A Large Volume Injection of CO_2 to Assess Commercial Scale Geological Sequestration in Saline Formations in the Big Sky Region

Project Number: DE-FC26-05NT42587

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Big Sky Carbon Sequestration Partnership

Montana State University

U.S. Department of Energy

National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Developing the Technologies and Building the Infrastructure for CO_2 Storage

August 21-23, 2012

Presentation Outline

- Goals and Objectives
- Project overview
- Kevin Dome characteristics
- Project design philosophy
- Infrastructure
- Modeling
- Monitoring
- Project Opportunities

Benefit to the Program

Program goals being addressed.

- Develop technologies that will support industries' ability to predict CO_2 storage capacity in geologic formations to within ±30 percent.
- Develop technologies to demonstrate that 99 percent of injected CO_2 remains in the injection zones.
- Conduct field tests through 2030 to support the development of BPMs for site selection, characterization, site operations, and closure practices.

Project benefits statement.

BSCSP supports Storage Program goals by 1) Testing storage capacity at a site including study of a natural analog and comparing actual storage to estimates. 2) Applying and refining computational tools to assess storage and subsurface CO_2 behavior 3) Applying RST logging, geochmical monitoring, and 4D, 9C seismic to CO_2 detection 4) Performic reservoir and cap rock analysis 5) Conducting a large scale field test and contributing learnings to best practices manuals.

Project Overview:
Goals and Objectives

The primary objective of the large volume sequestration test is to demonstrate that the target formation and other analogous formations are a viable and safe target for sequestration of a large fraction of the region's CO_2 emissions. Other objectives include improving the understanding of injectivity, capacity, and storativity in a regionally significant formation. The primary operational objectives are to safely procure, transport, inject and monitor up to one million tons of CO_2 into the target formation. Other operational objectives include understanding the behavior of the injected CO_2 within the formation, verifying and improving predictive models of CO_2 behavior and monitoring, verification and accounting (MVA) methodology. The objective of the post-injection phase is to assess any resultant changes from the CO_2 injection and to continue to monitor the CO_2

Task 1.0 – Regional Characterization

Success will be demonstrated by the addition of data to the BSCSP Partnership databases that are critical to the implementation of large-scale carbon, capture, and storage (CCS) activities throughout the region.

Task 2.0 – Public Outreach

Success will be demonstrated by frequent engagement of multiple stakeholder groups.

Task 3.0 – Permitting and NEPA Compliance

Success will be demonstrated by acquisition of all required permits

Task 4.0 – Site Characterization and Modeling

Success will be demonstrated by completion of risk assessment, acquisition, processing and interpretation of 3D, 9C Siesmic, acquisition and analysis of well logs and cores, development of a static geologic model and initial flow modeling.

Task 5.0 – Well Drilling and Completion

Success will be demonstrated by drilling and completion of wells

Task 6.0 – Infrastructure Development

Success will be demonstrated by installation of the pipeline, compression station, well shacks, monitoring equipment, and remaining infrastructure

Project Overview: Goals and Objectives

Task 6.0 – Infrastructure Development

Success will be demonstrated by installation of the pipeline, compression station, well shacks, monitoring equipment, and remaining infrastructure

Task 7.0 – CO_2 Procurement

Success will be demonstrated by demonstrating adequate production of CO_2 from the production wells

Task 8.0 – Transportation and Injection Operations

Success will be demonstrated by establishment of appropriate flow rates, injection pressure, and flow continuity from the production well, compressor, pipeline, injection well system.

Task 9.0 – Operational Monitoring and Modeling

Success will be demonstrated by ability to directly or indirectly detect subsurface CO_2 via RST logging, geochemical analysis of formation fluids, and seismic. Additionally, success will be demonstrated by deployment and successful operation of assurance monitoring techniques.

Task 10.0 – Site Closure

Success will be demonstrated by transfer of the well to private sector partner and completion of site closure activities.

Task 11.0 – Post Injection Monitoring and Modeling

Success will be demonstrated by the same criteria of Task 9

Task 12.0 – Project Assessment

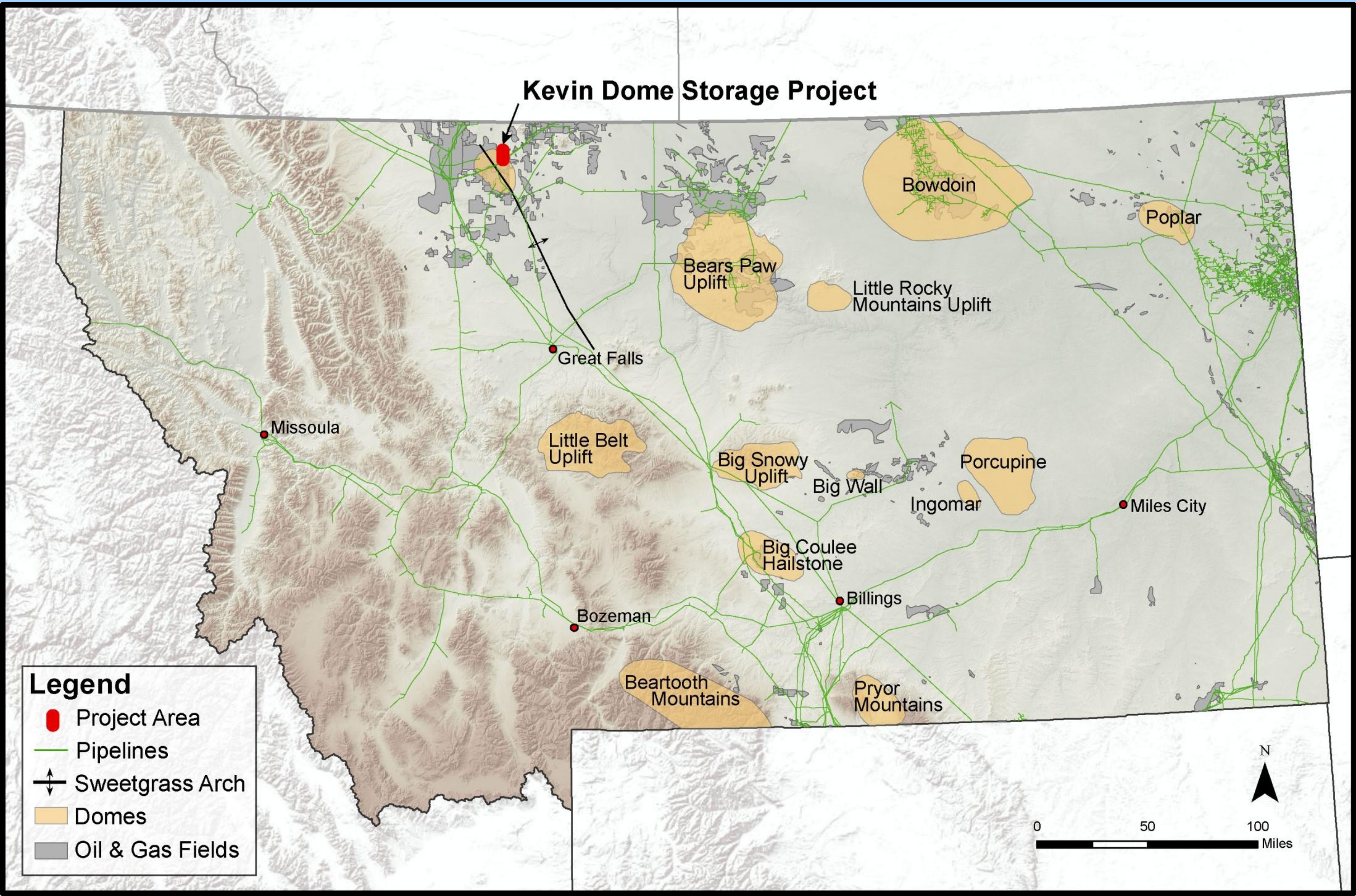
Success will be demonstrated by completion and submittal of quality annual assessment reports

Task 13.0 – Project Management

Success will be demonstrated by coordination of project activities, ability to adjust to new issues, completion of tasks, milestones, and deliverables

Technical Status

Kevin Dome Storage Project



Partners

- Infrastructure development
- Multi-component seismic
- Geophysical measurements
- Modeling
- Geochemical monitoring
- Assurance monitoring
- Safety assurance

Universities	Private Companies	National Laboratories
Montana State University	Vecta Oil and Gas	Los Alamos National Laboratory
Oregon State University	Altamont	Lawrence Berkeley National Laboratory
Washington State University	Schlumberger Carbon Services	Idaho National Laboratory
Columbia University		
Barnard College		

Large Scale Test - Pragmatic Issues

- **<u>Reasonably large quantity source of CO2</u>**
  - No pure anthropogenic sources
  - Capture facility costs do not fit budget
  - Commercial CO2 used for EOR - $35- $40 per Tonne – not affordable unless doing EOR
  - Need pre-commercial source that is inexpensive to develop
- A good quality storage reservoir
- Good quality seals
- All in close proximity

Kevin Dome Project

- Kevin Dome is a naturally occurring CO_2 reservoir in north central Montana (estimated 600,000 tonnes CO_2)
- BSCSP is proposing to produce 1 million tonnes of CO_2 from the dome and then inject it into the Duperow Formation.
- After a post-injection monitoring period, Vecta plans to re-produce the injected $CO_2$for EOR tests

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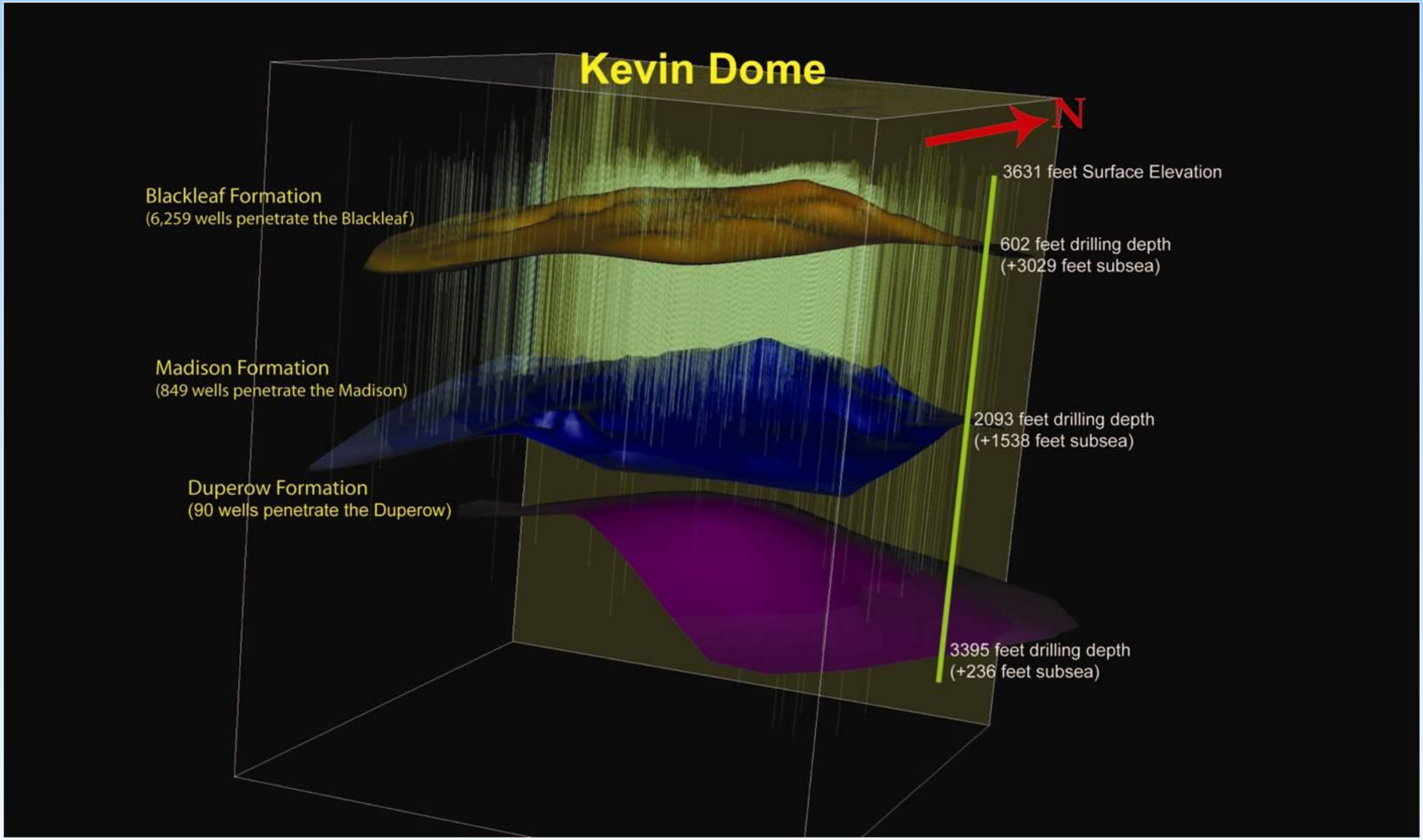
Kevin Structure Tops & Well Penetrations



