Area 1: Geomechanical Monitoring for CO_2 Hub Storage: Production and Injection at Kevin Dome Phase III DE-FE0023152

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Lawrence Berkeley National Laboratory

U.S. Department of Energy

National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Transforming Technology through Integration and Collaboration

August 18-20, 2015

Presentation Outline

- Program Goals
- Benefit to the Program
- Project Goals and Objectives
- Methodology
- Expected Outcomes
- Tasks
- Deliverables / Milestones / Decision Points
- Summary

Benefit to the Program

Program Goals Addressed

1. Develop and validate technologies to ensure 99 percent storage permanence;

   Project targets cost effective monitoring of reservoir and seal geomechanical performance

2. Develop technologies to improve reservoir storage efficiency while ensuring containment effectiveness;

   Addresses containment

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Benefits Statement

The project will conduct research under *Area of Interest 1 Geomechanical Research*, which **seeks technologies that "Increase the current ability to understand, measure, and predict the geomechanical effects of CO_2 injection into the subsurface" and which provide "Highly spatially-resolved data of subsurface stresses and strains".**

- This project will use cost effective microseismic monitoring and InSAR surface deformation measurements combined with state of the art coupled modeling and inverse modeling.
- The project addresses Research Need 1-1 in that it seeks an "Improved understanding of geomechanical processes and impacts critical to $scCO_2$ injection operations" by investigating pore-pressure perturbations and coupled geochemical/geomechanical processes.
- The project will leverage Fossil Energy's existing investment in the Big Sky Phase III project to provide excellent research value at relatively low cost by utilizing extensive characterization and monitoring datasets which will be available for constraining and validating the piloted techniques, including surface-to-TD sonic logs, core studies of elastic properties, VSP constraints on seismic velocities, and most crucially a unique 4D 9C surface survey.

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Project Overview: Goals and Objectives

The objectives of the proposed work are:

1. To improve understanding of geomechanical processes and impacts critical to supercritical CO_2 injection operations
2. To advance tools and techniques to assess the geomechanical properties of reservoirs and sealing formations.

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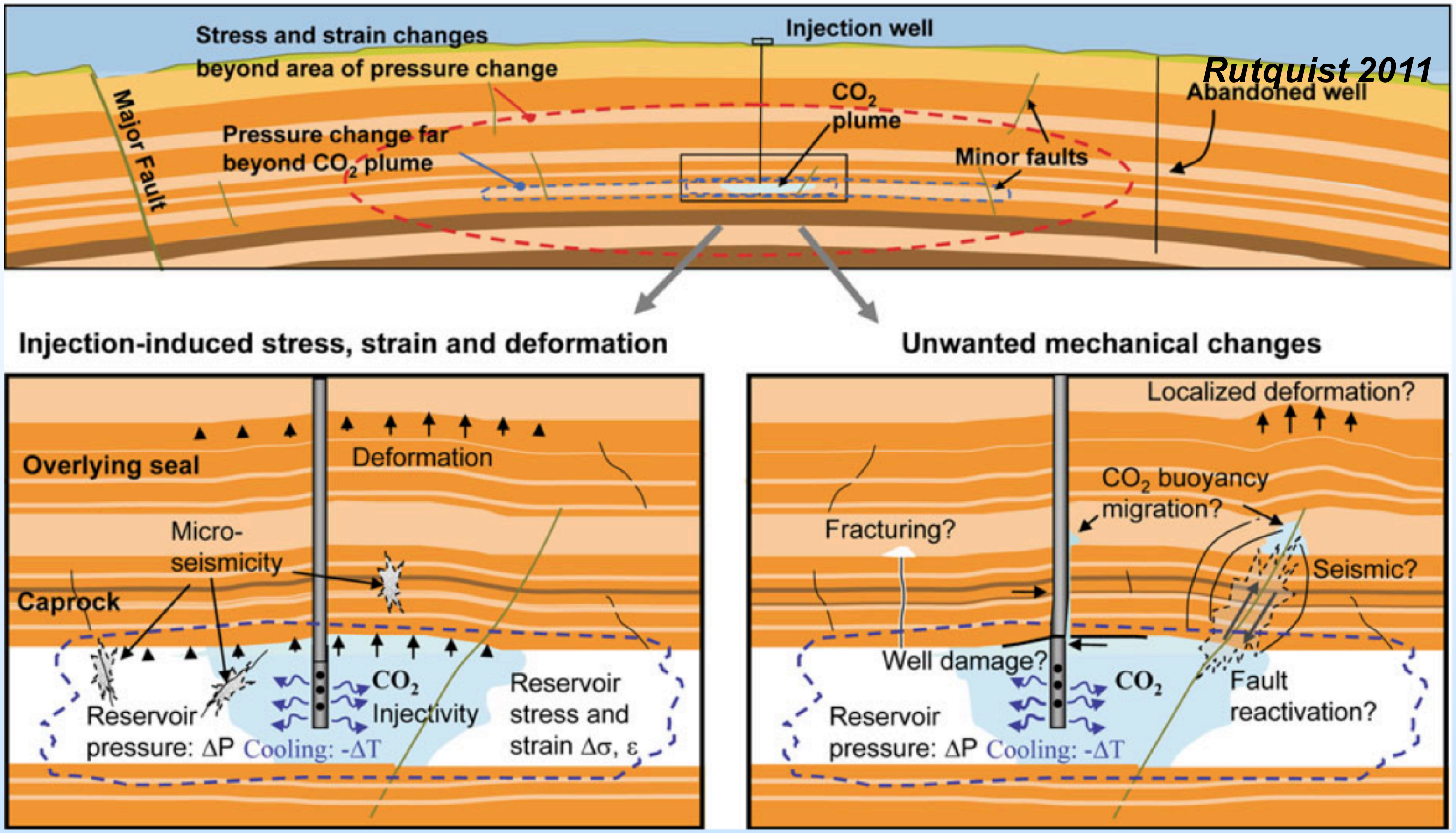
Why Monitor Geomechanical Signatures?

Substantial GCS-induced deformation (seismic or aseismic) has the potential to

1. Interfere with caprock & wellbore sealing performance
2. Generate seismic events which imperil public acceptance of GCS



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Realistic Scenarios During Injection

1. Re-activation of stressed faults in either the caprock, reservoir, or basement
   [GCS Example, Decatur site, IL]

2. Tensile expansion of existing open fractures
   [GCS Example, In Salah, Algeria]

Neither case resulted in measured leakage

1. Decatur injection continues : no evidence of issue of seal integrity issues
2. In Salah injection discontinued : opening of vertical fracture above injection zone

Appropriate monitoring techniques? Optimal case involves

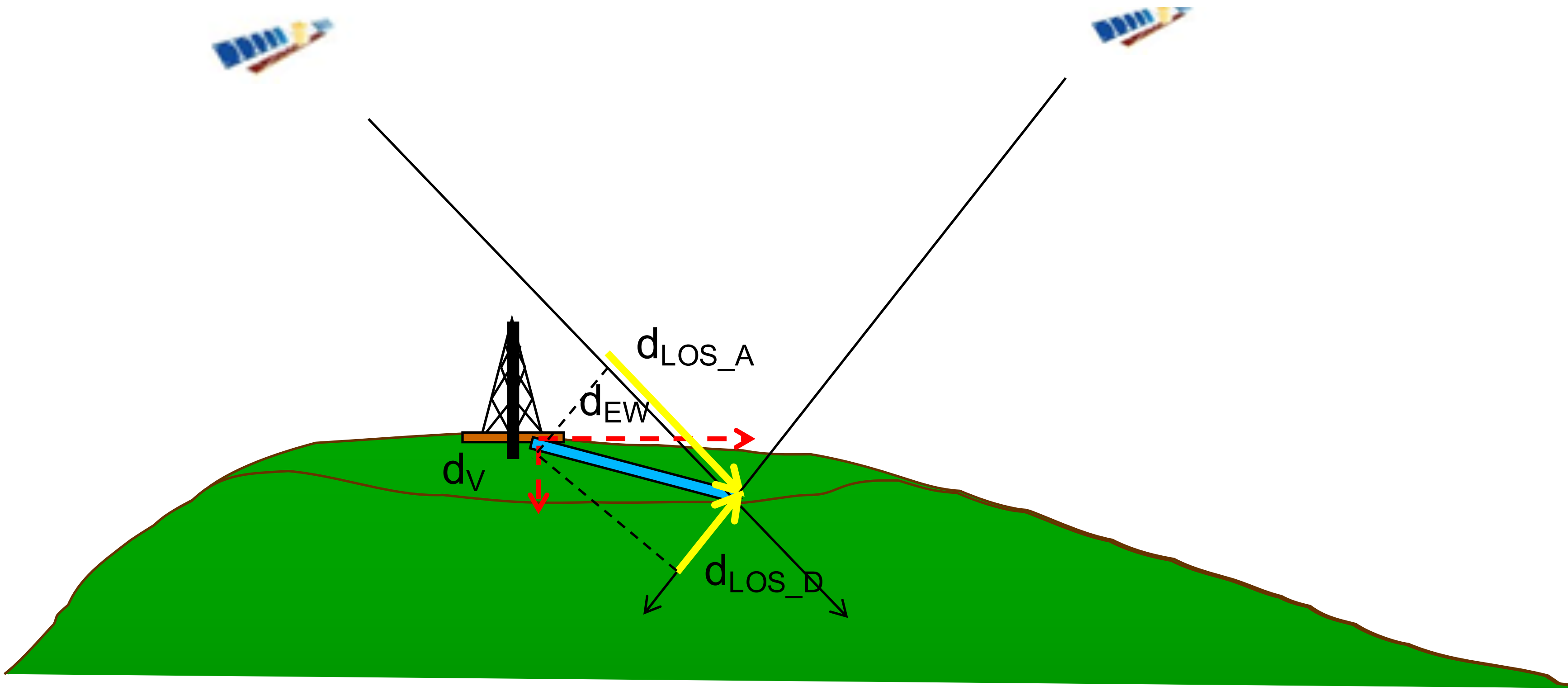
1. Low-cost approach which provides significant areal information on geomechanical pertrubations
2. Sensitive to small changes yet with sufficient spatial information to evaluate reservoir integrity
3. Potential to model/invert observations and deduce detailed geomechanical changes in the reservoir zone.

Our approach : Coupled InSAR & MEQ verified by modeling and 4D seismic.

Technique : Timelapse InSAR

Concept : Use satellite Synthetic Aperture Radar (SAR) and interferometry + various orbital geometries to extract the east-west and vertical components of displacement.

Result : Economic approach to measure vector surface deformation over large areas. Sensitive (mm to sub-mm) and with reasonable time resolution (depends on orbital parameters, ~15 days).

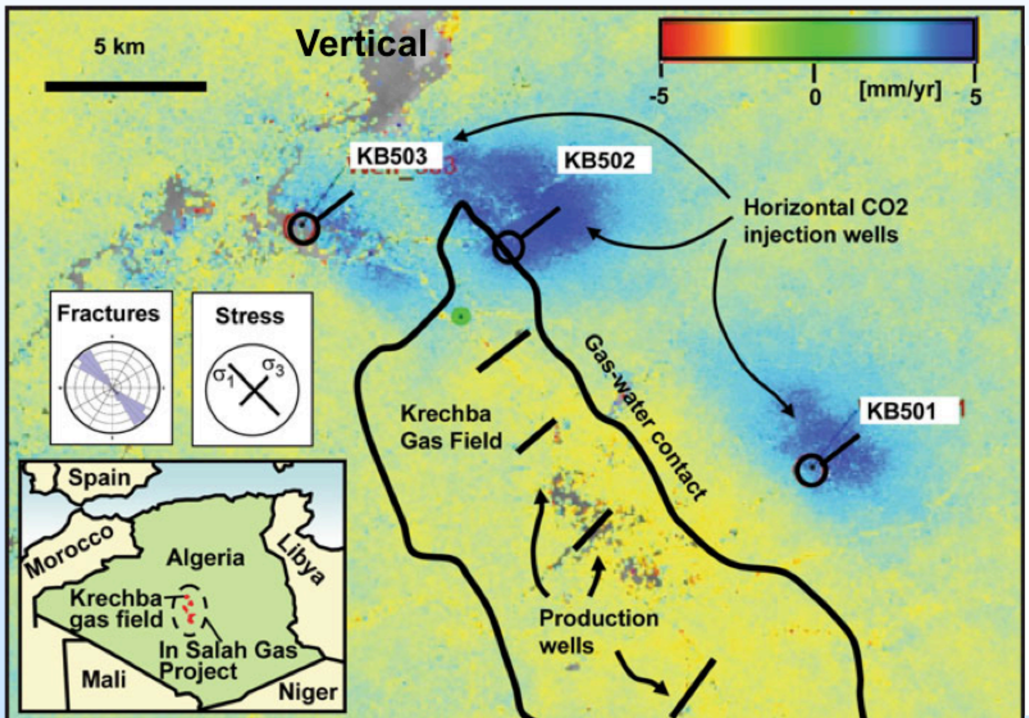


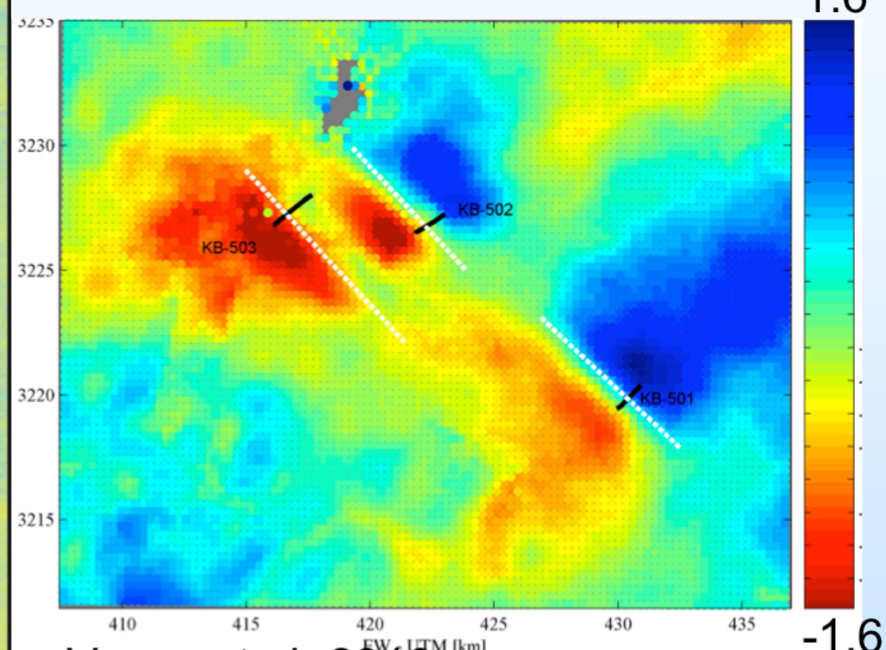
InSAR Monitoring Example : In Salah

Example : InSAR study at the In Salah GCS site in Algeria.

Result : Detection of zone of uplift near several injection wells. After analysis, determined to be vertical fracture re-opened by pore pressure increase.

Benefit : Provided guidance in injection process (CO_2 injection halted) and detailed spatial information augmented monitoring.





