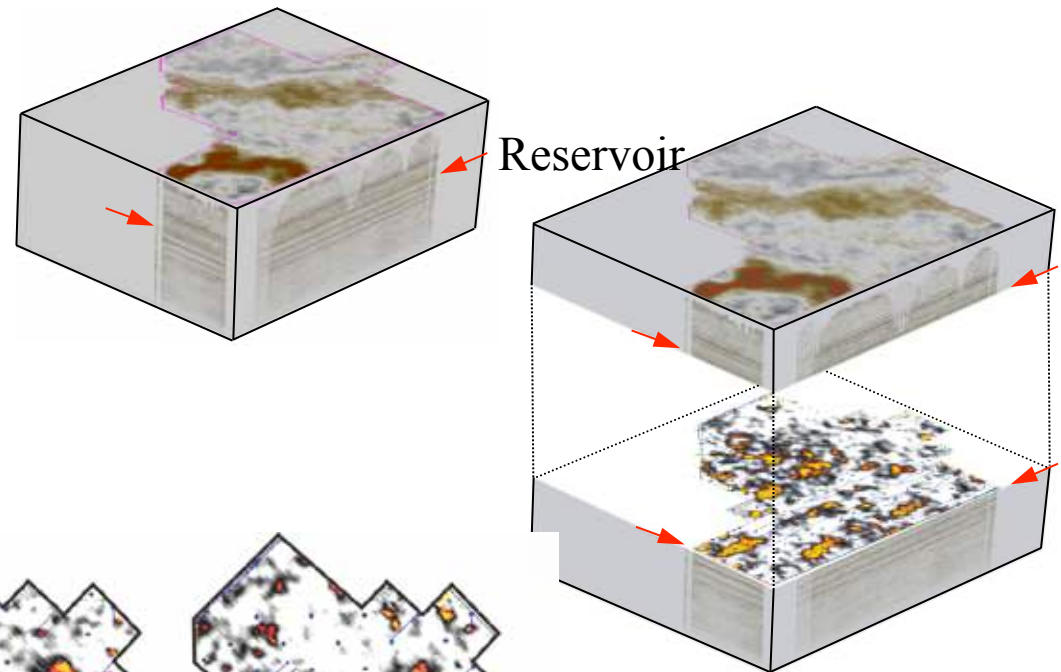
I E A G H C  
WEYBURN-MIDALE  
CO<sub>2</sub> MONITORING  
AND RESEARCH CENTRE



# 3D Time-Lapse Seismic: CO<sub>2</sub> Distribution

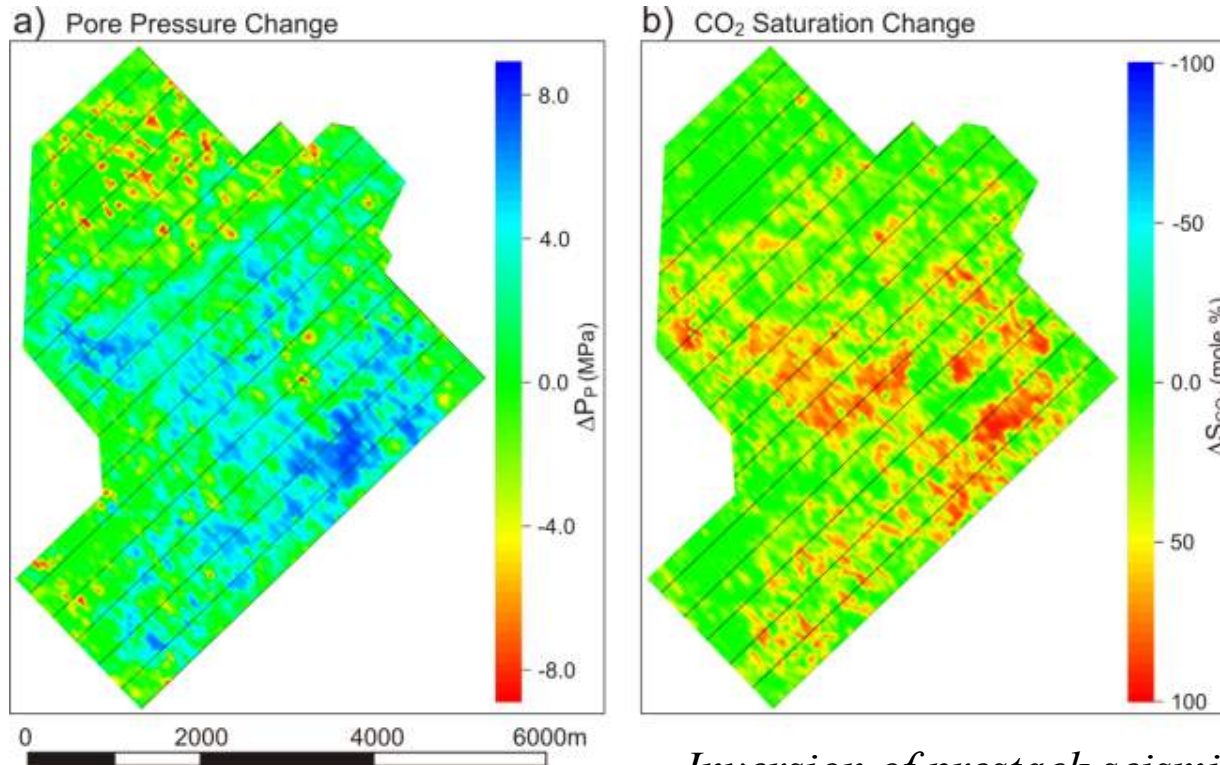
*Monitoring regional subsurface distribution of CO<sub>2</sub>:*