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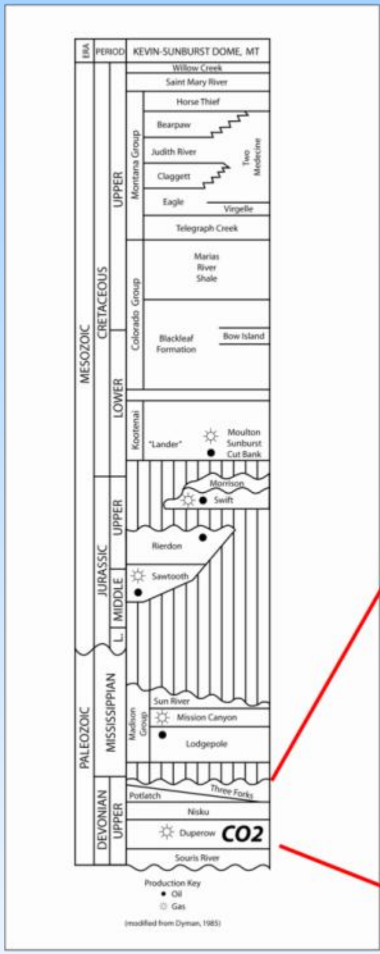
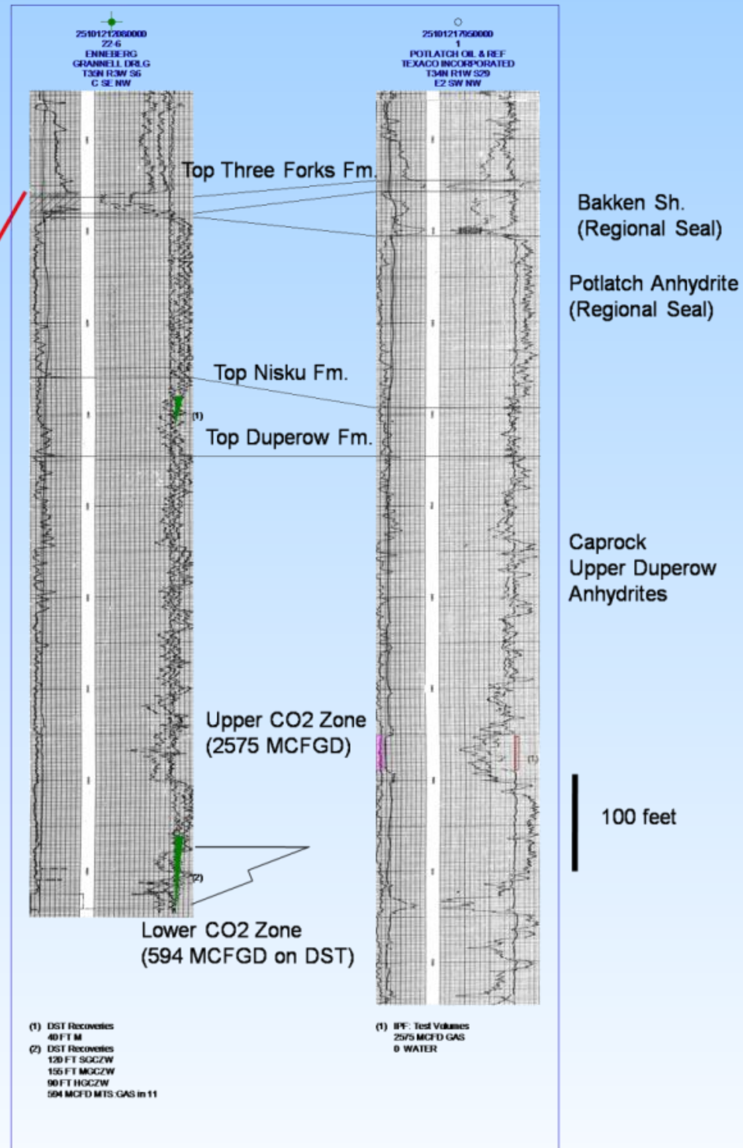
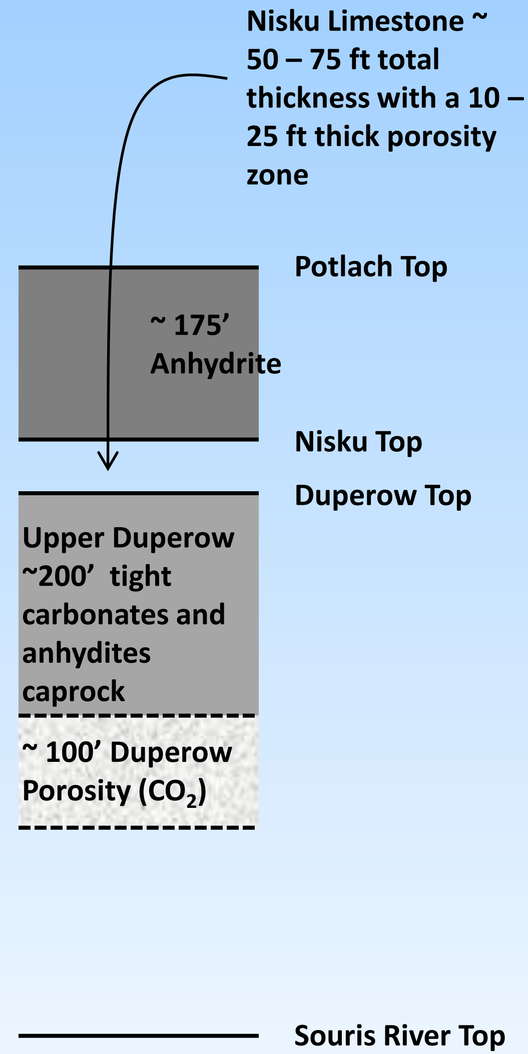
Stratigraphy







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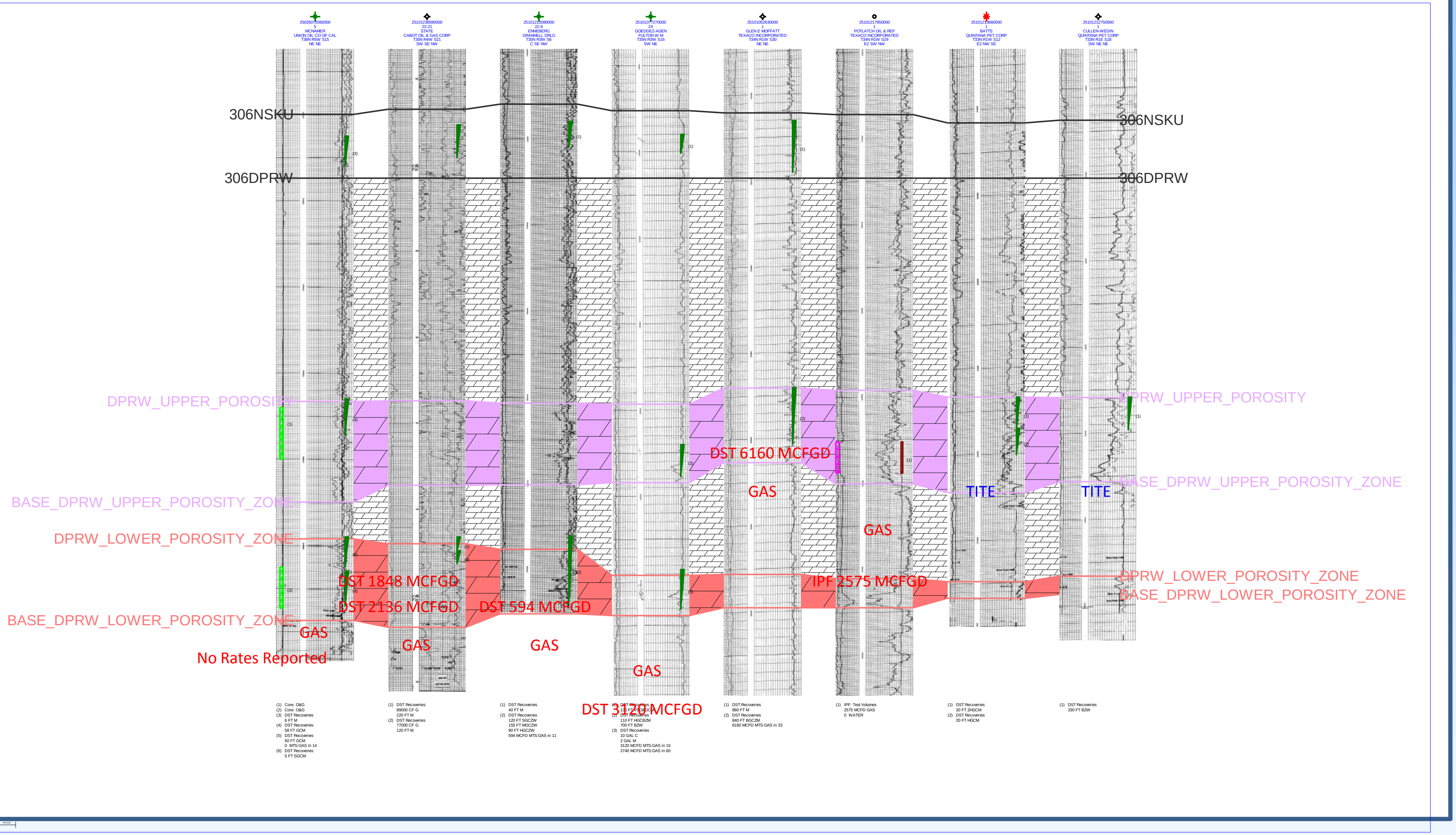
NW - SE Cross Section Kevin Dome



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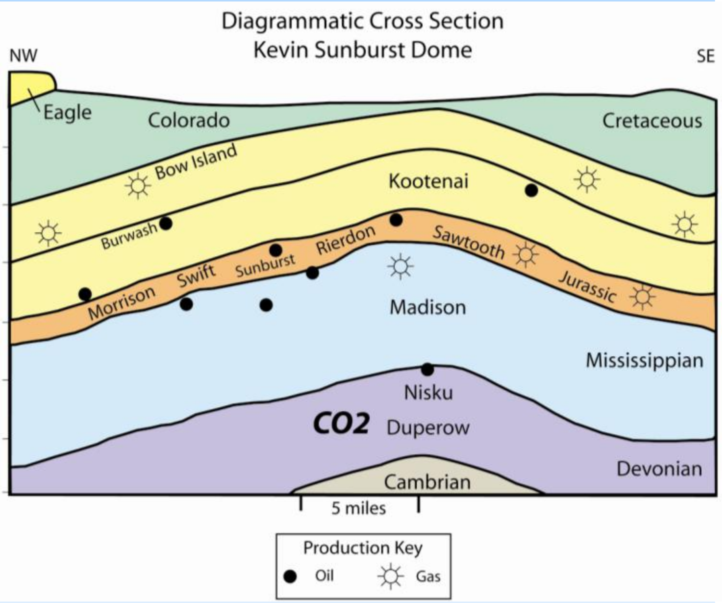
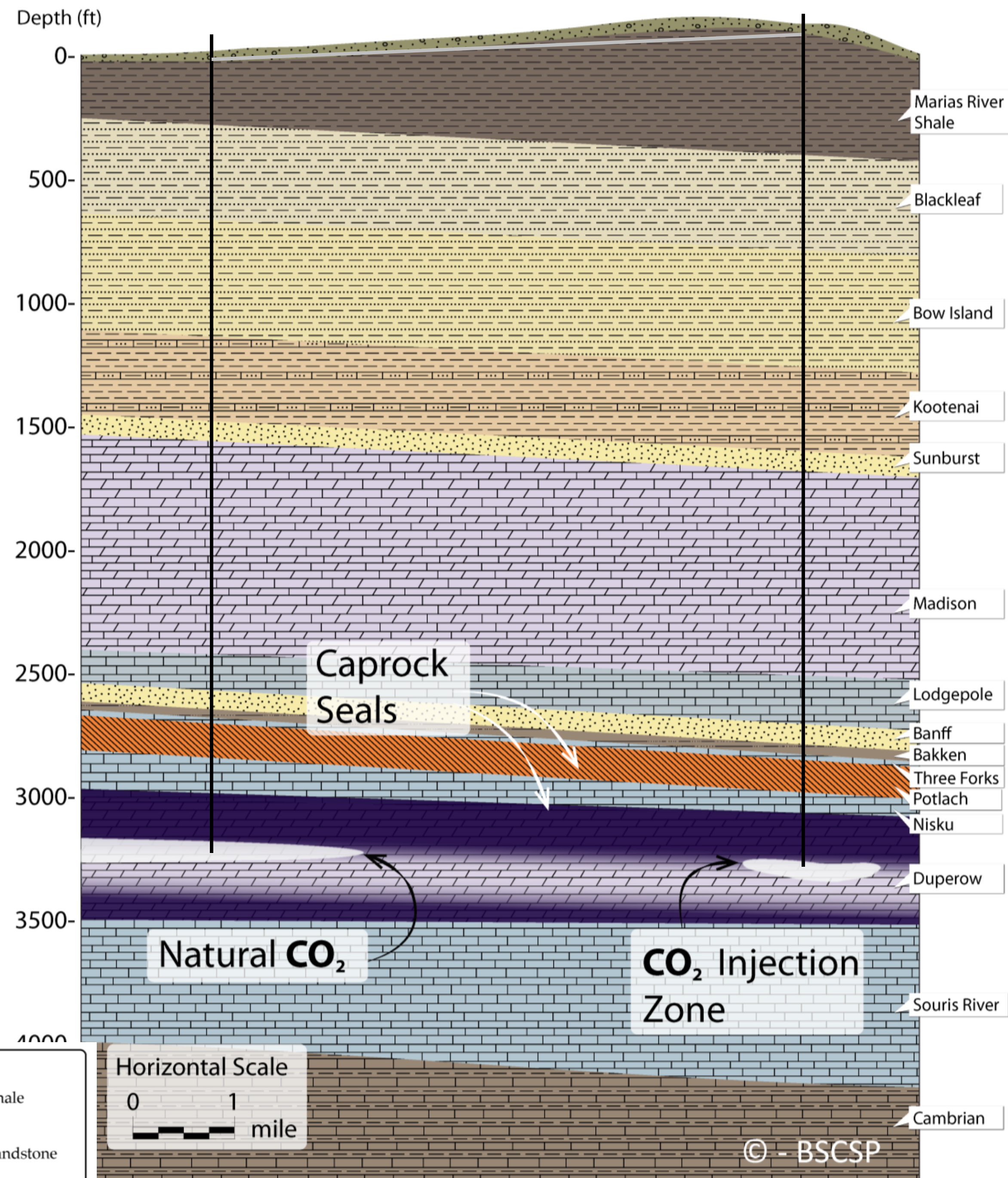
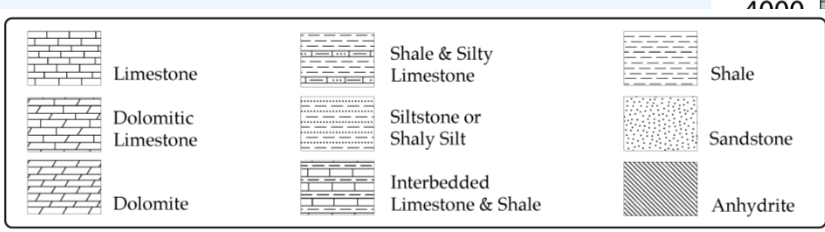
Kevin Dome

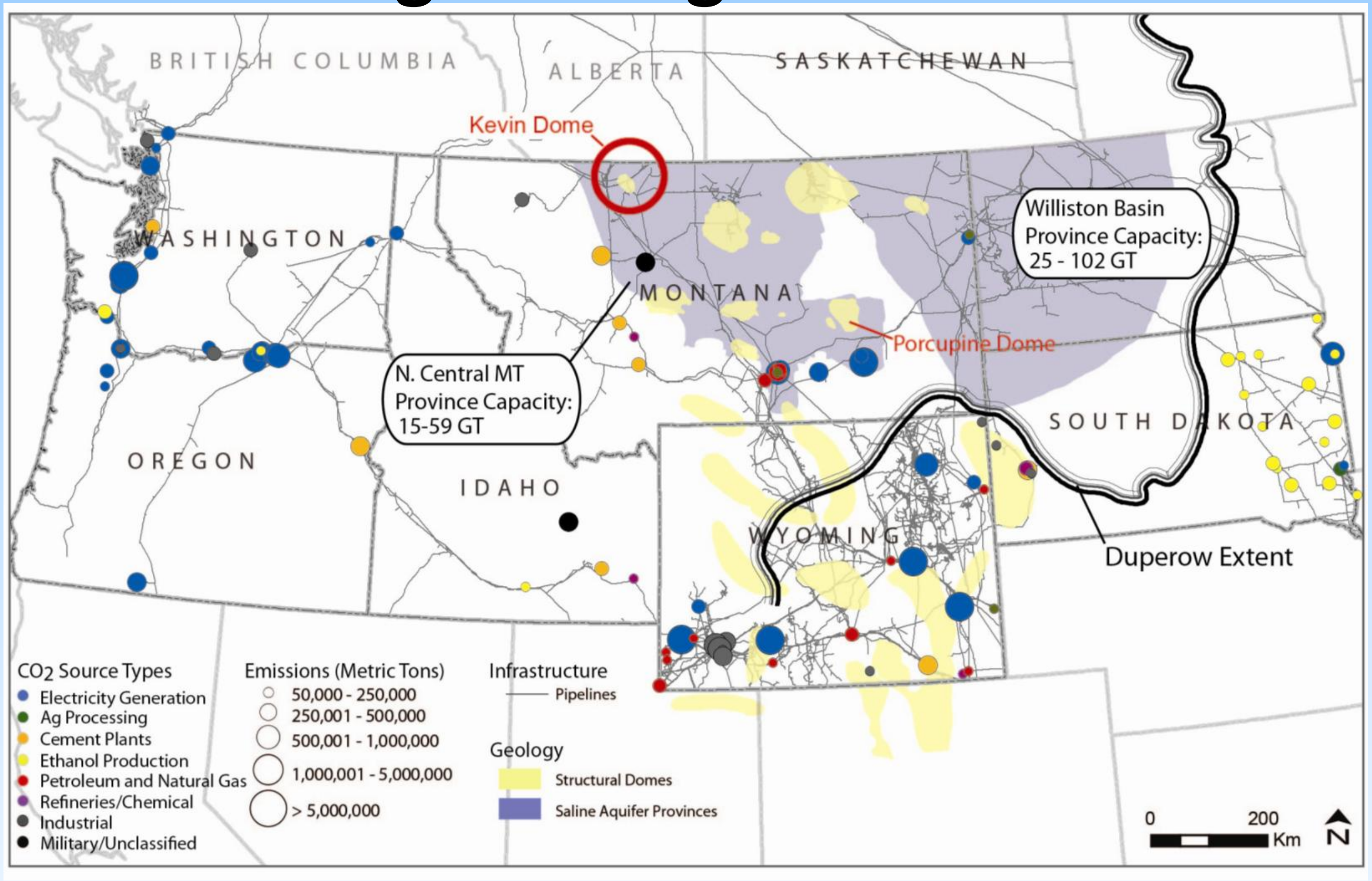






isclaimer: This graphic is a generalized representation of the subsurface at Kevin Dome. The horizontal and ertical scale are independent of one another to fit view on a single page. Surface infrastructure not to scale.