Vasco et.al. 2013

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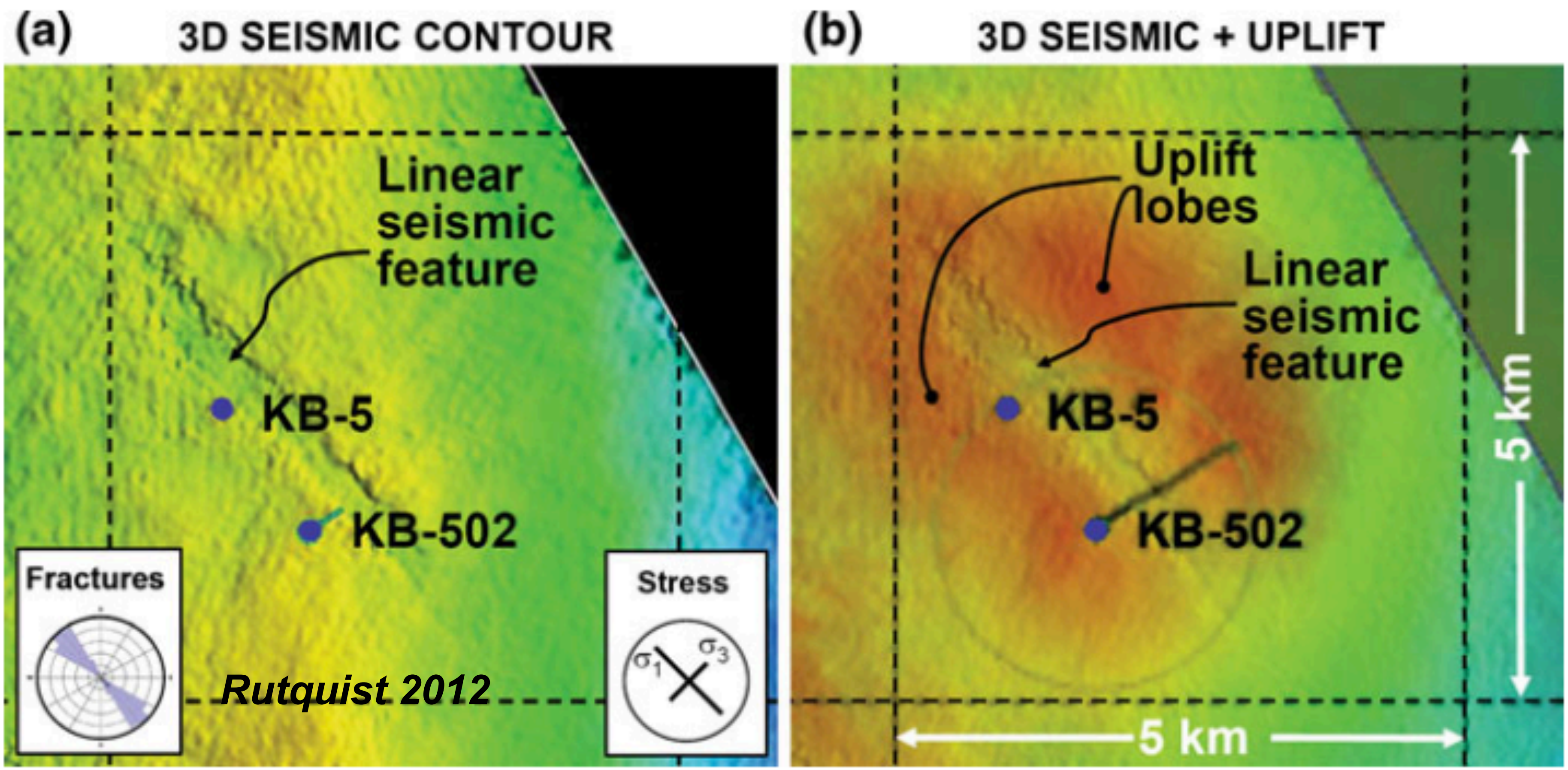
InSAR Monitoring Example : In Salah

Example : Post-analysis revealed uplift coinciding with previously un-mapped lineament/fracture zone.

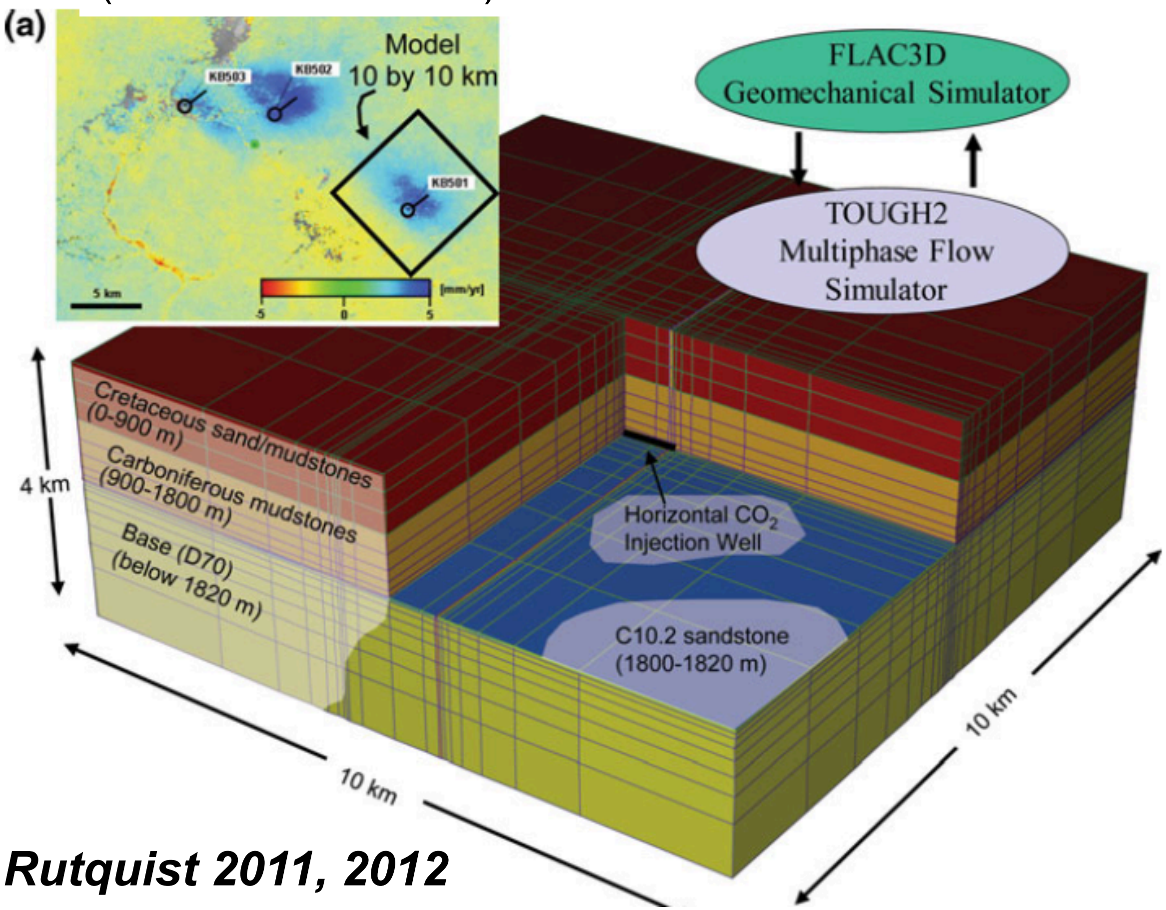
Demonstrates utility of combining InSAR with 3D/4D reflection imaging, mapping between a structural feature and a mechanical perturbation.

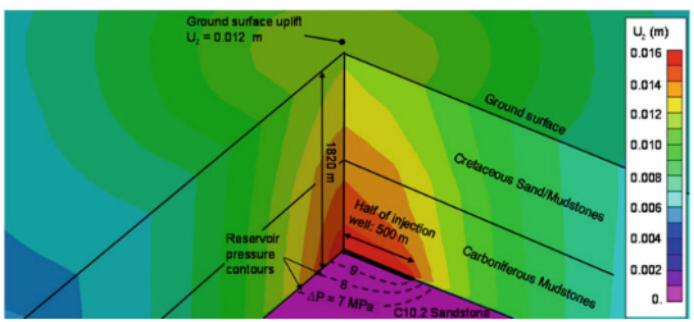


Modeling InSAR Surface Deformation

Modeling : InSAR can also provide constraints for detailed coupled multiphase flow + geomechanical simulation. Allows inference of processes in the reservoir zone.

Estimate of fracture behavior at depth from surface deformation measurement – but this requires a coupled model linking CO2 injection to geomechanics (TOUGH2+FLAC3D)





Rutquist 2011, 2012

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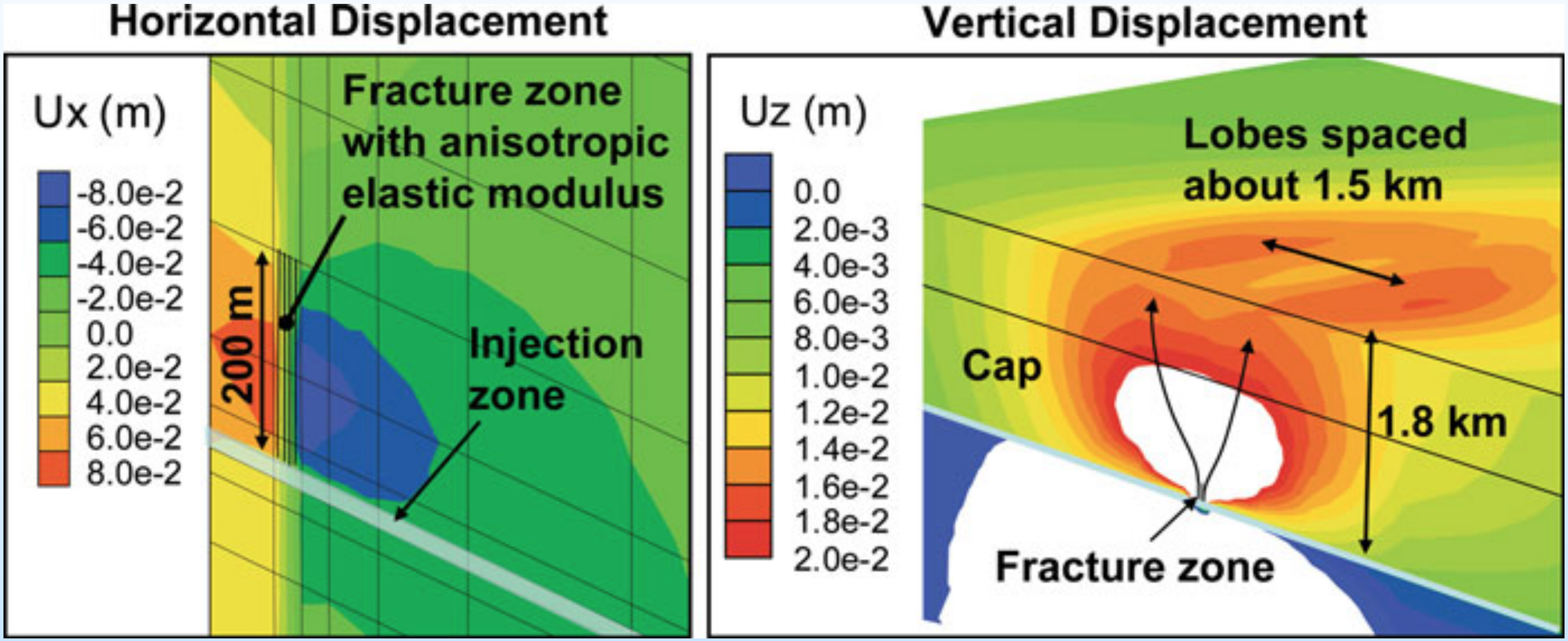


Rutquist 2011, 2012

Technique : Micro-EarthQuake (MEQ) Monitoring

Concept : Use surface or borehole seismometers to track small earthquakes (typically < M1.5, often very small M~ -1.0) induced by CO_2 injection.

Sensitivity depends on deployment type (surface vs. borehole).

Spatial accuracy depends on network design and velocity model accuracy.

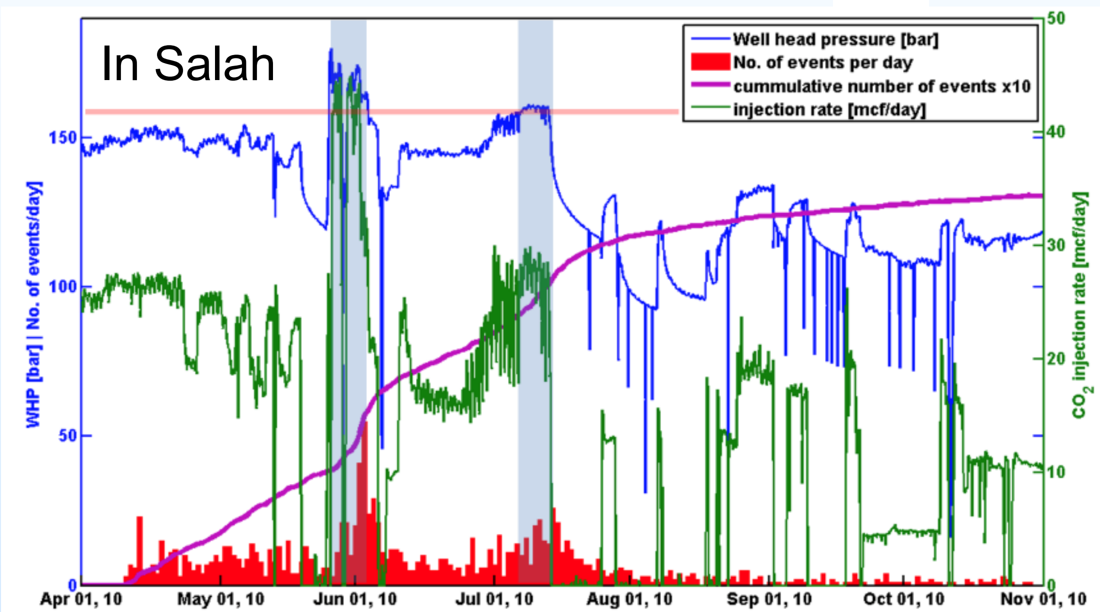
Advantages : Relatively inexpensive & directly sensitive to induced events which might compromise seal integrity.

MEQ Monitoring Example in GCS

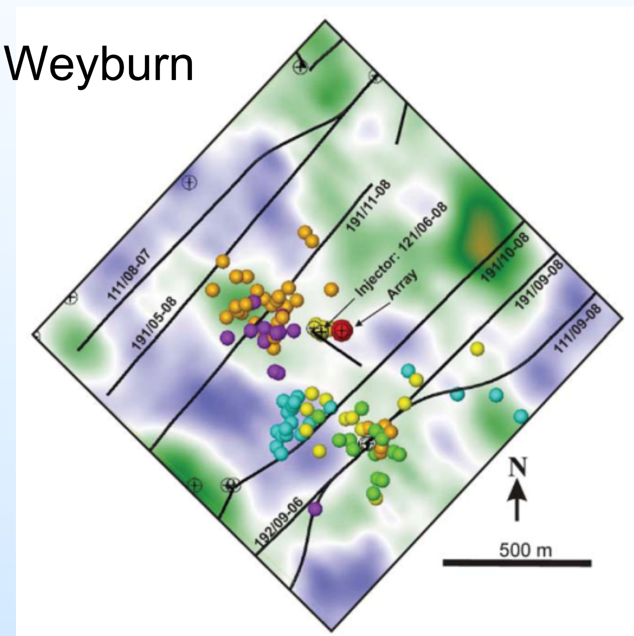
Evidence of injection related MEQ at several GCS sites (In Salah, Decatur, Weyburn).

Generally small magnitude (< M1.5) in comparison to large events triggered by water injection.

Important monitoring modality given induced pore-pressure variations.



