The Aquistore Project: Commercial-Scale CO_2 Storage in a Saline Aquifer in Saskatchewan, Canada

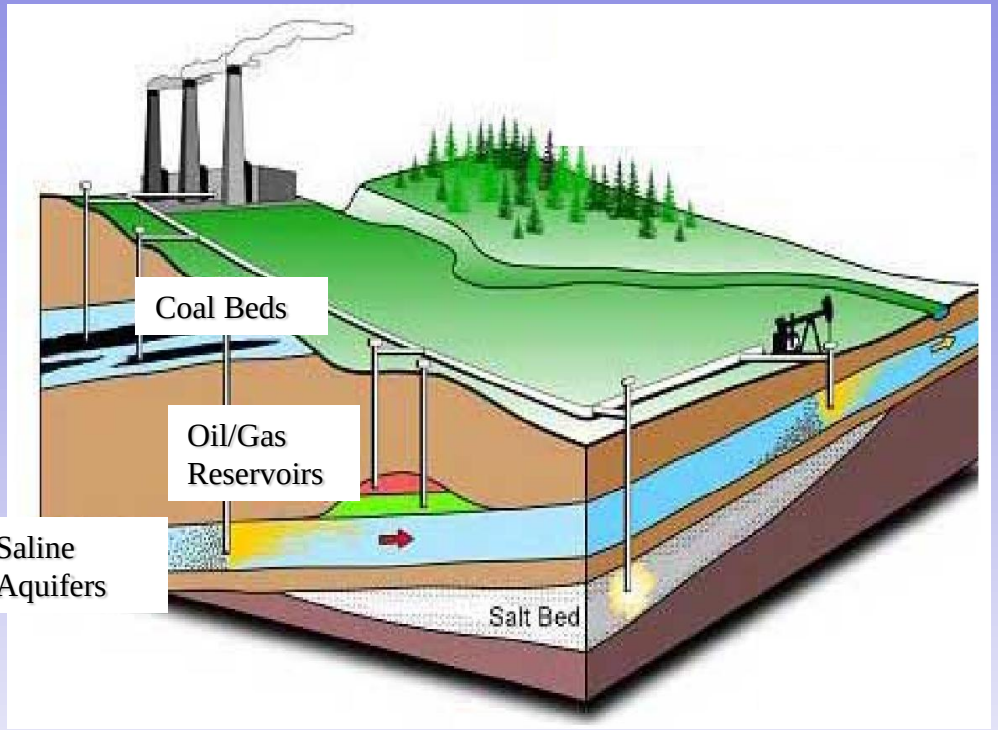
Don White, Geological Survey of Canada

Aquistore

Geological Storage

Sedimentary Basins

- Depleted oil and gas reservoirs
- Coal beds
- Saline aquifers
- Gas hydrates*



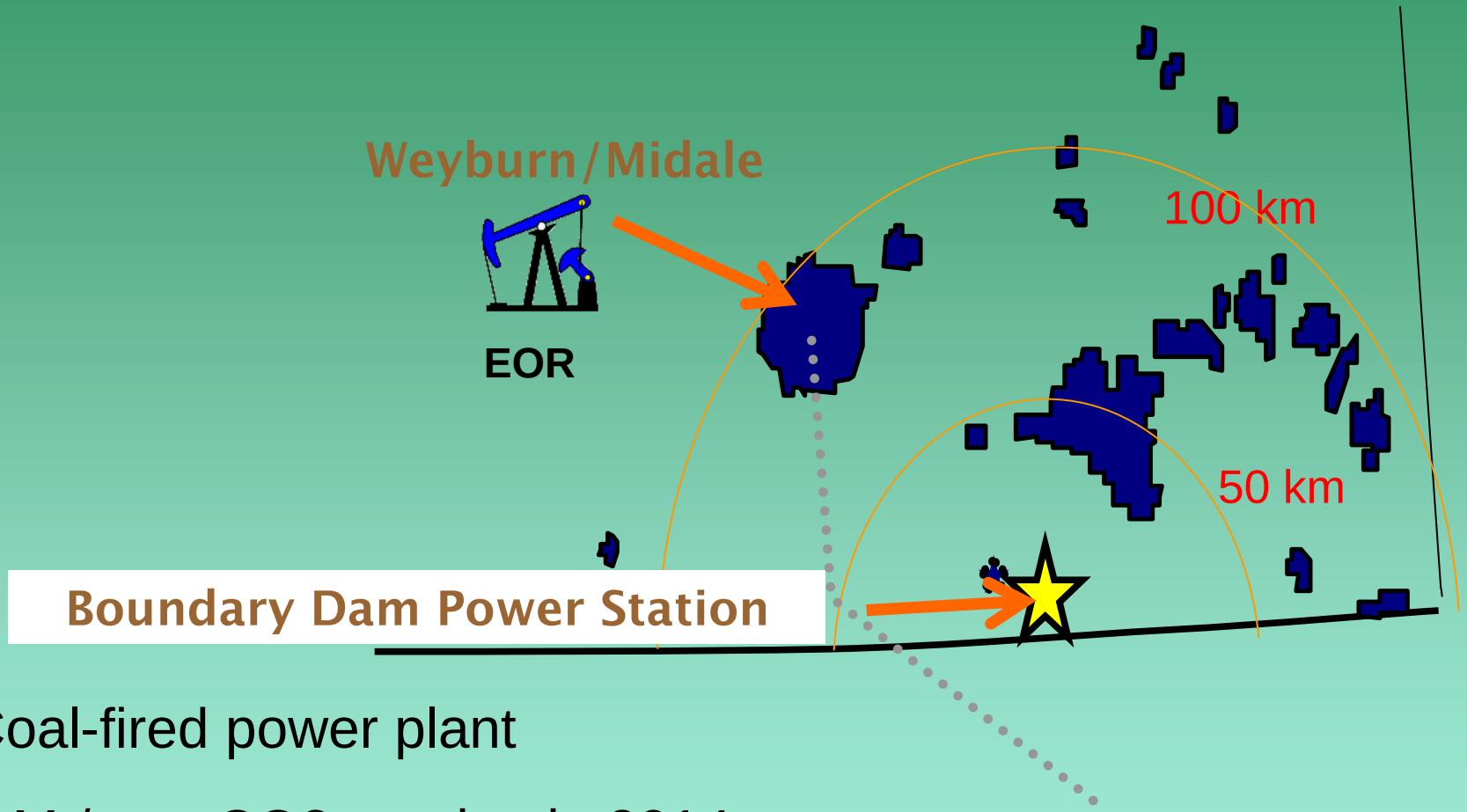
Other

- Deep Ocean
- Marine sediments
- Ultramafic rocks

*** Arctic Canada, East and West Coasts**

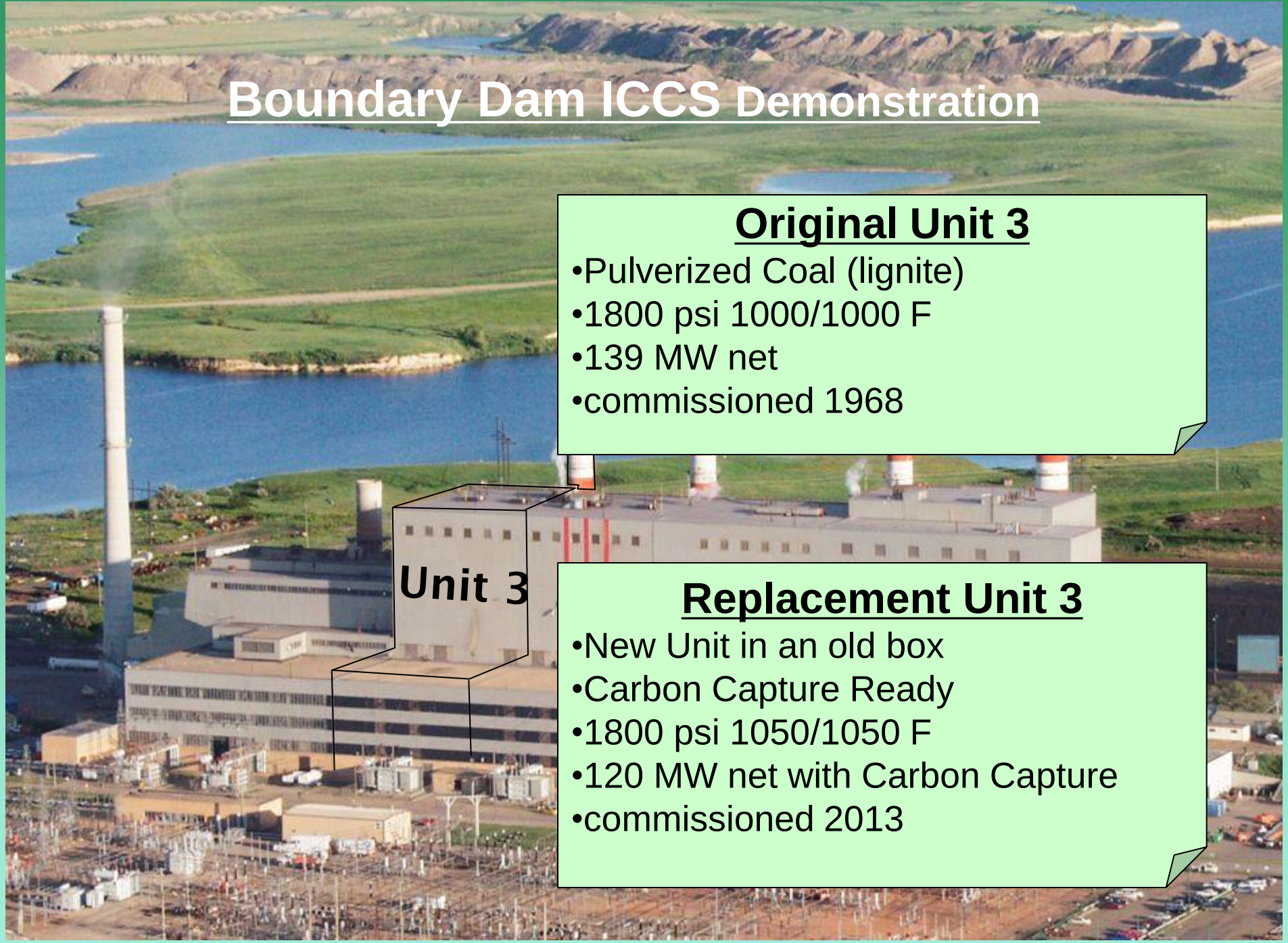
Boundary Dam/Aquistore Projects

Boundary Dam CCS Project



- Coal-fired power plant
- 1 Mt/year CO_2 starting in 2014
- 90% of CO_2 for EOR
- Deep saline aquifer storage and EOR (Aquistore)

Boundary Dam ICCS Demonstration



Original Unit 3

- Pulverized Coal (lignite)
- 1800 psi 1000/1000 F
- 139 MW net
- commissioned 1968

Replacement Unit 3

- New Unit in an old box
- Carbon Capture Ready
- 1800 psi 1050/1050 F
- 120 MW net with Carbon Capture
- commissioned 2013

Boundary Dam ICCS Demonstration: 2011 Conceptual Model

Capture Plant: 2012


SaskPower
Powering the future®

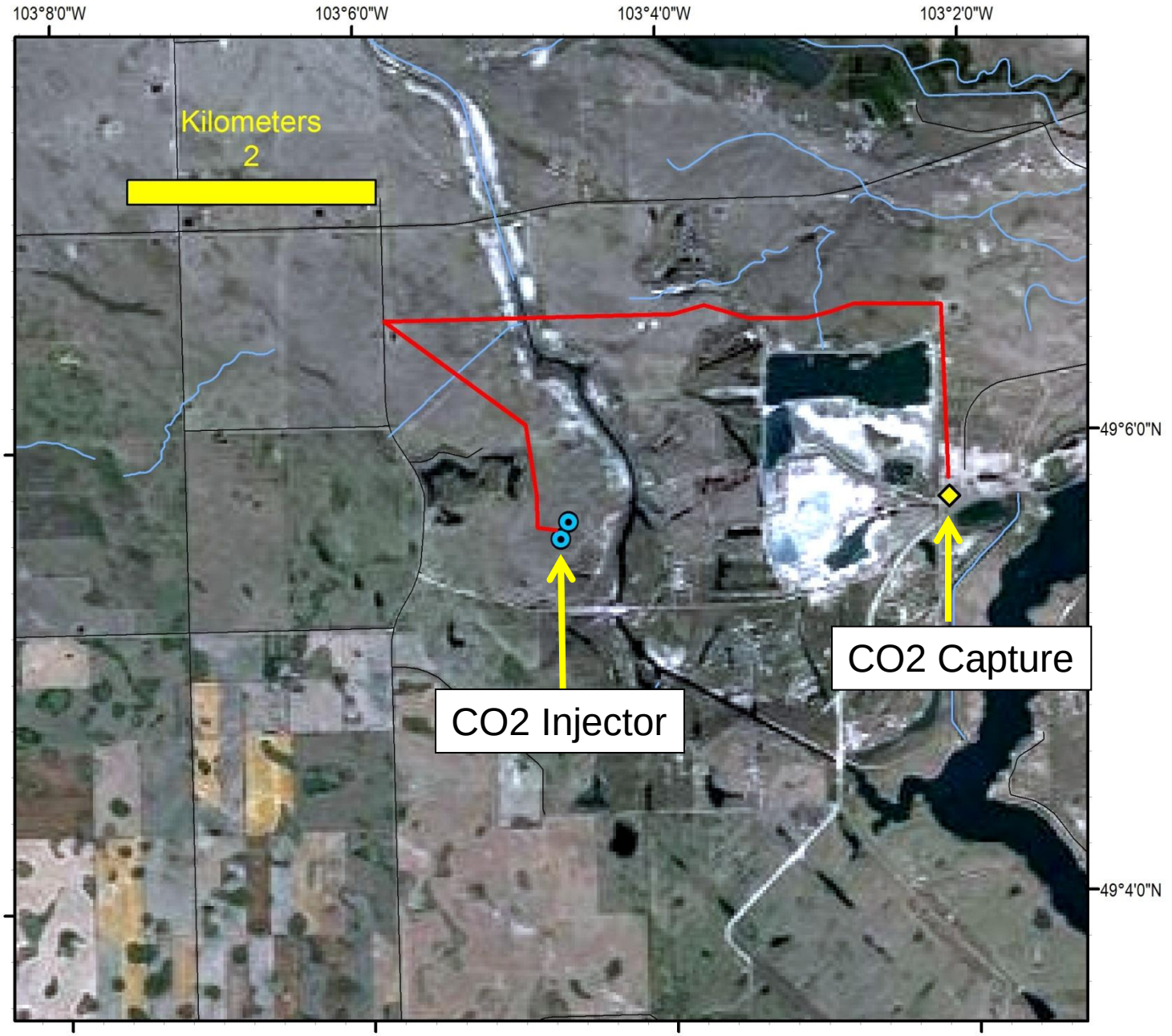
SaskPower
Powering the future®


2013
SaskPower
Boundary Dam
SaskPower
Powering the future

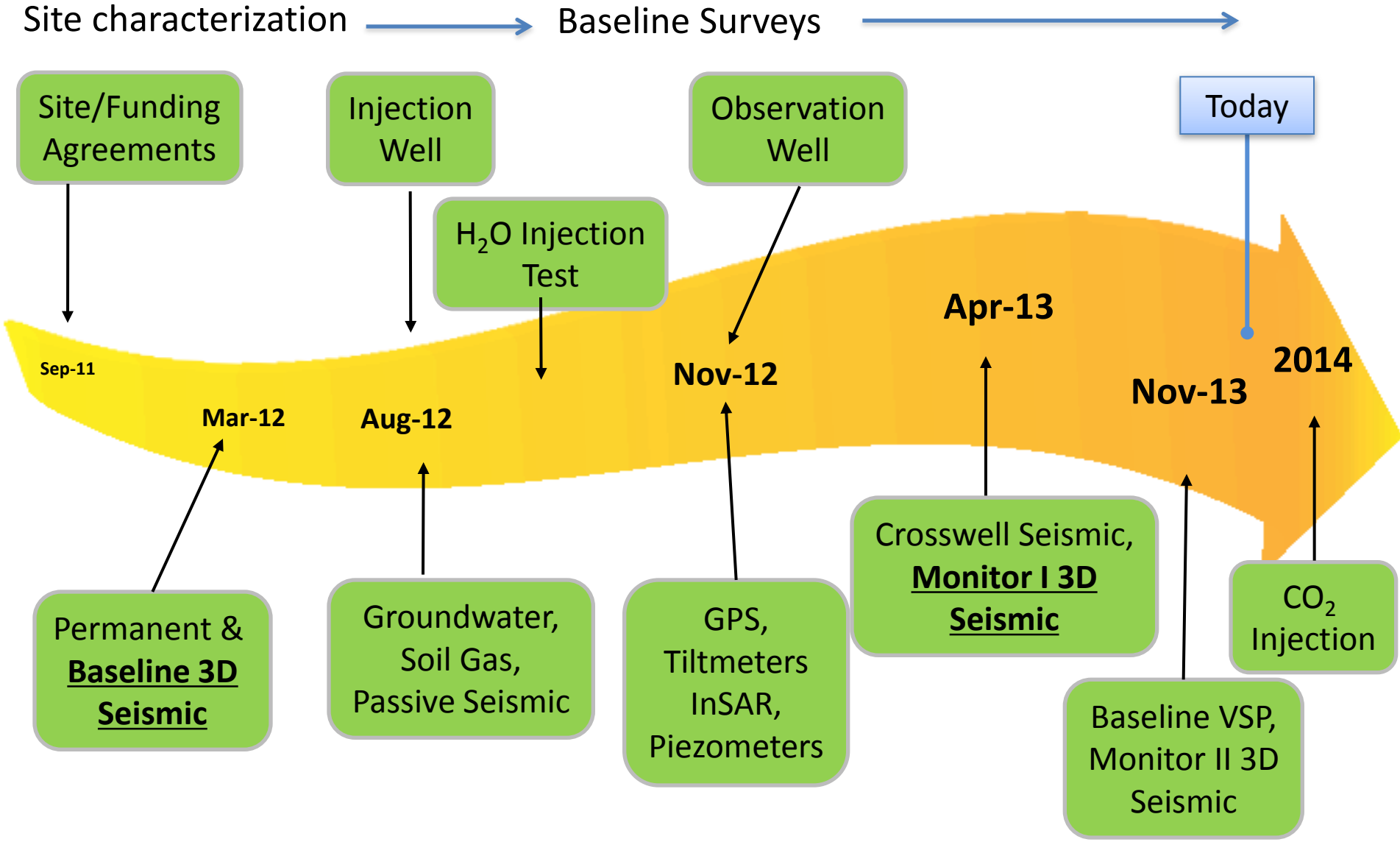
Capture Plant: 2013

Aquistore Project Overview

- CO_2 storage research monitoring project
- Variable injection rates: 0-1500 tonnes CO_2/day
- Buffer protection and long-term storage option for SaskPower's Boundary Dam Carbon Capture Project


103°8'0"W
103°6'0"W
103°4'0"W
103°2'0"W
Kilometers
2
49°6'0"N
49°4'0"N
CO2 Injector
CO2 Capture