Regional Significance



- **The Duperow has large potential capacity in central Montana and the Williston Basin**
- **Large structural closures, and in particular, domes, represent an attractive early sequestration target in the Big Sky region.**

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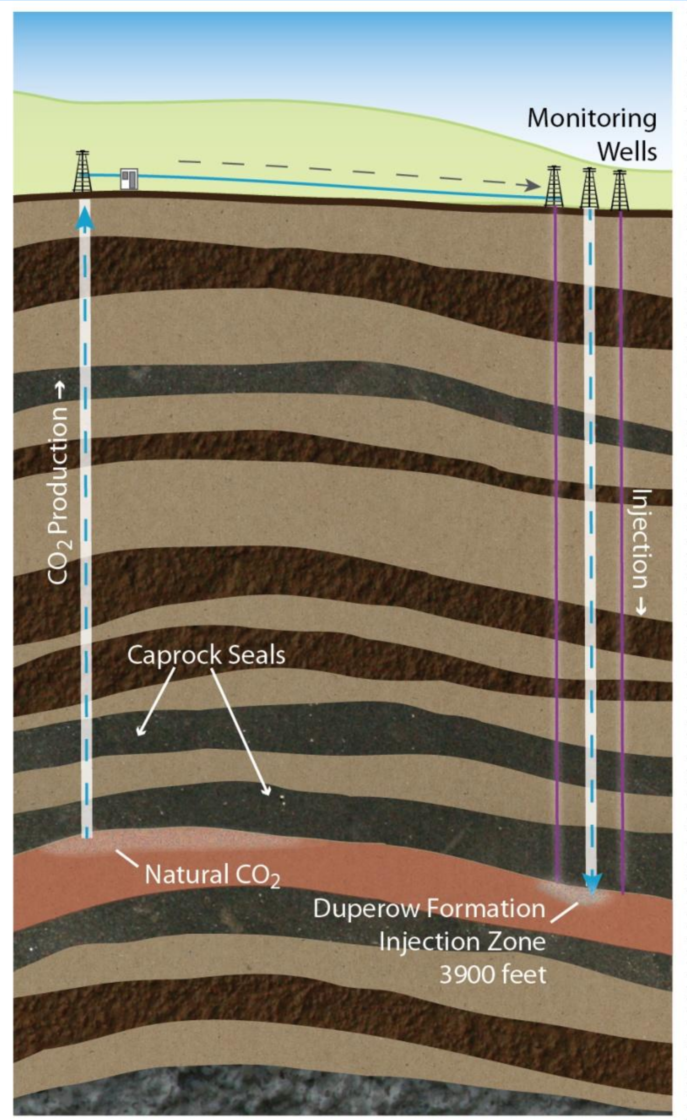
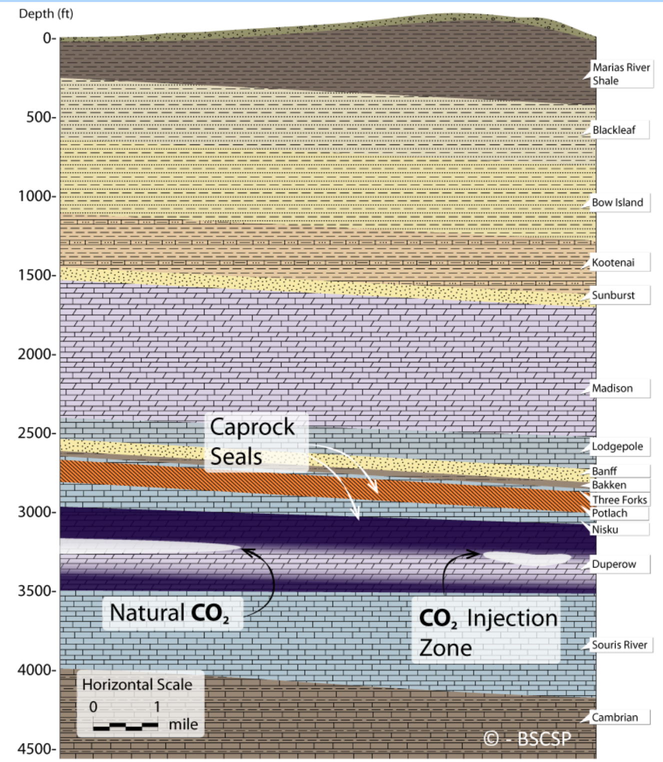
Project Design Philosophy



- Drill into natural accumulation, Product it, Pipe CO2 laterally, re-inject it
- Decisions on how to do this affects the amount of science that results from the project
- We can leverage
  - Site Properties and Characteristics,
  - Team Capabilities and Expertise,
  - Existing Collaborations
- We considered what research issues can be addressed by this project while still meeting DOE program requirements (these are well aligned anyway)
- Not many large scale demonstration projects are pursued world wide – we should do everything we can to maximize what we learn from them and share knowledge and opportunities

Site Properties and Characteristics

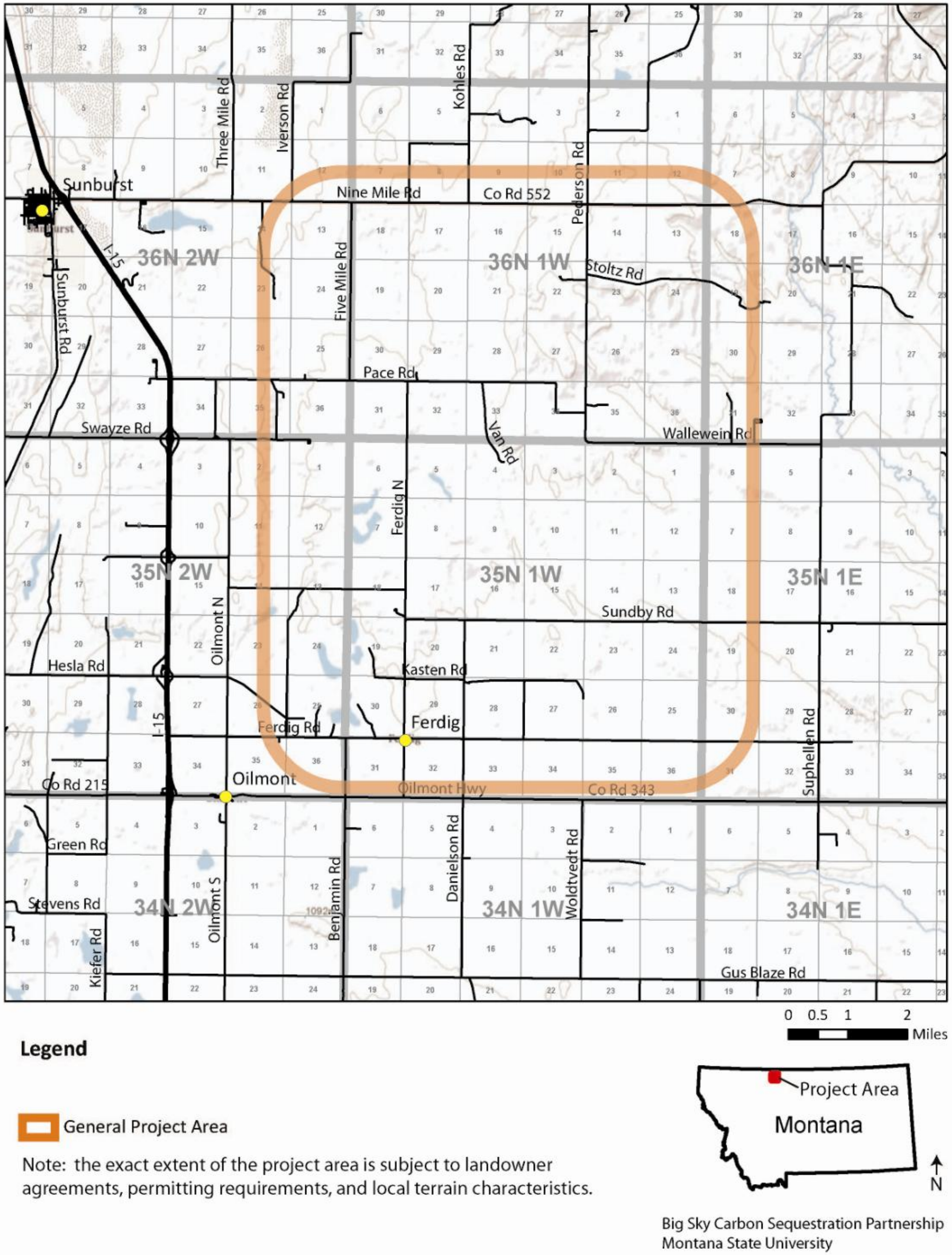


Disclaimer: This graphic is a generalized representation of the subsurface at Kevin Dome. The horizontal and vertical scale are independent of one another to fit view on a single page. Surface infrastructure not to scale.

- We must drill our own producing wells
  - Opportunity to study the natural accumulation
  - Opportunity to study long term effects
  - Turns CO_2 procurement cost into scientific opportunity
- CO_2 is in a reactive rock
  - Opportunity to study geochemical effects on both reservoir rock (long term fate of CO_2) and caprock (storage security)
  - To accomplish this, injection should be in water leg of the same formation
  - Still retain engineered system learnings on injection, transport, capacity, etc.
- Wells are shallow and relatively inexpensive
  - Potential to have more monitoring wells
  - Can afford cores, logs (rig costs lower)
- Duperow has two porosity zones
  - Opportunity to perform stacked storage or detection limit test depending on the fluid fill in second porosity zone

Team Capabilities and Expertise

- Strong Geophysical Partners (Vecta, SR2020, Schlumberger
  - Sophisticated logging, downhole measurements
  - Multi-component seismic
  - Main cost share partners so every DOE dollar spent on geophysics returns $1.25 - $2.00
  - Coupled with cheaper monitoring wells
- Excellent core flood & flow facilities
  - Parallel studies for geochemical rates, induced permeability changes, etc.
  - Data to inform coupled model efforts
- Strong Geochemical partners
  - Natural and introduced tracers
  - U-tube technology, monitoring wells
- Strong Modeling team
  - Comprehensive suite of codes
- Development of near surface monitoring
  - Opportunity to learn about deployment



General Location

- East of I-15
- South of Nine Mile Road
- North of Oilmont Road

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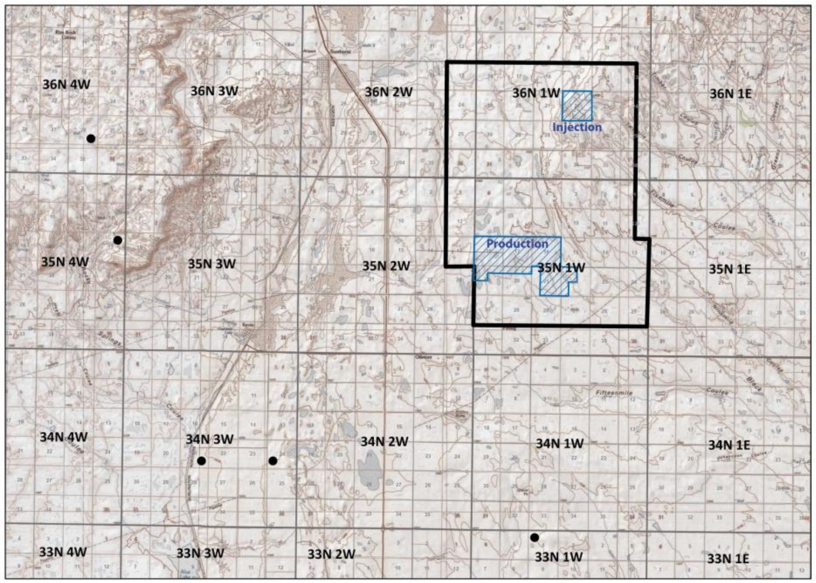
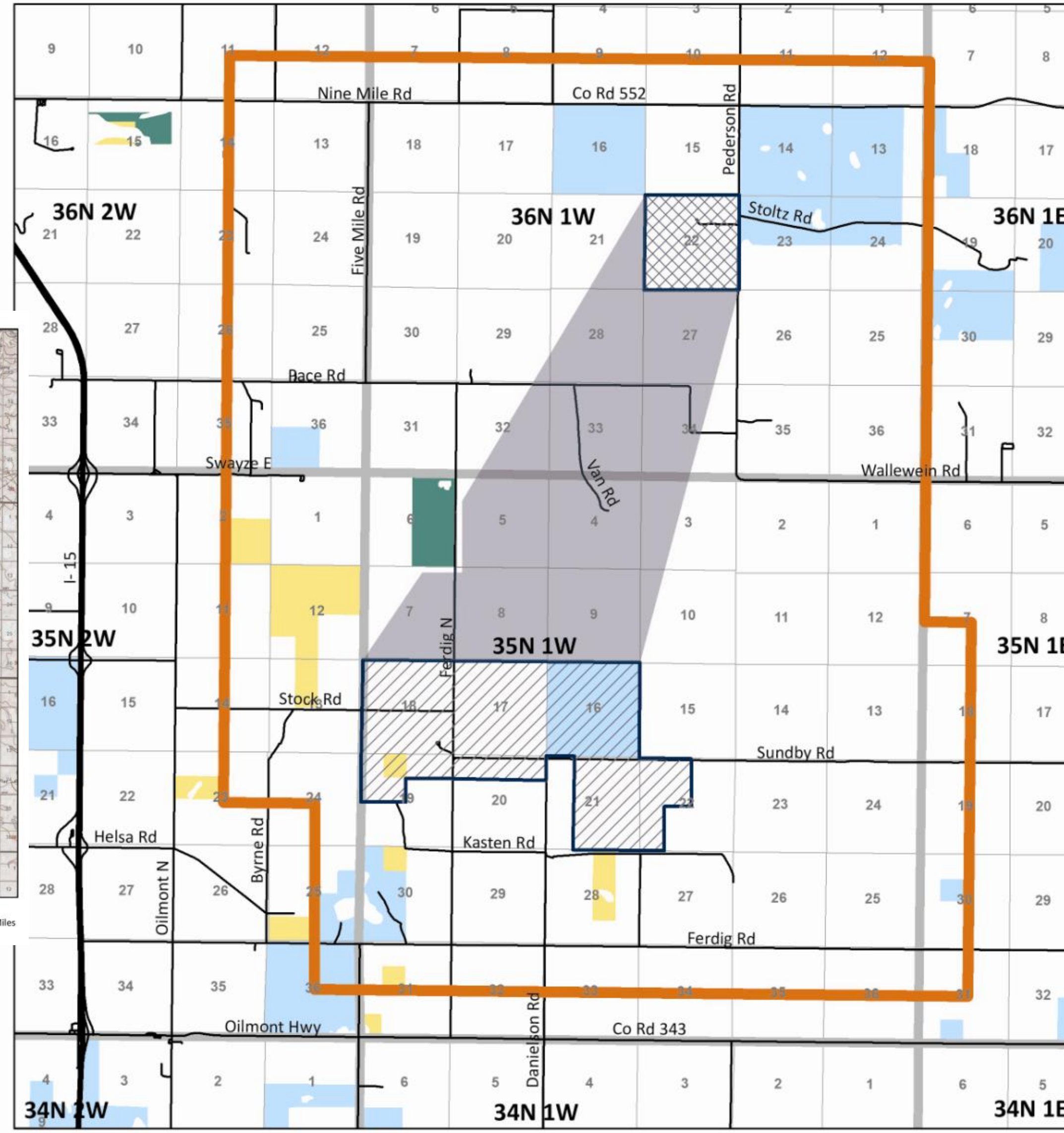
Seismic Area, Production and Injection Zones