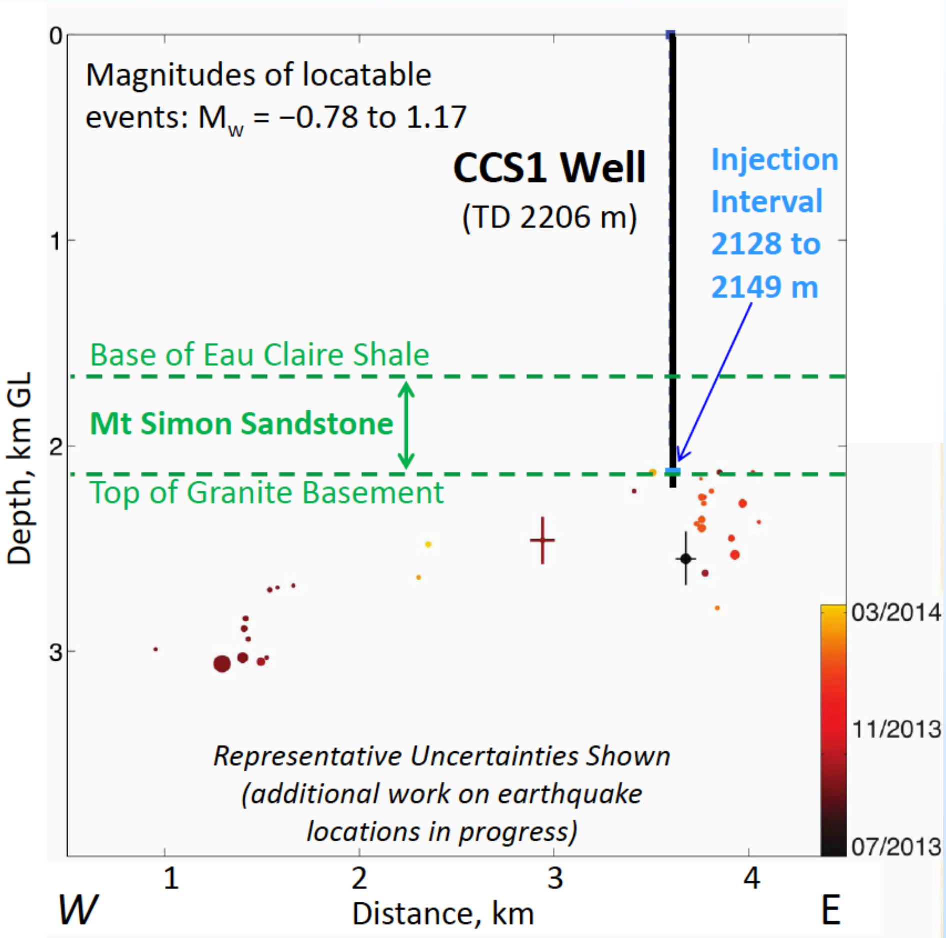
Oye et.al. 2012, GHGT 11

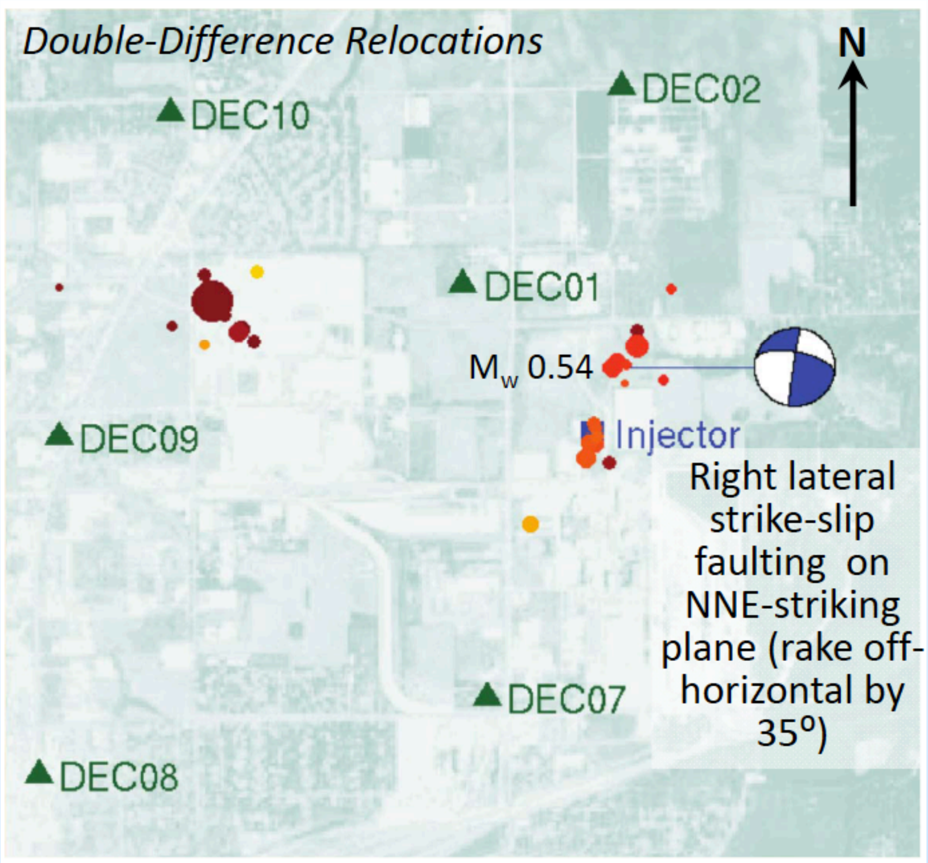


Verdon et.al. 2010, TLE

MEQ Monitoring Example in GCS : Decatur Project

Example : Decatur/ADM phase 3 injection site (~1000 tons/day). Monitored using network of surface and borehole geophones. Events detected but largely localized in unmapped fault in granitic basement. No sign of activity in seal (Eau Claire).



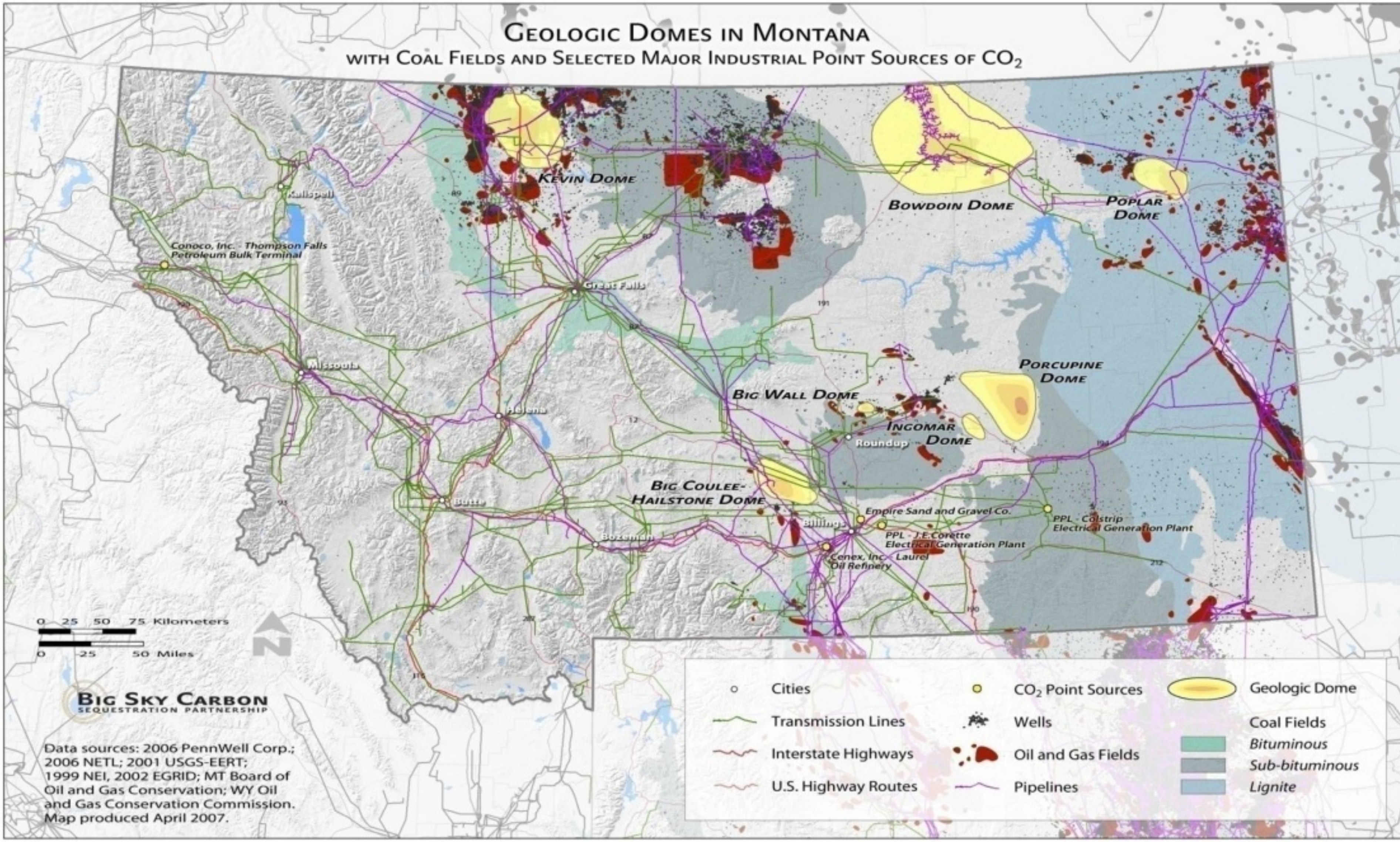


Hickman et.al. 2014, CCUS 13

Methodology

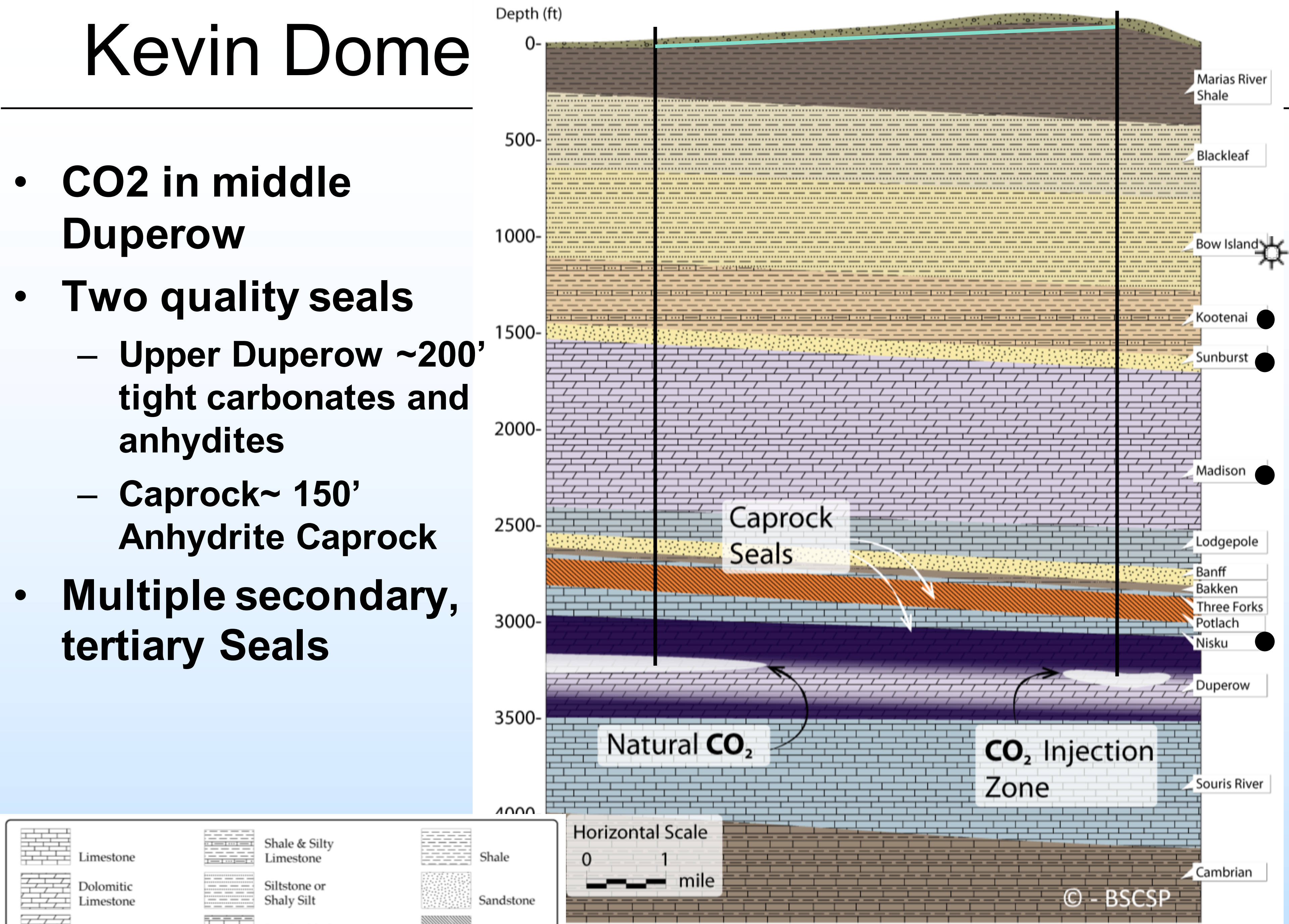
- Use spatially and temporally resolved satellite deformation monitoring (InSAR) to detect geomechanical perturbations induced by injection and/or production
- Invert InSAR data for changes in reservoir volume and pore pressure. Validate pore pressure variation against core-calibrated impedance inversions derived from a 4D 9C seismic volume.
- If dipole signatures of surface deformation are detected (indicative of a tensile opening event) attempt to evaluate the fractured zone using either scattered energy or anisotropy metrics in the 4D 9C volume.
- Use microseismic (MEQ) monitoring to map interactions between induced stress changes and fault reactivation on the small scale.
- The temporal and spatial correlation of this pressure pulse with MEQ activity will allow delineation of induced events and potential analysis of stressed faults in the injection region.
- Integrate data using a state-of-the-art coupled modeling framework (TOUGH-FLAC) to allow a detailed understanding of subsurface interactions and safe operating conditions.