Aquistore Project Timeline



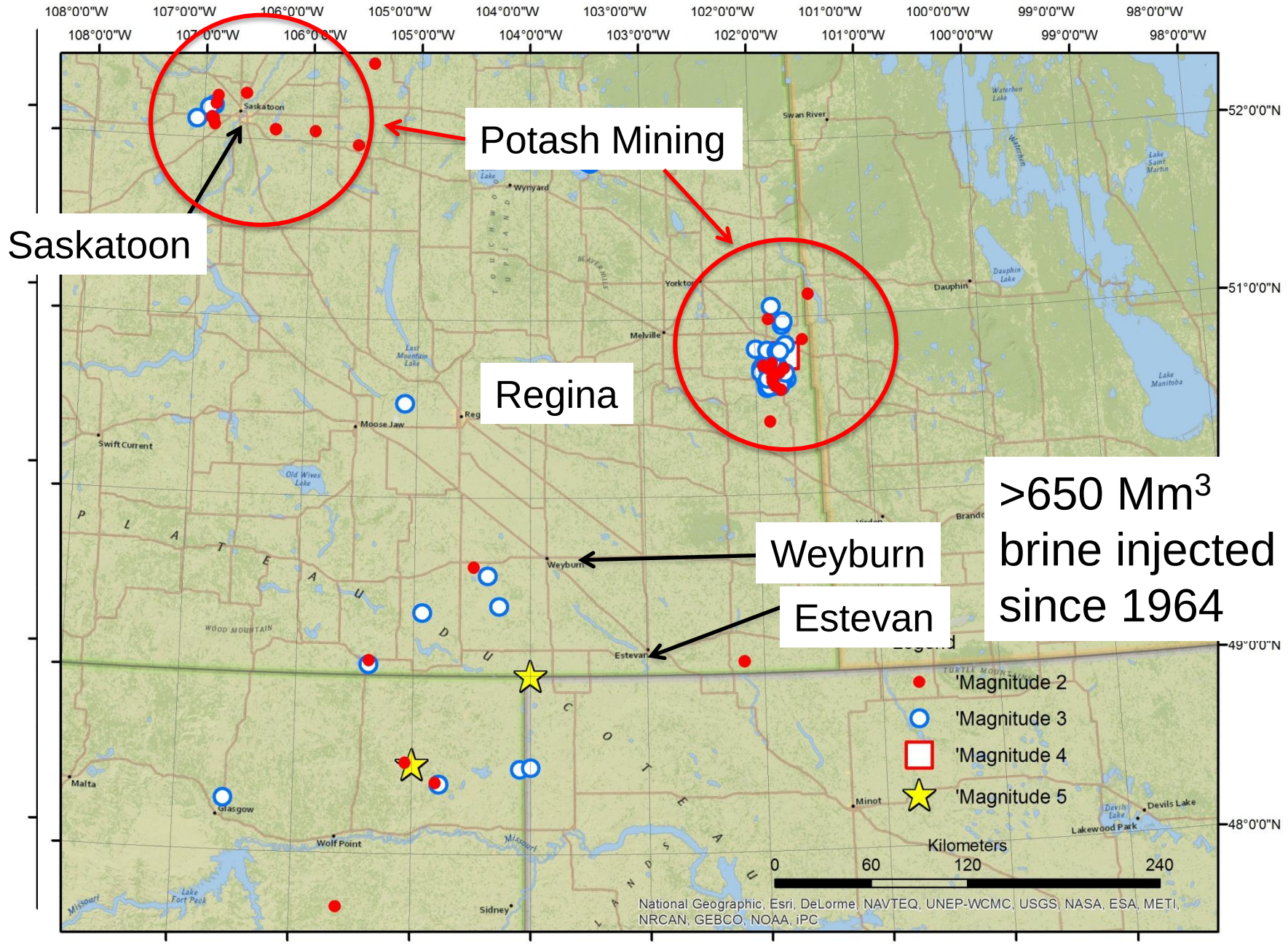

BAT-009
BREATHING AIR TRAILER
BAT-009
BREATHING AIR TRAILER
NABORS DRILLING
RIG 60 AC
DANGER
H2S GAS MAY BE PRESENT
MUSTER POINT

AQUISTORE Project: Task List

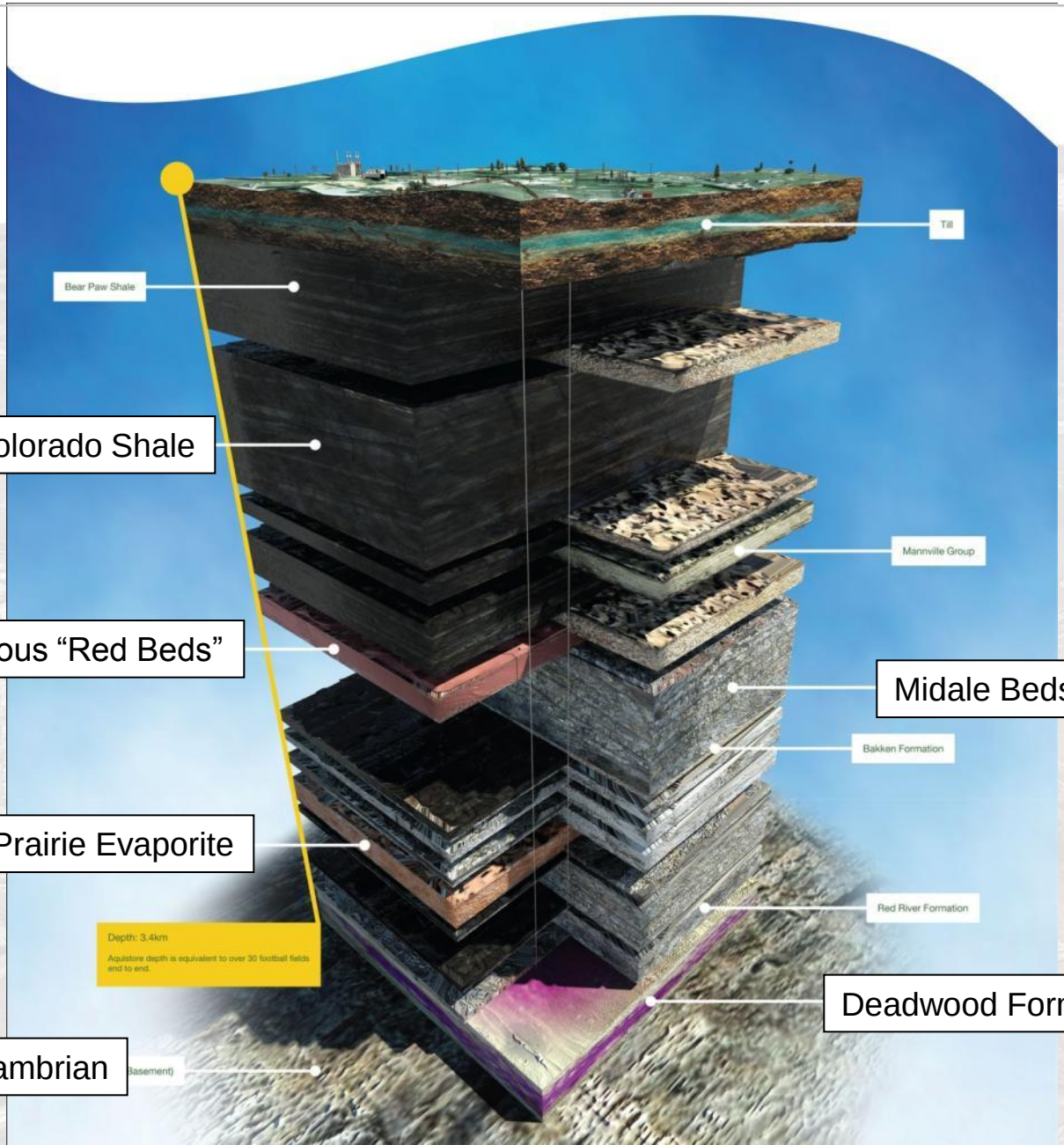
1. Site Suitability
2. Detailed Site Characterization
3. Geophysical Monitoring
4. Geochemical Sampling and Analysis
5. Reservoir Surveillance Wells
6. Numerical Simulations
7. Risk Assessment Management Framework
8. Commercialization / Economic Analysis

GEOLOGICAL CHARACTERIZATION

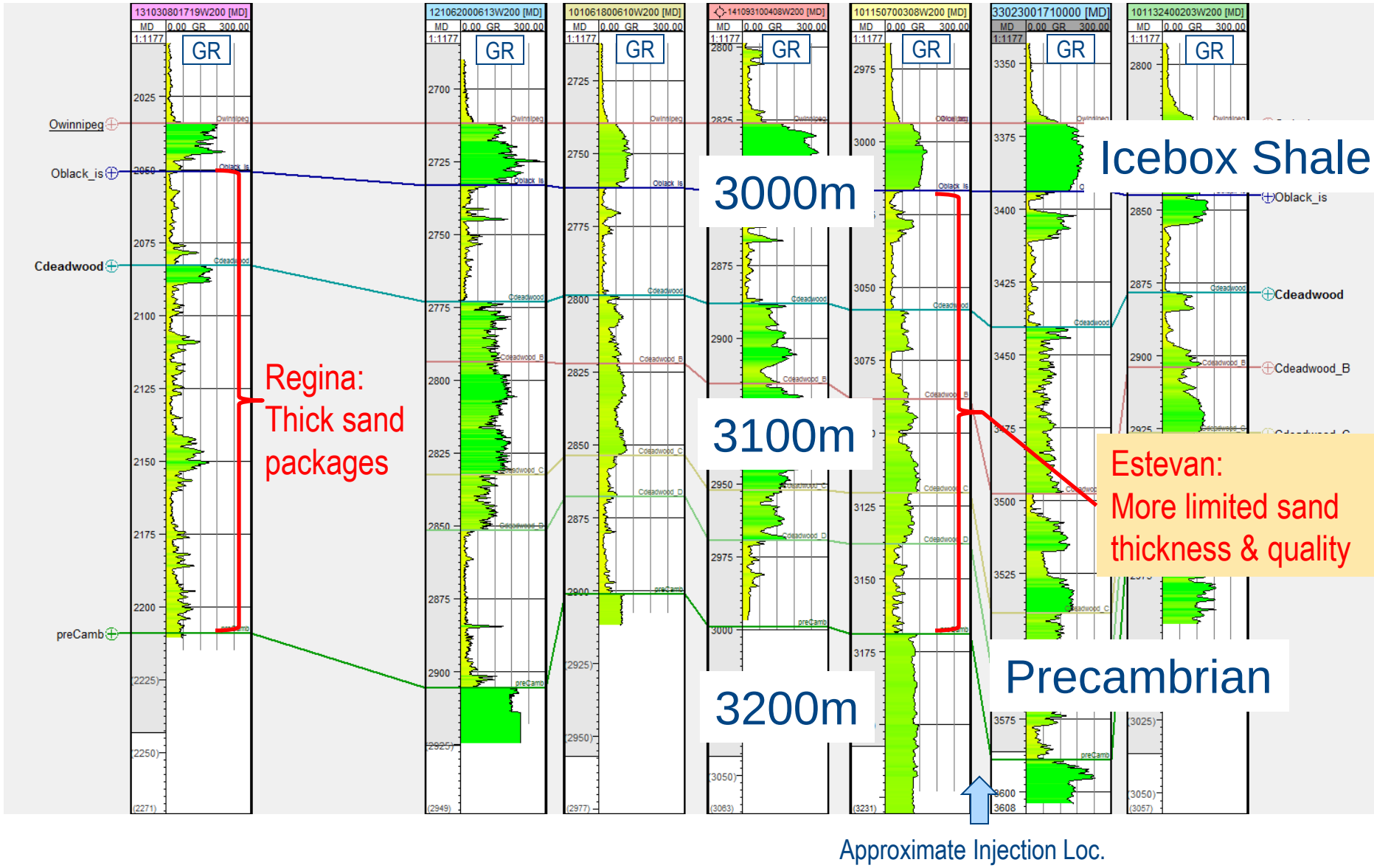
Record of Seismicity



Subsurface Model

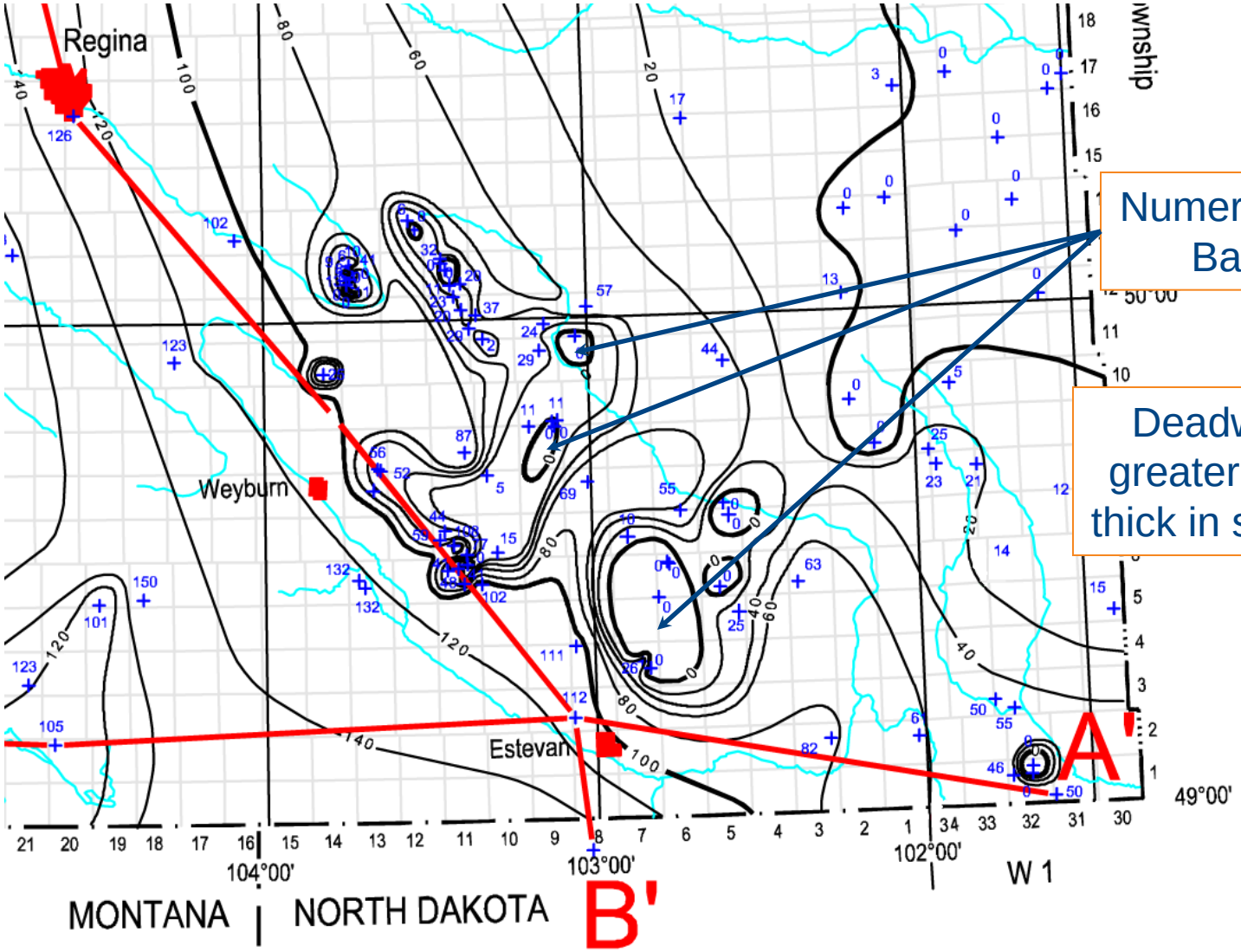


Reservoir Injection Rate Capacity



Deadwood Fm. Thickness

Schlumberger
Carbon Services

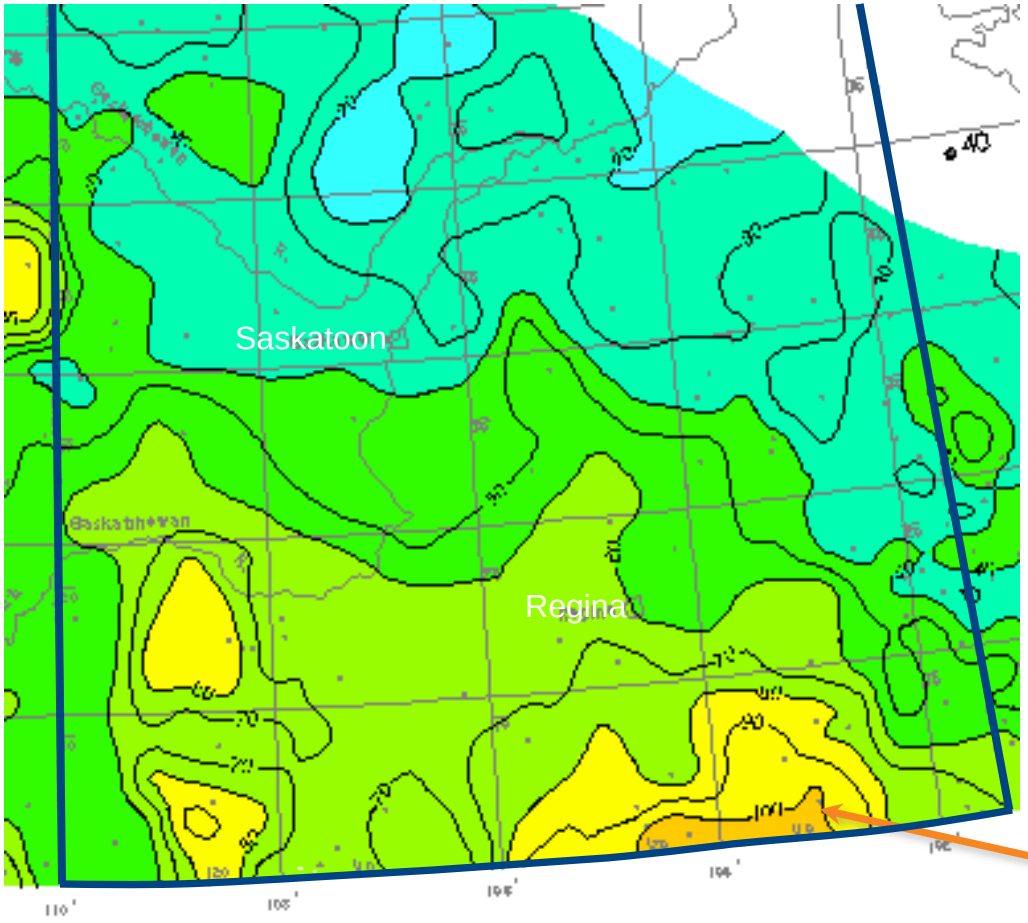


Numerous PreCambrian Basement Highs

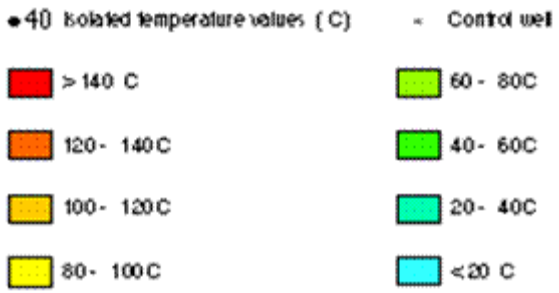
Deadwood Formation greater than 100 meters thick in study area (328 ft)