Big Sky Carbon Sequestration Partnership
Sept. 28, 2011



Legend

Infrastructure

- Injection Area
- Production Area (including the gathering system and compressor station)
- Pipeline Area
- Seismic Survey Area

Land Ownership

- B.L.M.
- Bureau of Indian Affairs
- State of Montana
- U.S. Fish and Wildlife Service
- Private Land

0 0.5 1 2
Miles

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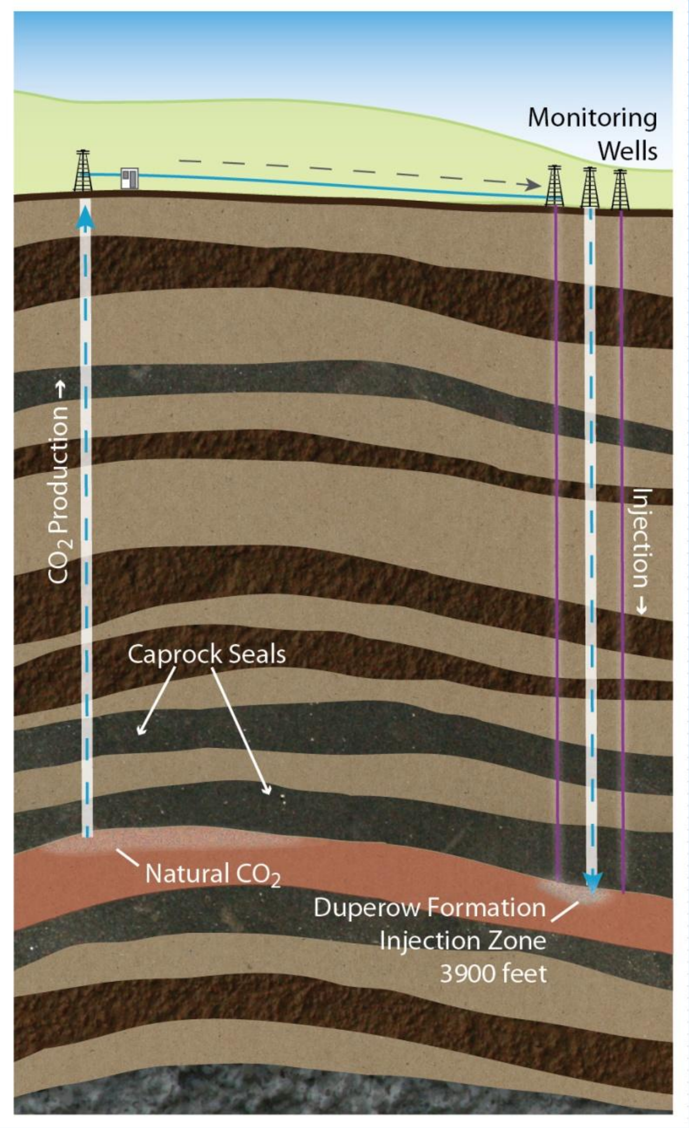
Project Overview

- Permitting & Public Outreach
- Site Characterization
- Infrastructure Development
  - 5 Production Wells,
  - 1 Injection Well,
  - 4 Monitoring Wells, Pipelines Compressor
- Injection Operations – 4 years
- Monitoring & Modeling
- Site Closure



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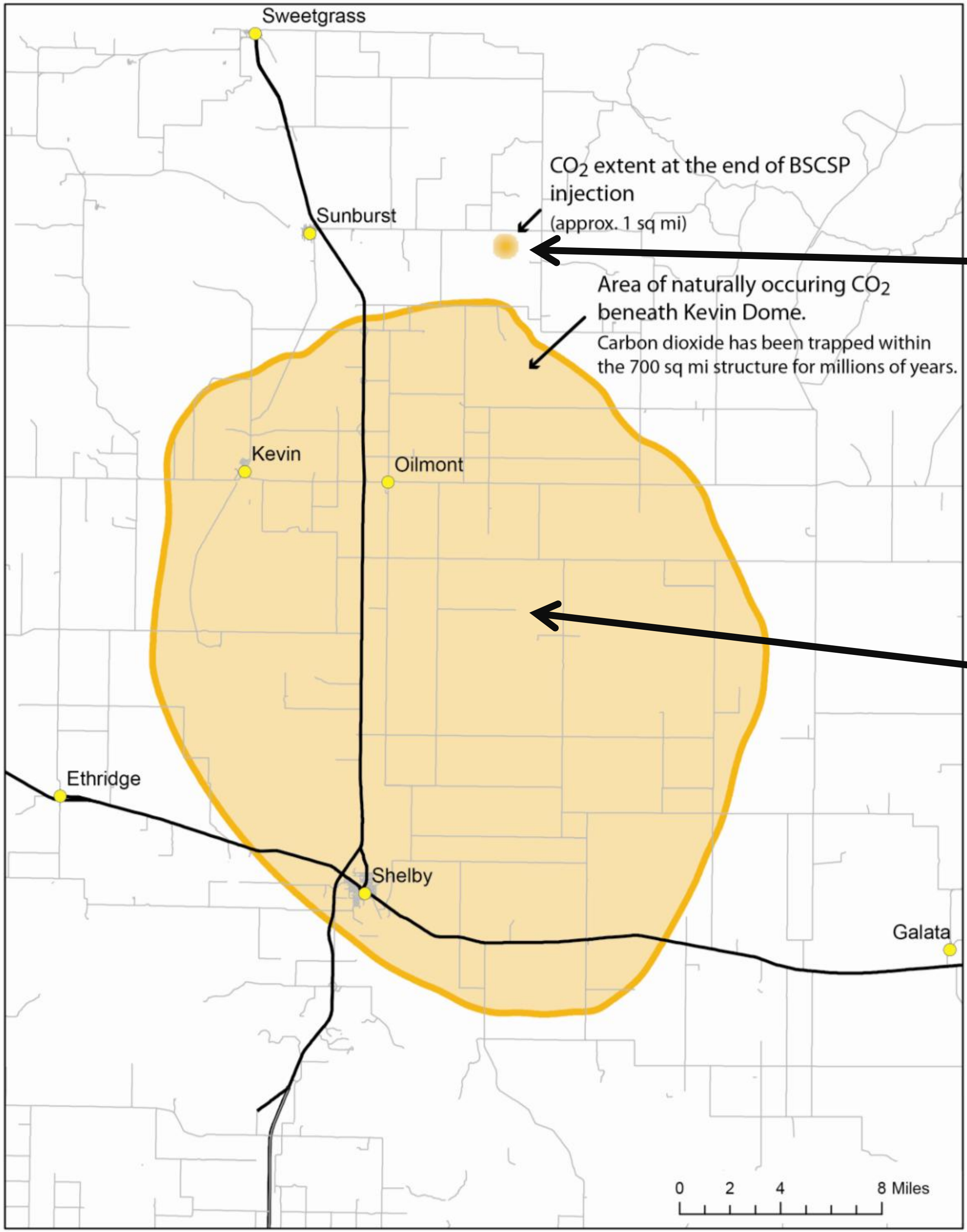
Kevin Dome CO2



Estimated Area of Big Sky Storage Test (Approx. 1 sq. mi.)

Estimated Area of <u>Natural</u> CO_2 Already in Kevin Dome (Approx. 500 sq. mi.)

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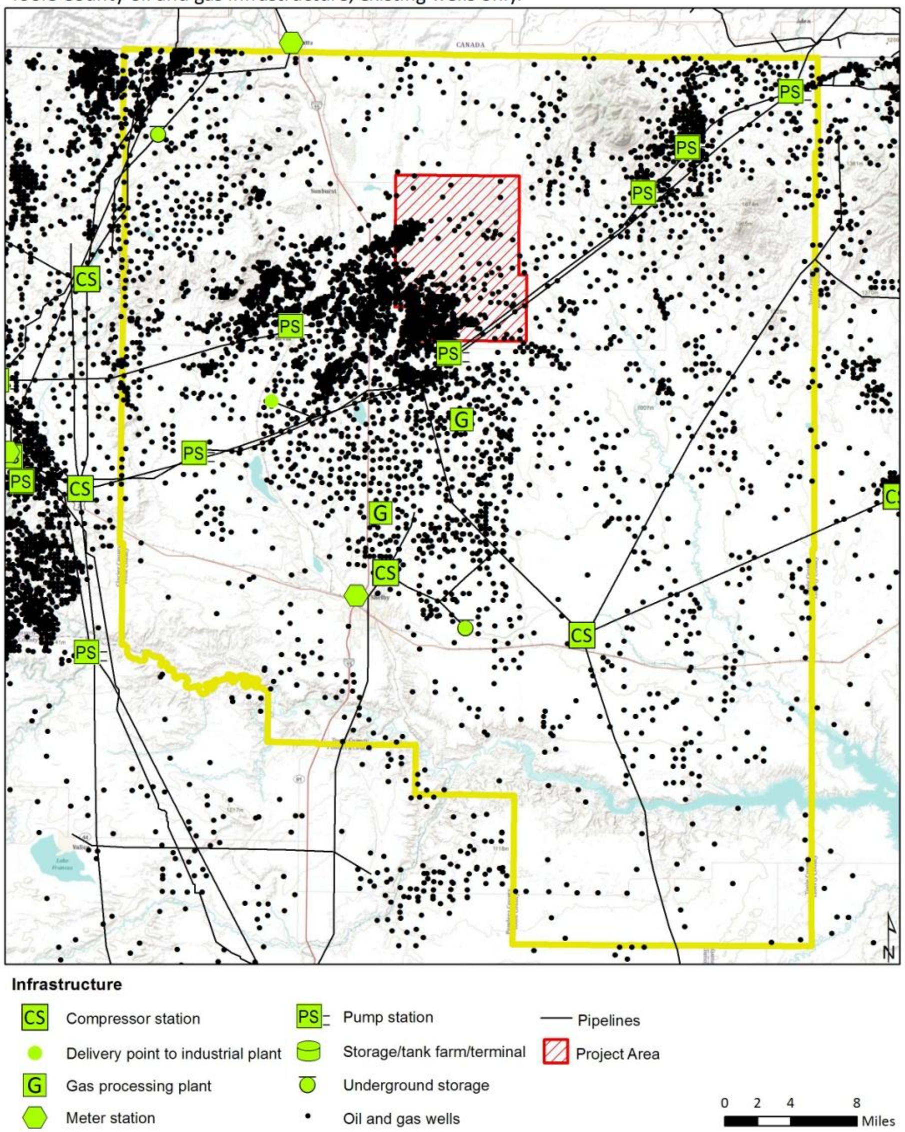
Wells

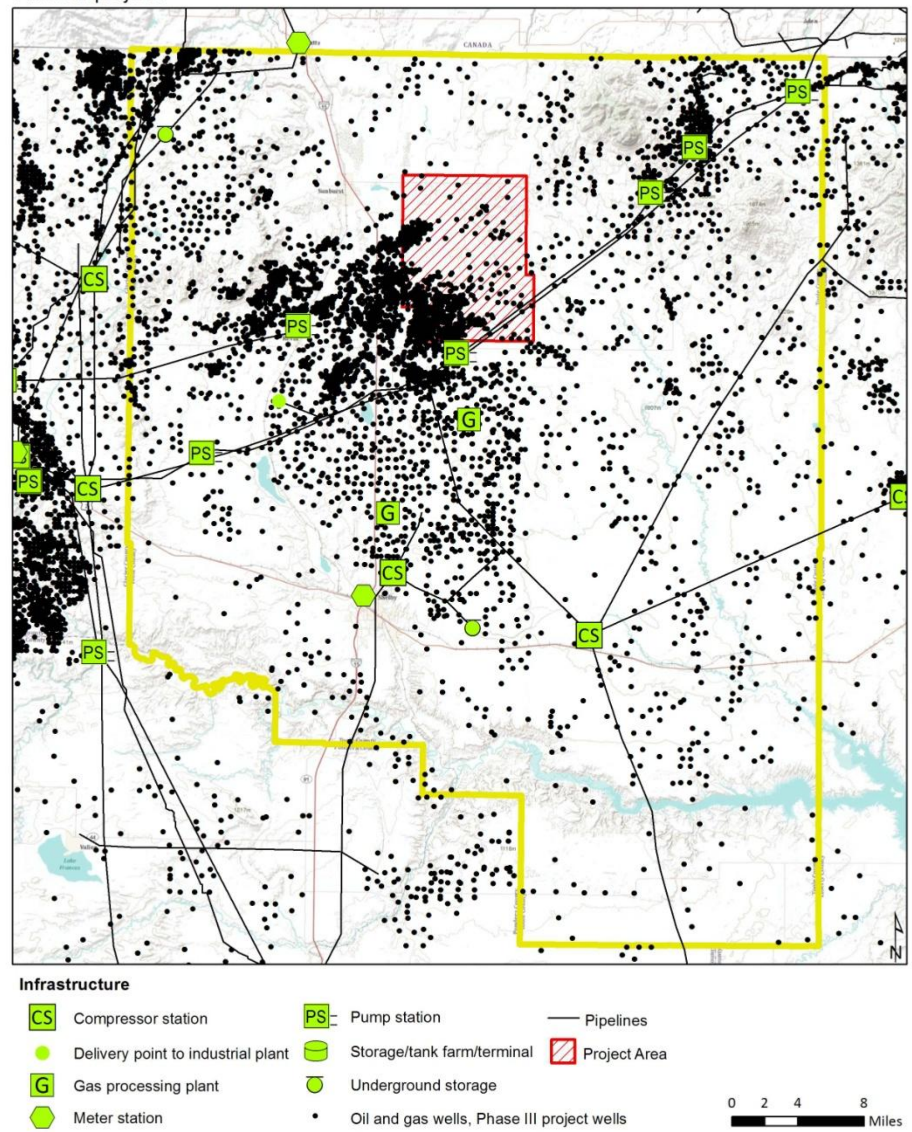
Existing Infrastructure

Toole County oil and gas infrastructure, existing wells only.