Project Site



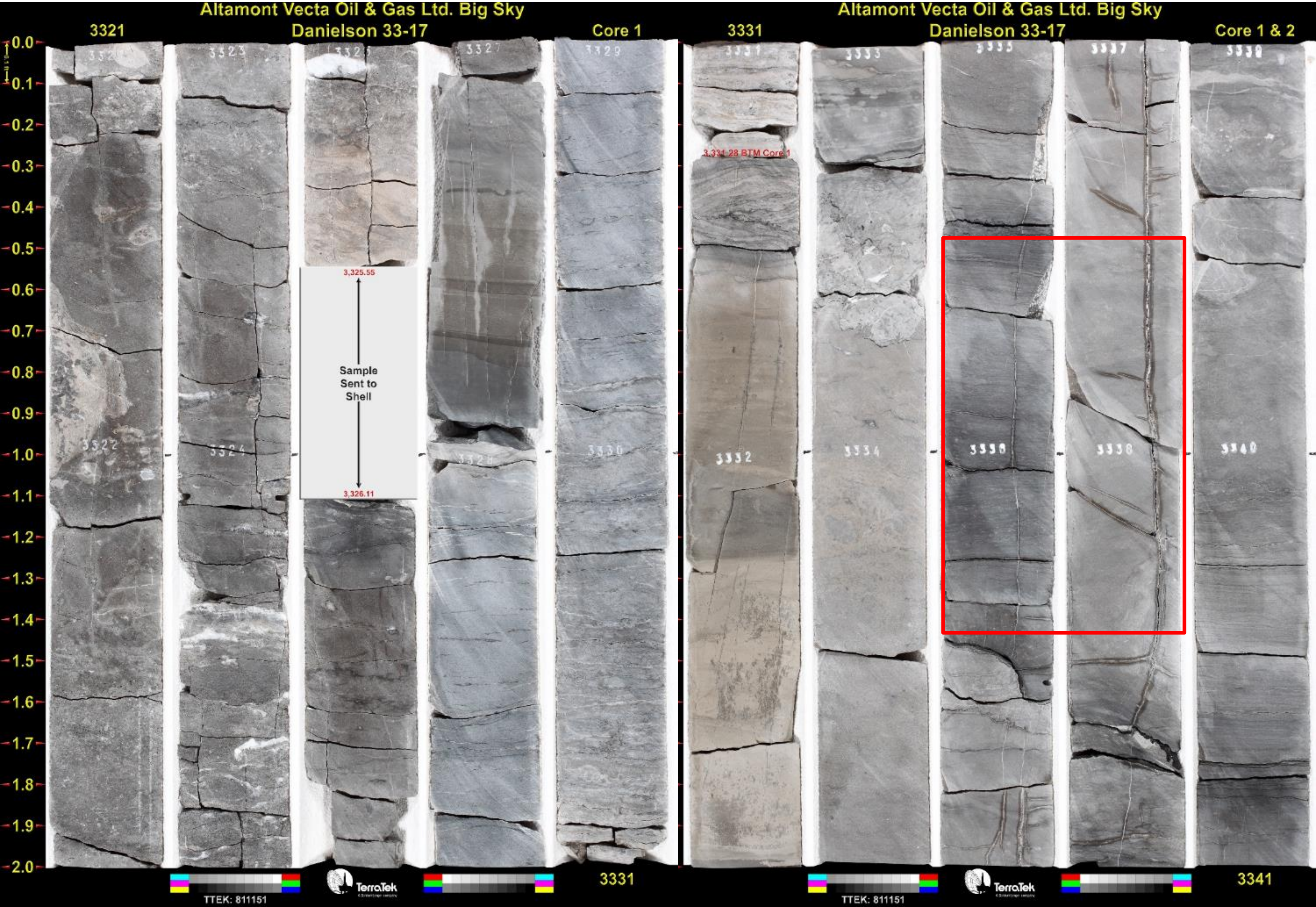
Kevin Dome

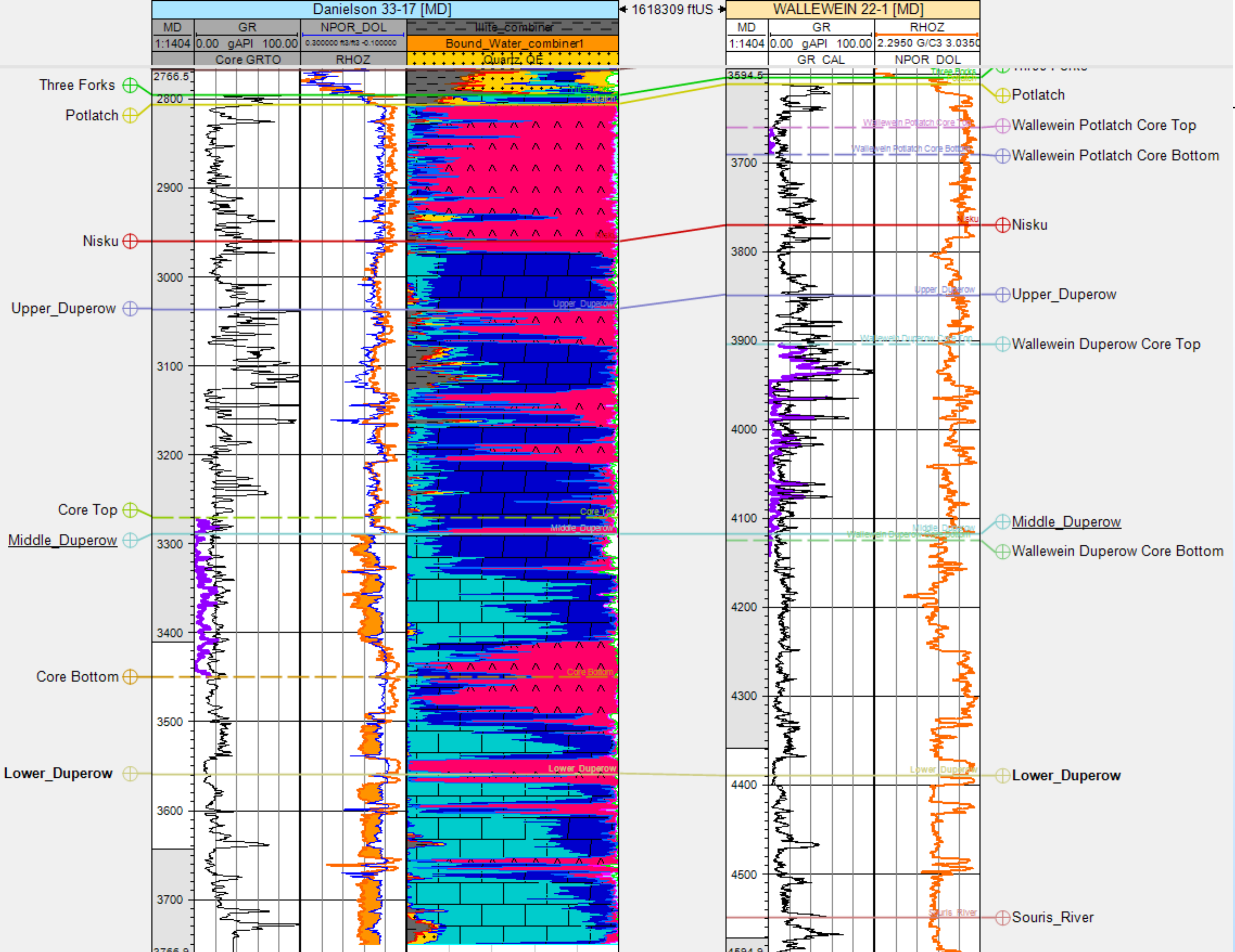
- **CO2 in middle Duperow**
- **Two quality seals**
  - **Upper Duperow ~200' tight carbonates and anhydites**
  - **Caprock~ 150' Anhydrite Caprock**
- **Multiple secondary, tertiary Seals**



claimer: This graphic is a generalized representation of the subsurface at Kevin Dome. The horizontal and tical scale are independent of one another to fit view on a single page. Surface infrastructure not to scale.

Middle Duperow – Fractures




Danielson 33-17 [MD]
1618309 ftUS
WALLEWEIN 22-1 [MD]
MD
1:1404
GR
0.00 gAPI 100.00
Core GRTO
NPOR_DOL
RHOZ
Illite_combiner
Bound_Water_combiner1
Quartz, QE
GR CAL
RHOZ
2.2950 G/C3 3.0350
NPOR_DOL
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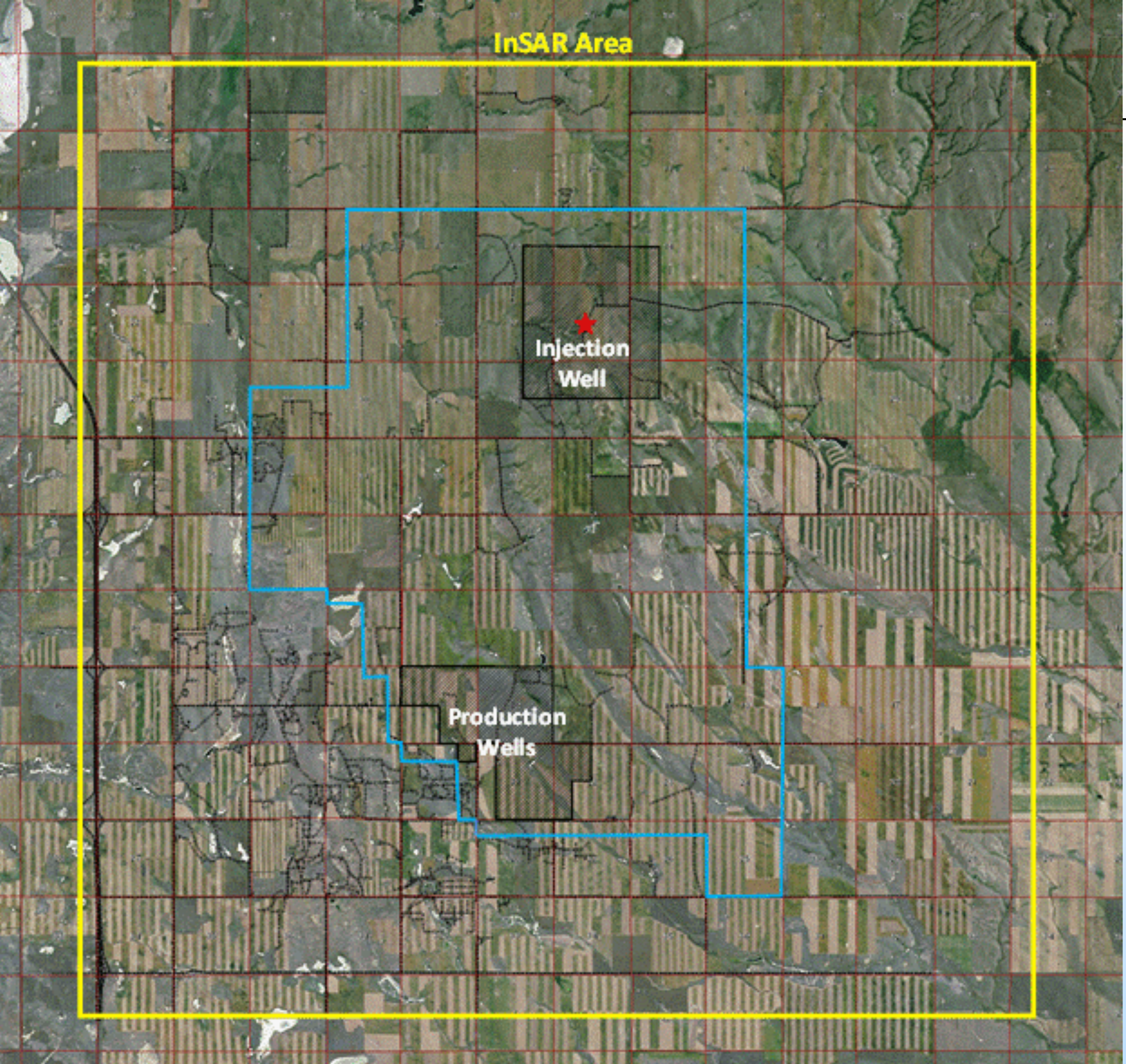
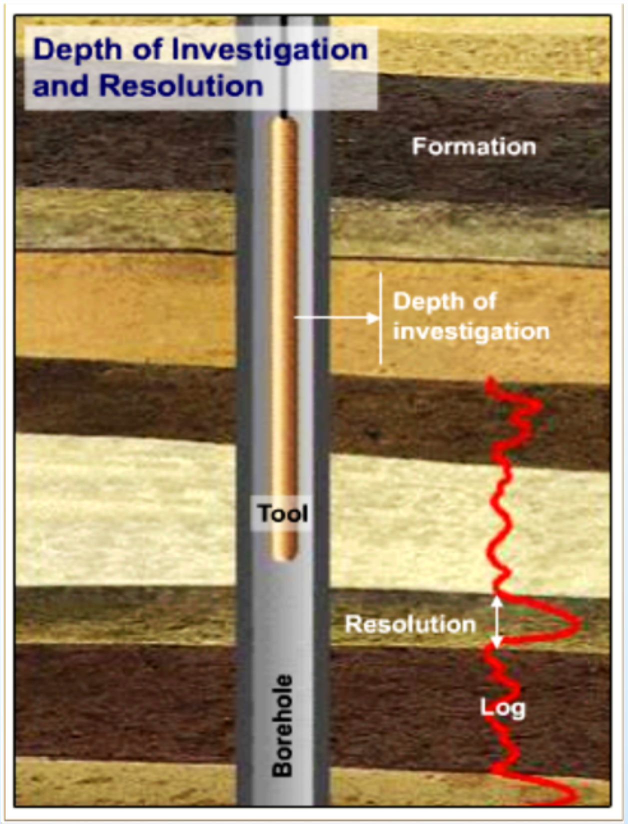
3600
3700
3766.9
3594.5
3700
3800
3900
4000
4100
4200
4300
4400
4500
4594.9
Three Forks
Potlatch
Nisku
Upper_Duperow
Core Top
Middle_Duperow
Core Bottom
Lower_Duperow
Wallewein Potlatch Core Top
Wallewein Potlatch Core Bottom
Wallewein Duperow Core Top
Wallewein Duperow Core Bottom
Souris_River


InSAR Area
Injection
Well
Production
Wells

Geophysical Characterization & Monitoring: Well Logging



Logs	Wells			
	1^{st} Prod	Inj	Mon	All
Downhole P & T	Cont.	Cont.	Cont.	Cont.
Gamma Ray	Init	Init	Init	Init
Resistivity	Init	Init	Init	Init
Porosity	Init	Init	Init	Init
Density	Init	Init	Init	Init
Caliper	Init	Init	Init	Init
P&S Sonic	Init	Init	Init	Init
Sonic Scanner	Init	Init	Init	
Isolation Scan	Init	Init	Init	
FMI	Init	Init	Init	
NMR	Init	Init	Init	
Natural Gamma	Init	Init	Init	
Elemental Spec	Init	Init	Init	
Cement Eval	Init	Init	Init	Init
Pulsed Neutron	Init	Annual	Annual/ 2 Annual	Init

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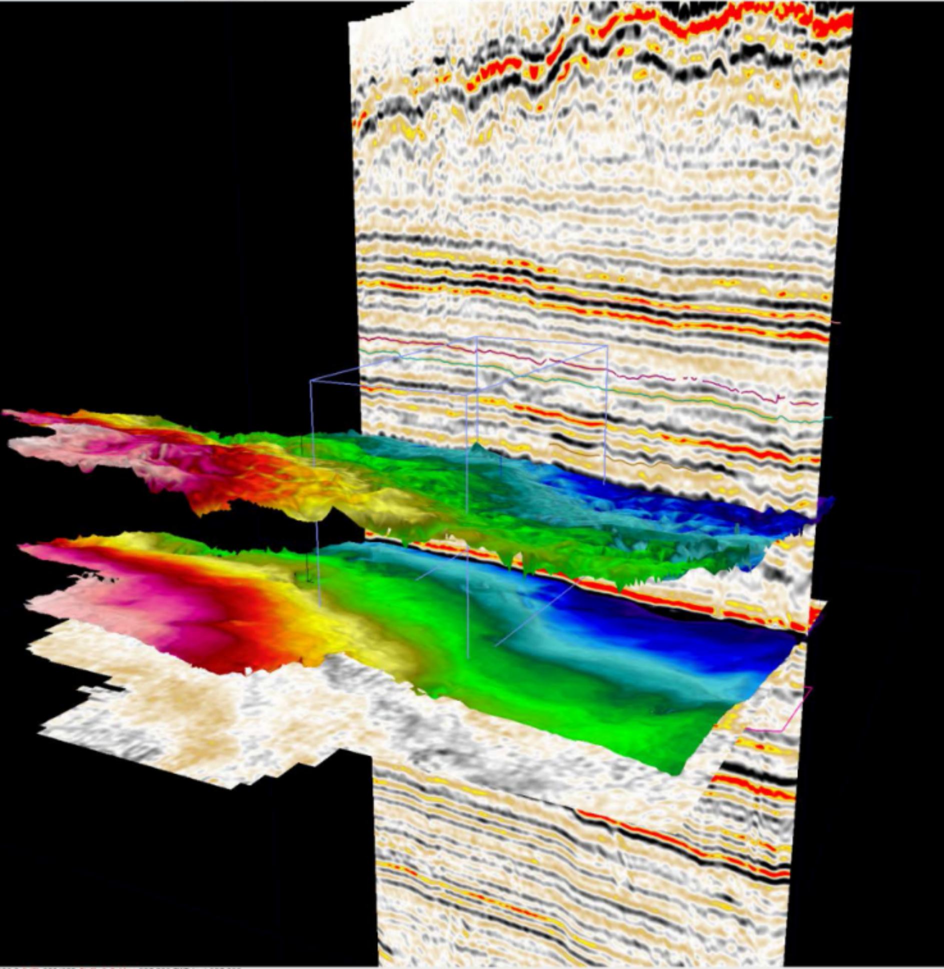
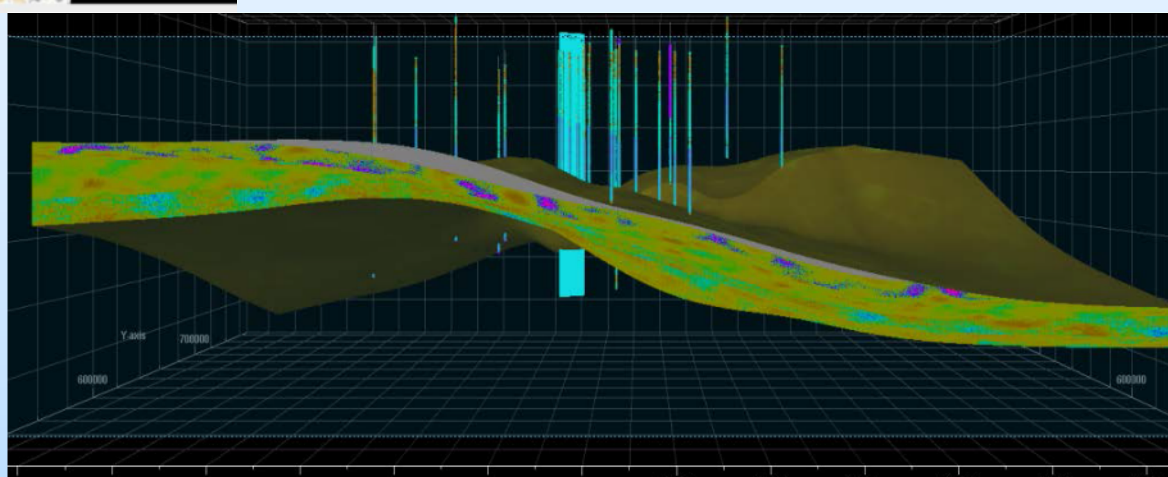


BSCSP Seismic Data and Static Geologic Model

Geologic model (Petrel, bottom) incorporating logs, petrophysical, and seismic data. Dome structure confirmed by seismic (top). BSCSP Kevin Dome



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Project Site

- The project will be executed at the Big Sky Phase III Kevin Dome, MT sequestration site to allow observations at injection rates relevant to commercial GCS deployment.
- The Kevin Dome is unique in that it encompasses spatially separated production and injection zones, allowing observation of both polarities of pore pressure perturbation during operation.
- The site is analogous to a CO_2 hub which functions as both a GCS repository as well as temporary storage facility to supply the needs of enhanced oil recovery.
- Such sites, will likely experience a wide range of pore-pressures during injection and draw-down periods
- Thus, the project will address geomechanical impacts of both sequestration and utilization activities.
- Extensive characterization and monitoring datasets will be available for constraining and validating the piloted techniques, including surface-to-TD sonic logs, core studies of elastic properties, VSP constraints on seismic velocities, and most crucially a unique 4D 9C surface survey which will provide a comparison to pore pressure maps derived from surface deformation measurements.
- Furthermore, this project will study a carbonate reservoir, subject to potential reactive geochemistry which could cause creep compaction. The integrated modeling and monitoring will allow unique field scale constraints on such coupled geochemical/geomechanical processes.

Methodology

The project will install:

1) surface microseismic sensors in the CO_2 production region;

2) surface and borehole microseismic sensors in the CO_2 injection region; and

3) Interferometric synthetic aperture radar (InSAR) reflectors in both regions.

Data generated by these sensors will be collected, processed, analyzed, and interpreted for a period of approximately 24 months.

Methodology

Data will be integrated with the Transport of Unsaturated Groundwater and Heat (TOUGH) suite of codes and the Fast Lagrangian Analysis of Continua (FLAC) code (combined as the TOUGH-FLAC simulator) to do the following:

1. Compute initial predictions of pressure perturbations, surface deformation, and microseismic event (microearthquake-MEQ) generation using coupled fracture flow and geomechanical modeling.
2. Monitor deformation caused by injection and production using InSAR.
3. Monitor microseismic activity in the injection and production regions.
4. Invert deformation data for pressure distribution and validate against 4-dimensional (4D) seismic changes.
5. Update models (with iterations) using inversion and monitoring results to infer couplings between pore pressure changes and MEQ activity.
6. Assess geomechanical processes and field data critical to supercritical CO2 injections.