Geothermal Regime: T at Precambrian Surface

Schlumberger
Carbon Services



Contour Interval = 10° C



Normal Geothermal Gradient Approximately 20-30° C per km

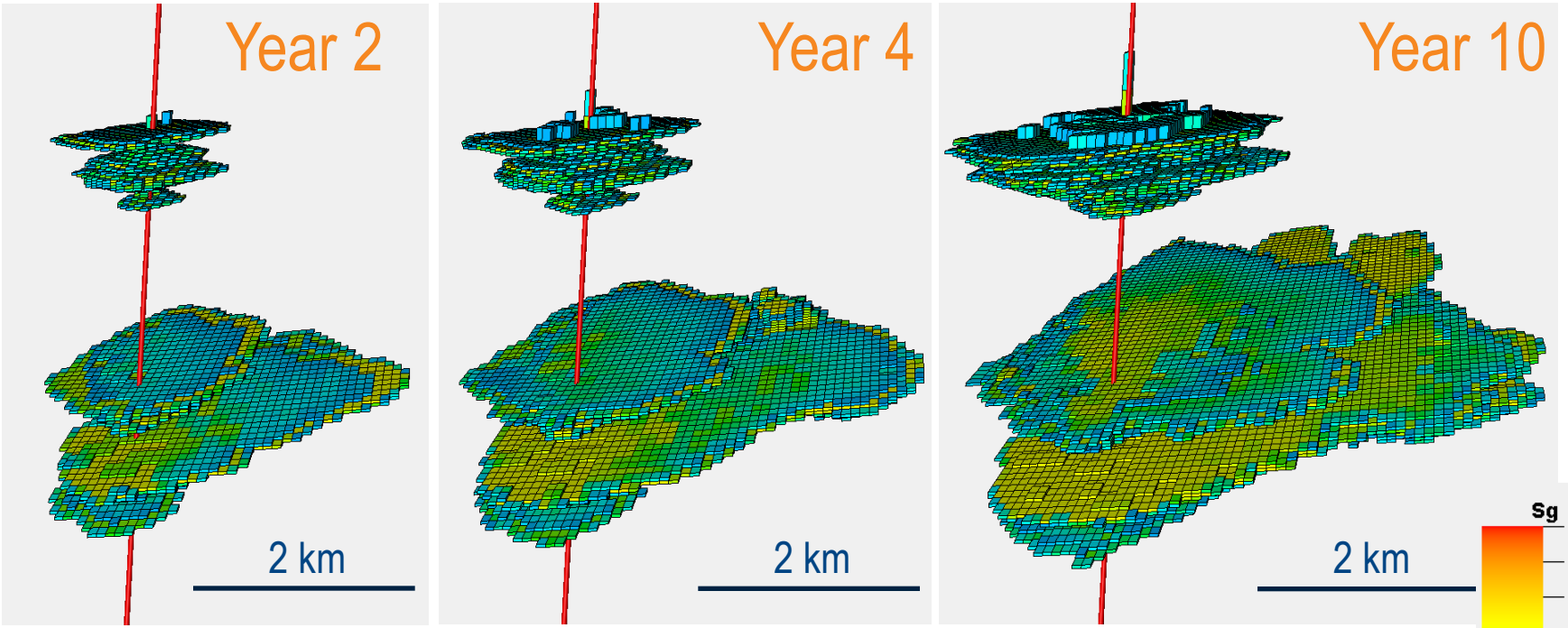
Target Depth Temp. ~95-100° C

Approx. Project Location

ptrc
Petroleum Technology Research Centre

CO_2 Saturation

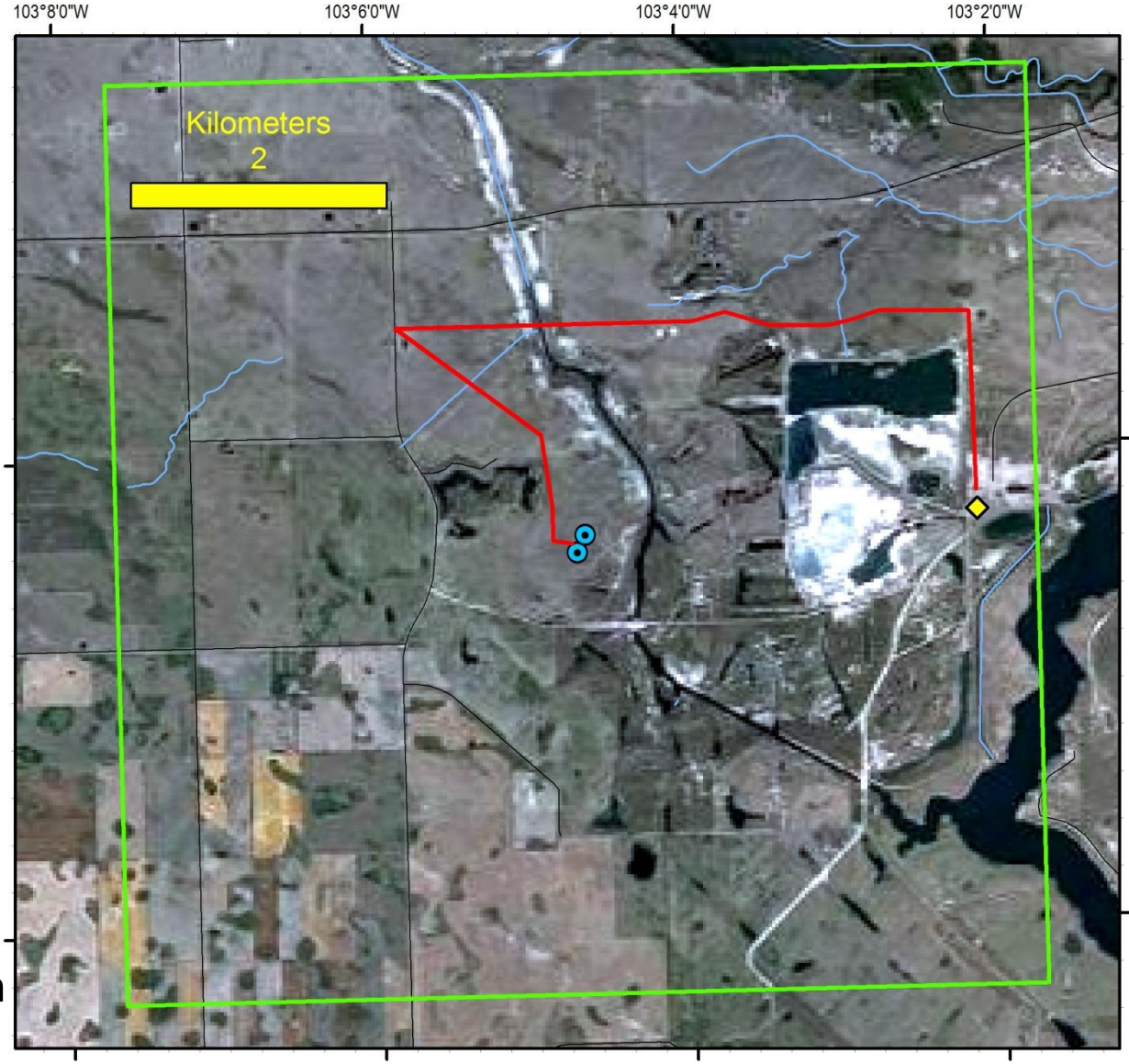
Schlumberger
Carbon Services



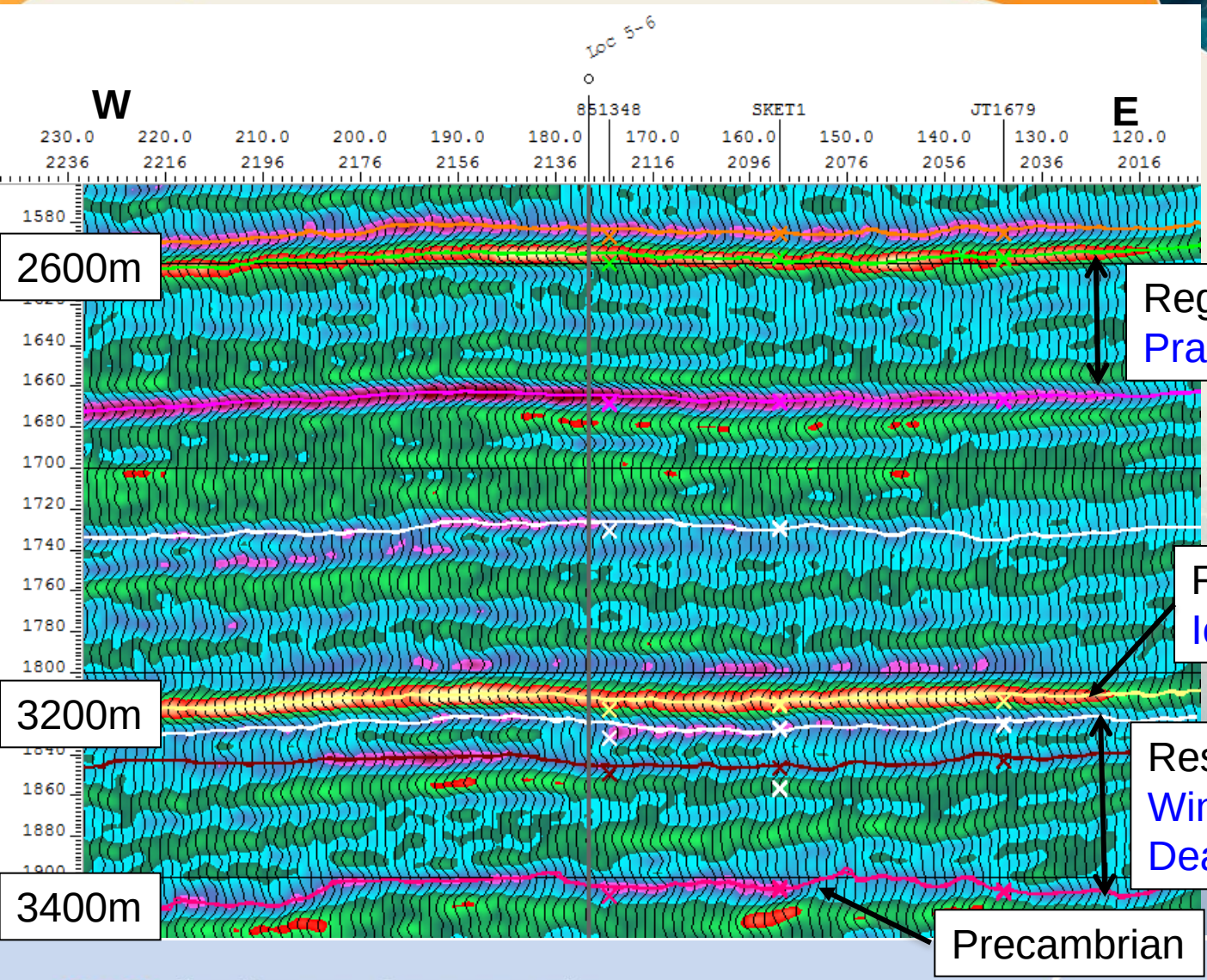
Case 1: 2000 T/d (Winnipeg and Lower Deadwood)

3D Seismic Survey

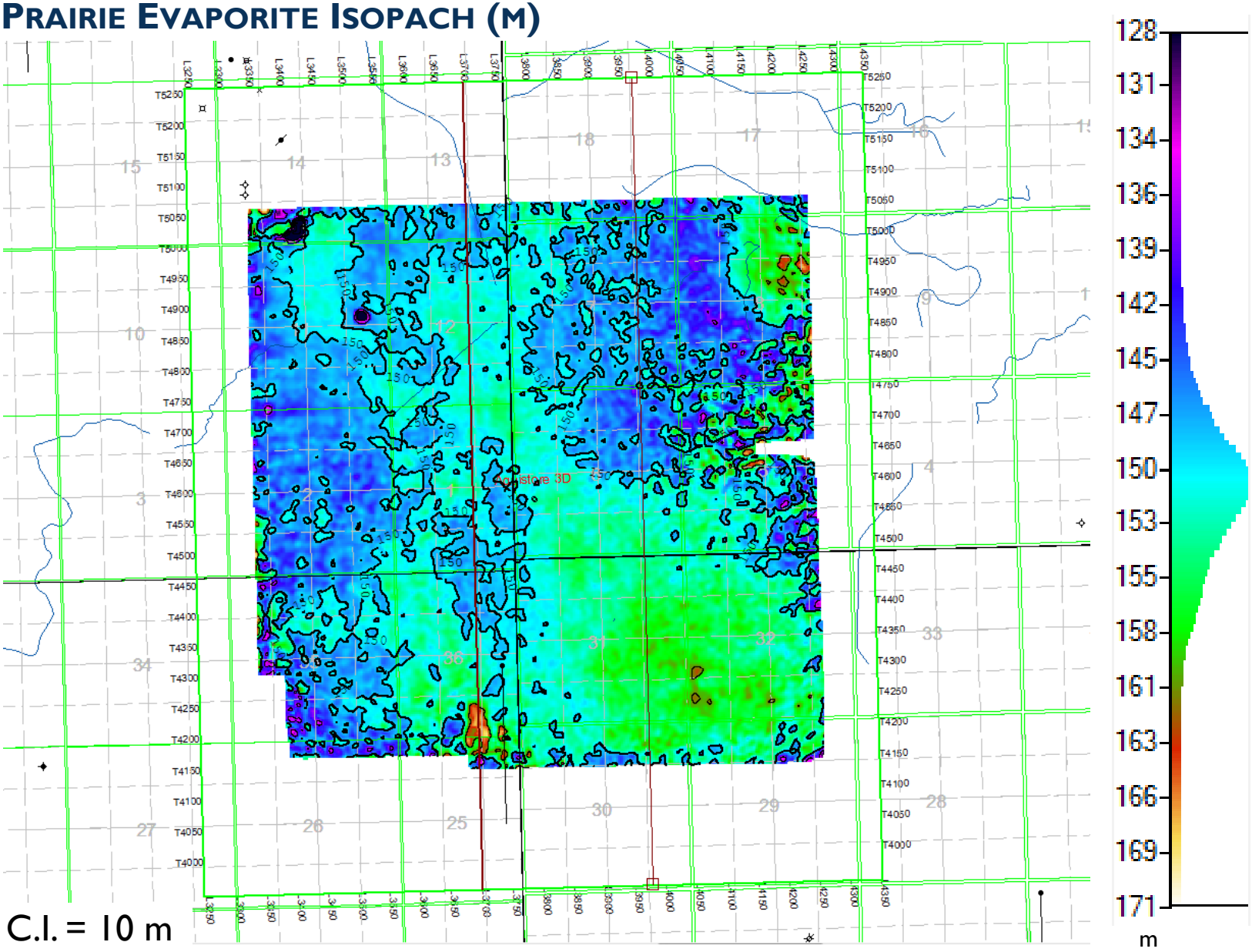
- Size : 30 km^2
- Acquisition : UniQ
- Acquired March 2012
- Vibroseis source:
  - 2-100Hz sweep
  - 5 sec record length
  - 2ms sample rate
  - 288 m line interval,
  - 36 m in-line
- Receivers:
  - 288m line interval
  - 6m in-line
- 2411 shots
- 18100 geophones
- Natural bin size: 3m x 18m
- Full fold: 88
- Offset range: 220m to 5388m



3D Seismic Interpretation

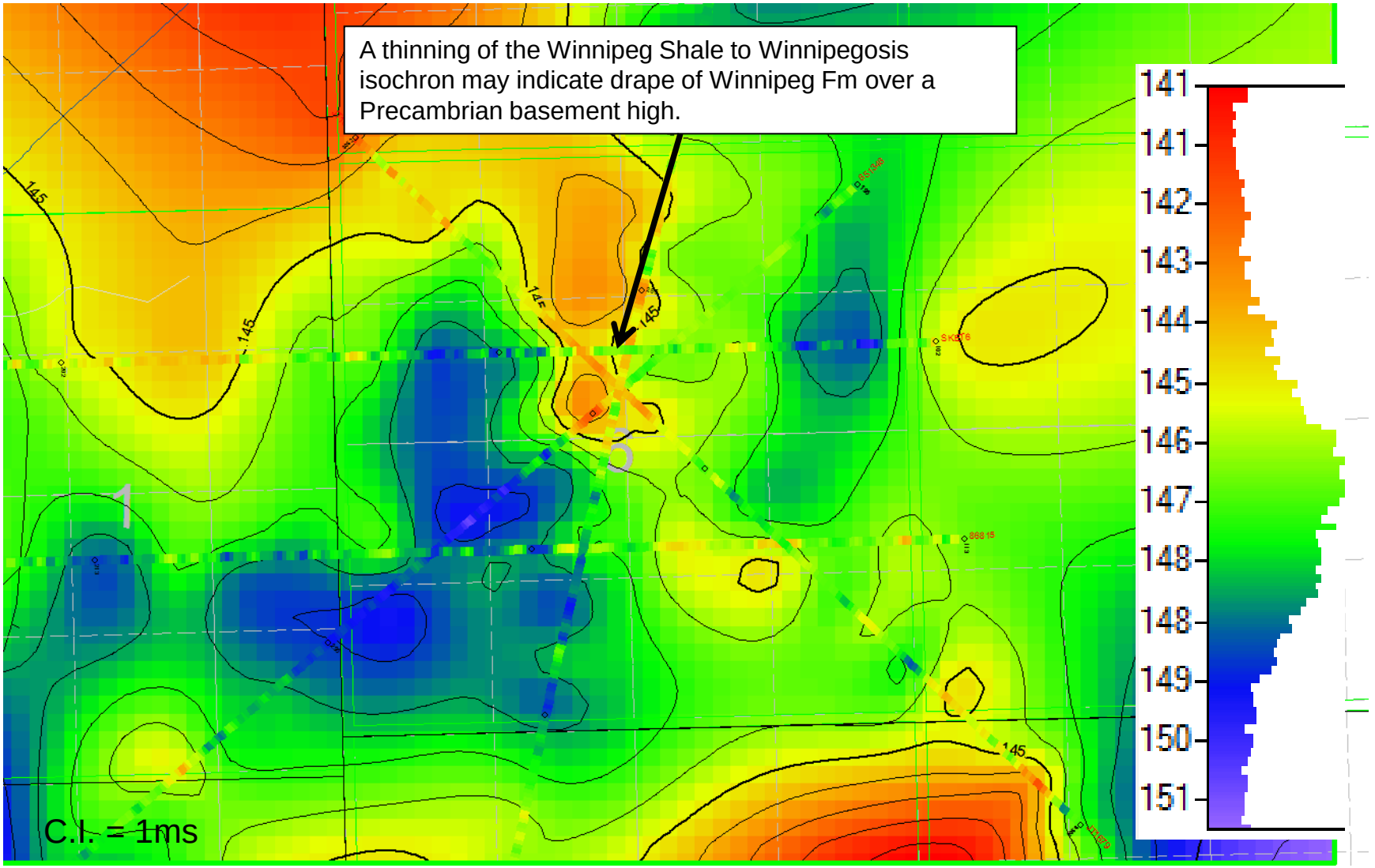


Prairie Evaporite Isopach (m)