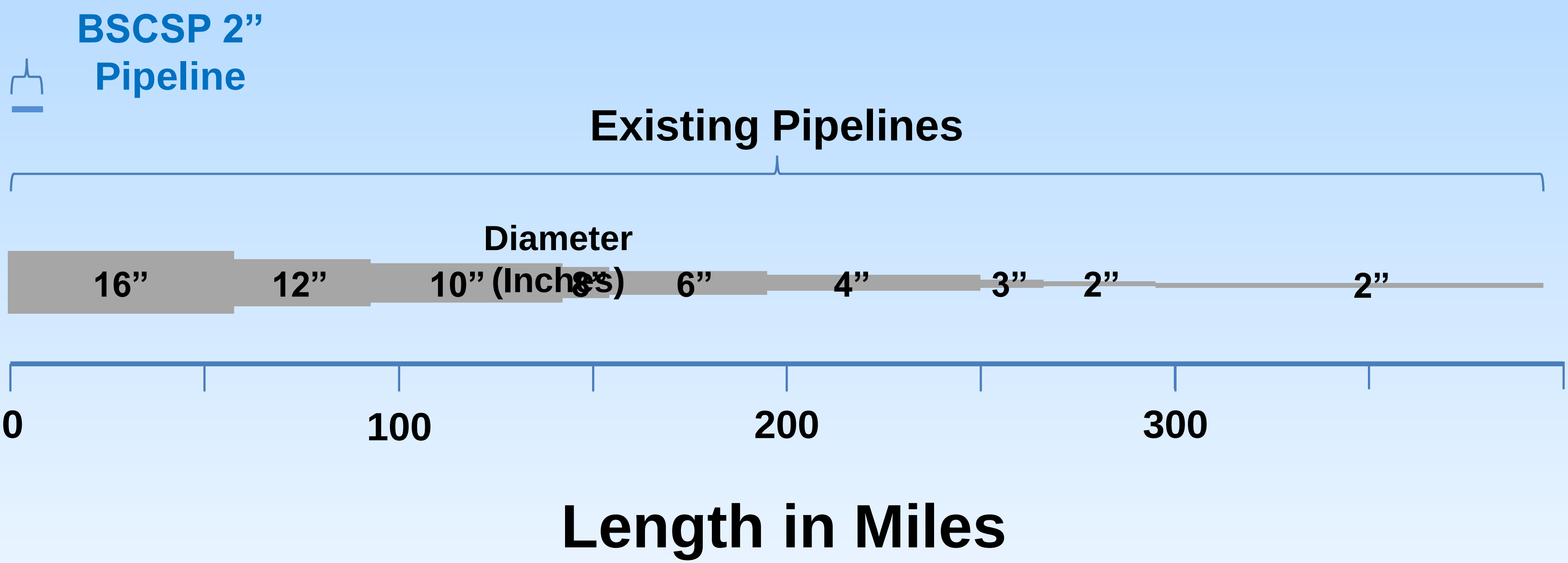
Big Sky Infrastructure Added

Toole County oil and gas infrastructure, existing and including the 10 wells planned for the BSCSP Phase III project.



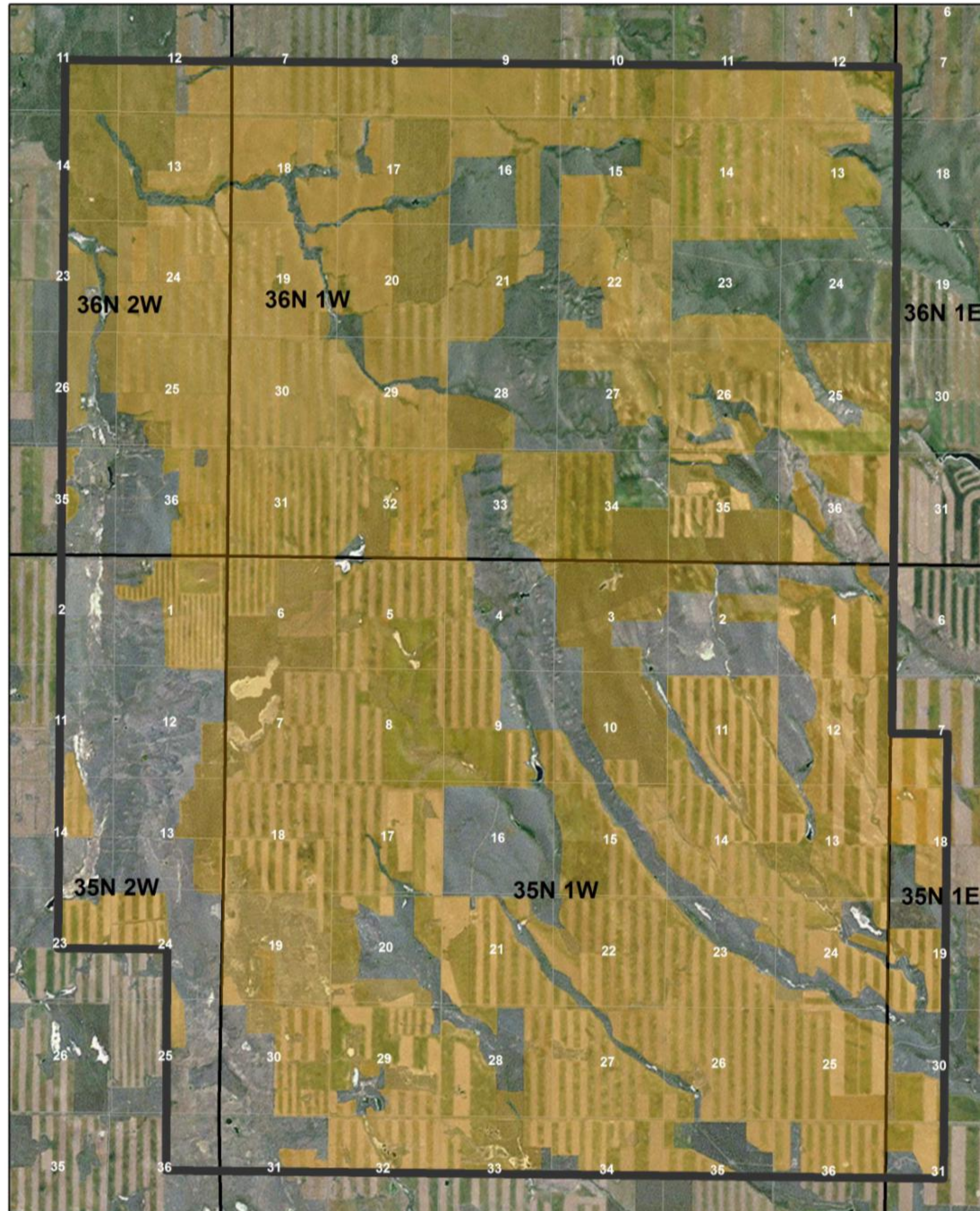
Miles of Pipeline in Toole County

Source: PennWell Database + Local Company Website



Population Centers

Archeology



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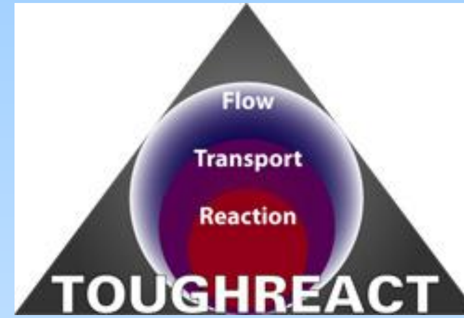
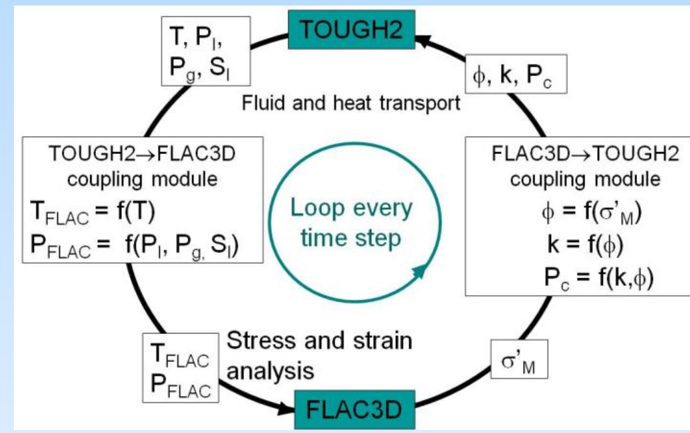
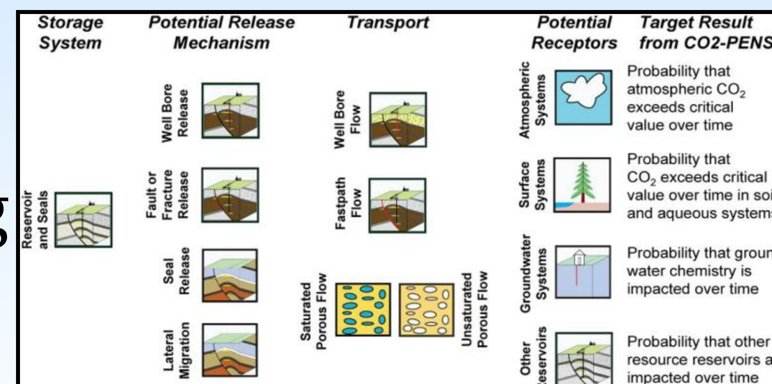
Modeling

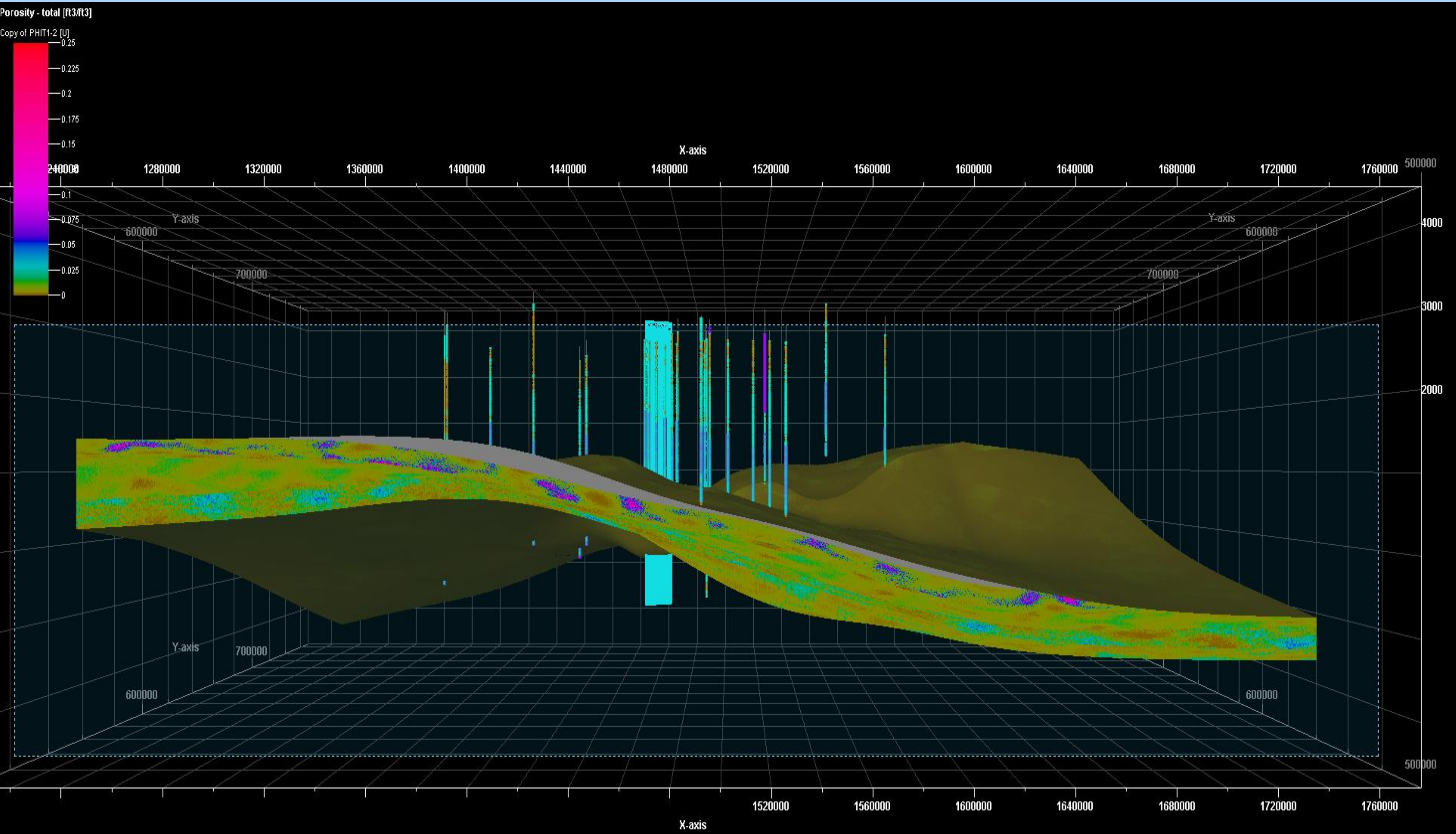
- Geostatic Model (Petrel)
- Multiphase Flow and Reactive Transport Modeling (Eclipse, TOUGH2 and TOUGHREACT)
- Modeling of Geomechanics and Caprock Sealing Performance (TOUGH-FLAC)
- Coupled Reactive Transport - Geomechanical Modeling (TOUGHREACT-FLAC)
- Geochemical Modeling
- Risk Management and Modeling (CO2-PENS)