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Expected Outcomes

- An evaluation of efficacy of reasonably priced geomechanical monitoring technologies
- An improved understanding of pore-pressure perturbations due to injection and withdrawal of CO_2
- An improved understanding of coupled geochemical/geomechanical processes.
- Production of a benchmark integrated dataset for testing coupled forward models

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Task/Subtask Breakdown

1.0 - Project Management and Planning

2.0 - Permitting / Compliance and Infrastructure

- 2.1 - Infrastructure Design
- 2.2 - Permitting
- 2.3 - Infrastructure Installation
- 2.4 - Compliance

3.0 - Geomechanical Modeling

- 3.1 - Initial Modeling
- 3.2 - Inverse Modeling

4.0 - Geomechanical Monitoring / Data Acquisition

- 4.1 - Microseismic / Data Acquisition
- 4.2 - Deformation Data

5.0 - Data Processing, Analysis and Integration

- 5.1 - Microseismic data processing
- 5.2 - InSAR data processing
- 5.3 - Validation of InSAR inversion using 4D 9C seismic
- 5.4 - Data Integration

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2.0 – Permitting / Compliance and Infrastructure

2.1 - Infrastructure Design

– Decide layout of InSAR reflectors and surface and borehole microseismic monitors taking into account array design for effective monitoring, topology, cultural resources, access, and landowner stipulations.

2.2 – Permitting

– Assess and apply for necessary permits.

– Adhere to the existing Programmatic Agreement established by the Department of Energy for BSCSP to protect the cultural resources.

2.3 - Infrastructure Installation

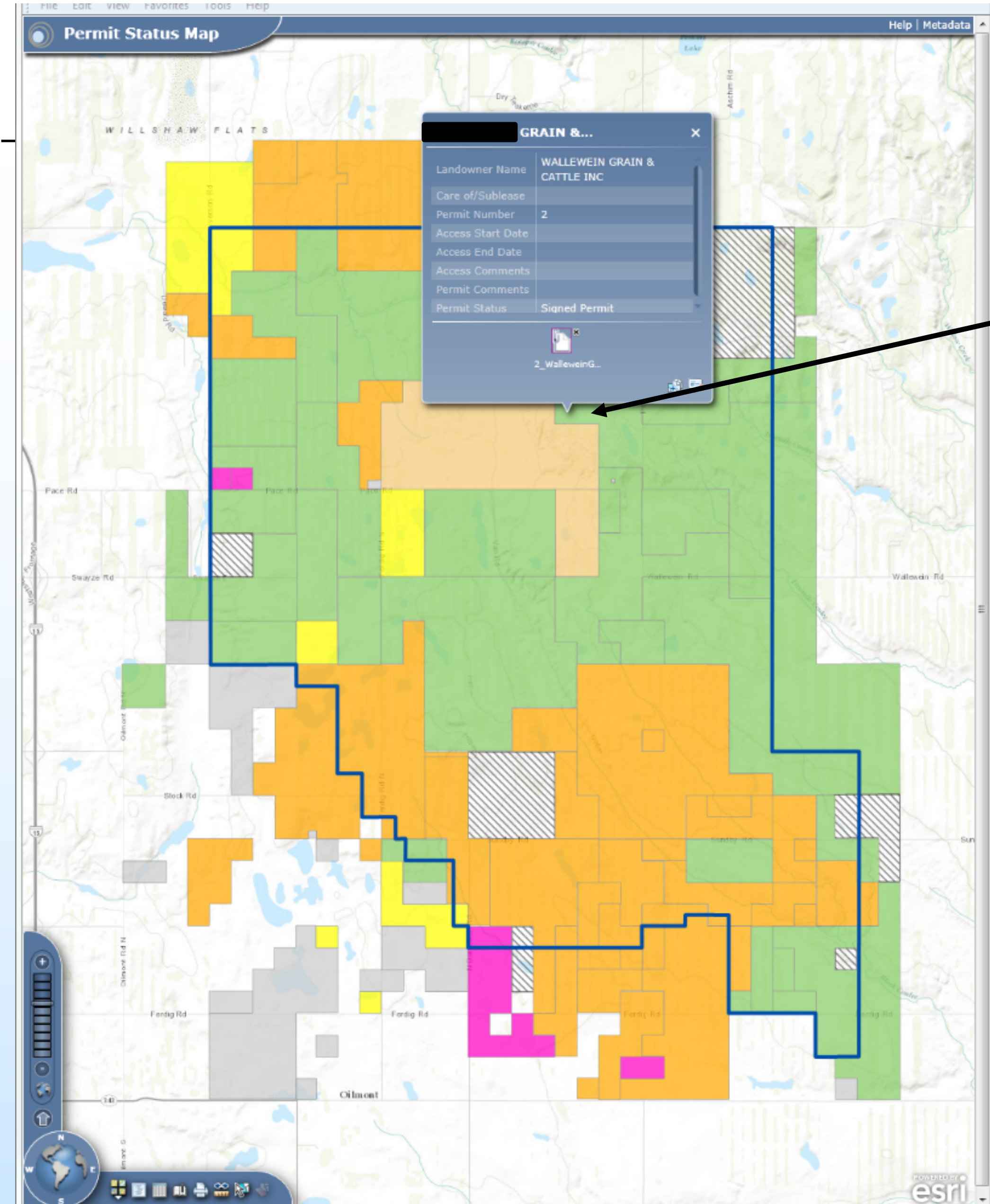
– Contract and oversee installation of surface microsesmic monitors,

2.4 – Compliance

– Develop and disseminate compliance procedures for access to infrastructure.

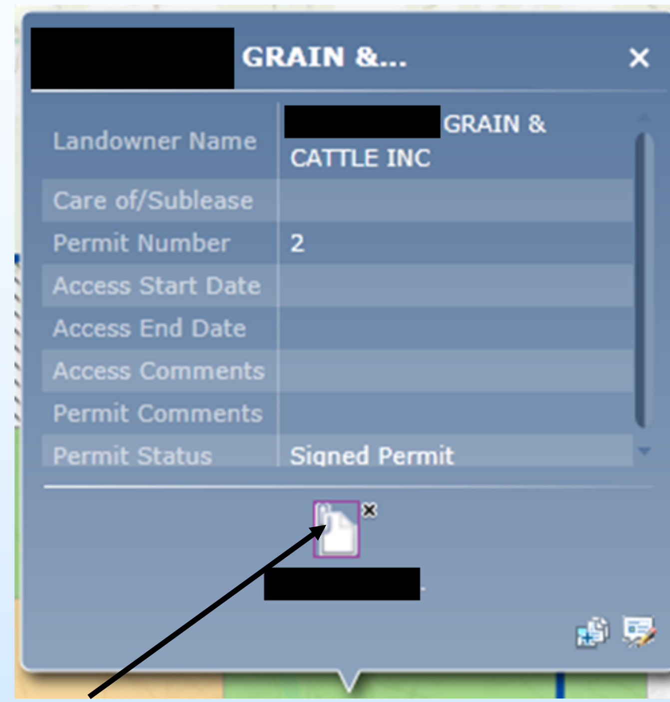
– Site access will be controlled by the Site Manager.

– Prepare any reports required by regulatory agencies..



Permit Status Map

Click on area pops up permit information balloon



Click on icon brings up pdf of permit

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Planned MEQ Deployment

Network :
Network will include a small number of surface stations & shallow (< 100 m) borehole-deployed 3C sensors. Network geometry currently being determined. Bulk of stations near injector with some coverage of production zone.

Sensors :
GeoSpace GS-11D 4.5 hz 3-C phones, potentially augmented by a 1 hz and broadband stations at surface.

Acquisition :
Continuous acquisition with GeoEMS portable 24 bit recorders. Telemetry for detected events and instrument health. Systems will be hardened for winter operations.


GS-11D


Version 3.0


Modification for Winter Operation

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Infrastructure Requirements

MEQ :
Surface footprint : < 1 m square + shallow well
Site work : shallow (< 200 ft) slim well (2” ID).
Power : 100% solar, keep panel above snow
Telemetry : health + triggered events
Service : for failure & download of continuous data

Planned locations : 3-5 wells, potentially secondary surface locations
Challenges : Drill rig, permitting, land owner access

InSAR Reflectors :
Surface footprint : < 1 m square
Site work : drill hole to 7 ft for foundation
Power : 100% passive
Telemetry : none
Service : none

Planned locations : 10-16 depending on cost

Challenges : foundation design & land owner access

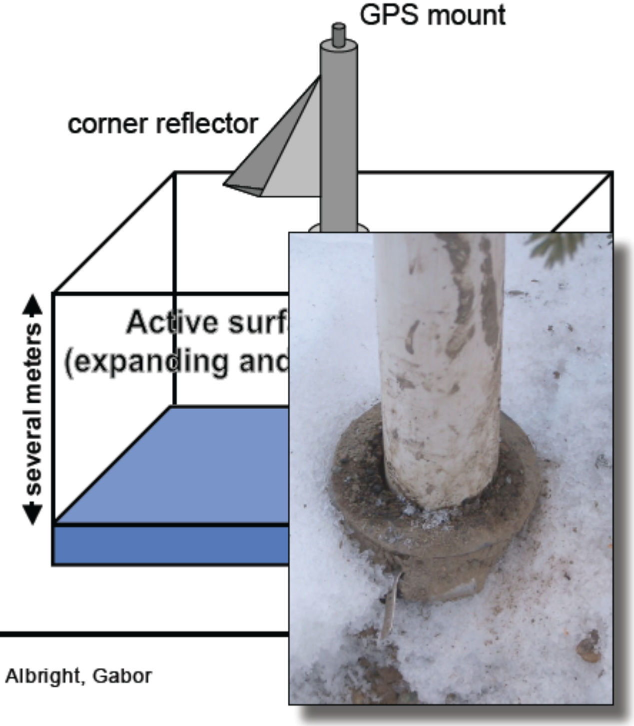
Modification for Winter Operation

Installation design, frost heave issues

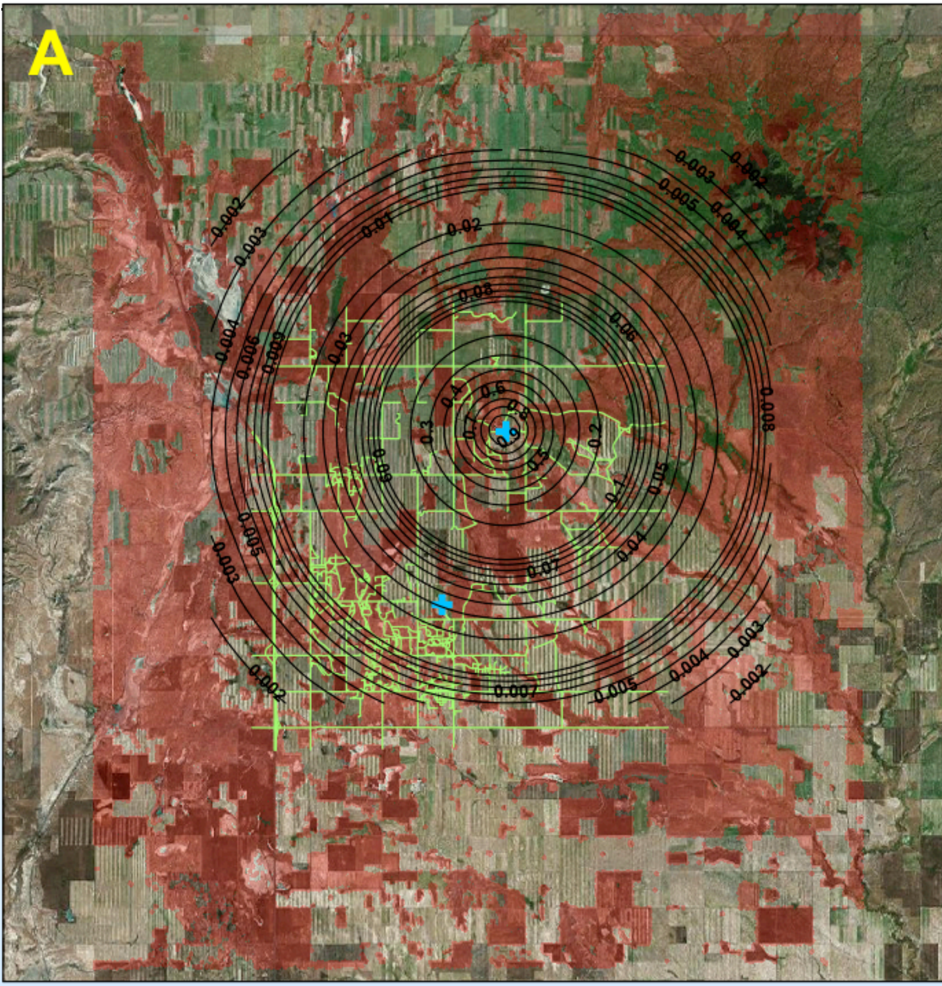
Customized Corner Reflector Mounting

- Application: Observe change of permafrost
- Problem: Avoid surface deformation caused by thaw and refreeze of top soil

- Two shell system:
  - Outer shell is influenced by thermal expansion and contraction of soil
  - Inner tube shows isolated permafrost motion
  - Corner reflectors & GPS mounted on inner tube



Surface Deformation and Persistent Scatterers



N
W E
S

Legend

Deformation (mm/yr)

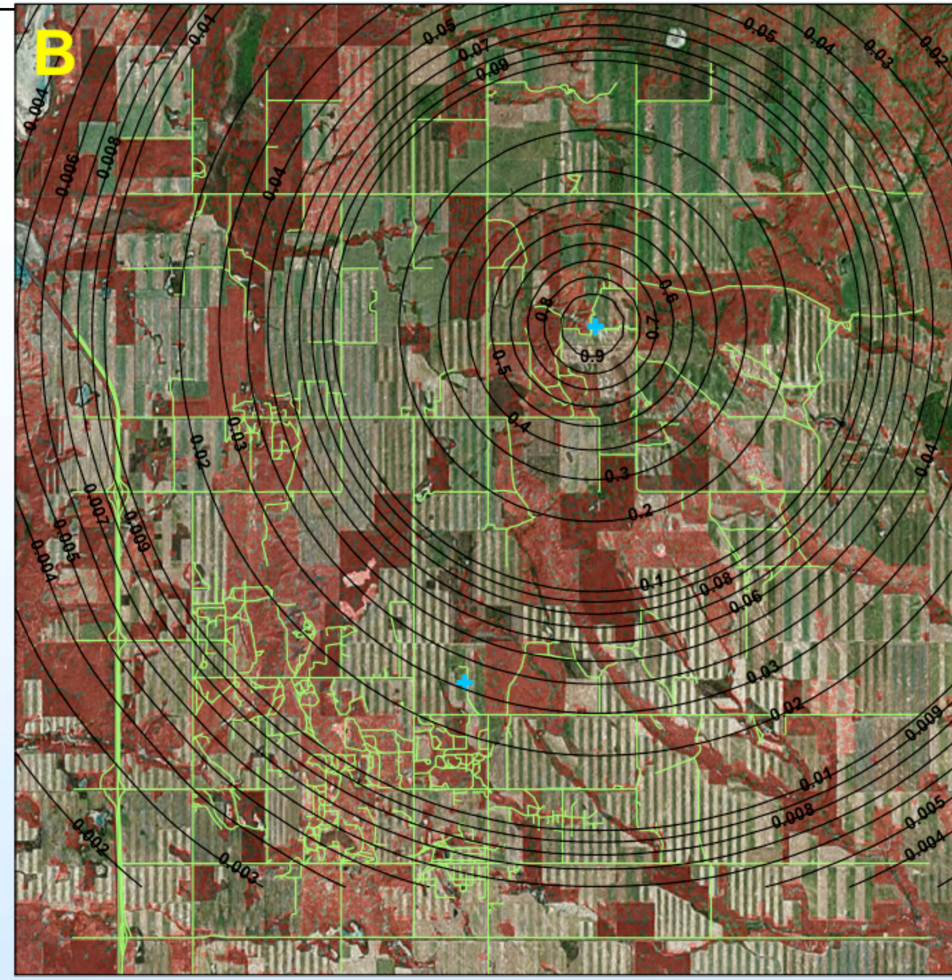
BSCSP Wells

LocalRoads

Persistant Scatter

0 2 4 8 12 16 Kilometers

1 cm = 3 km



N
W E
S

Legend

Deformation (mm/yr)