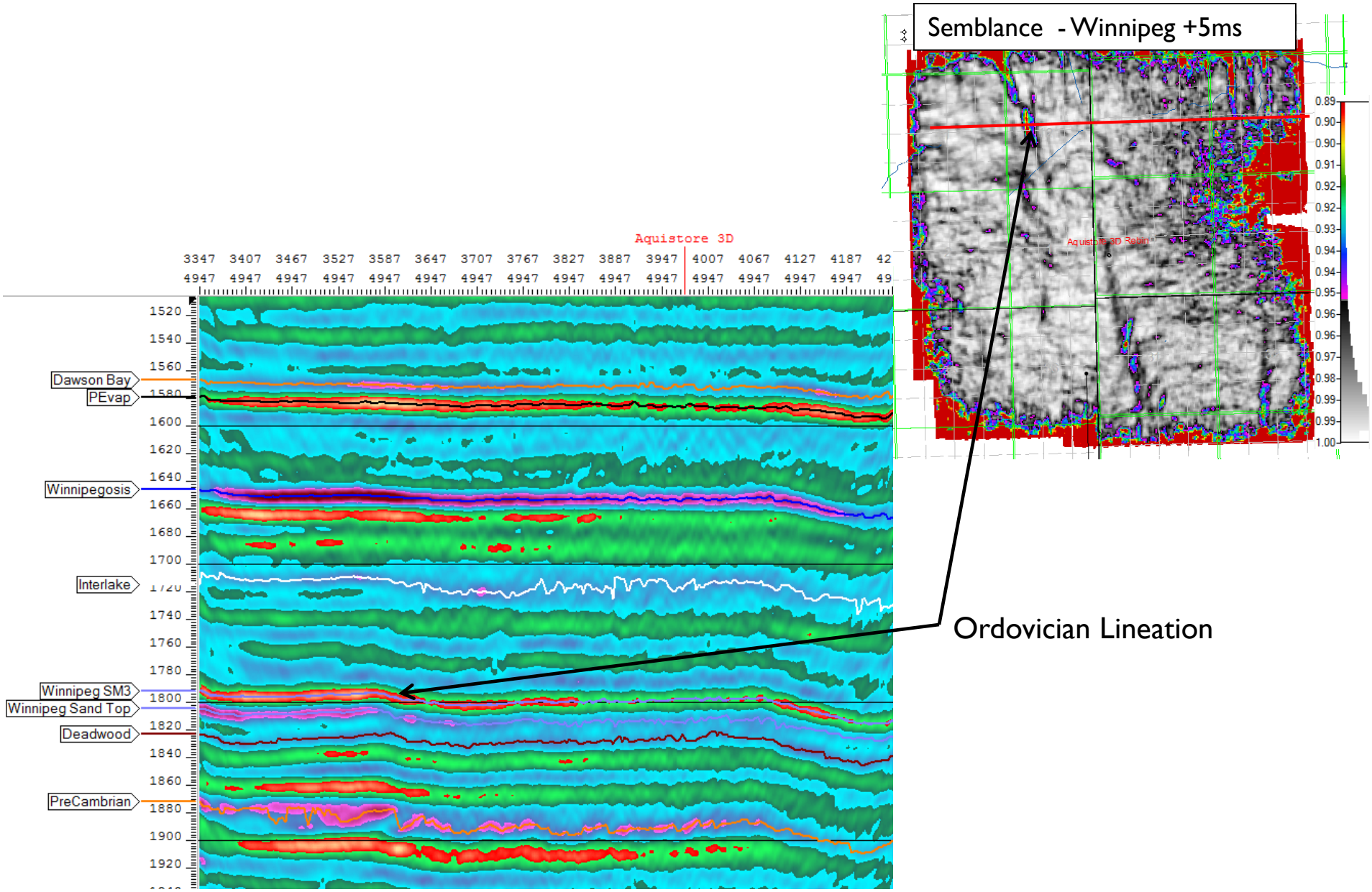


Winnipeg to Winnipegosis Isochron Grid (ms)

RPS Boyd PetroSearch



Ordovician lineation



MONITORING RESEARCH

Monitoring Program

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

Surface-based:

- Regional 3D seismic survey
  - Geological characterization
  - Baseline & time-lapse (?)
- Permanent seismic array
  - Time-lapse imaging
- Electrical/electromagnetic
- Gravity

Plume

- Passive seismic (broadband & short period array)
- InSAR
- GPS
- Tiltmeters

Deformation

- Groundwater & Soil gas monitoring

Leakage

Down-hole

- Cross-well seismic & VSP
- Cross-well & surface-to-downhole electrical monitoring
- Real-time P & T
- Passive seismic
- Fluid sampling
- Time-lapse logging
- Distributed Acoustic/Temperature Sensors (DAS/DTS)
- Heater cable
- Gravity

In Situ

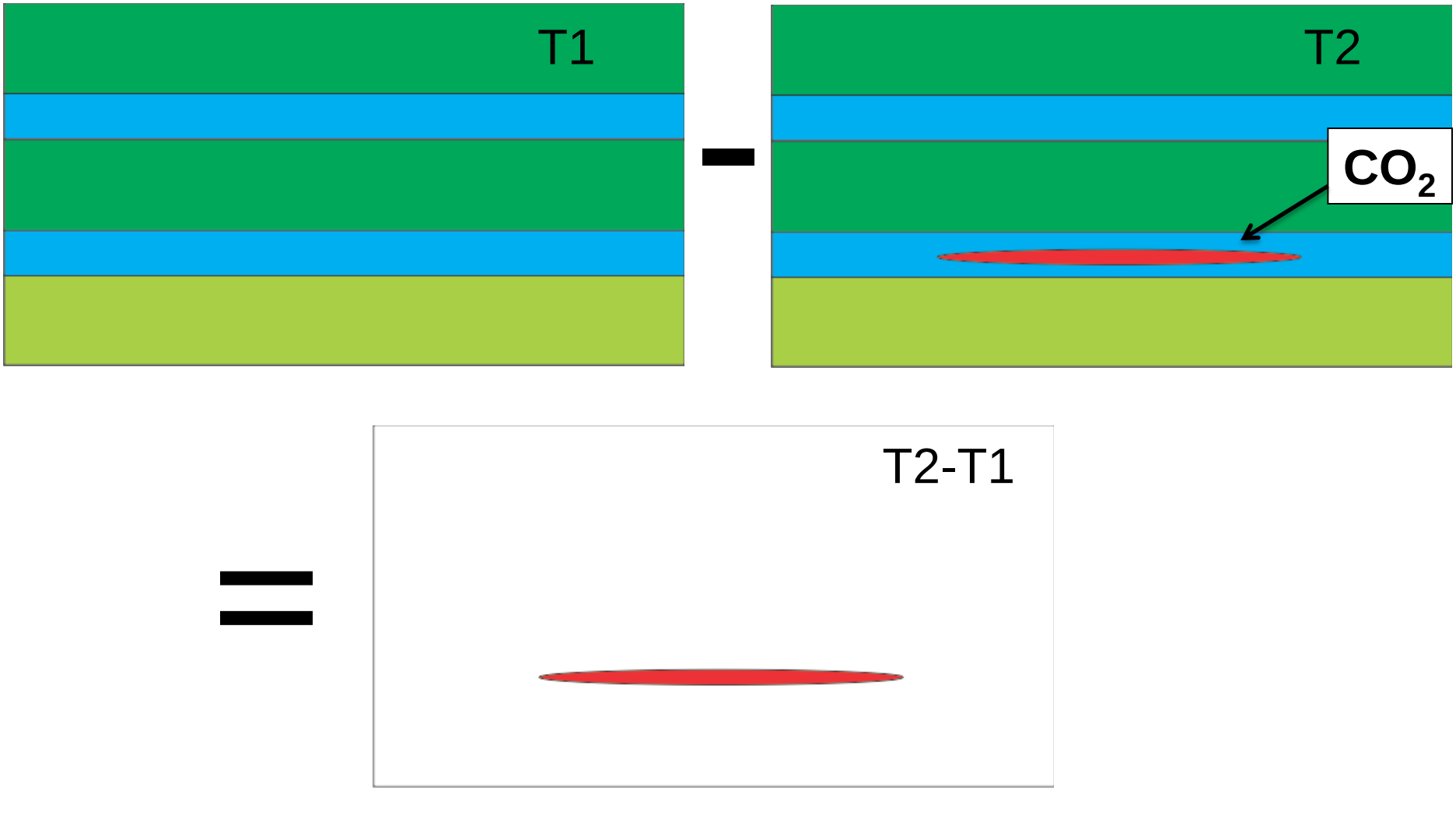
PLUME MONITORING

Time-Lapse Imaging

−

=

Seismic Time-Lapse Imaging

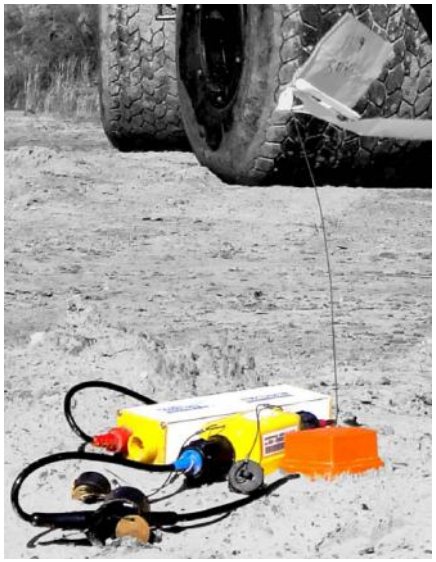


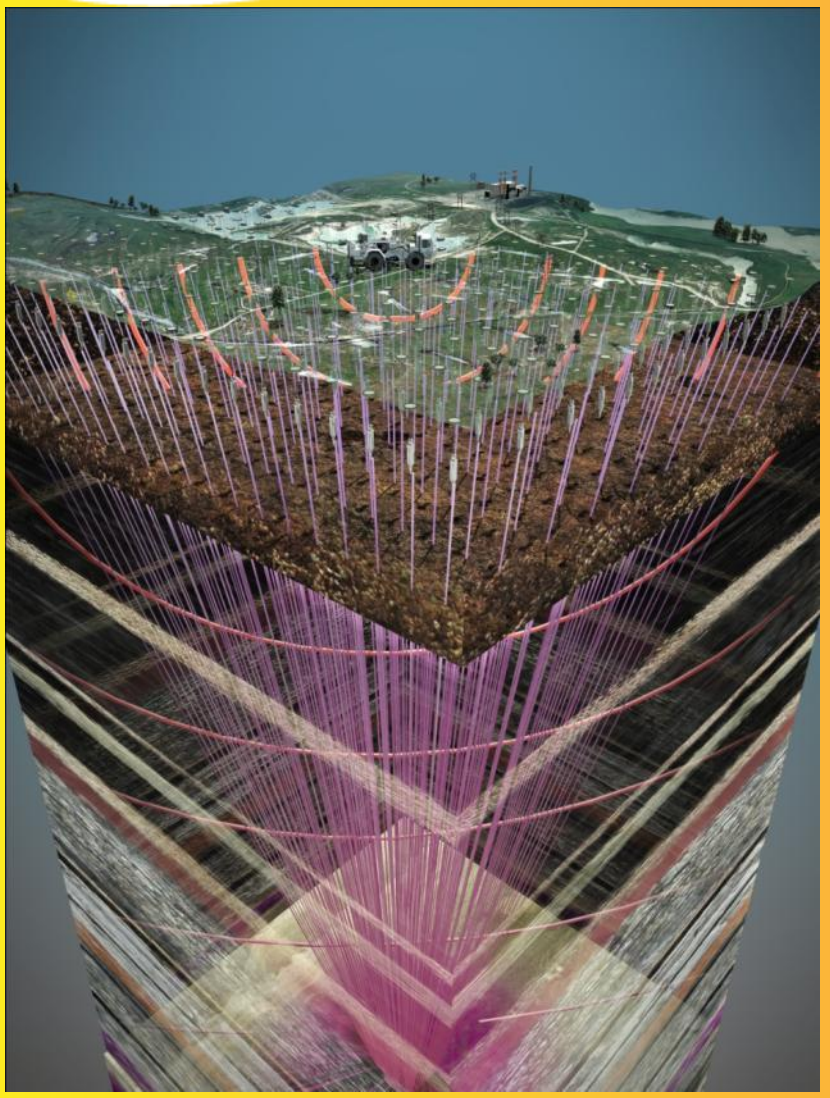
Time-Lapse Seismic Imaging: Repeatability Factors

- Seismic Methodology
  - Acquisition geometry (source and receiver locations, numbers of sources and receivers, recording patch)
  - Data processing
- Subsurface conditions
  - Near-surface condition variations (dry or wet, frozen)
  - Variations in the overburden above the target zone

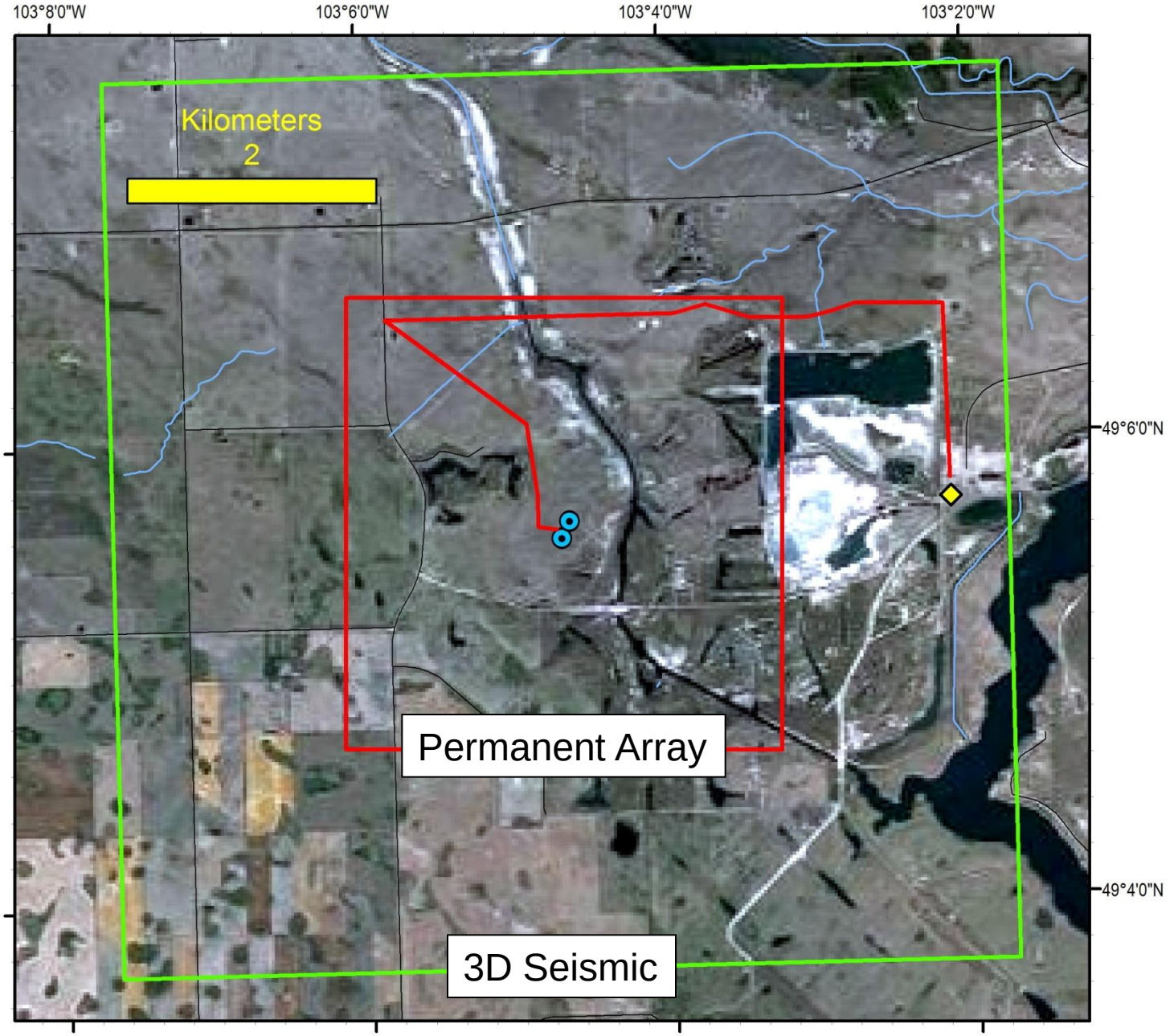
Permanent Seismic Array

- Active source and passive monitoring
- 630 geophones over 6.25 km2
- 20 m depth
- Receiver lines 144m, in-line 72m
- Baseline dynamite survey:
- 260 shots, 1 kg at 15 m depth
- Source lines 288m, in-line 144m