- *Verifying storage conformance*
- *A primary input for updating reservoir models*
- *Optimal resolving capability*
- *Sensitive to low CO<sub>2</sub> saturations*
- *Data repeatability is fundamental*





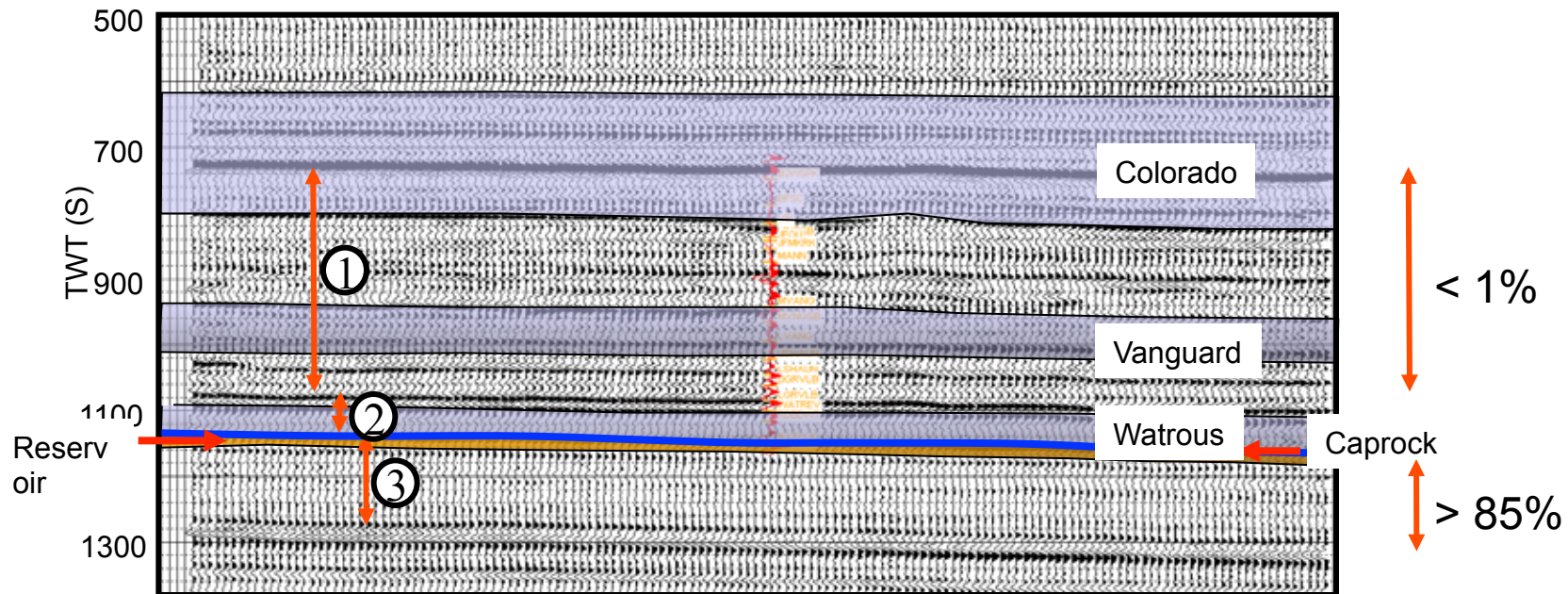
# 3D Time-Lapse Seismic: Pressure vs. CO<sub>2</sub> Saturation



*Inversion of prestack seismic data:*

- *Semi-quantitative CO<sub>2</sub> 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*