BSCSP Wells

LocalRoads

Persistant Scatter

0 0.75 1.5 3 4.5 6 Miles

0 1 2 4 6 8 Kilometers

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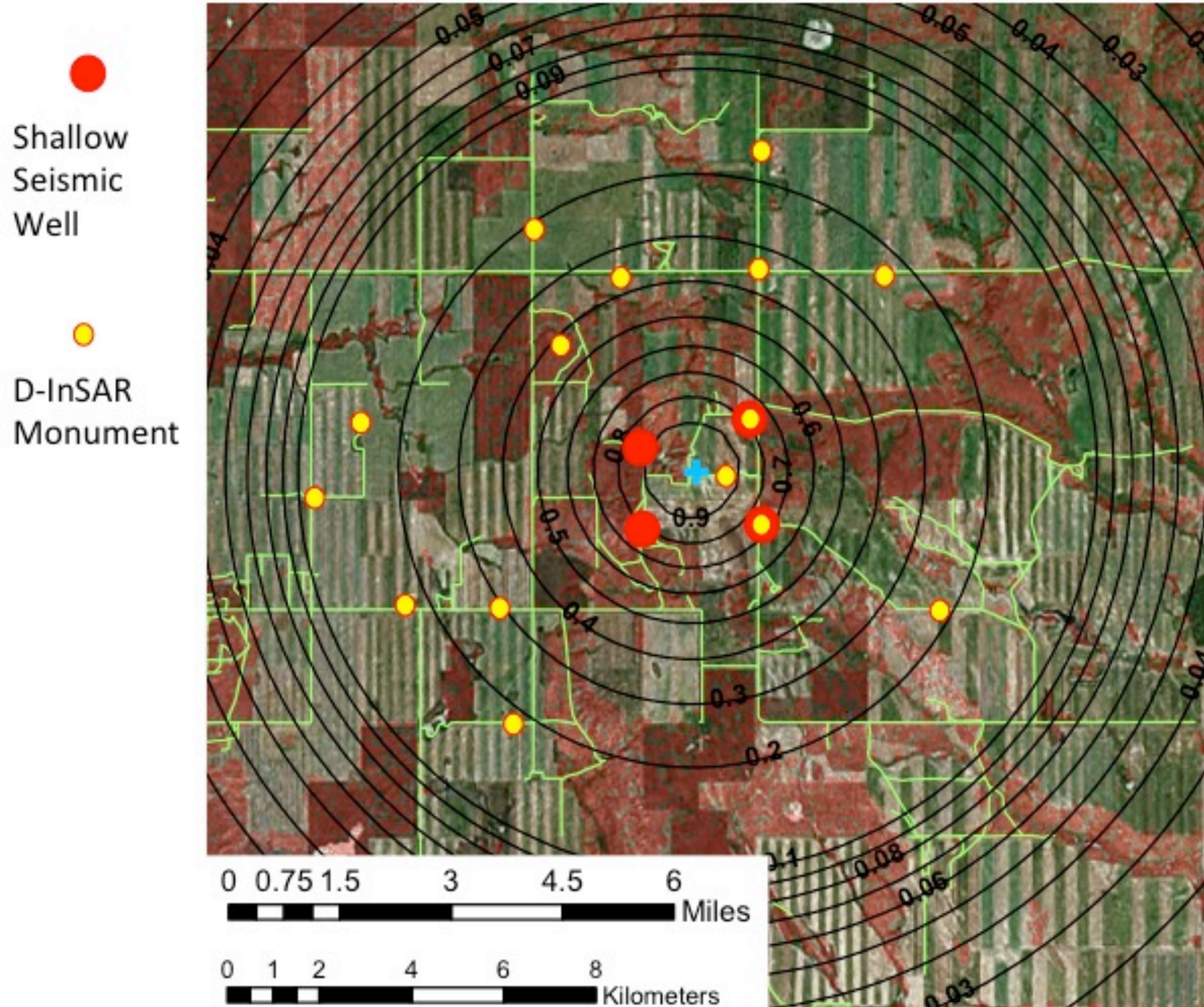
Preliminary map of seismic wells and D-InSAR monuments



3.0 - Geomechanical Modeling

3.1 - Initial Modeling

- Initial study will be conducted to assess the potential for induced seismicity as a result of activating small fractures and minor faults in the dome-shaped fractured reservoir and overburden rock.
- Ground surface deformations will be calculated for comparison to measured deformations obtained via InSAR monitoring.
- Potential compaction creep that might be dependent on temperature and CO_2 saturation will be assessed.
- MEQ generating will also be evaluated in this initial model.
- The baseline elastic model will be constructed from sonic log and core measurements acquired at both the production and injection locations, as well as 3D seismic survey velocity information.
- Results from the BSCSP modeling effort will be utilized in model construction.

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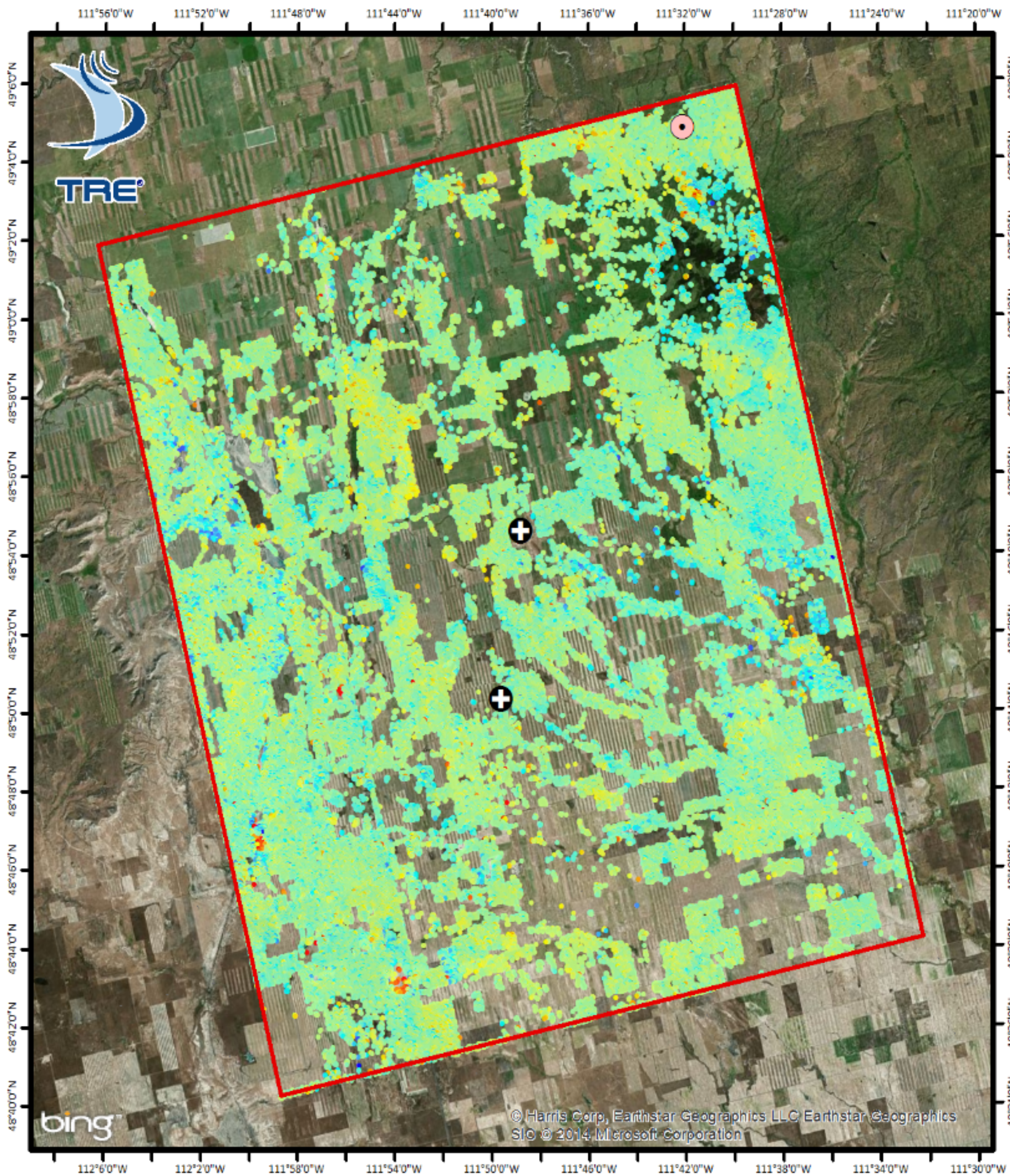
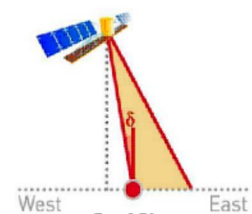
Preliminary Results : PS-InSAR Historical Analysis



Kevin Dome
USA

SqueeSAR™ analysis

Satellite	ERS
Geometry	Descending
Track	356
N. of Images	52
Date Range	21 Apr 1992 - 20 Oct 2000



δ = 25°

Surface Displacement Rate

-5 -2.5 0 2.5 5

[mm/year]

Wells

Reference point

Area of interest

N

0 5 10 Km

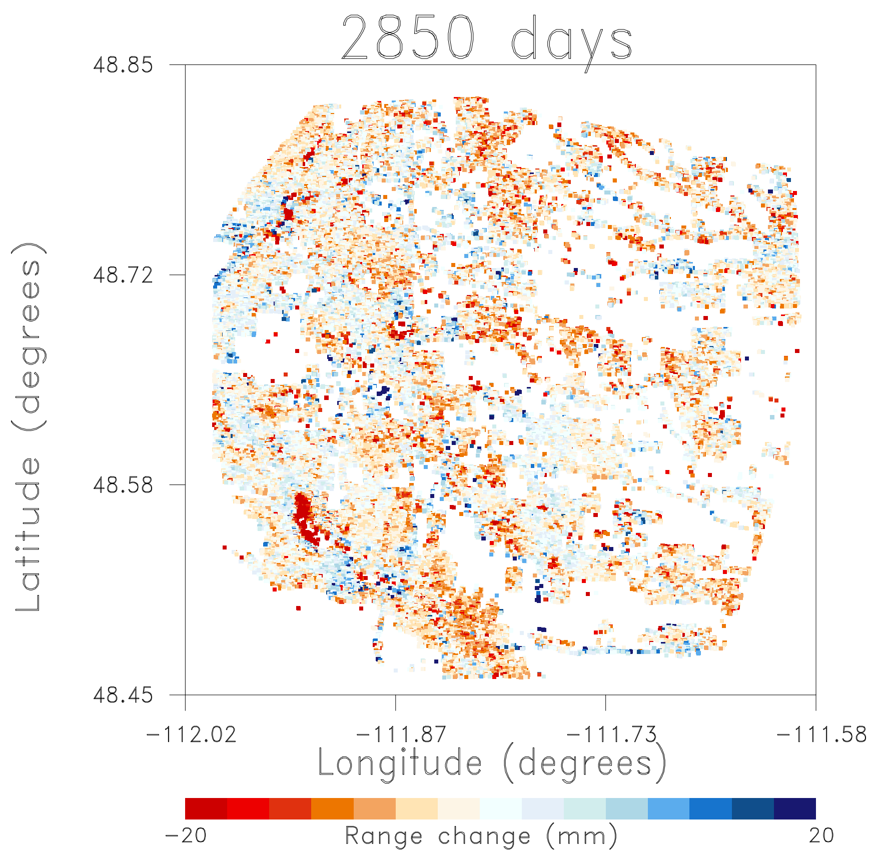
Map Projection:
WGS 1984 UTM Zone 9N

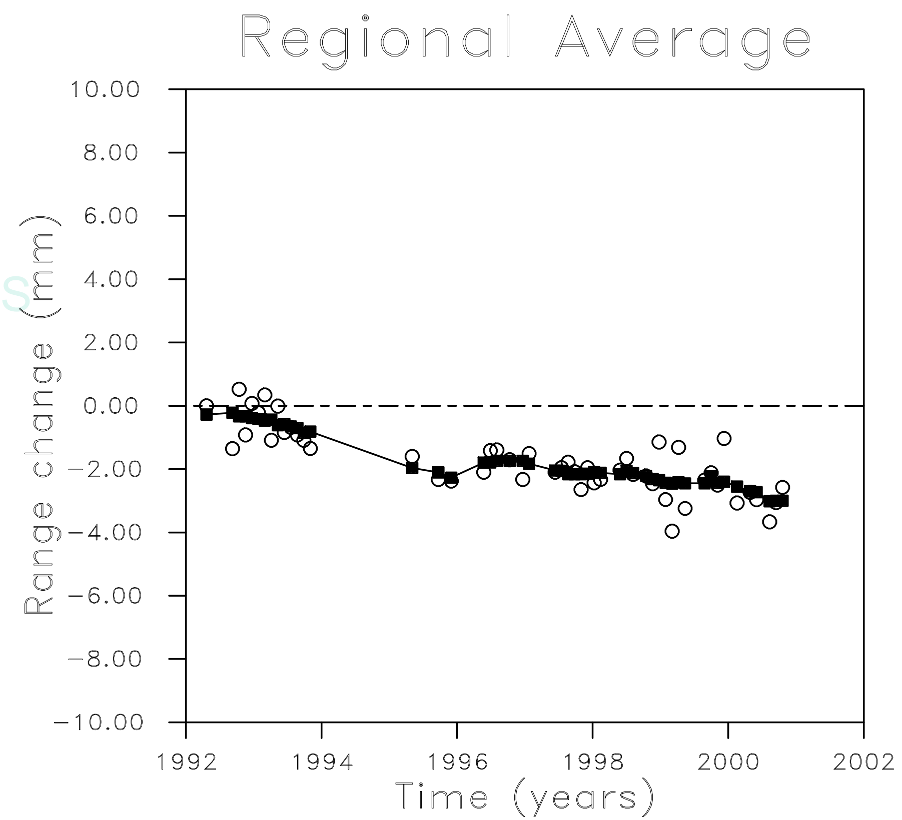
© TRE Canada 2014

Preliminary Results : PS-InSAR Historical Analysis

Preliminary Analysis : 1st historical swath analyzed : 1992-2002, persistent scatterer analysis on-going.

Trends : regional average shows historical subsidence, possibly production related



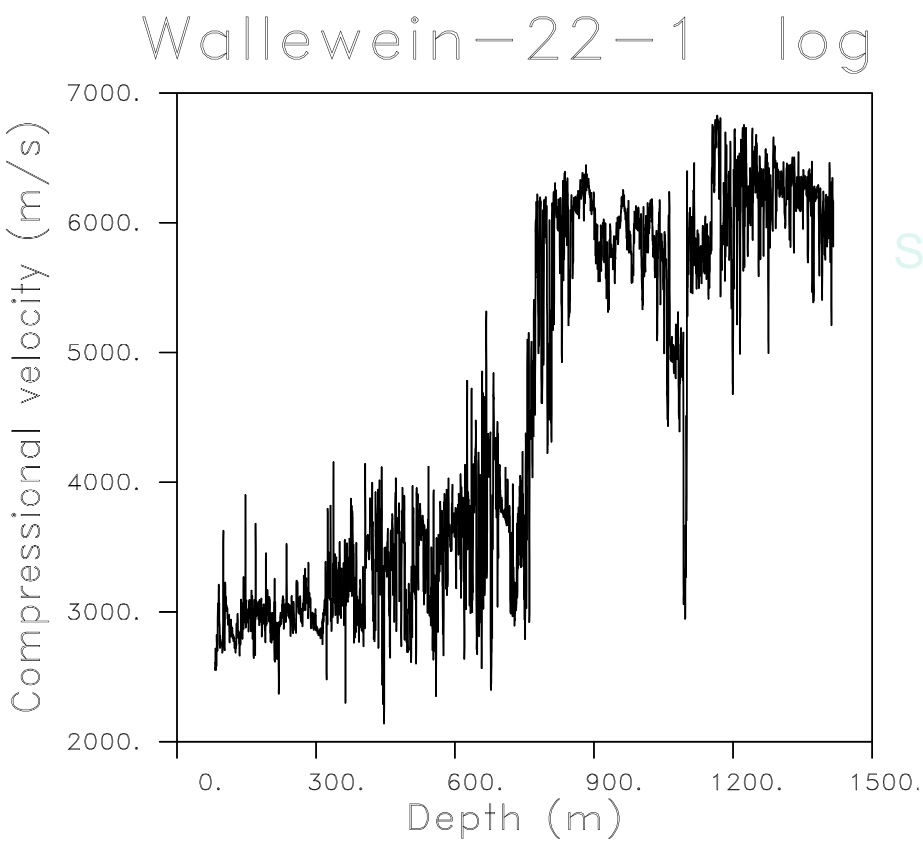


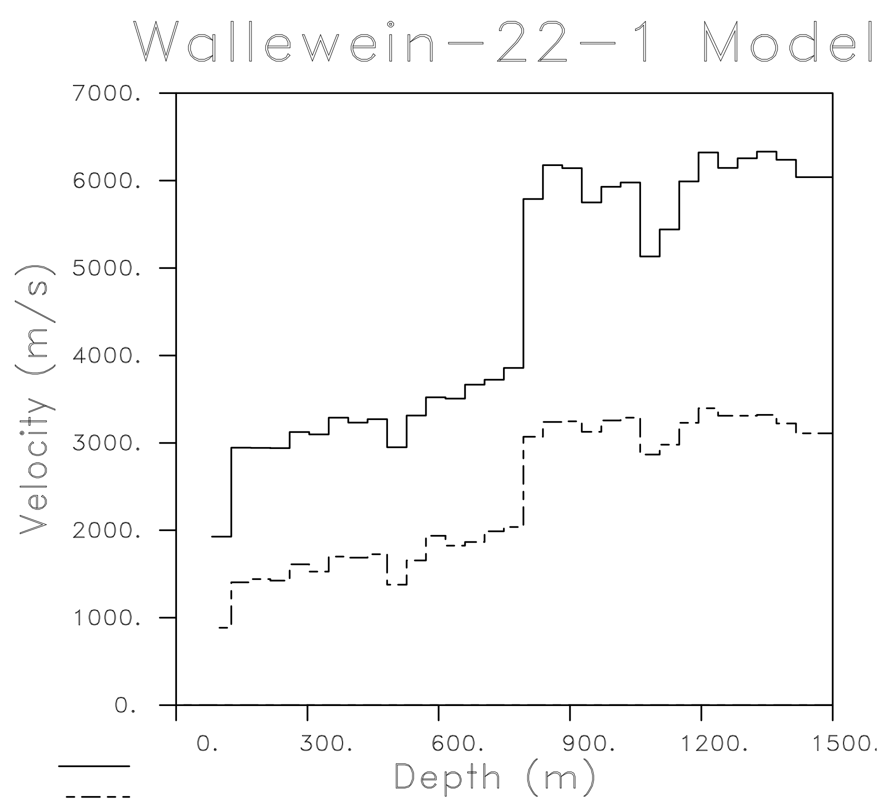
Preliminary Analysis : Simple Fracture Model

Goal : Simple elastic model for determining surface extent required for InSAR monitoring

Process : Developed preliminary elastic model based on sonic logs from Wallewein 22-1 well. Assumes layer-cake geology, blocked version of log.