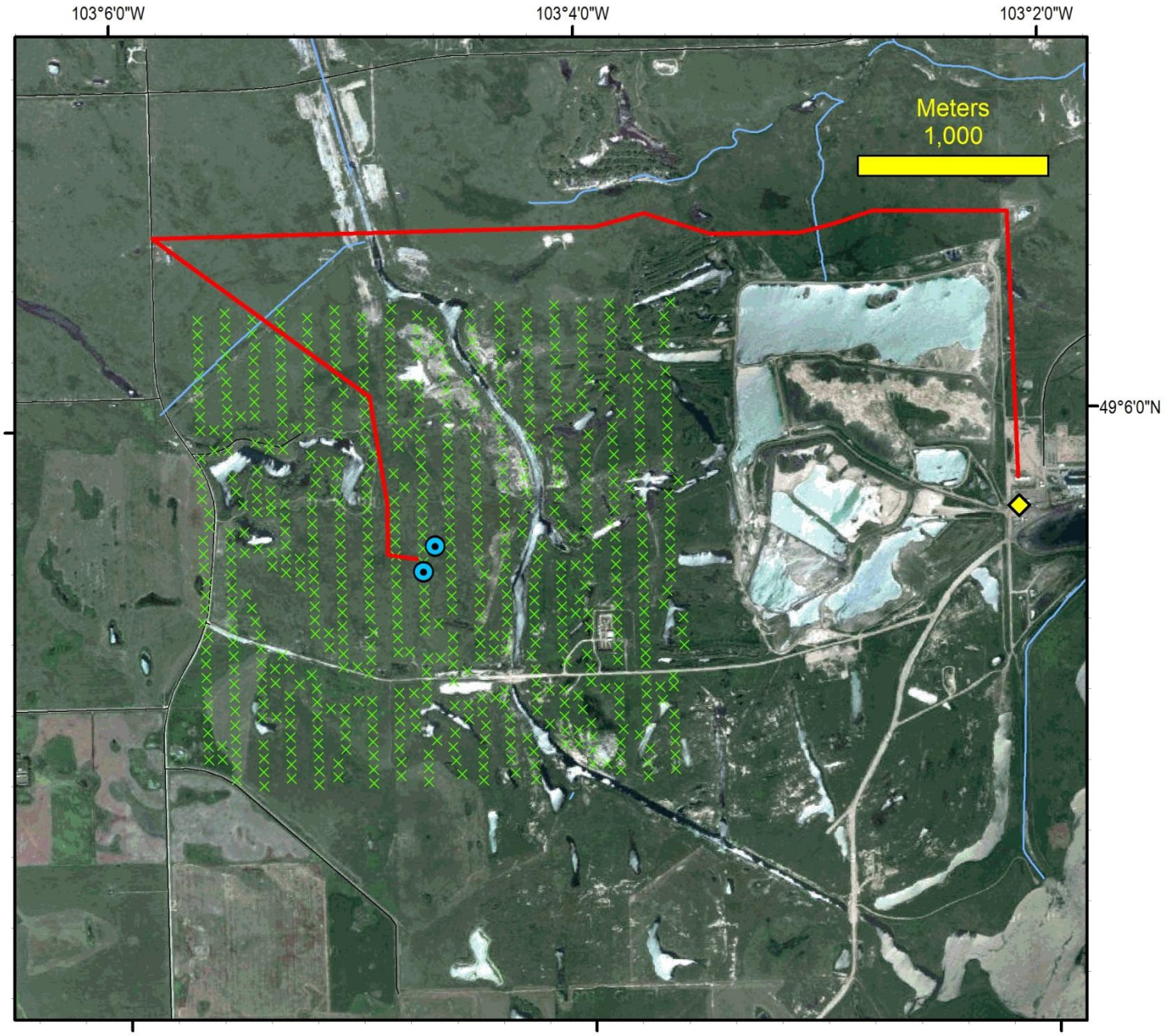




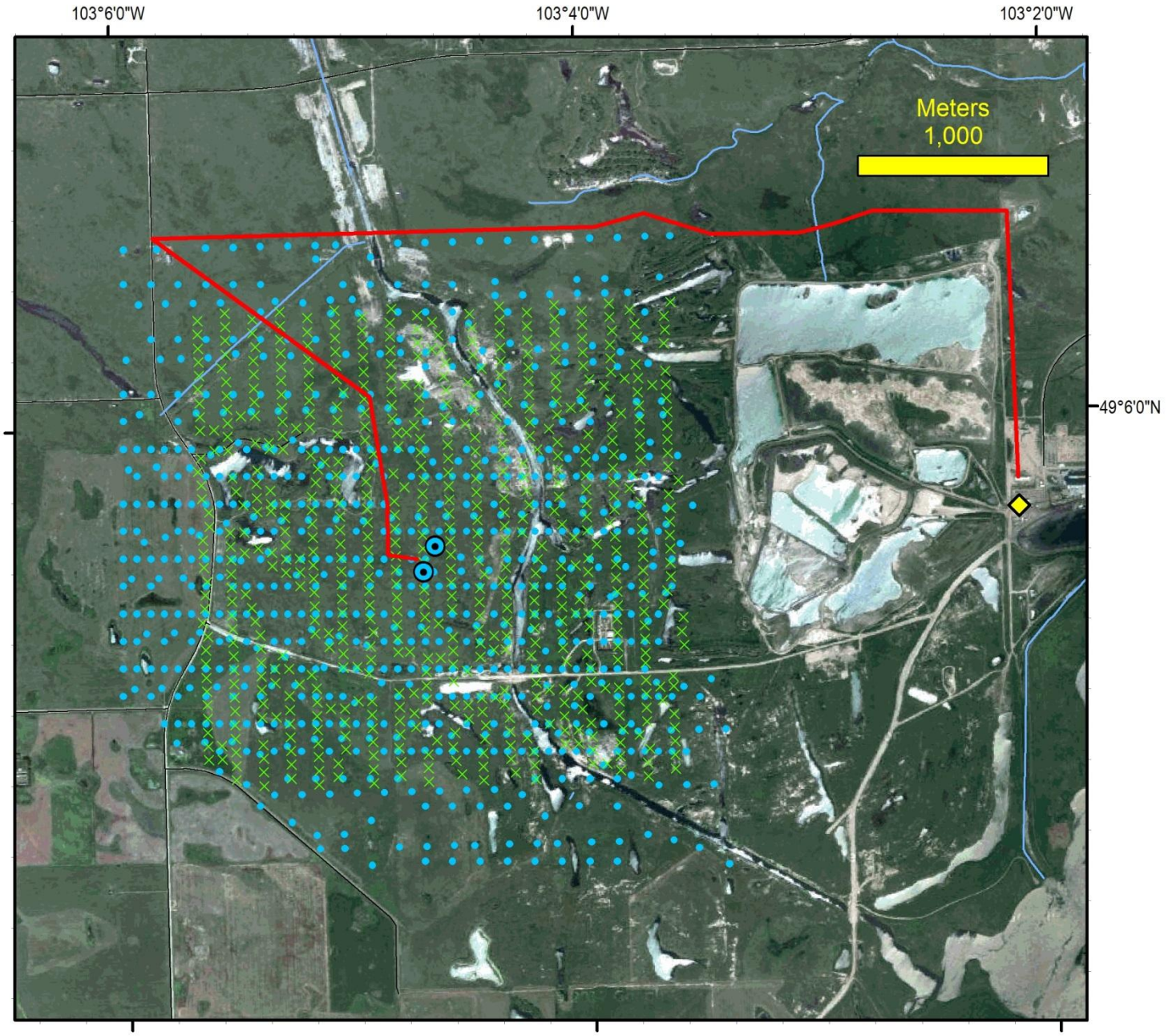
Permanent Seismic Array



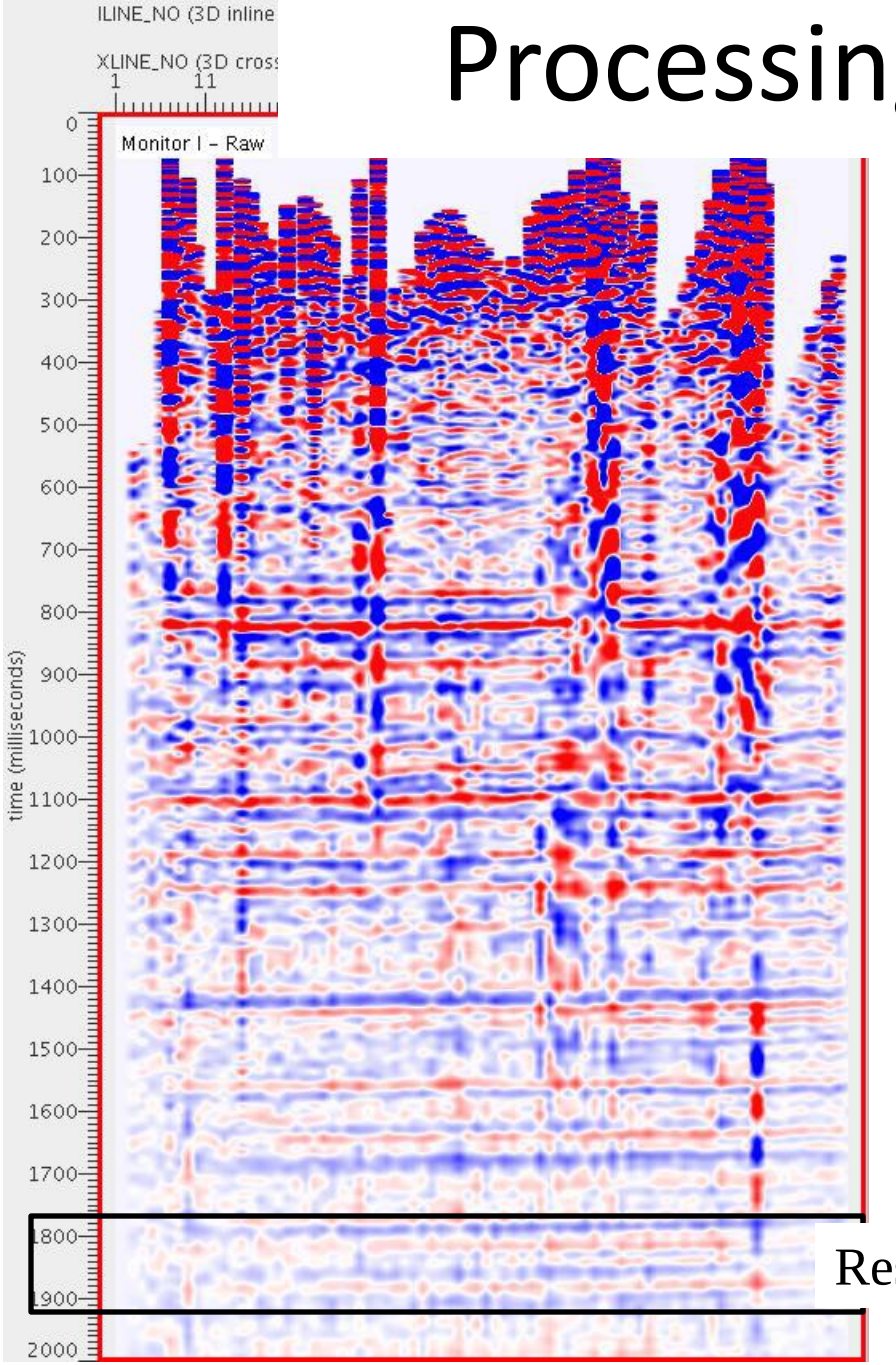
Time-Lapse 3D Seismic: Permanent Seismic Array