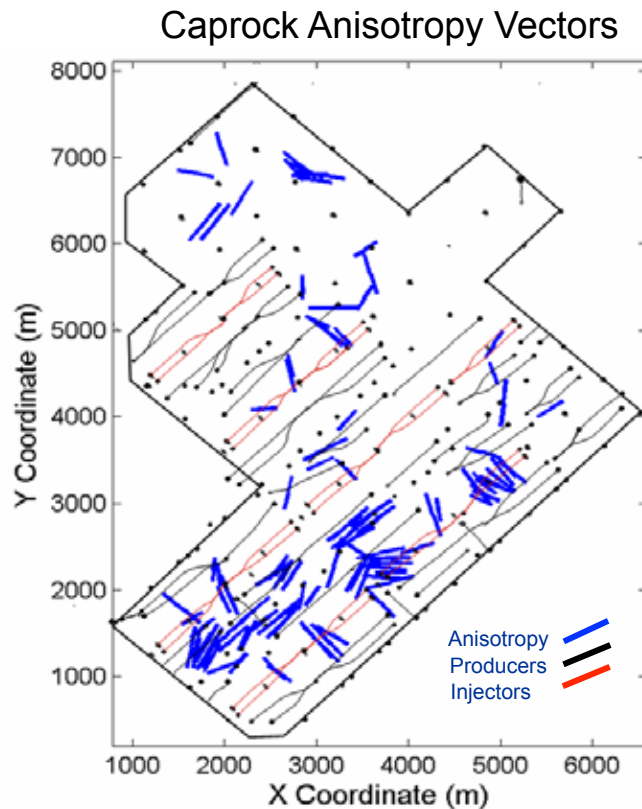
# 3D Time-Lapse Seismic: Containment



*Interval travel-time changes:*

- *Semi-quantitative apportionment of CO<sub>2</sub> within various layers of the storage complex*
- *Results are model-based*
- *Characterization of reservoir rock physics is essential*
- *Data repeatability is essential*