Assumptions : Injection across a large section of the middle Duperow [3965-4248 ft]. Assumes fluids are entering continuous vertical fractures (h = 250 ft). Worst case scenario.



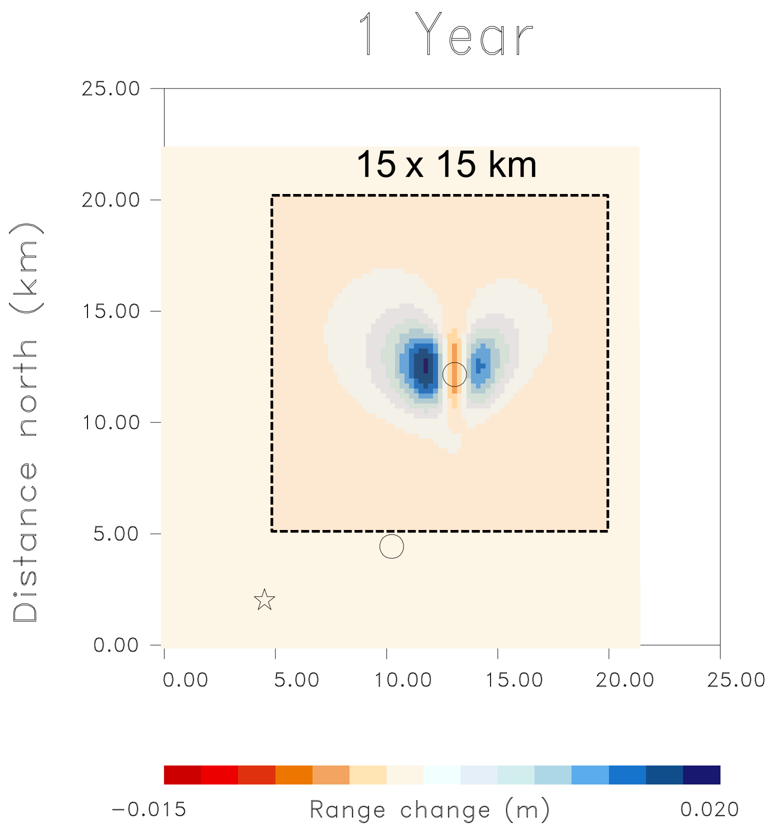


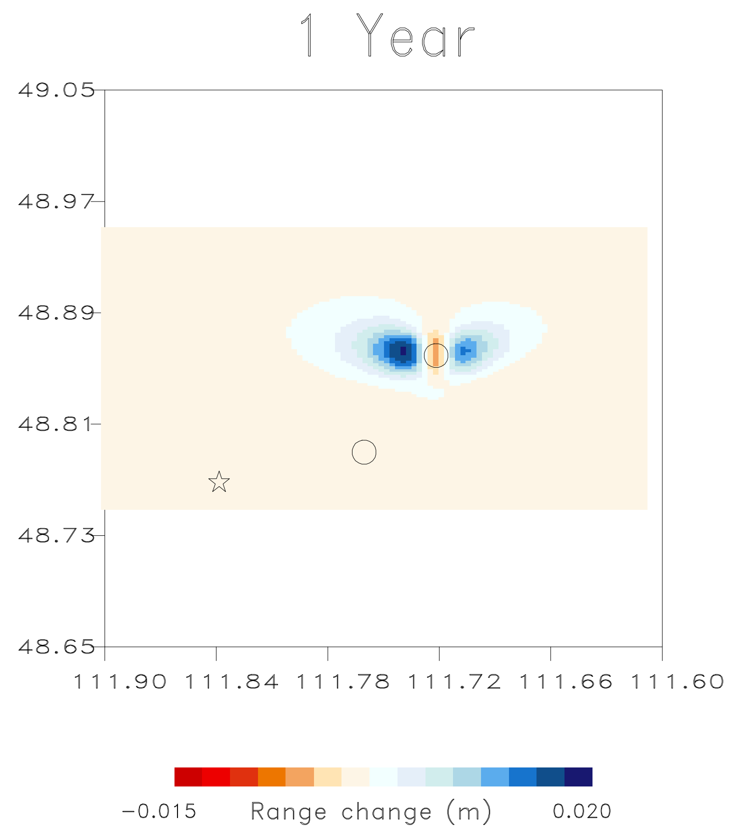
Preliminary Analysis : Simple Fracture Model

Goal : Simple elastic model for determining surface extent required for InSAR monitoring

Process : Developed preliminary elastic model based on sonic logs from Wallewein 22-1 well. Assumes layer-cake geology, blocked version of log.

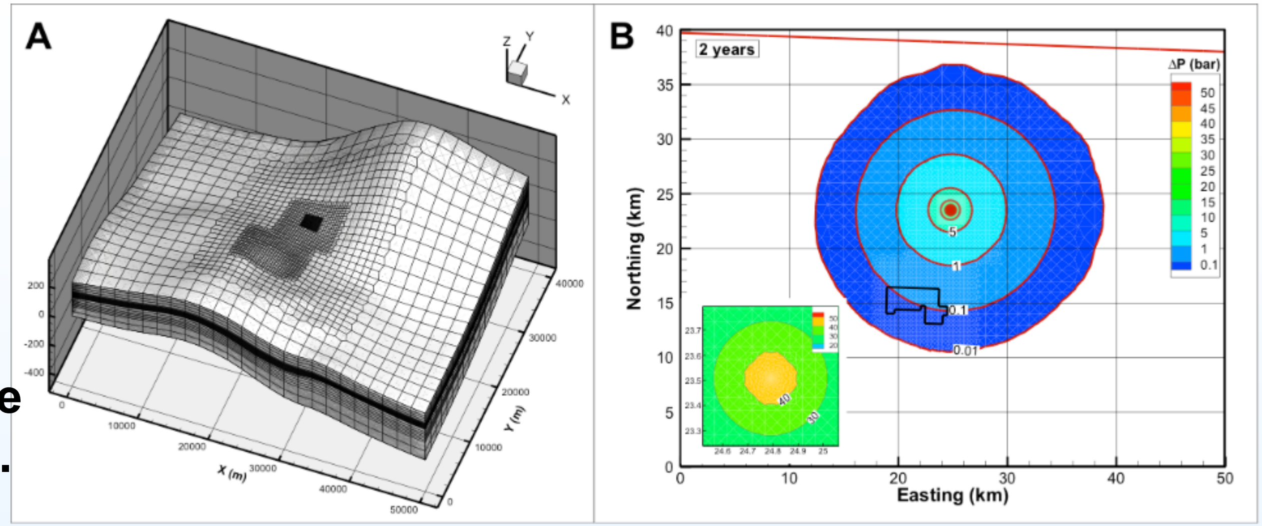
Assumptions : Injection across a large section of the middle Duperow [3965-4248 ft]. Assumes fluids are entering continuous vertical fractures (h = 250 ft). Worst case scenario.



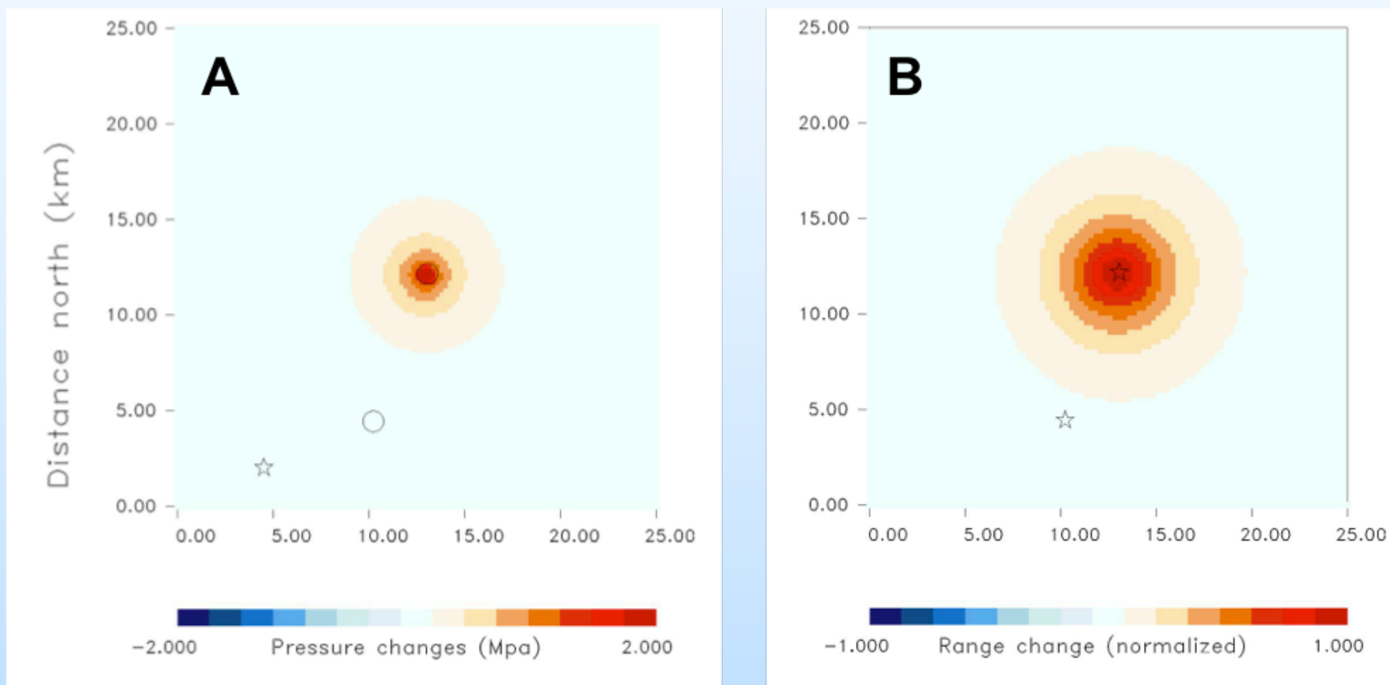


Uplift Modeling

Second generation BSCSP Kevin Dome TOUGH-2 model and pressure predictions. Panel (A) shows the geomodel and panel (B) shows pressure predictions at the top of the middle Duperow formation.



Updated pressure field (A) and resulting radial uplift (B) calculated using the updated flow model.



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Accomplishments to Date

- Historical InSAR data has been acquired and analyzed
- Persistent reflectors exist in the project area
- Preliminary Infrastructure design has started
- Final infrastructure design is devpendent on project aspects related to the BSCSP Phase III project

Synergy Opportunities

- Synergy exists with the Big Sky Carbon Sequestration Phase III Project.

Summary

– Persistent reflectors exist in the project area

– Final placement of infrastructure depends on BSCSP Phase III plans

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3.0 - Geomechanical Modeling

3.2 - Inverse Modeling

- Subsequent to the collection and evaluation of field data the geomechanical model will be updated to calibrate mechanical parameters, including stress field, elastic reservoir properties, pressure-dependent permeability, creep properties (if significant), and potential minor faults if detected from the monitoring data.
- In the end, the modeling will help to understand the underlying process related to field observations and this will help to assess geomechanical processes and field data critical to scCO_2 injections, in particular related to carbonate reservoirs.

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4.0 - Geomechanical Monitoring / Data Acquisition

4.1 – Microseismic / Data Acquisition

- MEQ surface stations will use GeoSpace GS-11D 4.5 Hz 3-C geophones or equivalent.
- MEQ data will have real-time preliminary events identified and meta-data transmitted via satellite.
- The full continuously recording data stream will be stored locally at each station.
- The continuous recorded data from surface and borehole seismometer stations on a periodic basis will be collected.
- This requires accessing the recorders in the field to download stored data.
- Routine maintenance of the recorder system will also be performed at these times.
- Satellite uplinks will provide remote assessment of recorder so unscheduled maintenance can be performed as needed.
- Coordinate with BSCSP active seismic surveys to capture data from wireless recorder arrays after deployment and before vibroseis shaking to get high spatial density data over a short time period for comparison

4.0 - Geomechanical Monitoring / Data Acquisition

4.2 – Deformation Data

- Data from InSAR and the Global Positioning System (GPS) will be acquired in order to evaluate the surface deformation associated with both injection and production from the Kevin Dome hub storage site.
- Given current satellite coverage, available X-band InSAR data has favorable temporal sampling with a time resolution of approximately 11 days.
- This frequency of satellite data will allow deformation associated with short term variations in injection and production to be monitored.
- Because there will be issues associated with snow cover in the winter months, methods will be investigated for maintaining data continuity by co-locating a radar reflector and a GPS station at a reference site.
- The data will be processed using a permanent scatterer technique, adapted to incorporate the GPS data.

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5.0 – Data Processing, Analysis and Integration

This task involves the comprehensive analysis of the geomechanical datasets acquired at the Kevin Dome site to examine the relationship between CO_2 injection, surface deformation, inferred pore- pressure perturbations, and measured microseismic activity.

5.1 – Microseismic data processing

- Microseismic data will be processed using a customized batch flow including (a) event identification, (b) automated onset picking, and (c) hypocenter inversion.
- The hypocenter result will include origin time, latitude, longitude, depth, coda magnitude, estimated residual errors, and the number of phases.
- The processing flow will result in an event catalog including time, location, magnitude, and mechanism (via moment tensor inversion), if recoverable.
- The temporal sequencing of events will be correlated with injection rates and downhole pressure measurements.
- The spatial distribution of events will be analyzed and compared to the pore-pressure inversions derived from InSAR surface deformation measurements.
- Improved accuracy of hypocenter estimation is expected due to the existence of numerous well-constrained seismic velocity measurements at the site including check-shots, VSP datasets, and sonic log data.
- Moment tensor analysis will be more challenging due to the relatively sparse array planned but will likely be possible for more energetic events
- The relative low cost of the planned surface MEQ stations allows flexibility to add stations if warranted by observed MEQ activity.