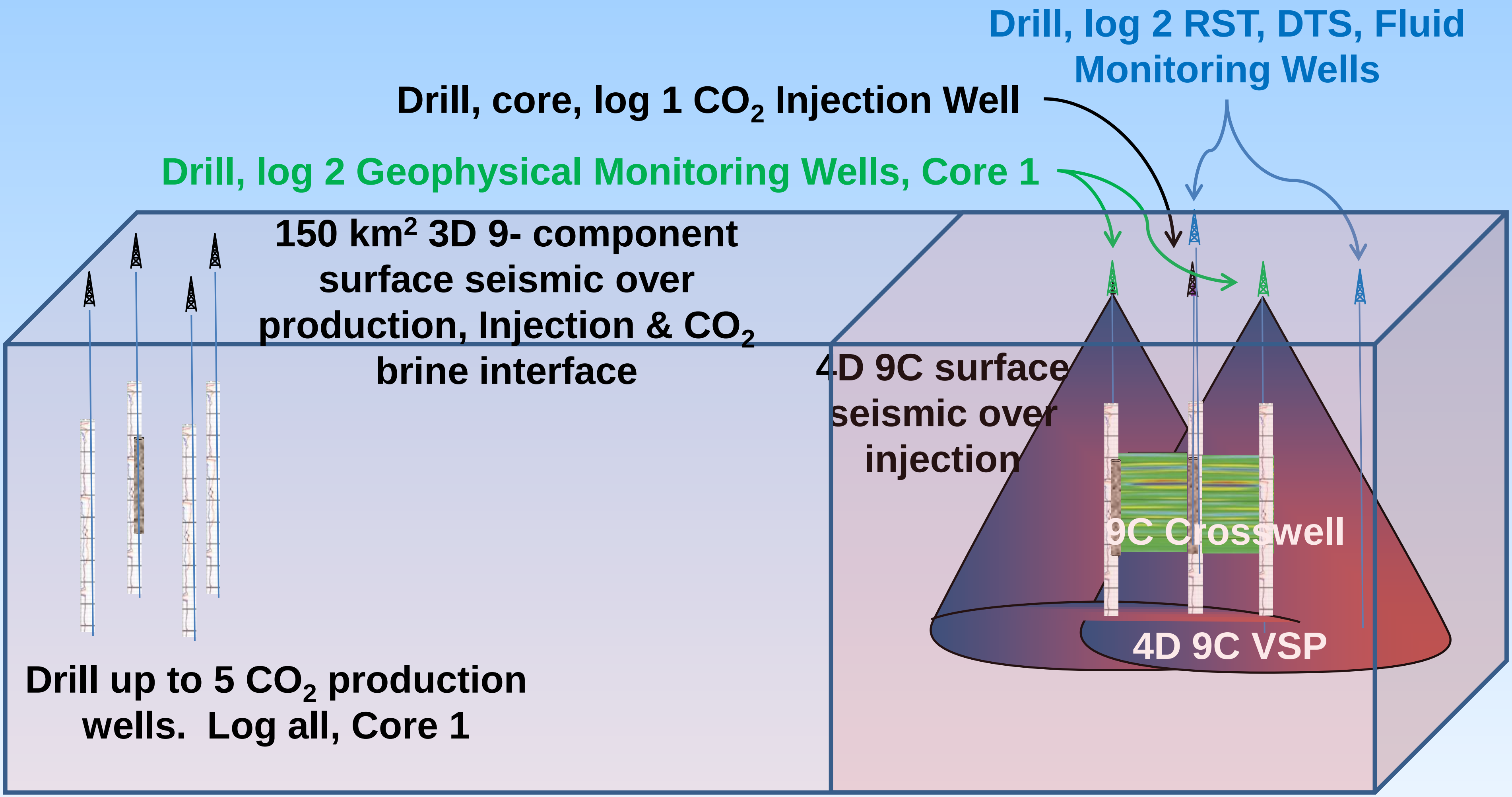




3-D Reservoir Model



Geophysical Program



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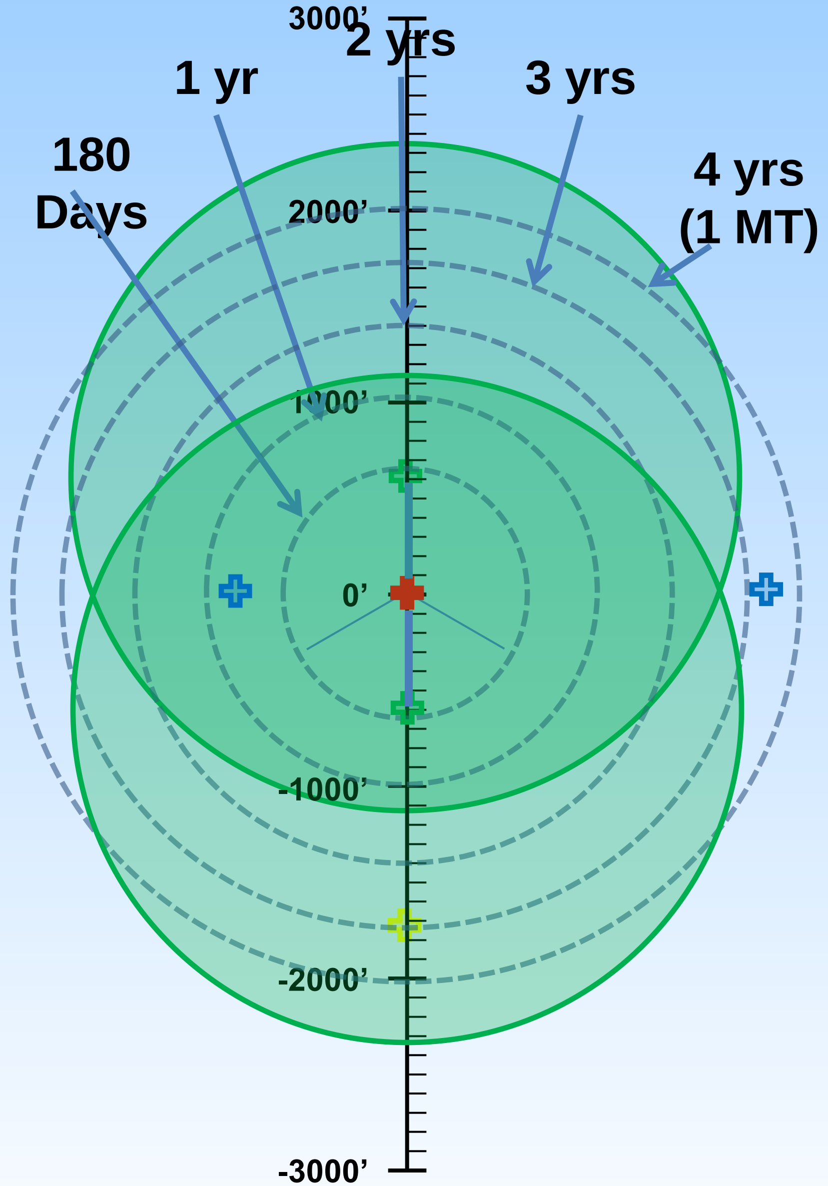
Monitoring Wells



Preliminary Simulation

Tough2, LBNL

12% porosity

50 mD permeability

700 tonnes / day

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Seismic program

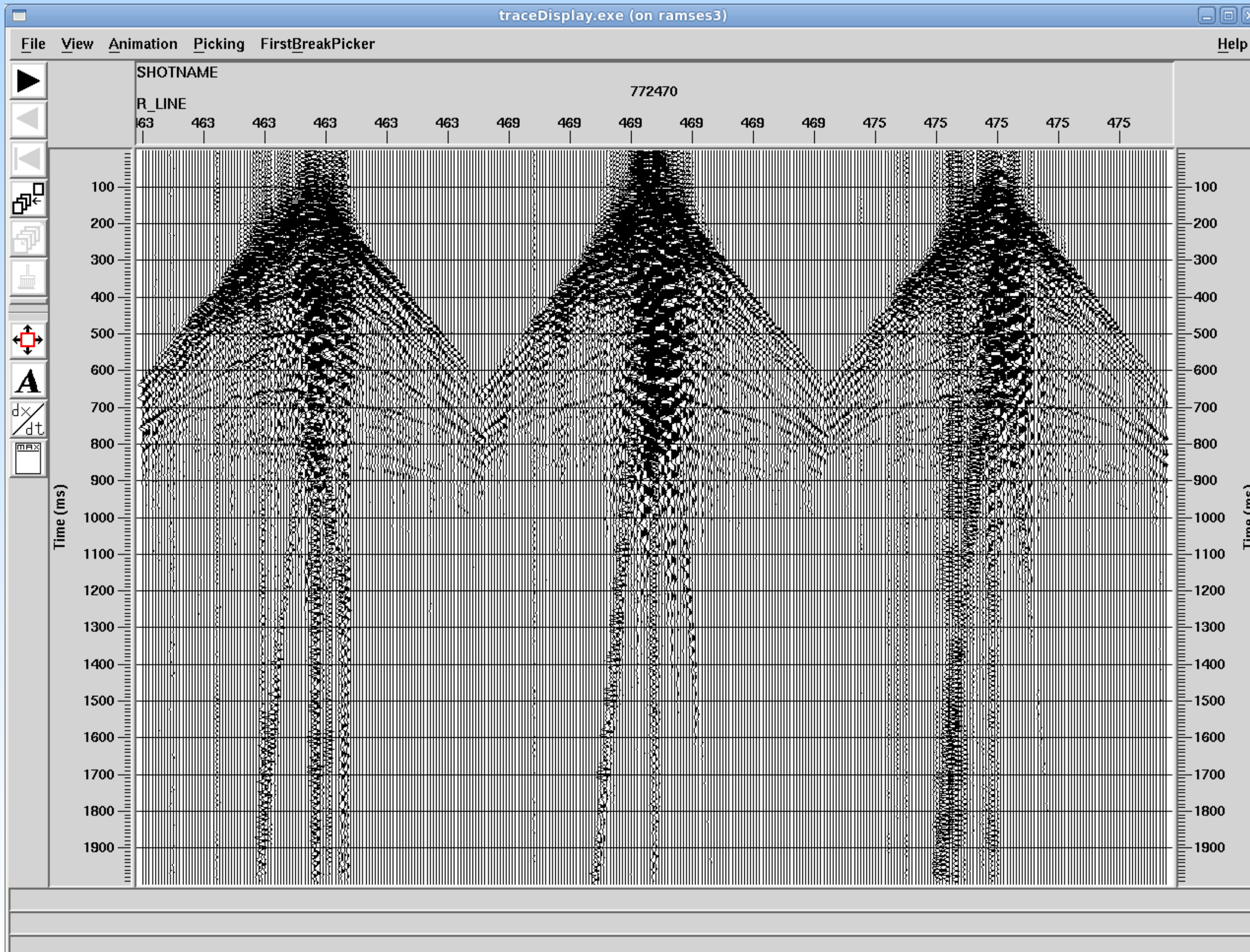
- Specialty is multi-component seismic,
  - shear-wave seismic data is a powerful tool for CO_2 monitoring and fracture detection in hard rocks
  - Vecta has been successful at imaging stratigraphically complex clastic and carbonate traps in environments similar to Kevin Dome
- Vecta owns its own shear-wave sources and receivers, allowing us to cost-effectively acquire multi-component data

	Cross Well	VSP (3D, 9C) (Months)	Surface (3D, 9C) (Months)
Seismic Survey Timing (Months)	0	0	0
		12	
		24	
		36	36
	50		84

Initial Seismic

- 10 sq mi shot
- 3D, 9C
- Initial processing underway
- Good reflections

Raw Shot Records   S-LINE : 772 STN: 470



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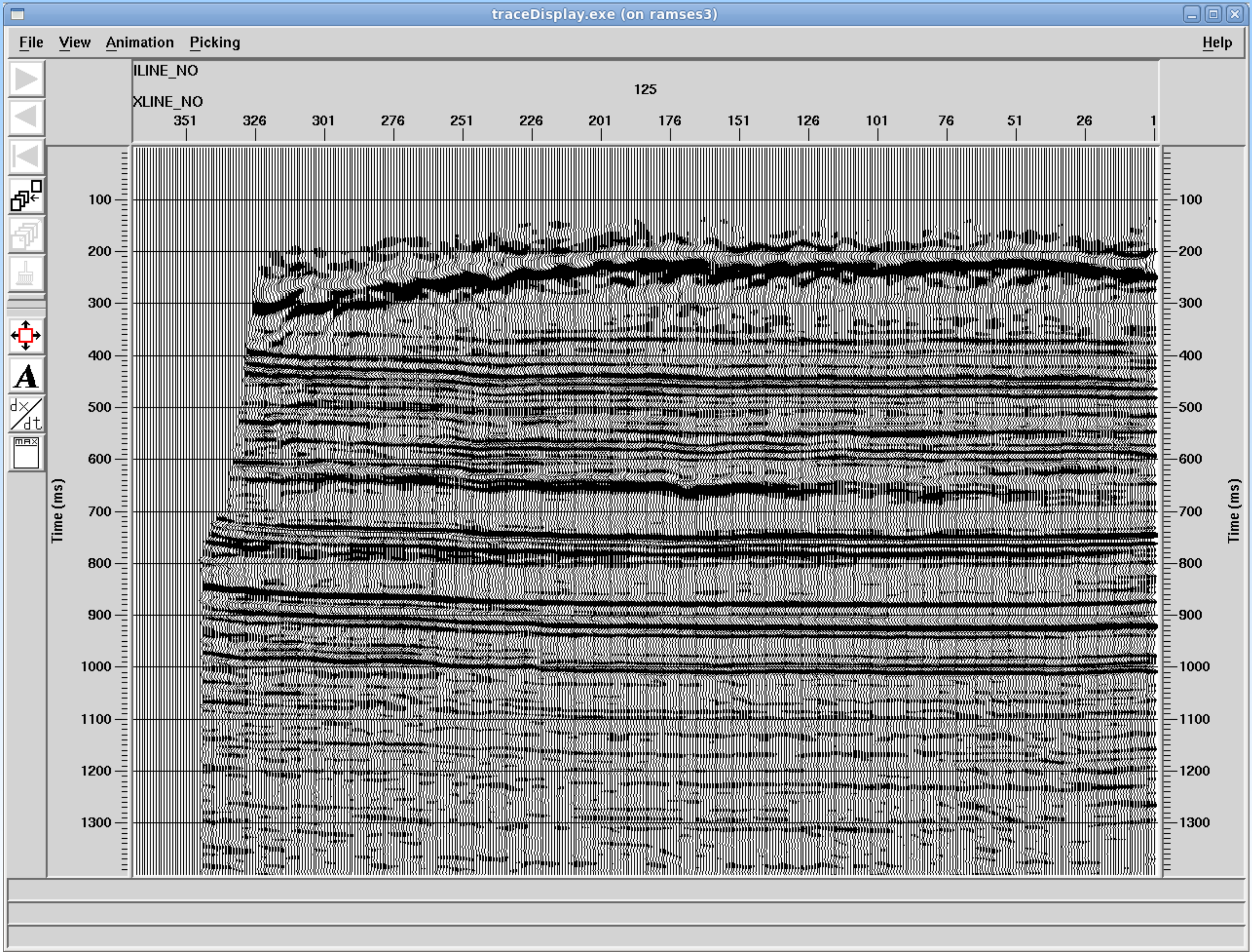
Post Stack Migration



Geophysical Characterization & Monitoring Well Logging

- All wells
  - Cement bond, Gamma / Density-Neutron, Resistivity, Sonic
- 1 Producer, Injector 4 Monitoring Wells
  - FMI, RST, MDT
- Annual Logging
  - Injector - MIT
  - Mon. Well – RST

Logs	Wells			
	All	1st Prod	Inj	Mon
Cement Bond	Init			
Gamma / Neutron	Init			
Resistivity	Init			
Sonic	Init			
FMI		Init	Init	Init
MDT		Init	Init	Init
RST		Init	Init	Annual
MIT			Annual	