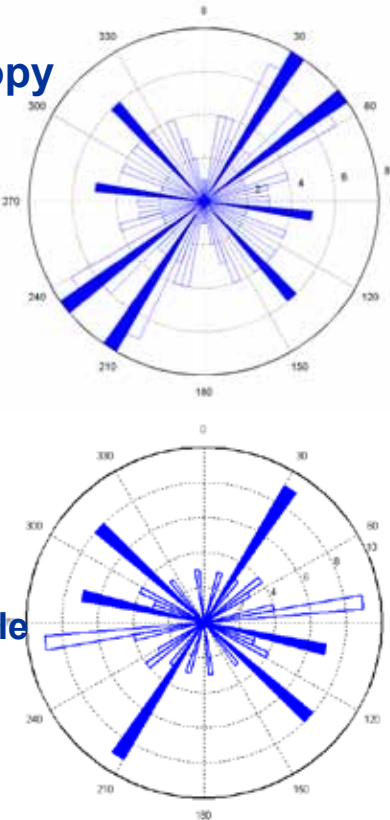
# Seal Integrity: Fracture Mapping



Anisotropy  
vectors

Bunge,  
2000

Reservoir  
oriented  
core sample  
fracture  
analysis



*Seismic anisotropy as a proxy for vertical fracturing:*

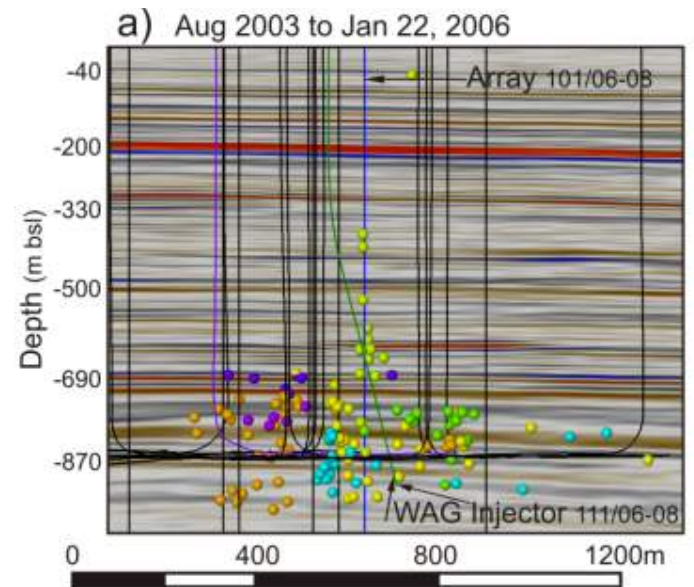
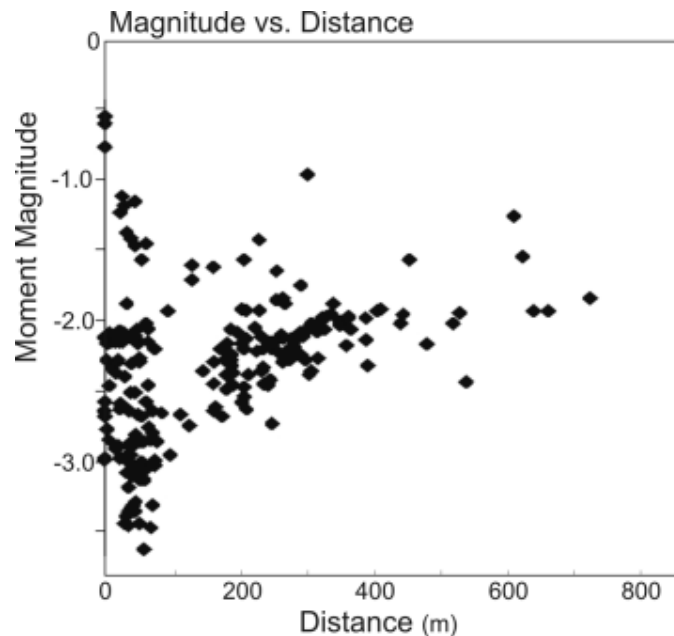
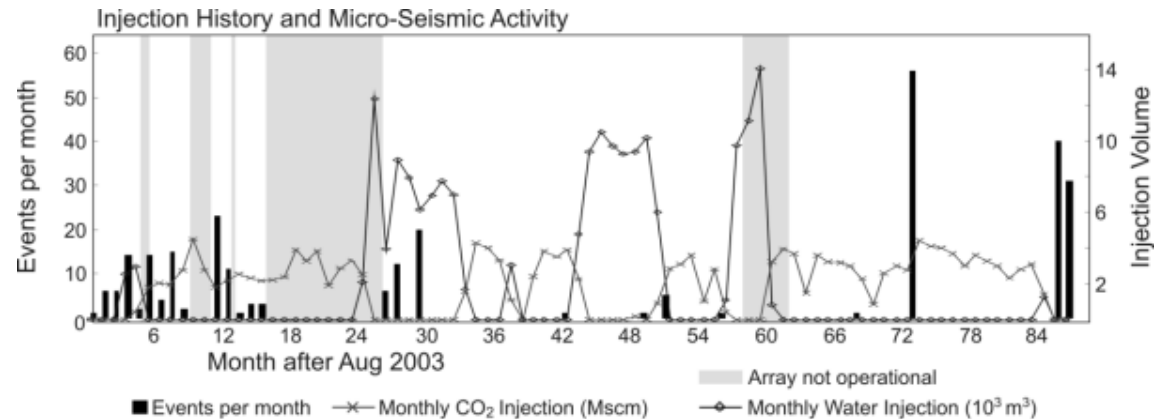
- Means of identifying potential fracture zones regionally
- Scale of individual fractures and hydraulic conductivity is not resolved
- “Fracture zones” may warrant subsequent attention