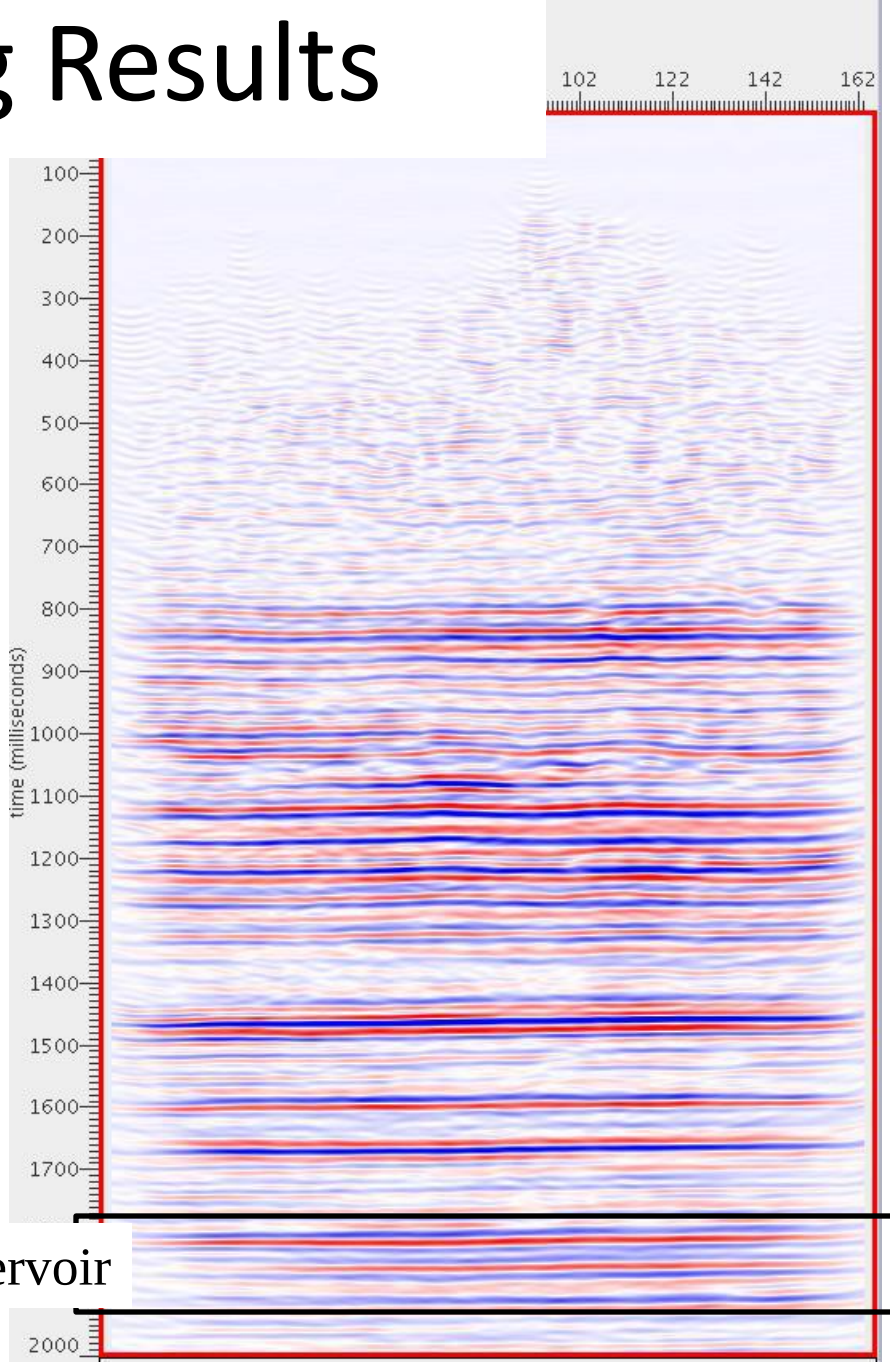


Time-Lapse 3D Seismic: Permanent Seismic Array



Processing Results



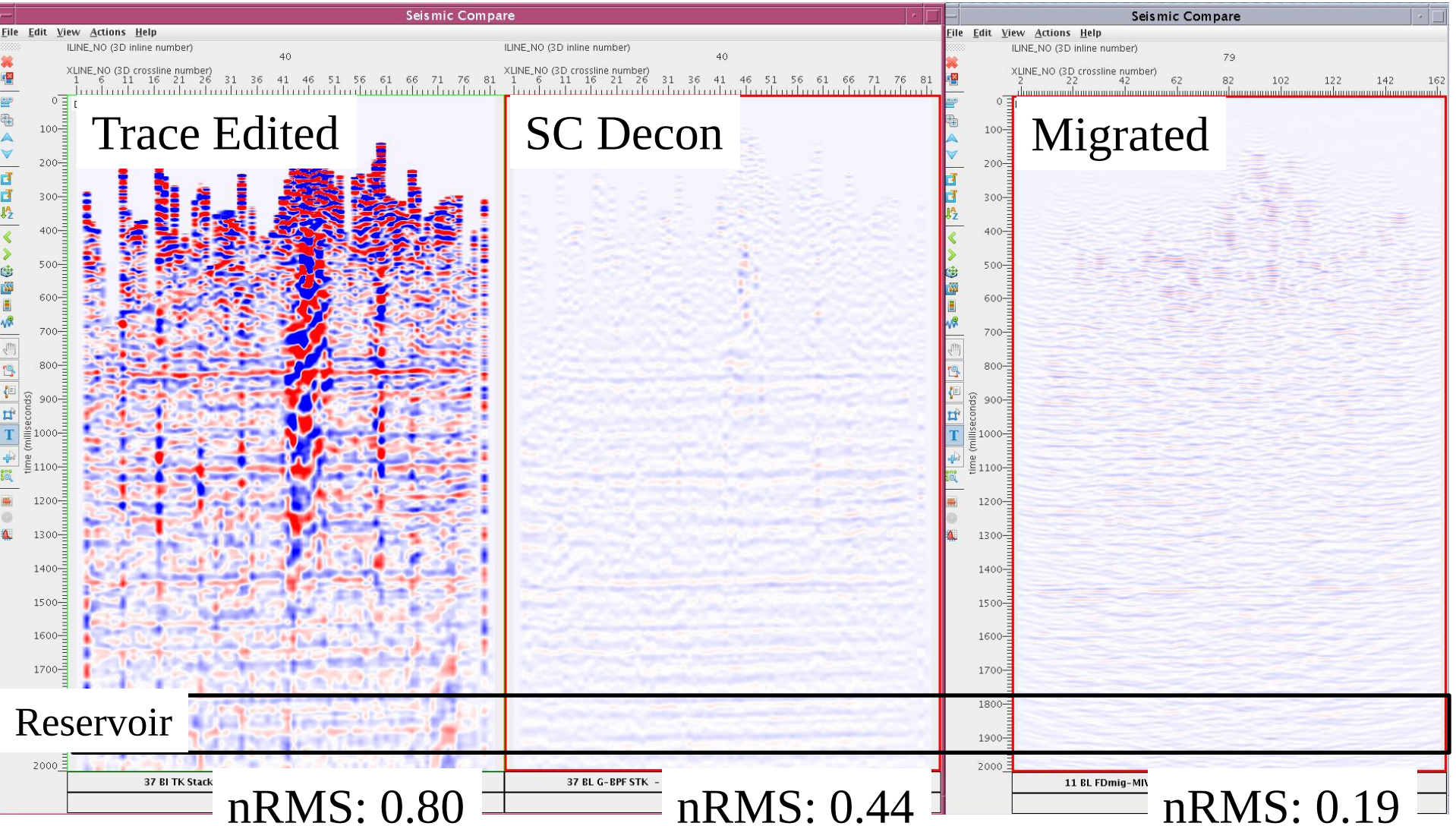


Reservoir

Raw Stack

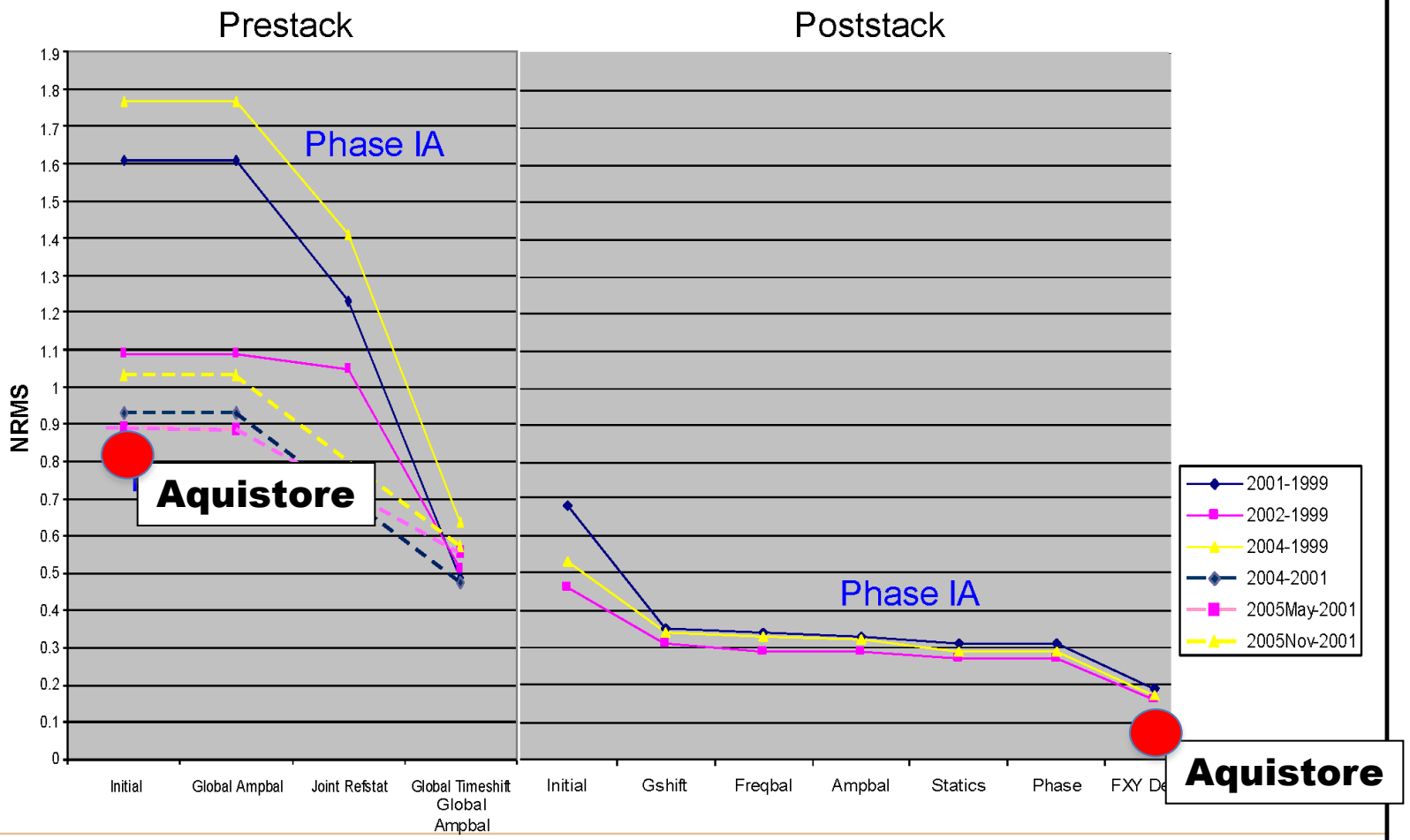
Migrated

Time-Lapse Differences



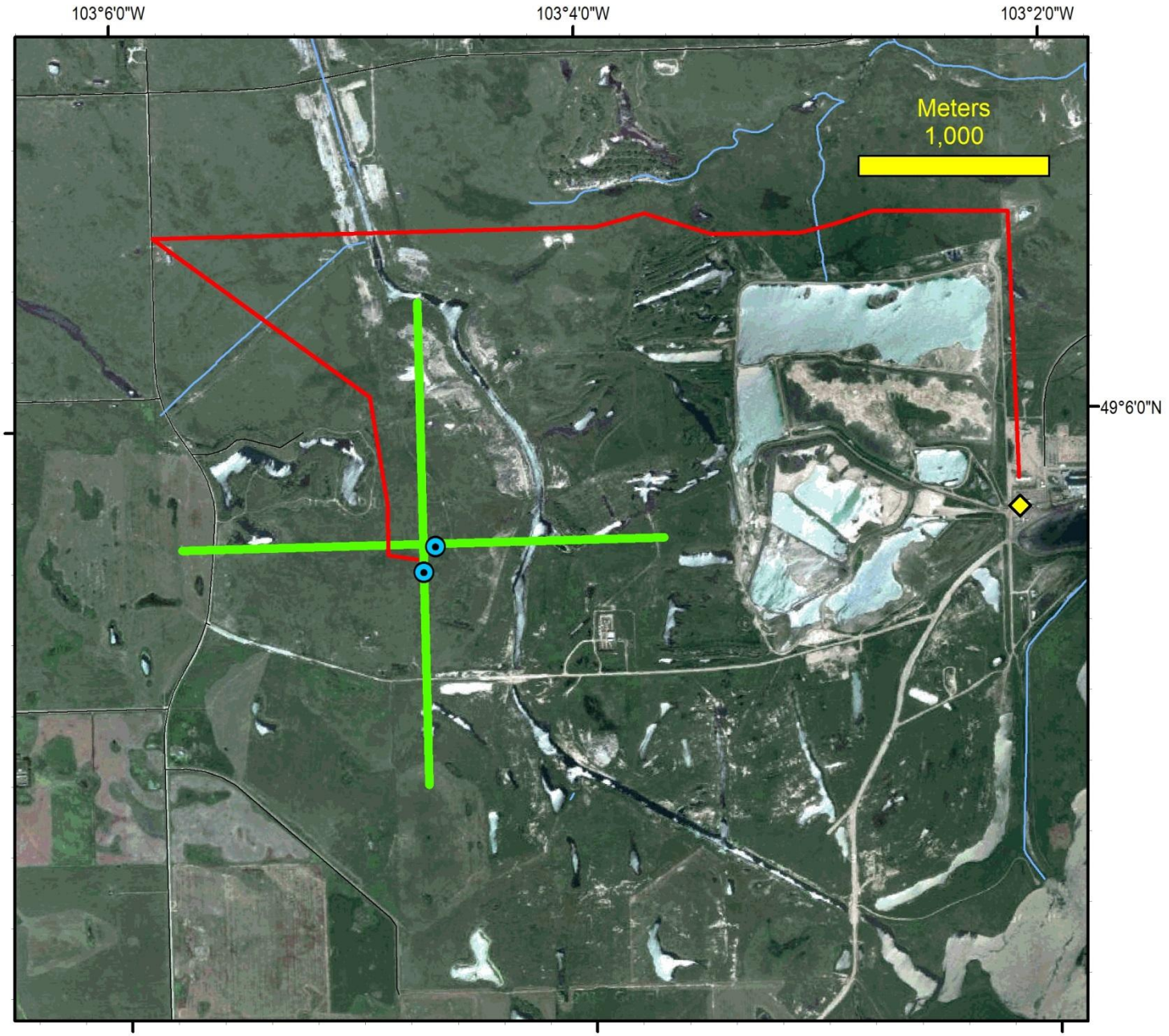
Improved Data Repeatability

Weyburn NRMS during processing flow

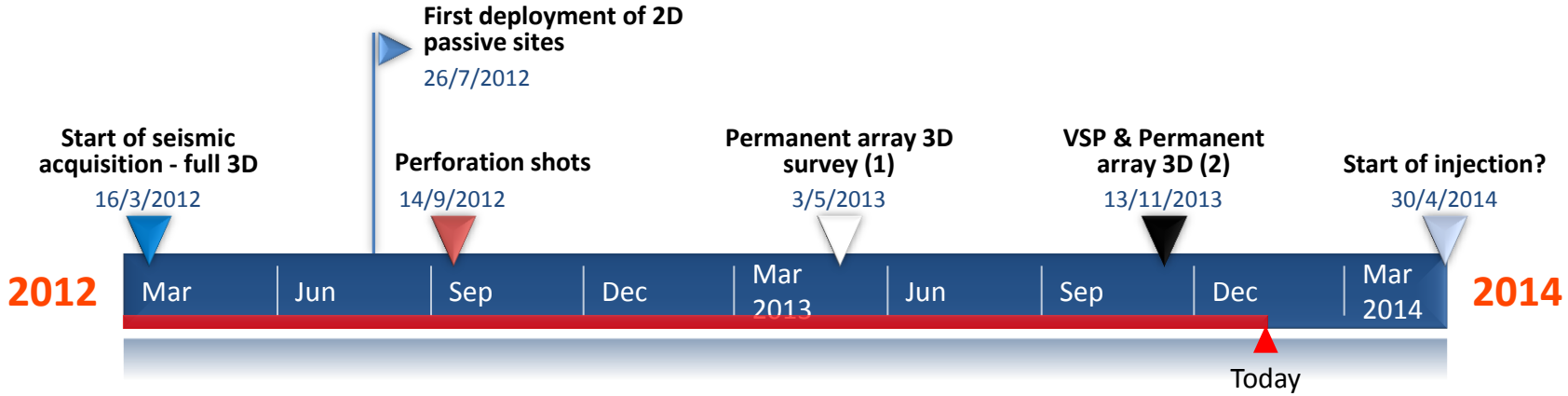


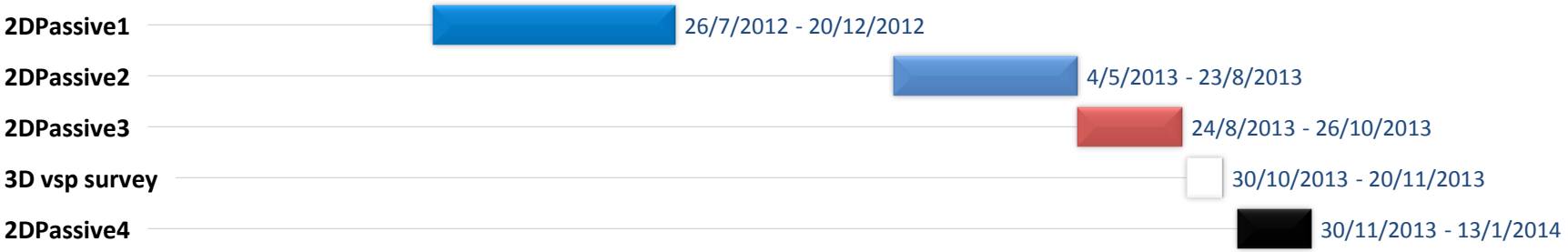
DEFORMATION MONITORING

Microseismic Monitoring Array

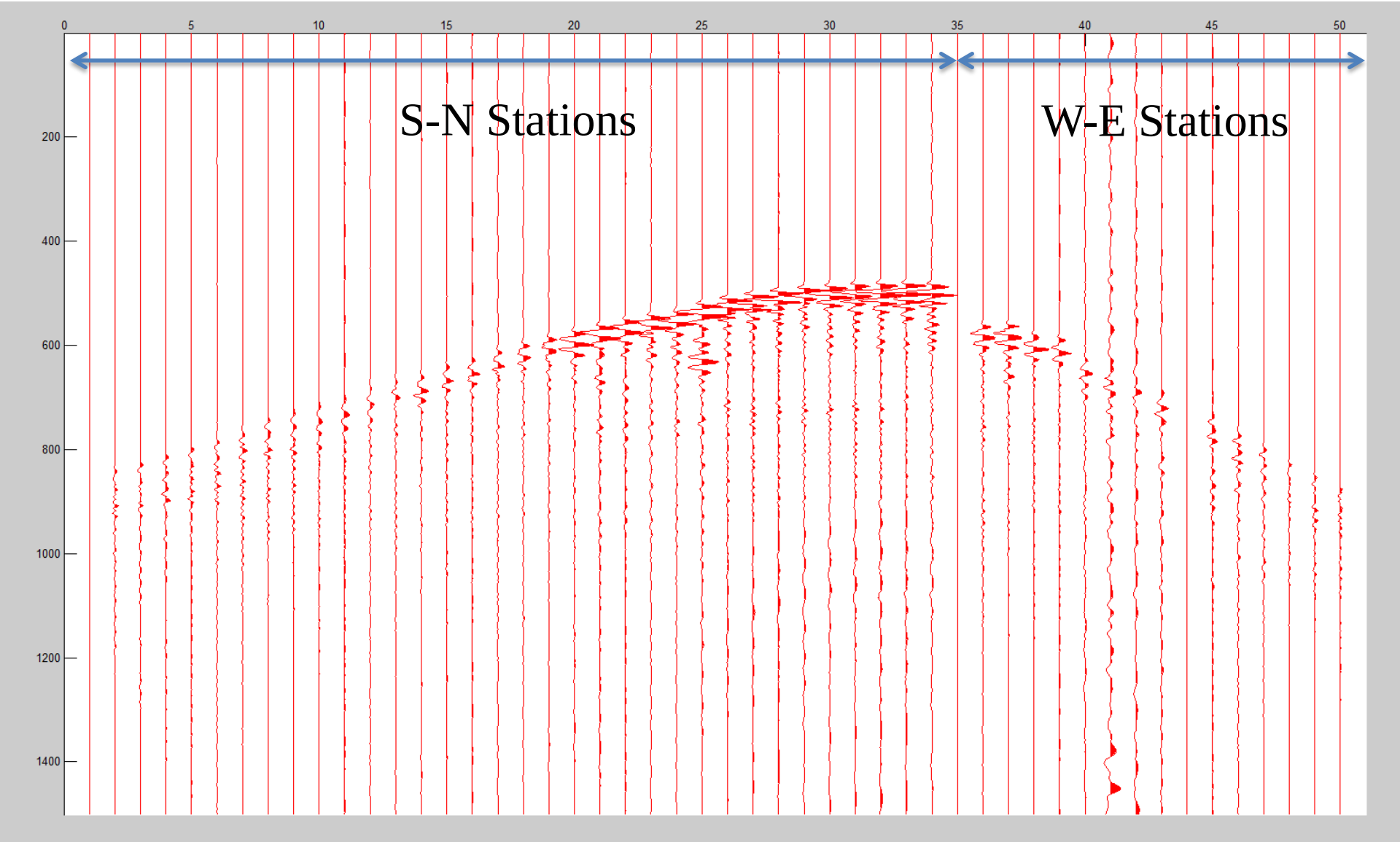