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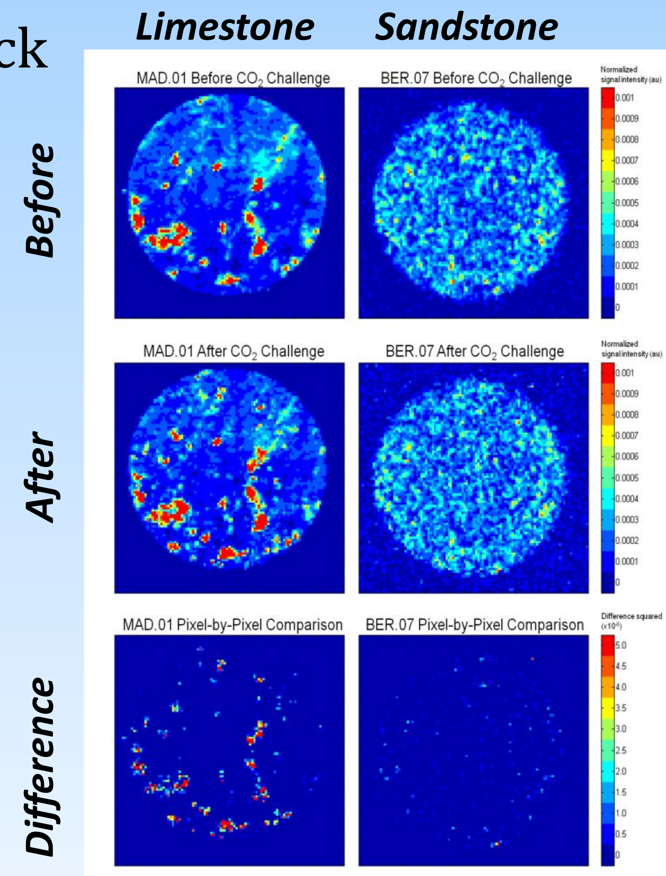
Cores

- 540 ft of cores to be cut from 1 producing well, the injector and 1 monitoring well
- Coring will include reservoir rock and cap rock
- Side Wall Cores from injector & 1 monitoring well post injection
- Core Testing & Analysis
  - Relative Permeability
  - Rock physics properties
  - Geochemical behavior



Experimental Design

- Flow-through Reactor
- Real-time P, T, pH, Cond.
- Sampling of Brine Chemistry

Physical Changes in Rock Core

- Microstructure: Optical & SEM
- Porosity: CT & NMR
- Permeability

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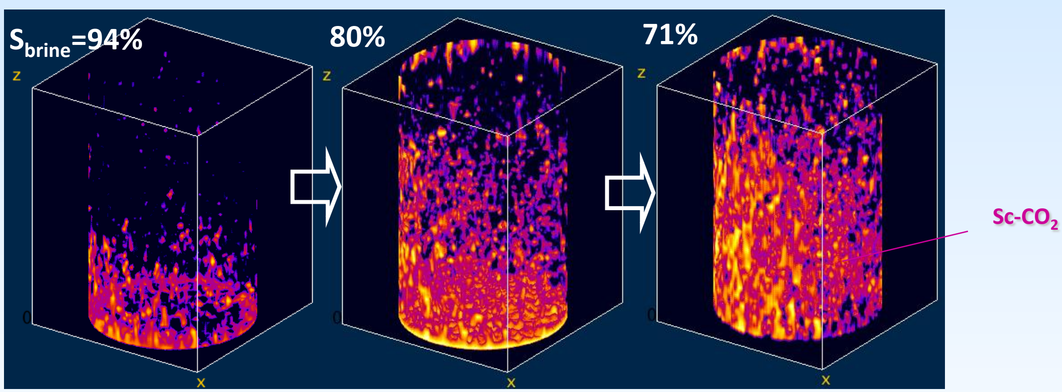
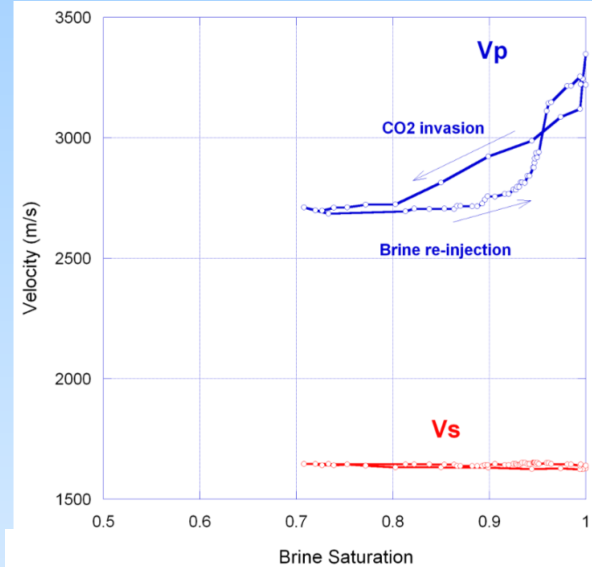
CO_2 Impact on Seismic Properties – LBNL's Split Hopkinson Resonant Bar Apparatus

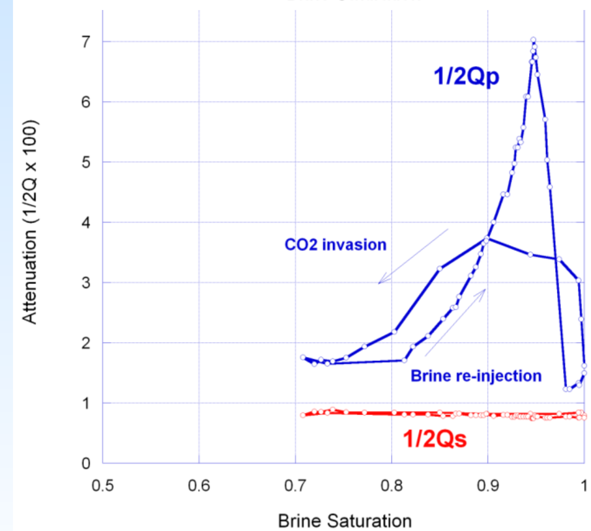
Resonant Bar Inner Chamber and housing

X-ray CT imaging of resonant bar enclosed in thermal jacket



X-ray images of CO_2 core flood





Seismic properties as f(S_{CO2})

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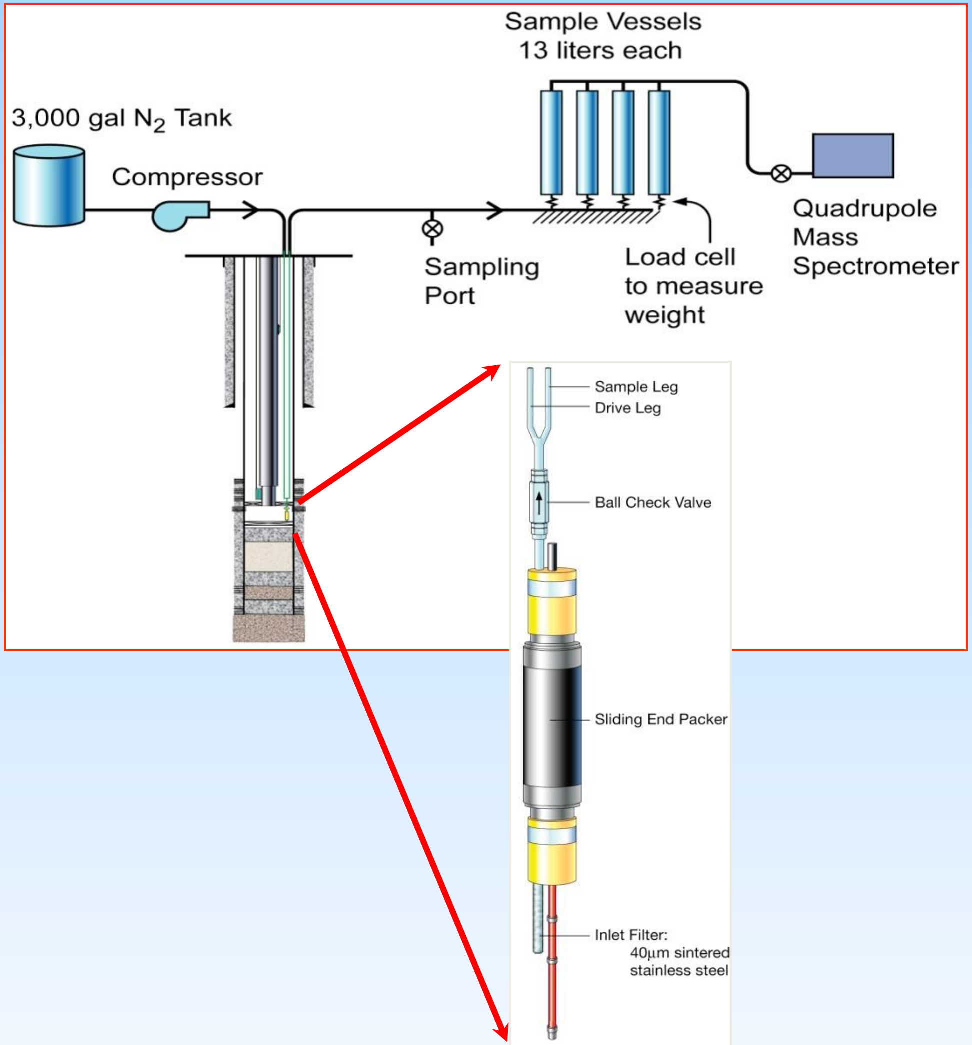
Courtesy S. Nakagawa and T. Kneafsey, LBNL

Geochemical Monitoring

- Fluid Sampling
  - Monthly Via U-tube in all monitoring wells until
- Tracers
  - Phase partitioning tracers
  - SF_6
  - $^{14}CO_2$
  - Rare earth element
- Core Testing & Analysis
  - CO_2 flood and flow experiments
  - Comparison of cores from gas cap with cores from injection zone pre- and post- injection

Analyte	Method	Purpose
Cations (aq)	ICP-MS	Basic water chemistry
Cations (s)	Microprobe, ICP-MS (whole rock digestion)	Whole rock chemistry
Anions (aq)	Ion Chromatography	Basic water chemistry
Anions (s)	Ion Chromatography (whole rock digestion)	Changes in rock chemistry throughout experiments
Mineralogy	XrD	Rock phase determination pre and post experiment
REE (s)	ICP-MS, XRF	Water chemistry mineral dissolution ppt
Trace elements) (aq)	ICP-MS	Water chemistry evolution
Trace elements, including REE	ICP-MS LASER ablation, Microprobe, XRF	Evolution of minerals phase during experiment
pH, alkalinity, temp	P-T electrode	Water chemistry

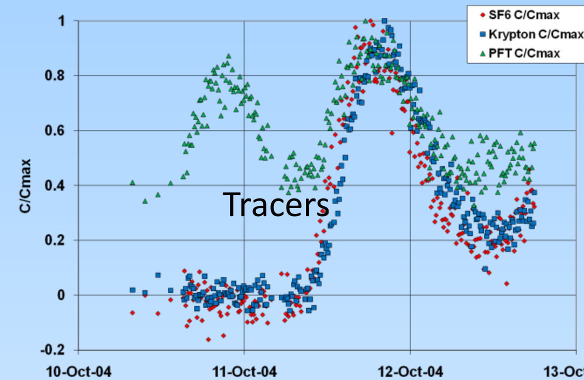
U-Tube Fluid Sampling – Multiphase samples provide insights into reservoir processes



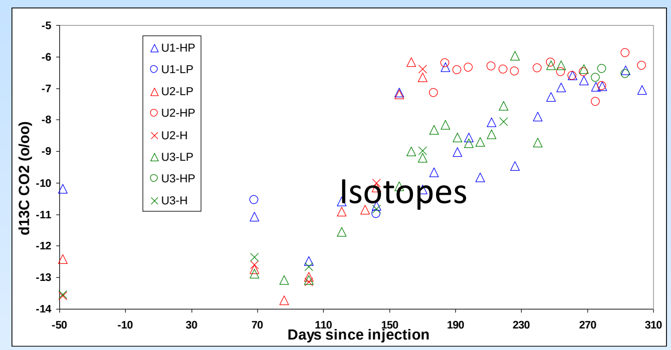
Schematic of initial U-tube System at Frio Brine Pilot

Courtesy B. Freifeld, LBNL

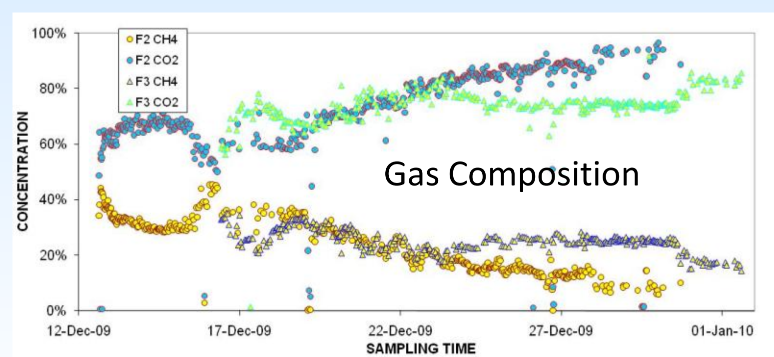
Frio Brine Pilot



Otway Project



SECARB Cranfield



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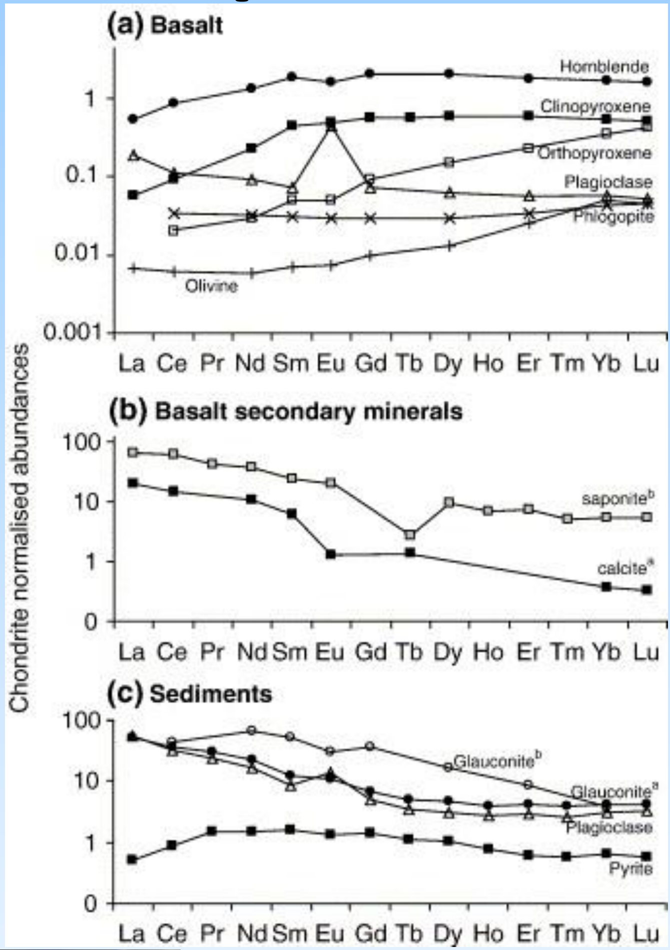
REE Tracer Development

REE (La-Lu) are effective Natural Tracers in geologic systems

- Long history of use in characterizing geologic systems and *sedimentary basin evolution*.
- REE are extremely sensitive to chemical changes imparted to brine chemistry during mineralization reactions, dissolution and transport reactions (Nelson D.T., 2005, Stetzenbach et al 2004, Wood et al 2006, McLing et al 2002, Roback and McLing 2001)
- Use as in-situ tracer for reservoir water displacement and leakage (Johannesson et al 2000).
- REE very sensitive to mineral dissolution and precipitation, parts per trillion detection with minimal sample prep
  - Samples will be collected during routine water sampling, no special tools required at Basalt and Kevin Dome Pilot.
  - Tracking CO_2 mass balance in CCS applications
- Laboratory Experiments useful in characterizing field collected data
  - Experiments will be carried out at INL Laboratories on reservoir rocks from both pilots