# Passive Seismic Monitoring

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

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



# 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

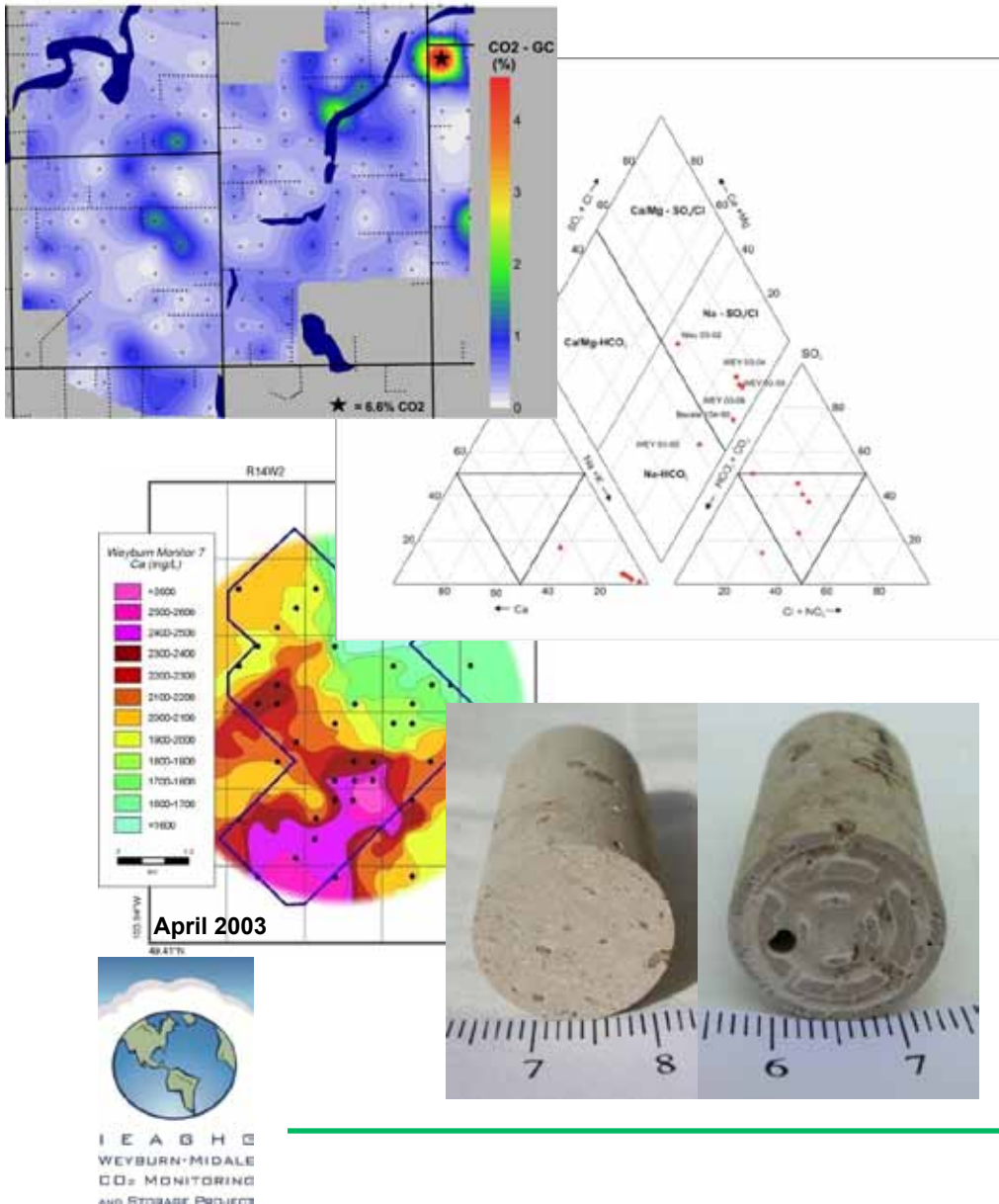
## 4.5 Reservoir fluids

4.5.1 Produced brines & gases

4.5.2 Produced hydrocarbons

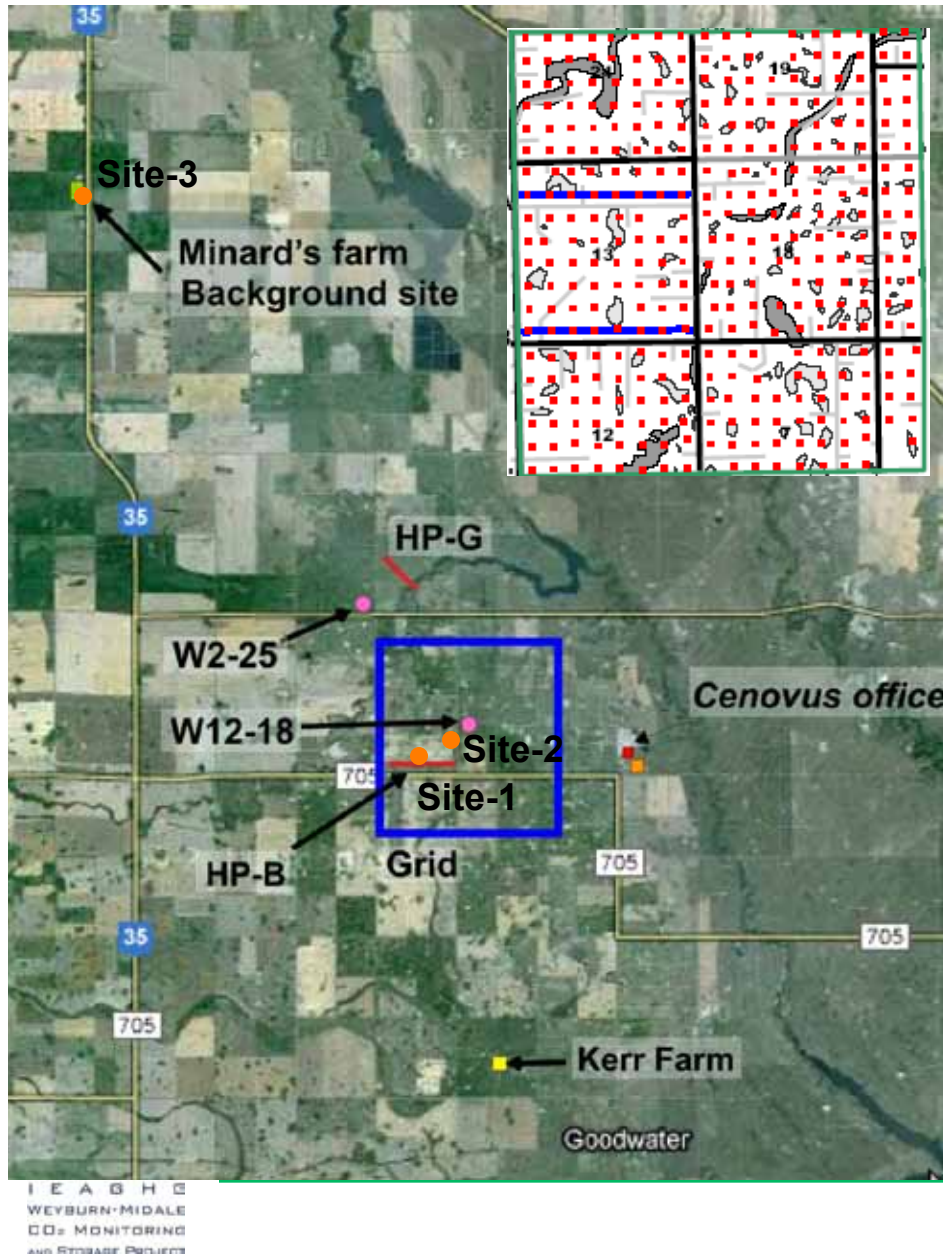