Passive Monitoring Array

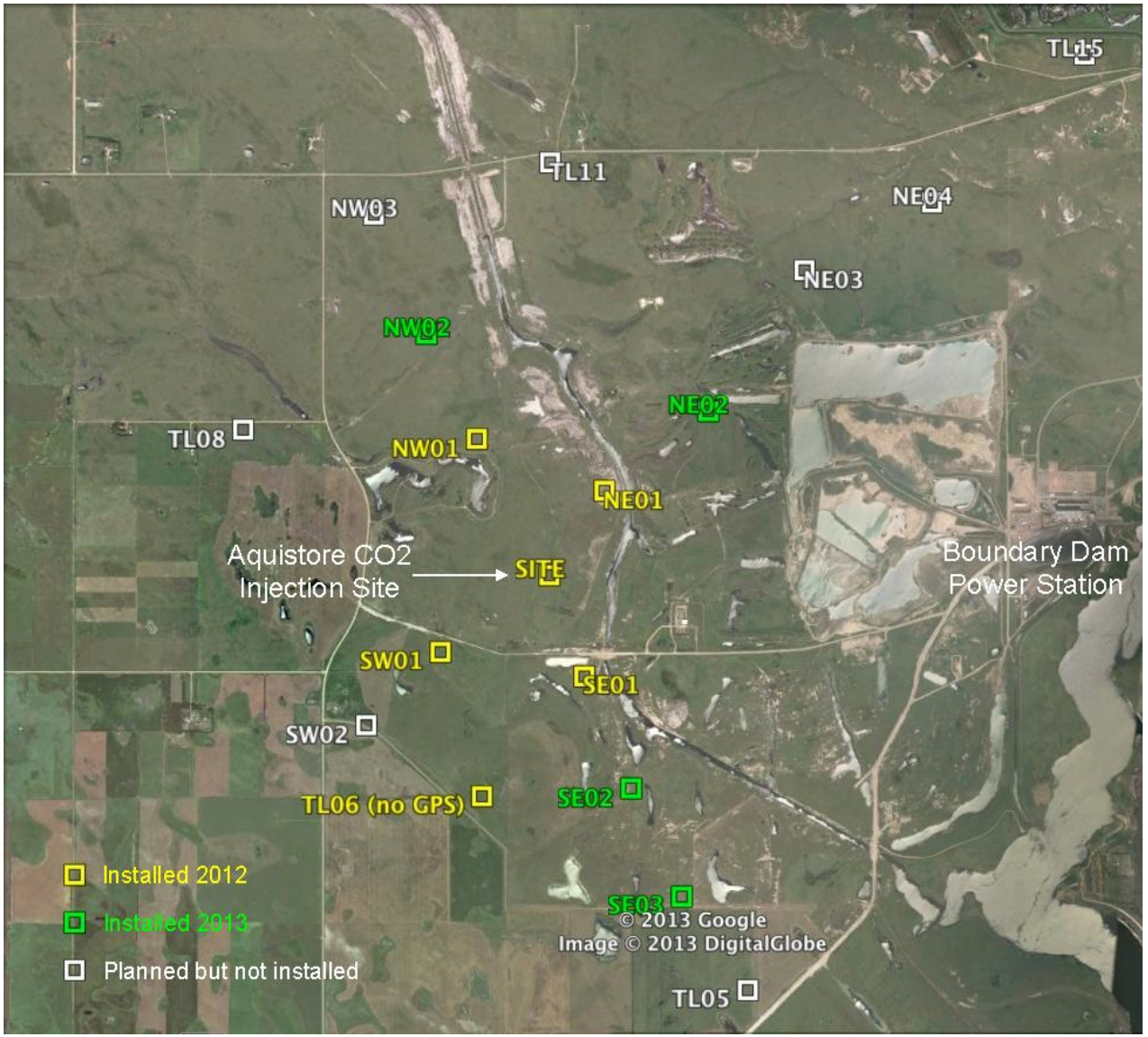




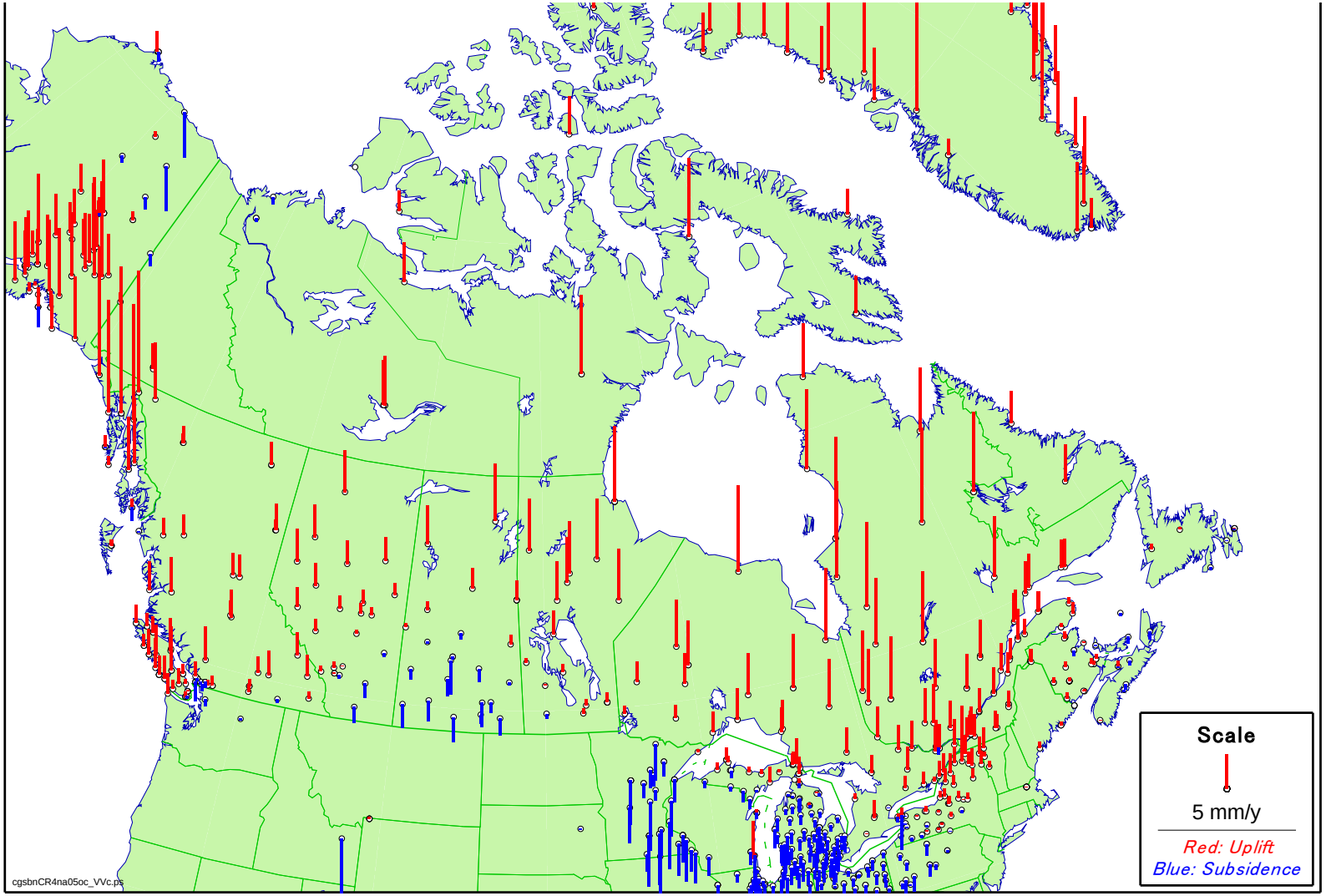
Passive Monitoring: Local Event



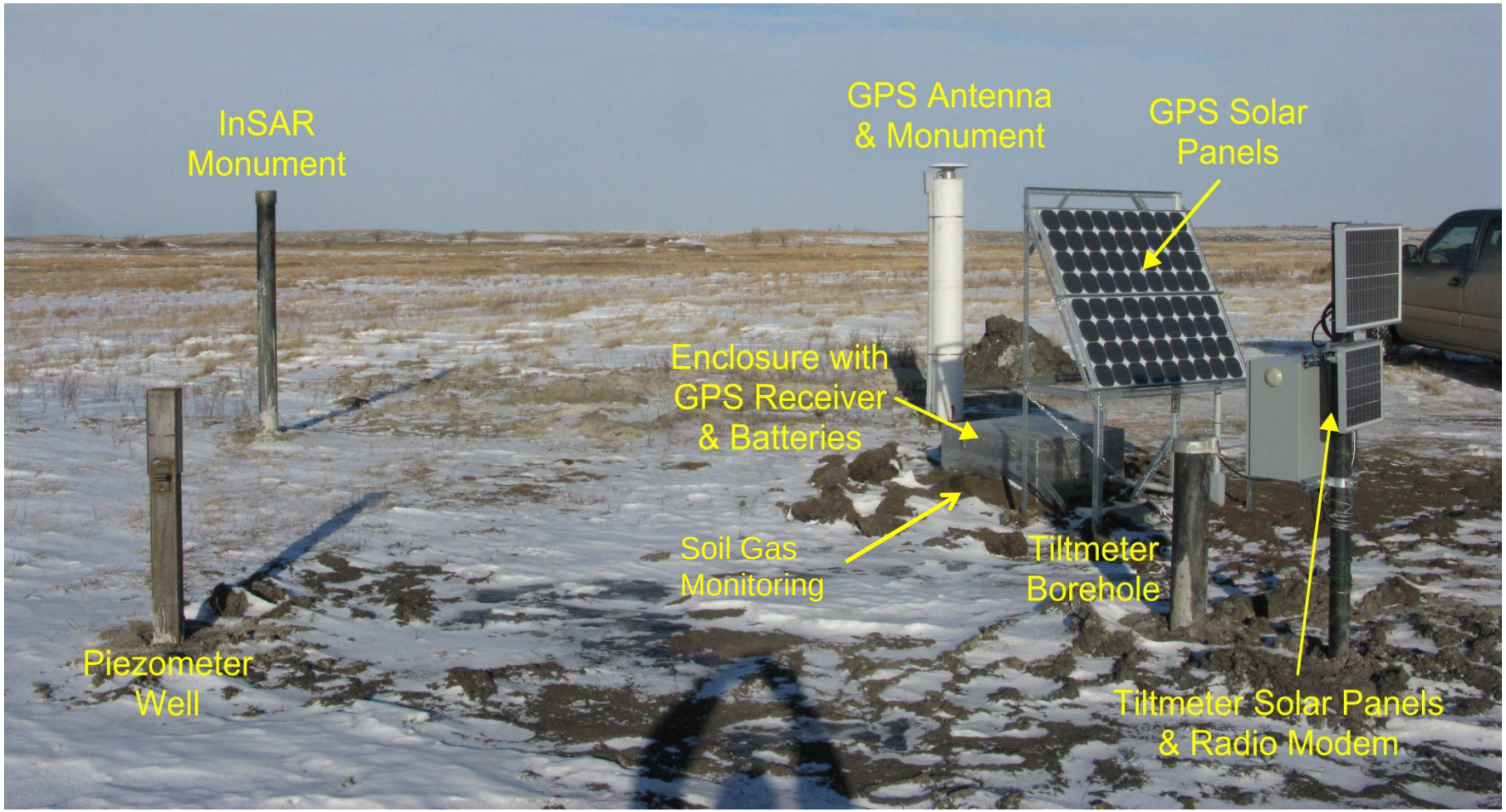
Surface Monitoring Sites



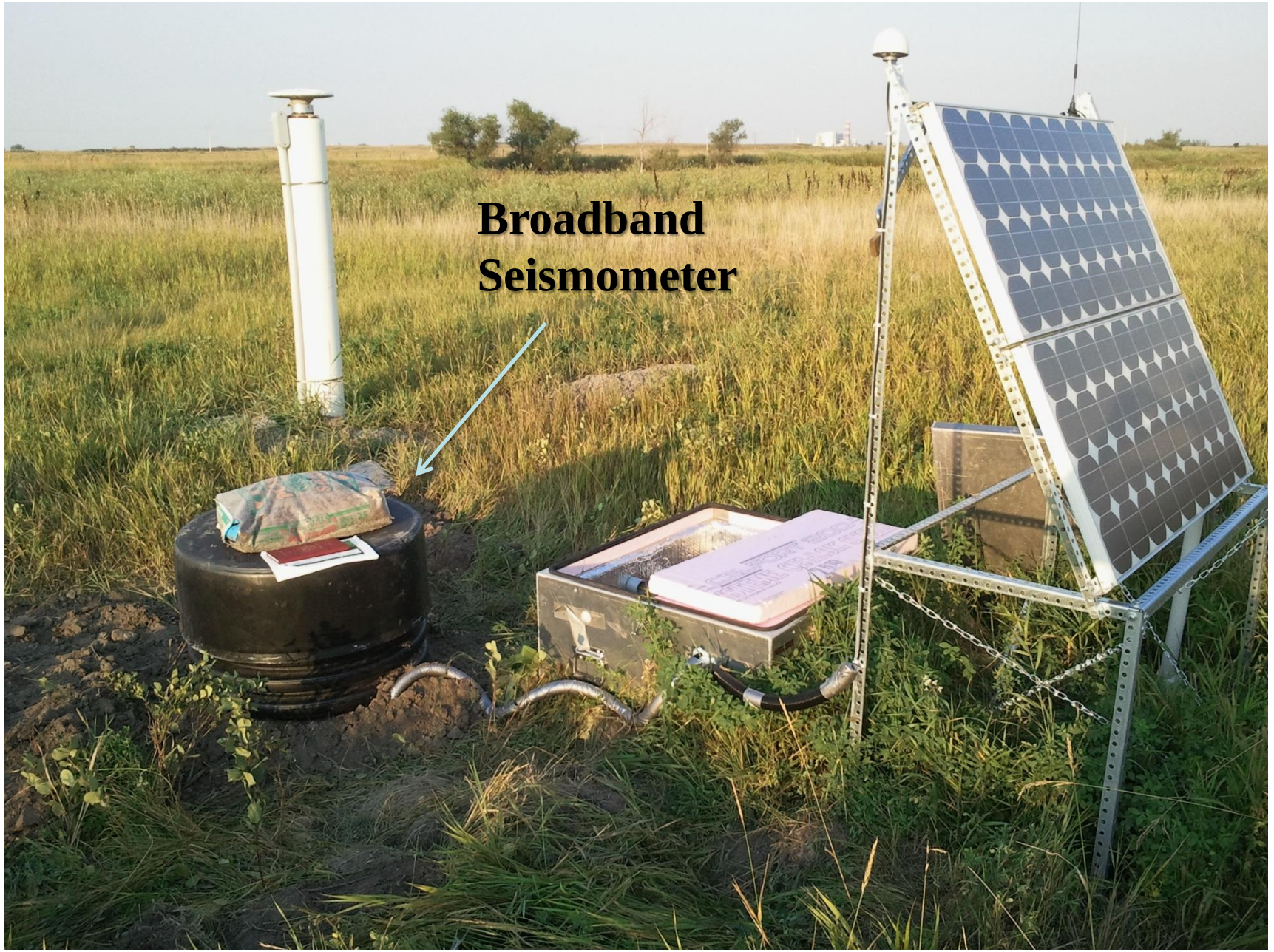
GPS: Background Ground Deformation



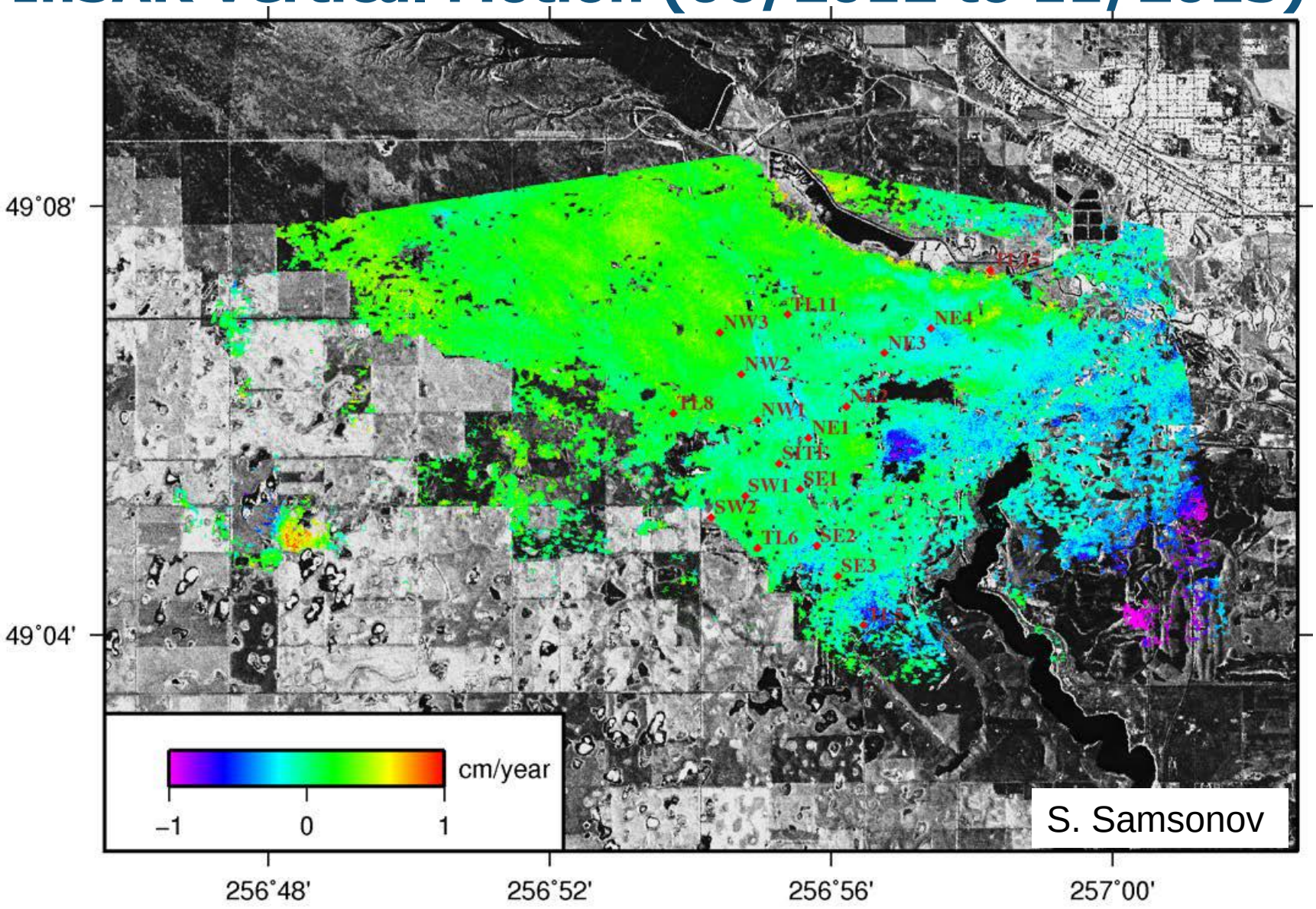
Surface Monitoring Site



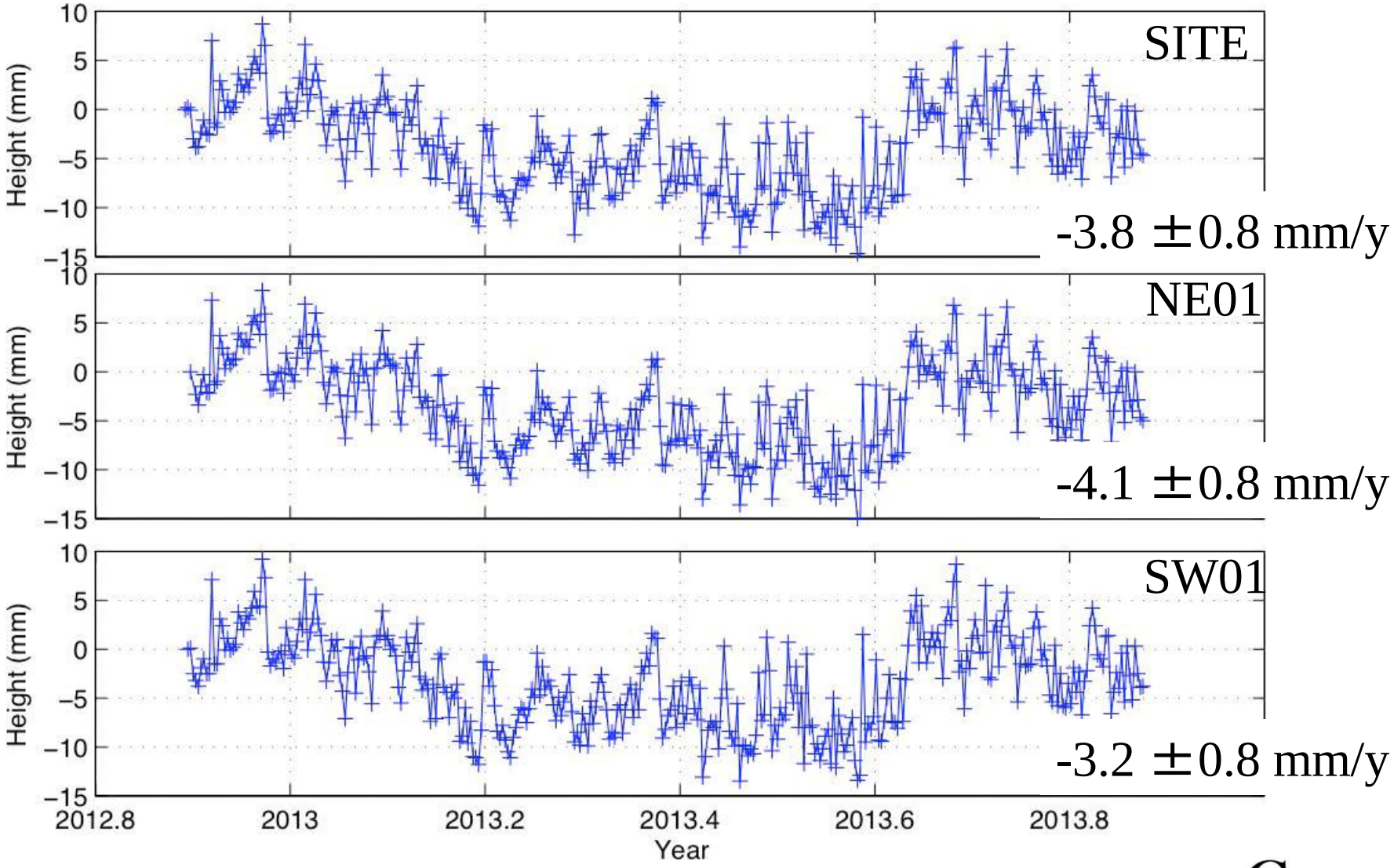
InSAR Reflector/ GPS Antenna


Broadband
Seismometer

InSAR Vertical Motion (06/2012 to 11/2013)



GPS Vertical Motion (06/2012 to 11/2013)