5.2 – InSAR data processing

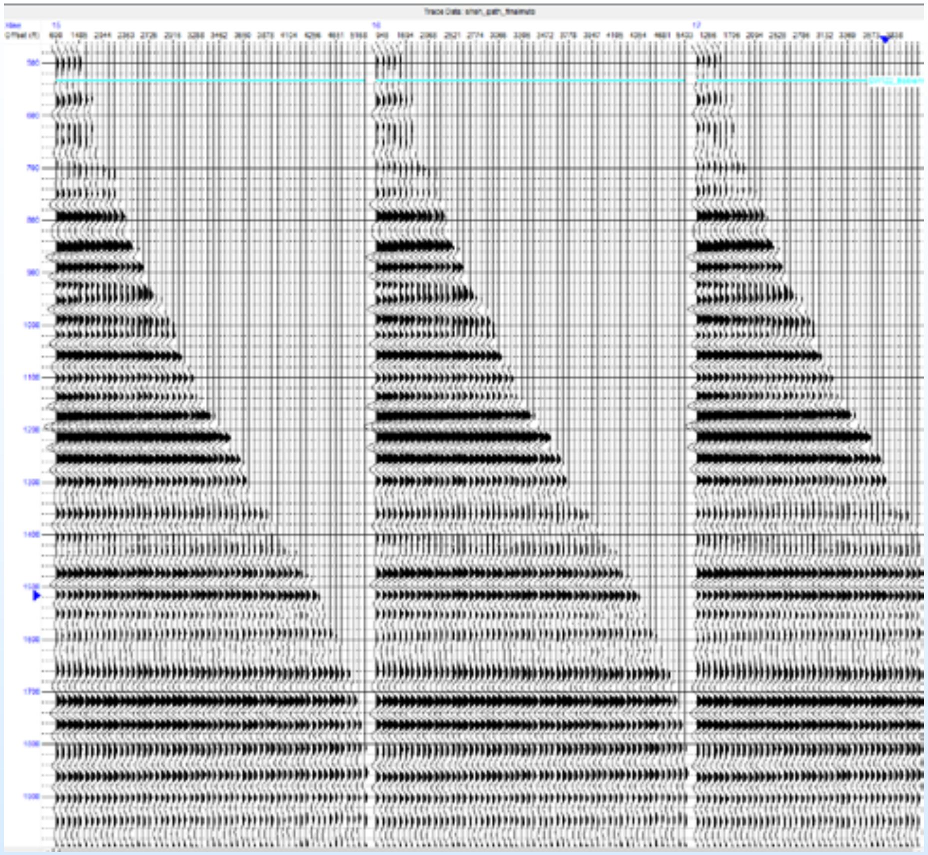
- Processed InSAR data will be acquired from (TRE).
- The magnitude of any observed surface deformation will be compared with predictions from a coupled geomechanical simulator.
- Special attention will be given to the temporal variations in the reservoir due to various production and injection activities.
- Deviations in the onset of deformation within the reservoir will be used to image heterogeneous flow within the reservoir.
- The displacement at the surface will be used to estimate strain at depth.
- The estimated strain will be mapped into stress changes within the overburden as a means of estimating stress changes above and within the reservoir.
- These estimates will be compared with the results of the TOUGH-FLAC geomechanical simulations.
- The correlation between the calculated stress changes and micro-seismicity will also be examined.

5.3 – Validation of InSAR inversion using 4D 9C seismic

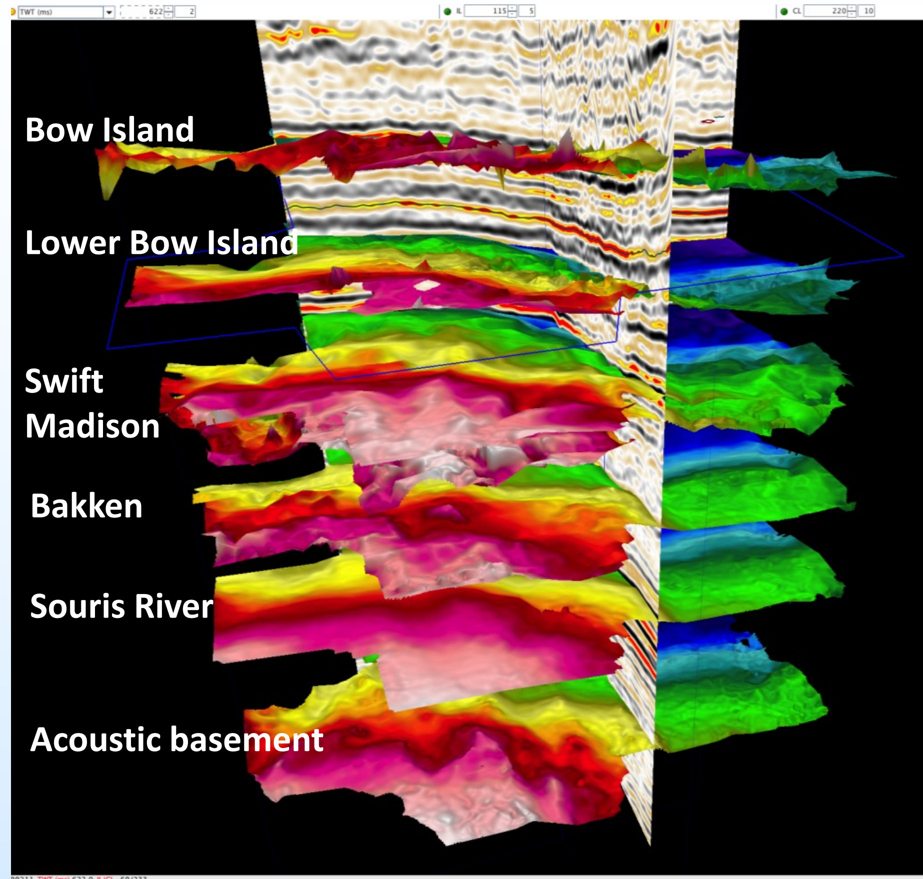
- The extensive BSCSP 4D 9C seismic dataset will be used to validate the inverted reservoir stress state changes derived from InSAR.
- Timelapse S-wave impedance inversion, derived from the S-S reflectivity volume, will be converted to an estimated change in pore-pressure using core calibration datasets.
- The use of S-S reflectivity should decrease the apparent effect of $scCO_2$ saturation in the near-injector region and provide an excellent comparison dataset for the InSAR-derived pore-pressure map.
- Both datasets will be compared to downhole pressure logs acquired at both the injector and monitor wells.
- If a dipole surface deformation response indicative of an open tensile fracture zone is detected, the 4D seismic dataset will be utilized to examine possible changes in anisotropy and/or scattering in the zone under consideration.
- This combination of 4D 9C seismic and timelapse InSAR will be a unique dataset for developing reservoir-scale pressure monitoring for GCS.

BSCSP 9-Component 3-D Seismic Available

Enhanced Utilization of Shear Waves



Shear wave shot gathers, BSCSP Kevin Dome



Structural surfaces from Shear Wave (SH) Seismic BSCSP Kevin Dome

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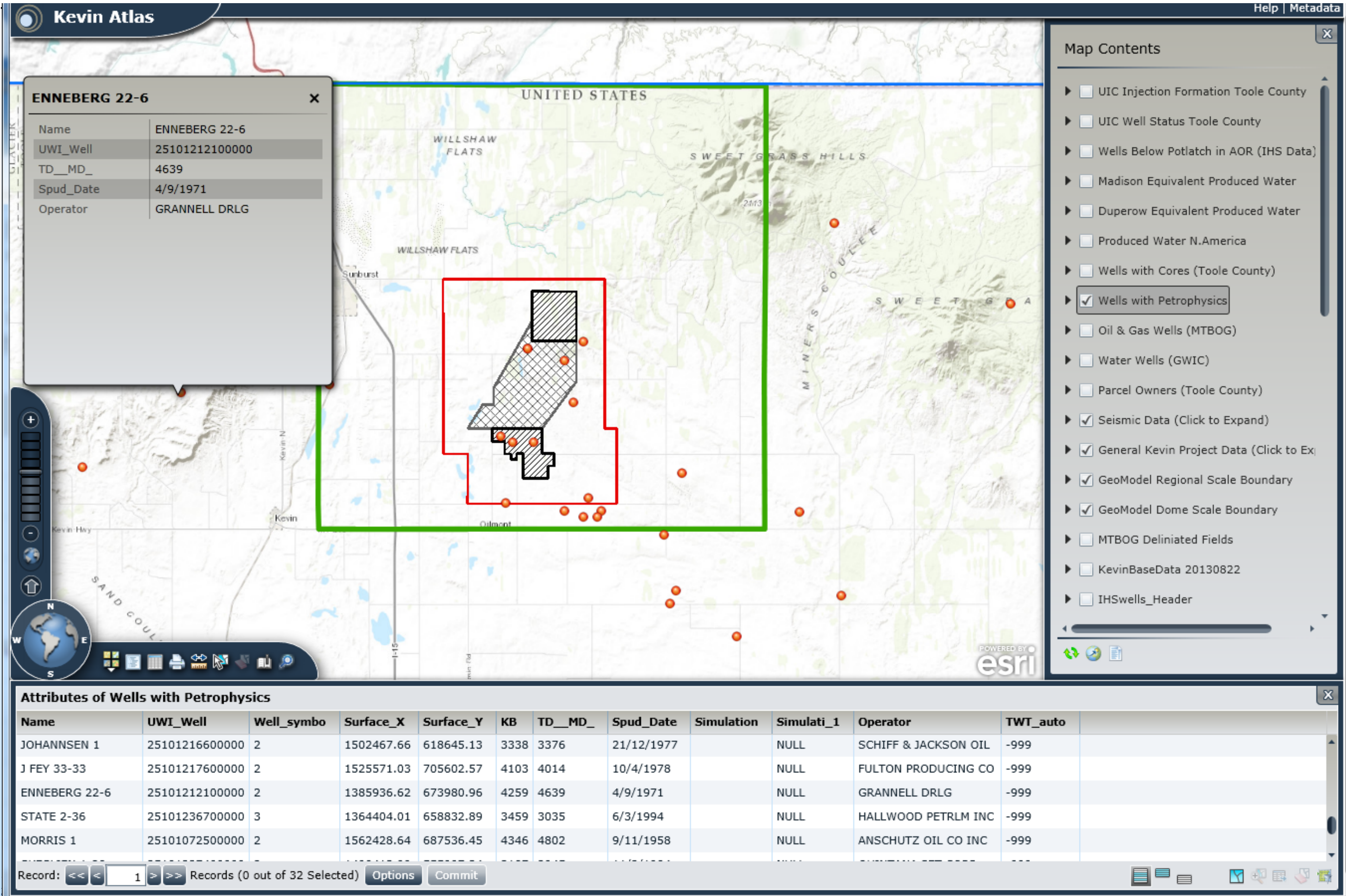
5.4 – Data Integration

- MSU's Data Management team will quality check data and make it available to project participants via the Kevin Atlas data sharing tools that are developed and maintained by BSCSP.
- Geomechanical data generated via this project will be integrated into the Kevin Atlas.
- All project data will be archived in a central repository at Montana State University's Research Computing Group facility. MSU will continue management, updates, and backups to the fileserver, webserver, and associated websites and databases to ensure a robust data management strategy throughout the life of the project.

Kevin Atlas


Kevin Atlas
Help | Metadata
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UWI_Well 25101212100000
TD__MD_ 4639
Spud_Date 4/9/1971
Operator GRANNELL DRLG
UNITED STATES
WILLSHAW FLATS
WILLSHAW FLATS
SWEET GRASS HILLS
Sunburst
Kevin
Oilmont
Kevin Hwy
Map Contents
UIC Injection Formation Toole County
UIC Well Status Toole County
Wells Below Potlatch in AOR (IHS Data)
Madison Equivalent Produced Water
Duperow Equivalent Produced Water
Produced Water N.America
Wells with Cores (Toole County)
Wells with Petrophysics
Oil & Gas Wells (MTBOG)
Water Wells (GWIC)
Parcel Owners (Toole County)
Seismic Data (Click to Expand)
General Kevin Project Data (Click to Ex
GeoModel Regional Scale Boundary
GeoModel Dome Scale Boundary
MTBOG Deliniated Fields
KevinBaseData 20130822
IHSwells_Header
Attributes of Wells with Petrophysics
Name | UWI_Well | Well_symbo | Surface_X | Surface_Y | KB | TD__MD_ | Spud_Date | Simulation | Simulati_1 | Operator | TWT_auto
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J FEY 33-33 | 25101217600000 | 2 | 1525571.03 | 705602.57 | 4103 | 4014 | 10/4/1978 | | NULL | FULTON PRODUCING CO | -999
ENNEBERG 22-6 | 25101212100000 | 2 | 1385936.62 | 673980.96 | 4259 | 4639 | 4/9/1971 | | NULL | GRANNELL DRLG | -999
STATE 2-36 | 25101236700000 | 3 | 1364404.01 | 658832.89 | 3459 | 3035 | 6/3/1994 | | NULL | HALLWOOD PETRLM INC | -999
MORRIS 1 | 25101072500000 | 2 | 1562428.64 | 687536.45 | 4346 | 4802 | 9/11/1958 | | NULL | ANSCHUTZ OIL CO INC | -999
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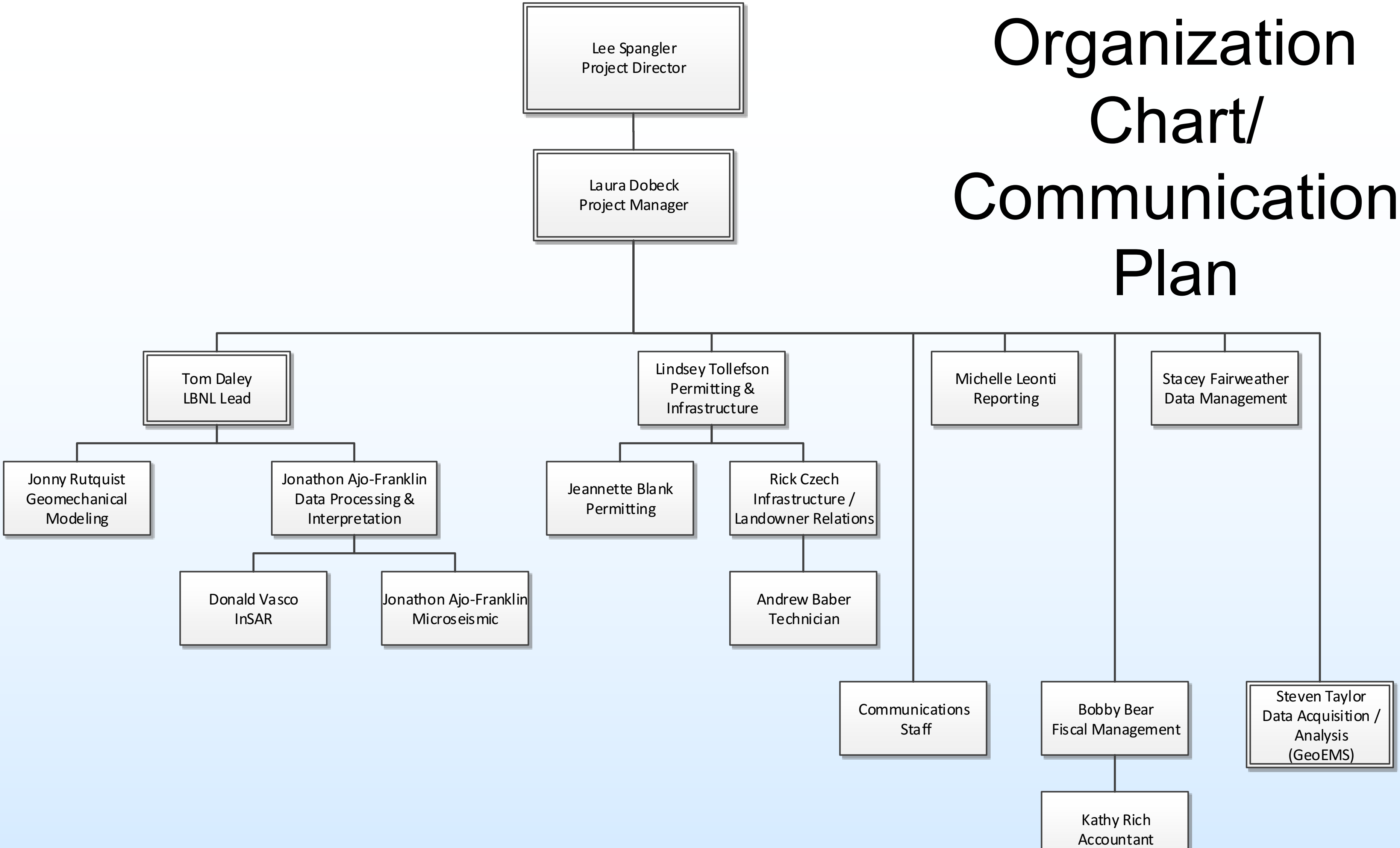
Appendix

- These slides will not be discussed during the presentation, but are mandatory

Organization Chart/ Communication Plan



- **Laura M. Dobeck – Project Management and Microseismic data acquisition**
- **Thomas M. Daley – Microseismic monitoring deployment, data analysis**
- **Jonny Rutqvist – Geomechanical Modeling**
- **Donald Vasco – InSAR data inversion and analysis**
- **Jonathan Ajo-Franklin – Microseismic monitoring deployment, data analysis**

Gantt Chart

Originally proposed chart below. Most activities are suspended until a reliable source of CO_2 for injection is identified.