## 4.6 Reservoir/caprock core

## 4.7 Recommendations





# Soil gas monitoring: Overview



## Research Providers

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

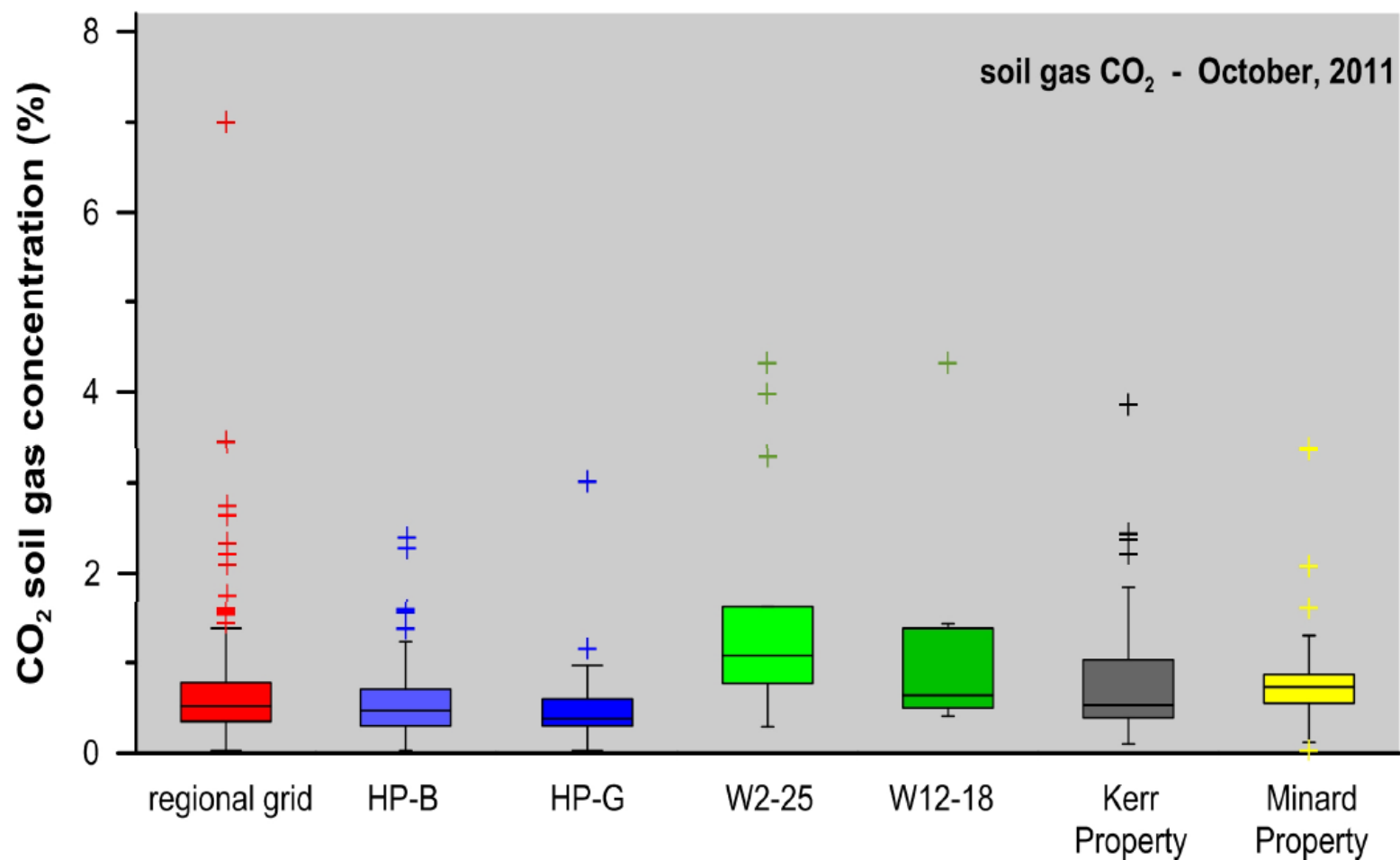
## Measurements

- ✓ CO<sub>2</sub>, O<sub>2</sub>, N<sub>2</sub> conc.
- ✓ CH<sub>4</sub>, C<sub>2</sub>H<sub>6</sub>, C<sub>2</sub>H<sub>4</sub> conc.
- ✓ Rn, He conc.
- ✓ CO<sub>2</sub> flux
- ✓ C isotopes