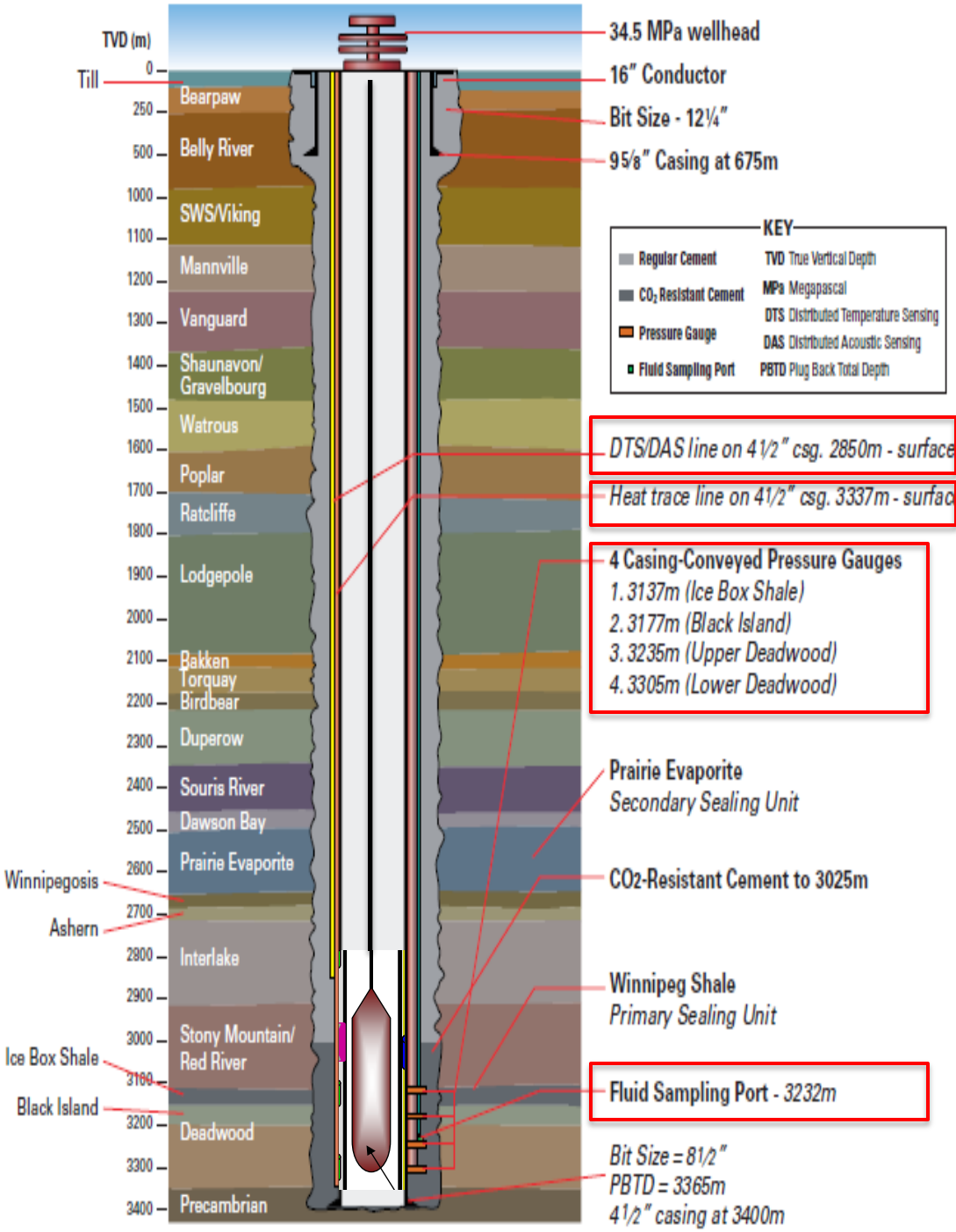


IN SITU MONITORING

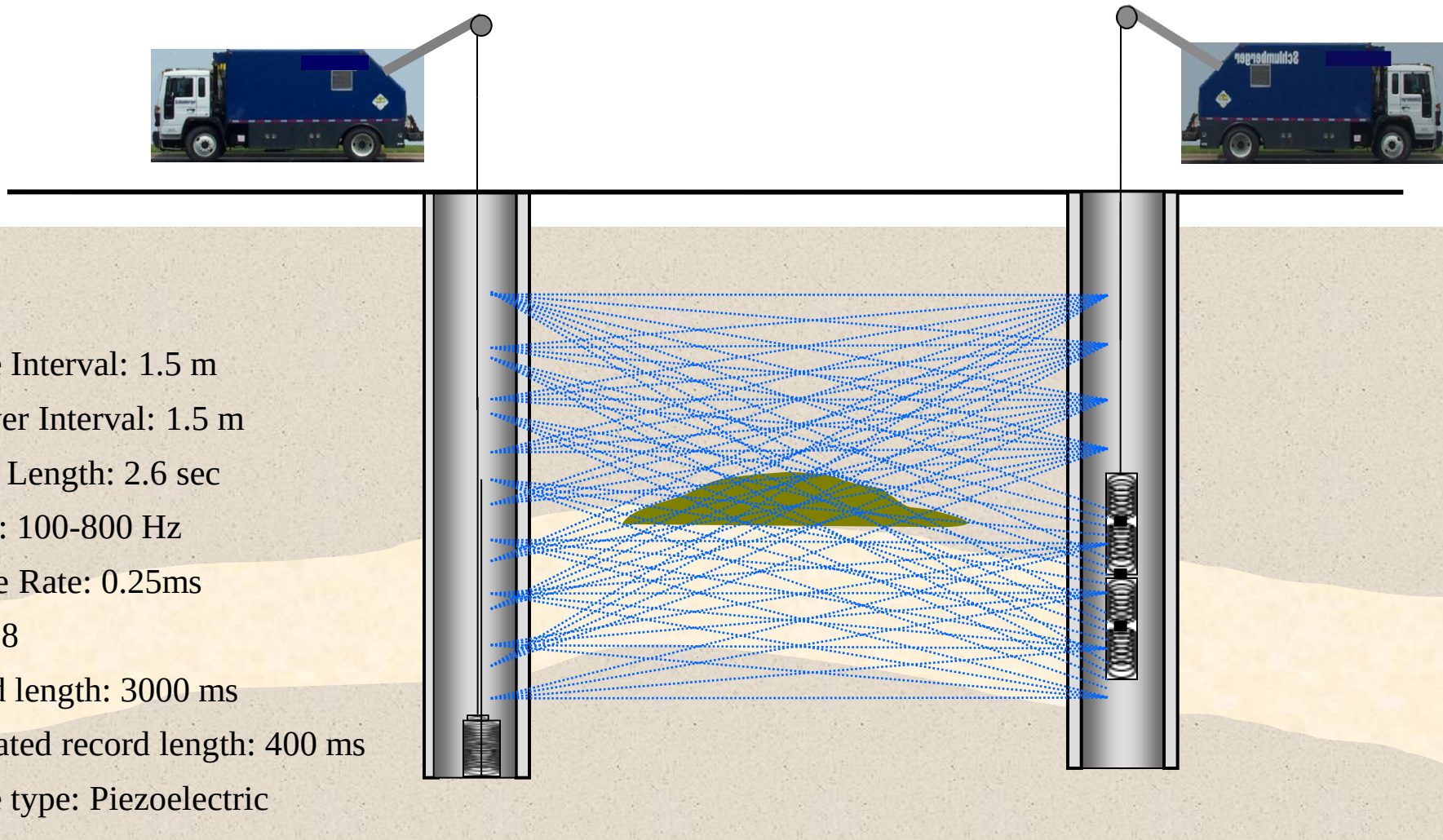
Observation Well Monitoring

Casing-conveyed instruments:
- Fluid sampling ports
- P/T gauges
- Fibre optic Temp. Sensor/ Acoustic Sensor
- Heat trace cable

Wireline instruments:
- Geophones
- Electromagnetic sensors
- Time-lapse logging (RST, sonic)
- Gravity



Data Acquisition



Source Interval: 1.5 m

Receiver Interval: 1.5 m

Sweep Length: 2.6 sec

Sweep: 100-800 Hz

Sample Rate: 0.25ms

Stack: 8

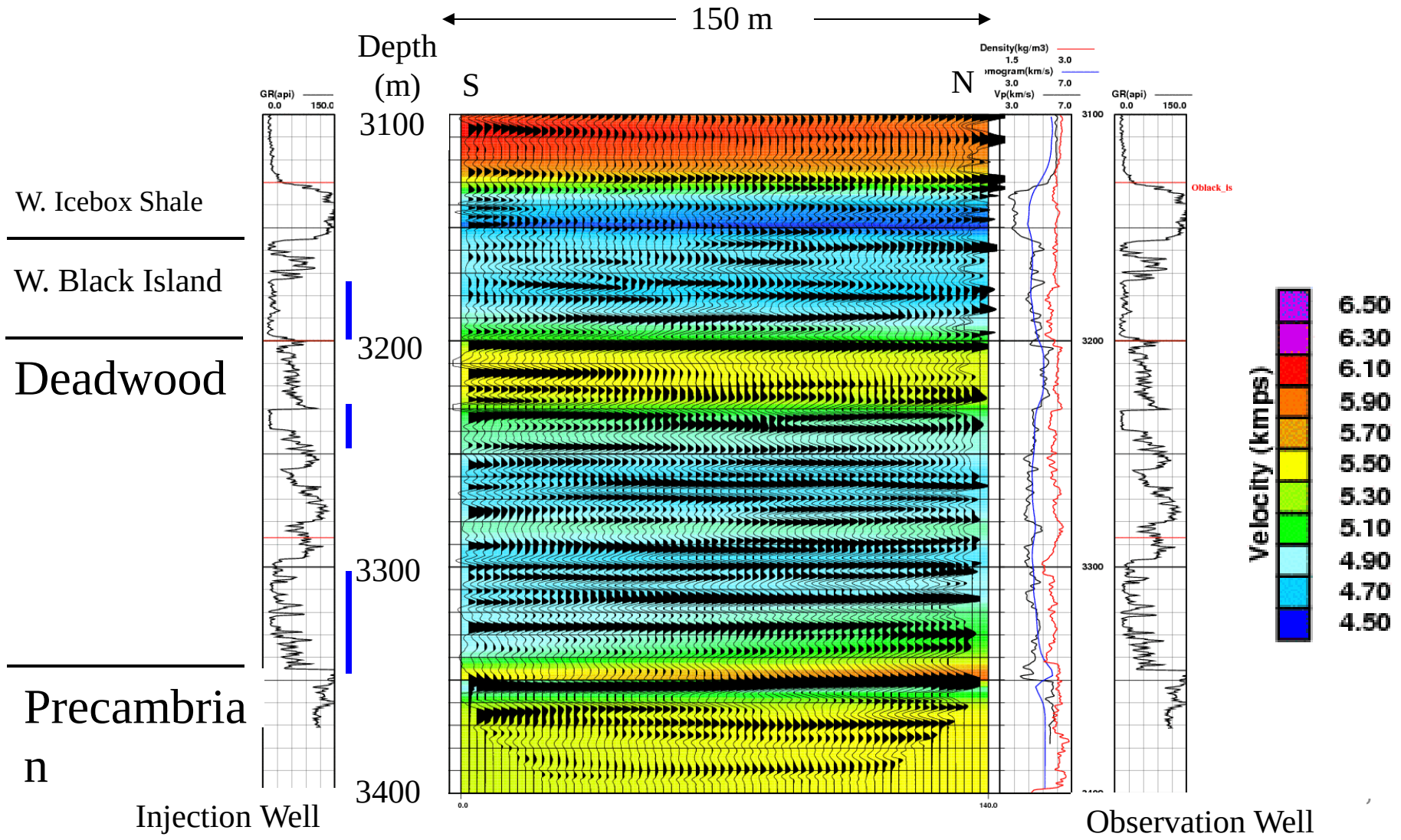
Record length: 3000 ms

Correlated record length: 400 ms

Source type: Piezoelectric

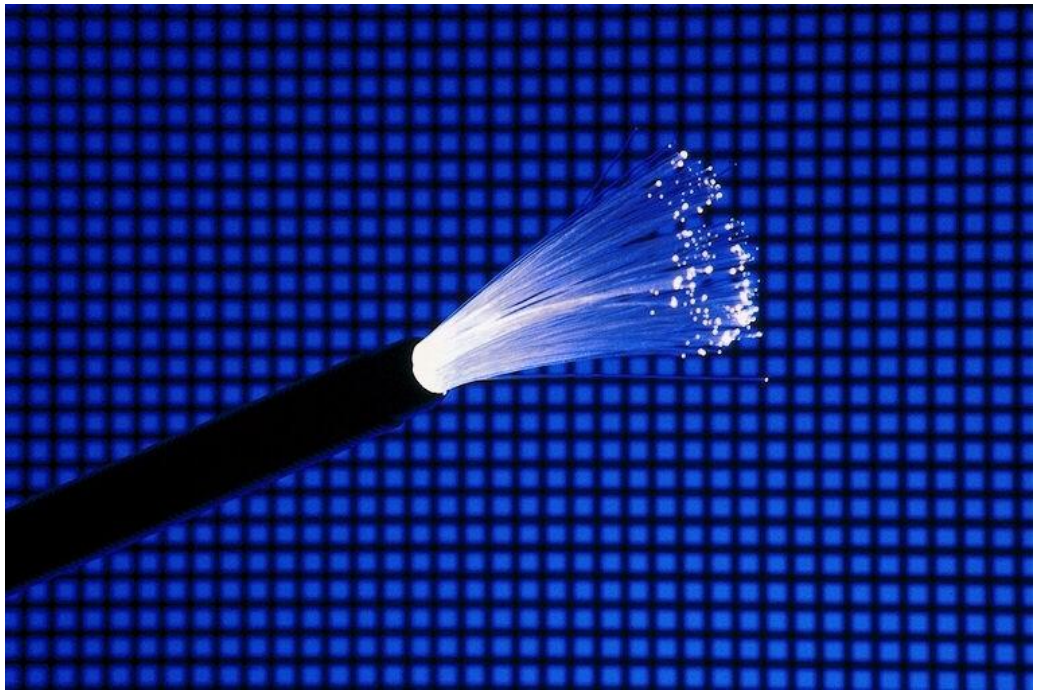
Receiver type: Hydrophone – 20 levels

Baseline Reflection Tomography Image



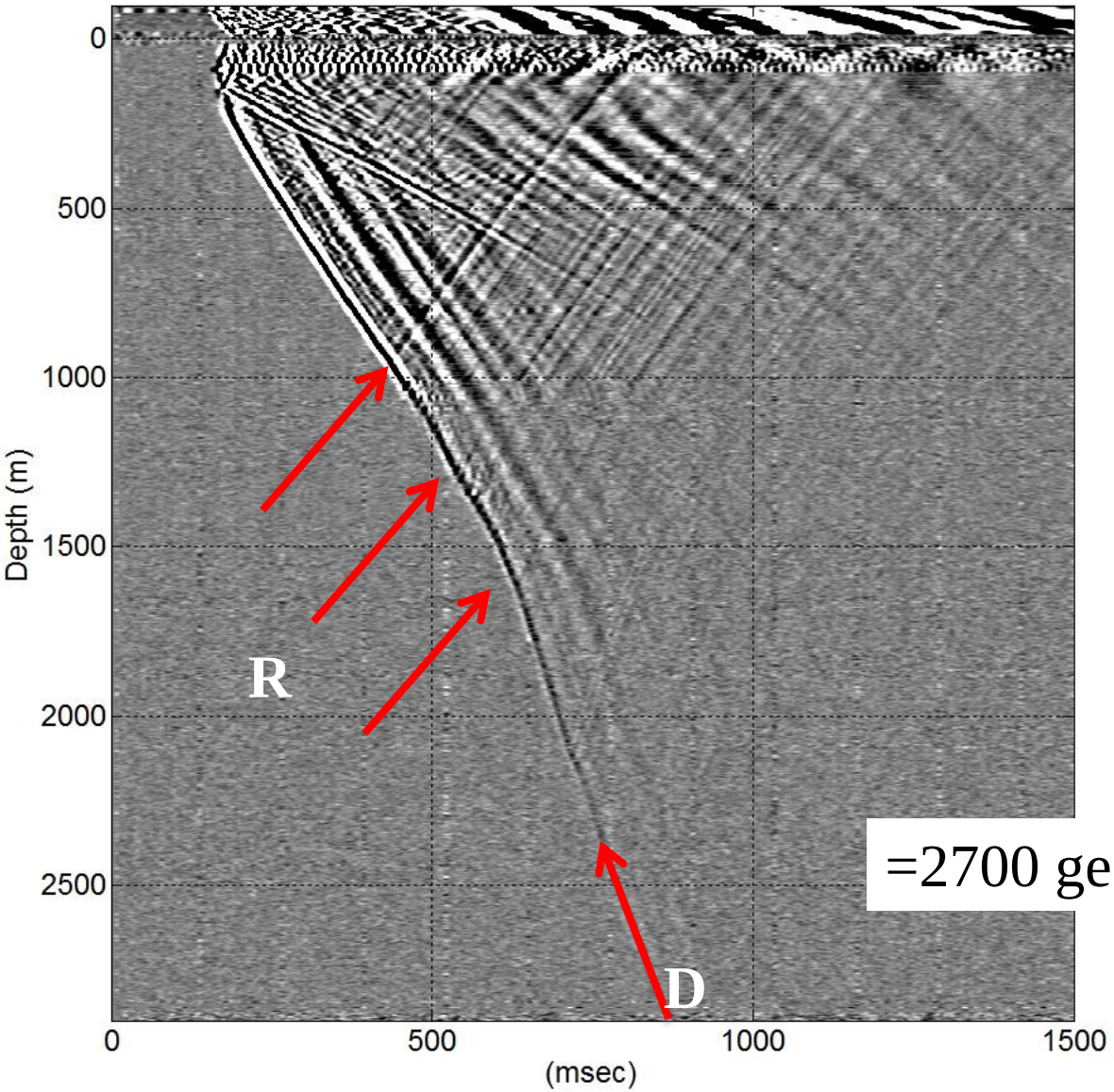
Geophones vs Fibre Sensors

40 mm



6 mm

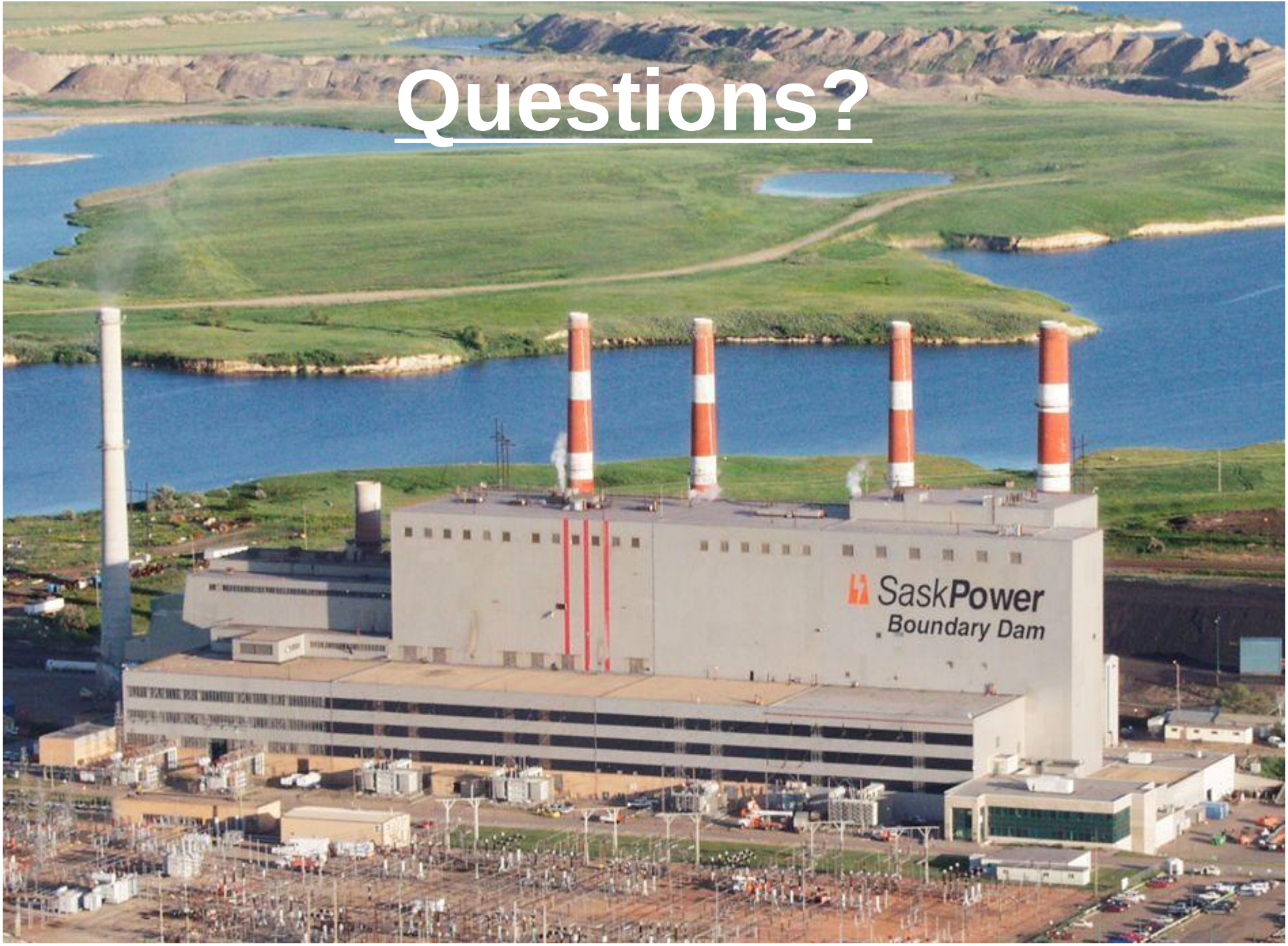
Acoustic SM Fibre Recording (DAS Raw)



=2700 geophone VSP!

Aquistore Team

- Monitoring Activities: Lisa Roach (GSC), S. Samsonov (CCRS), M. Craymer (CCRS), B. Roberts (GSC), J. Henton (CCRS), M. Czarnogorska, J. Silliker (CCRS), Tom Daley (LBNL), Michelle Robertson (LBNL)
- Management: Petroleum Technology Research Centre (Kyle Worth, Neil Wildgust, Aleana Young, Joseph Lazlo)
- Operations: Sask Power, Schlumberger Carbon Services (Jared Lee Walker, Marcia Couëslan, Bob Will, Wade Zaluski)
- Science & Engineering Research Committee: Rick Chalaturnyk (U Alberta), Chris Hawkes (U Sask), Ben Rostron (U Alberta), Jim Johnson (Schlumberger-Dole), Jim Sorensen (EERC), Don White (GSC)
- Contractors: Western-Geco, RPS Boyd-PetroSearch, Geospace, Silixa, Sercel


Questions?
SaskPower
Boundary Dam