## Methods

- ✓ Single-depth (BGS), depth-profile (StFX) CO<sub>2</sub>
- ✓ CO<sub>2</sub> flux (BGS)
- ✓ Continuous CO<sub>2</sub> (BGS), CO<sub>2</sub> flux (StFX)
- ✓  $\delta^{13}\text{CO}_2$ ,  $^{14}\text{CO}_2$

# Soil Gas Monitoring Data



# Wellbore Field Testing Program

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





# SaskPower Boundary Dam Project



# Phase 1: Demonstration & Evaluation

- site selection, permits, agreements, community engagement
- risk assessment, seismic surveys, monitoring programs
- evaluation/injection well
- observation/monitoring well
- test injection trucked in CO<sub>2</sub>





## Measurement Monitoring & Verification Program

Designed for: (1) project/plume monitoring; (2) public assurance; (3) research objectives

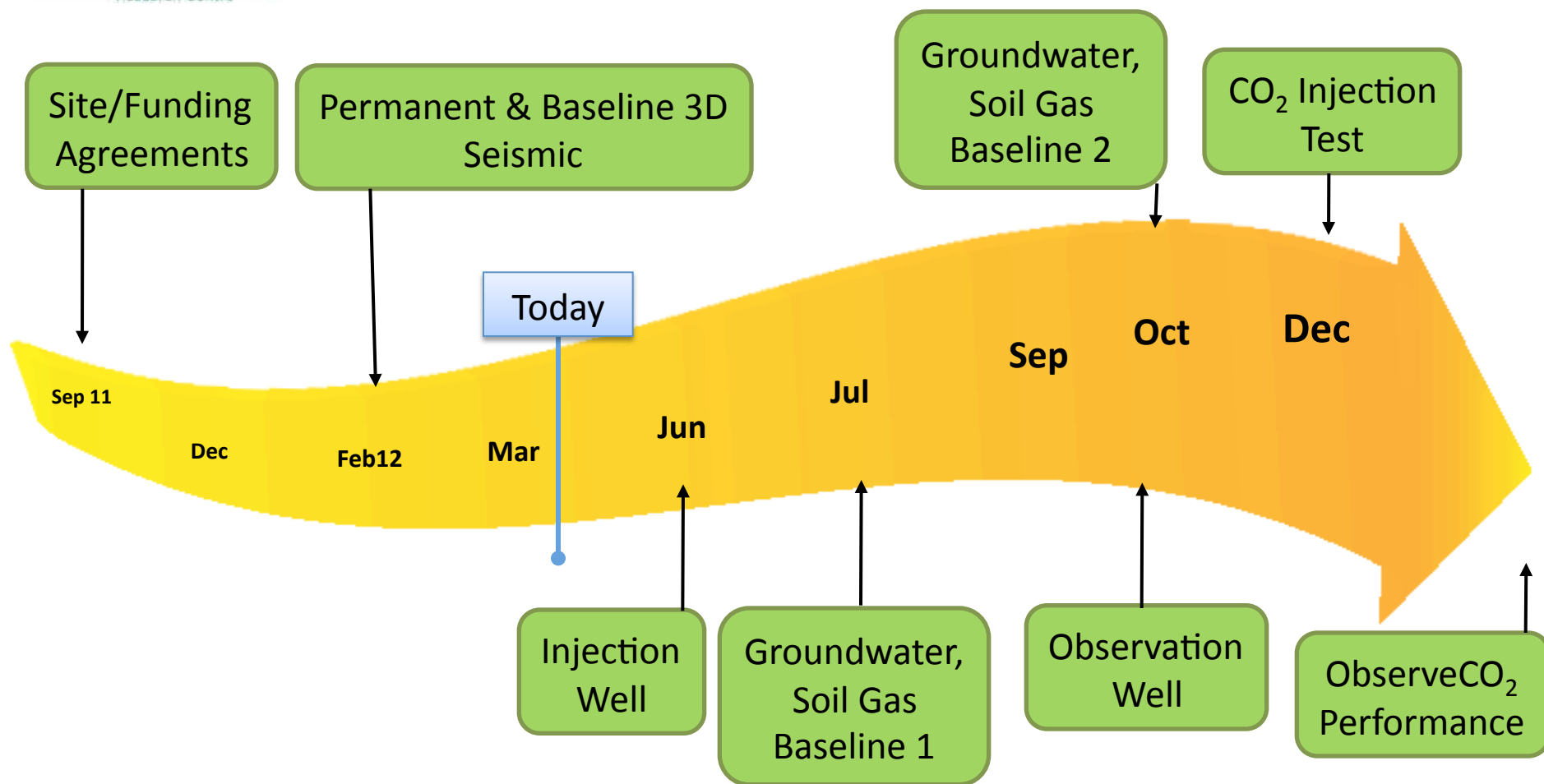
### Surface-based:

- Baseline 3D seismic survey
  - Time-lapse seismic surveys
  - Permanent seismic array
- Passive seismic
- Controlled-source electromagnetics
- Time-lapse gravity
- InSAR
- GPS
- Tiltmeters
- Groundwater & Soil gas monitoring

### Down-hole

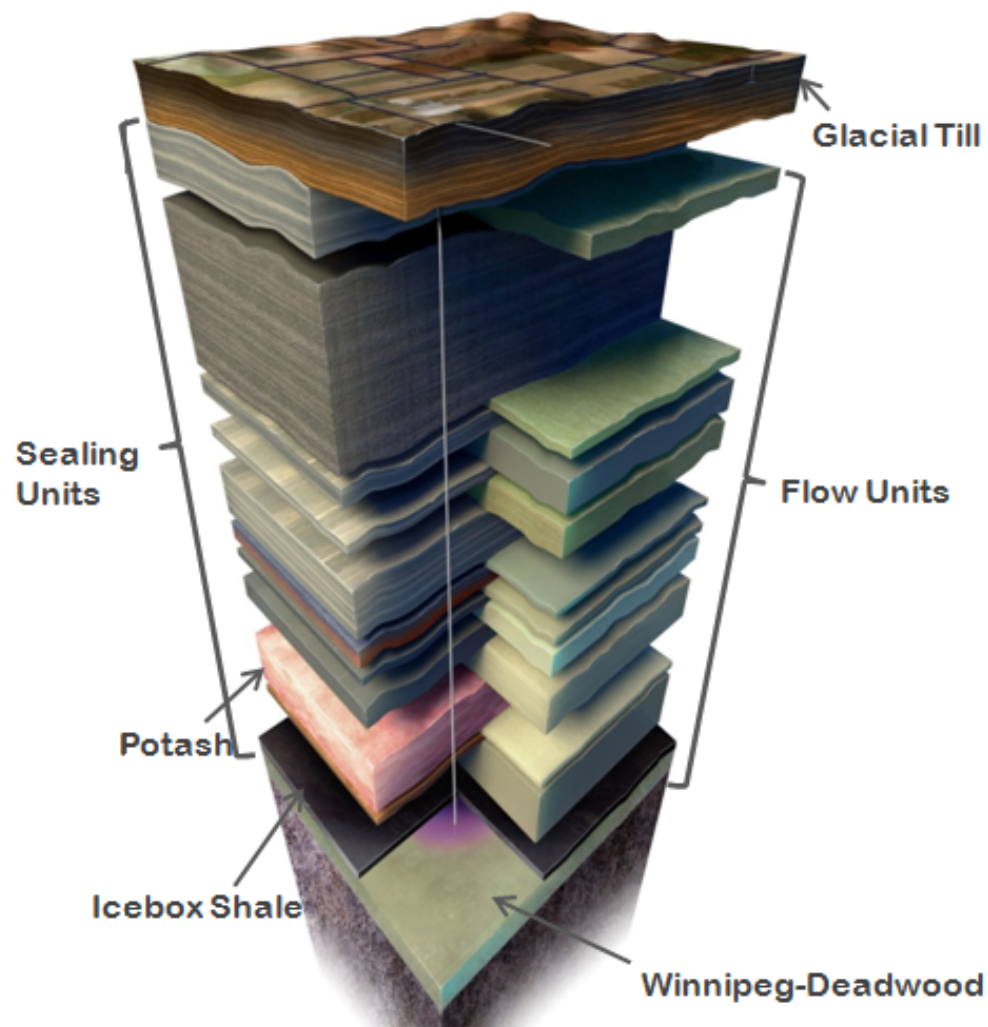
- Cross-well seismic & electrical monitoring
- Surface-to-downhole electrical monitoring
- Real-time P & T
- Passive seismic
- Fluid sampling
- Time-lapse logging & VSP's
- Cross-well seismic

# Project Schedule Summary: 2012



# Aquistore

Saskatchewan's  
Deep Saline  
CO<sub>2</sub> Storage  
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# Monitoring Lessons Learnt

1. 3D seismic surveys constitute powerful tools for monitoring of CO<sub>2</sub> distribution in the reservoir and for potential leakage
2. Characterization of the local rock/fluid/stress system is essential to the design of an appropriate monitoring plan and interpretation of geophysical data
3. Measurement of baseline (pre-injection) conditions should be considered a critical component of monitoring programs, whether focused on the reservoir, storage complex or wider environment