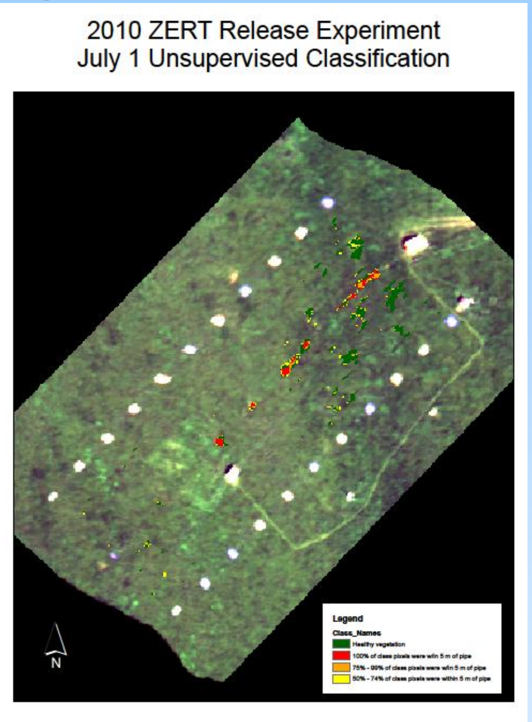
Assurance Monitoring

- **Eddy covariance**
  - Measure net CO2 flux by calculating turbulent fluxes within the atmospheric boundary layer
  - Spatial scale: m^2-km^2

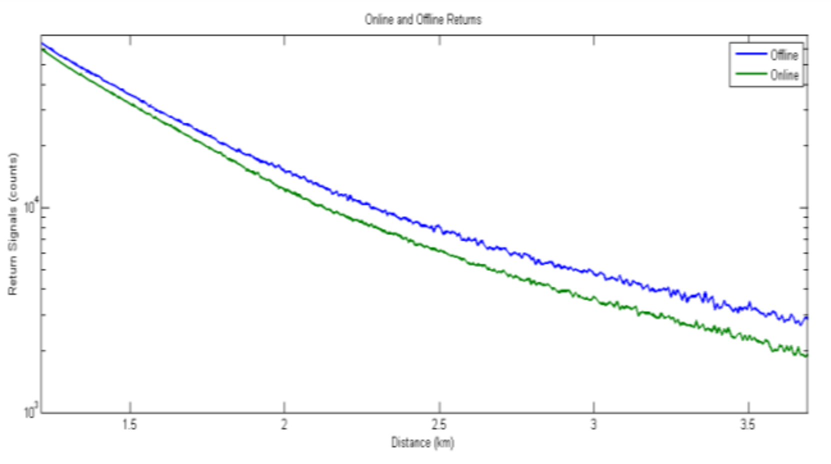
- **Soil flux surveys**
  - Measures soil CO_2 flux
  - Spatial scale: point measurements, establish a grid to cover larger areas
- **Drinking water monitoring**
  - pH
  - Conductivity
  - anions
  - carbonates
  - metals
  - temperature
  - alkalinity
  - cations
  - nutrients
  - tracers
  - inorganic, organic, and total carbon

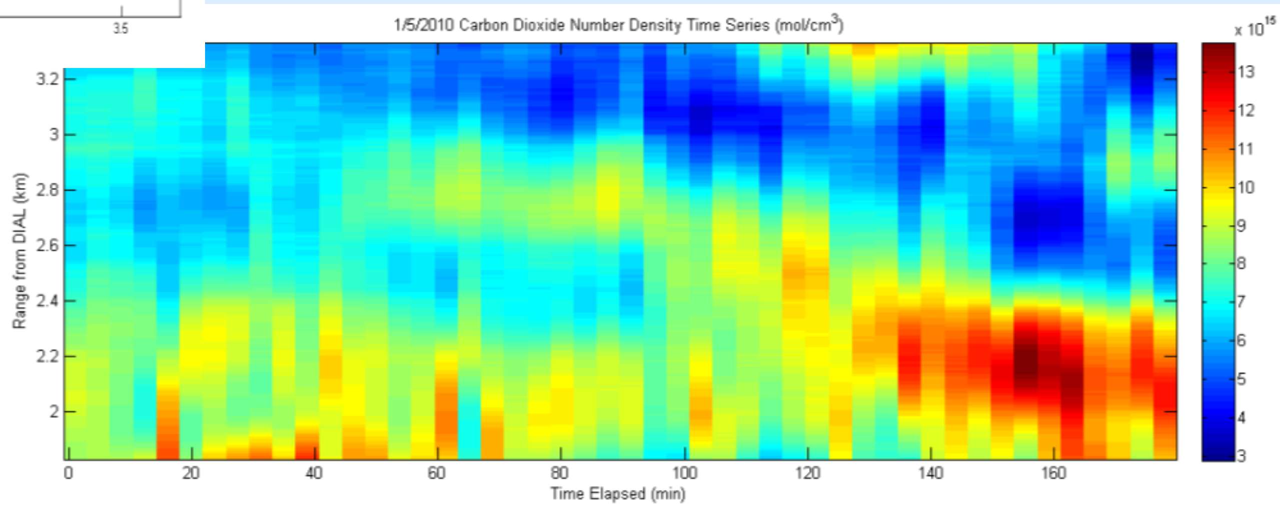
Assurance Monitoring

- Hyperspectral imaging



- Differential Absorption Lidar





Accomplishments to Date

- Multiple community outreach meetings held
- Draft EA complete, under final review
- Initial Risk Assessment performed
- Archeology survey mostly complete
- Static geologic model based on existing data complete
  - Grid exported to flow modelers
- Approximately 10 sq mi of 3D-9C seismic shot
  - P-wave processing underway
  - Data quality is good

Kevin Dome Project Opportunities

- Coupling the natural analog with the new injection allows comparison of long-term geochemical effects to short term in the new injection. Multiple approaches to investigate geochemistry are being deployed including new techniques that are under development
- Storage and withdrawal on the flank of a natural CO_2 dome mimics issues relevant to using domes as CO_2 hubs or warehouses for emplacement of anthropogenic CO_2 and withdrawal for EOR
- The natural analog allows us to look at changes in the rock matrix as a function of long exposure and how this might change seismic response
    - This also represents an unusual opportunity for coupled model studies
- The thin storage reservoir and relatively large number of project wells may allow study of pressure effects in both the storage and production regions
- The existence of multiple sampling wells, unique rock physics property measurements, and multicomponent seismic combined with plans to reproduce the CO_2 represent a unique opportunity to study mitigation methods and understand signals as $f(S_{CO2})$

Kevin Dome Project Opportunities

- We are using 3-dimensional -9 component seismic over 58 square miles including the CO_2 – brine interface. This will test to see if CO_2 fluid fill of pore space is detectable using multicomponent seismic without time lapse.
- Use of cores, well logs, crosswell seismic, VSP, and surface seismic will give us data at four different resolutions which can help us learn to scale computer simulations to different sizes.
- Both surface seismic and VSP are nine component. Nine component seismic using shear wave vibroseis trucks is not a common technique - Vecta has the only 3 operational shear wave vibroseis sources in North America.
- There are two porosity zones in the target formation. If both exist at the injection site we plan to inject in both testing stacked storage and detection of stacked storage.

Kevin Dome Project Opportunities

- Newly developed near surface techniques tested at the ZERT site will be deployed
  - Differential Absorption Lidar (DIAL)
  - Low cost, airborne hyperspectral imaging
  - Laser and hollow core fiber optic based distributed soil CO_2 concentration detection (possible)
- Newly developed geochemical monitoring techniques will be applied
  - Rare Earth Element natural tracers

Summary

Project is very early stage but has the potential for providing valuable information to the CCUS effort.

Questions?


RANKIN
NAGY
BJORKMAN
D.TOMSHECK
MORLEY
BERTHELOTE
ASCHIM
WALLEWEIN
TOMSHECK
KARST
CLARK
SIMONS


U.S. Customs and
Border Protection
Border Patrol Station
Sunburst, Montana

Scope of Work

Task 1.0 – Regional Characterization

Includes regional geologic resource studies, contribution to carbon atlas, terrestrial sequestration, & economic analysis

Task 2.0 - Outreach and Education

Project specific community engagement, development of outreach materials, legislative outreach, surveys

Task 3.0 – Permitting and NEPA Compliance

Permitting action plan, Permitting for seismic, drilling, pipeline, injection

Task 4.0 – Site Characterization & Modeling

Use of existing and acquired cores and cuttings, wireline well logs, petrographic analyses and initial seismic to develop geostatic model, initial mutiphase flow and reactive transport modeling, background assurance monitoring, risk modeling

Task 5.0 – Well Drilling and Completion

Well design, drilling of 5 production wells, 1 injection well and 4 monitoring wells, logging and coring

Task 6.0 – Infrastructure Development

Well pads, wells, pipeline, compressor, MVA infrastructure

Task 7.0 – CO_2 Procurement

Task 8.0 – Transportation & Injection Operations

Site operations & Injection will occur for 4 years, Closure Plan

Task 9.0 – Operational Monitoring & Modeling

Crosswell seismic , 3D-9C VSP, tracers, fluid sampling,

Task 10.0 – Site Closure

Well reclassification and transfer of responsibility to Vecta

Task 11.0 – Post Injection Monitoring & Modeling

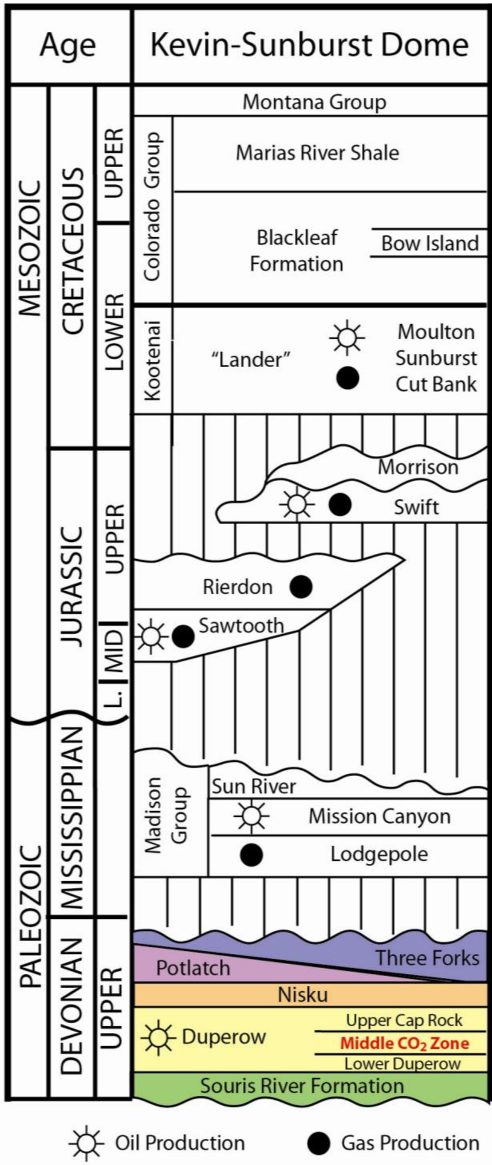
3D-9C surface seismic to create a 4D model, tracers, fluid sampling

Task 12.0 – Project Assessment

Annual assessment of all project components

Task 13.0 – Project Management

Kevin Dome



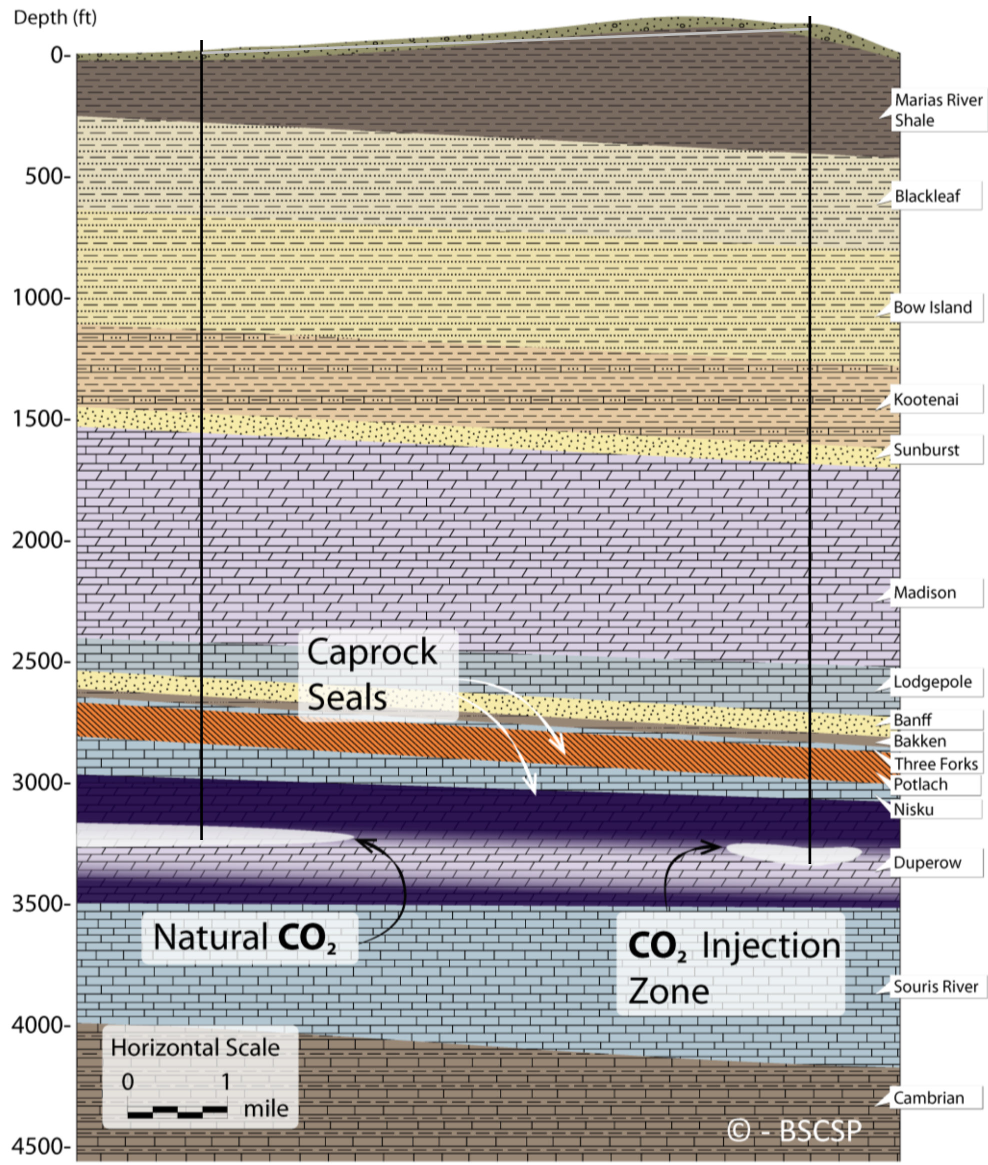
Characterization

Potlach Formation
Lithology: anhydrites
Thickness: ~ 175 ft
Importance: impermeable seal/caprock, natural trap

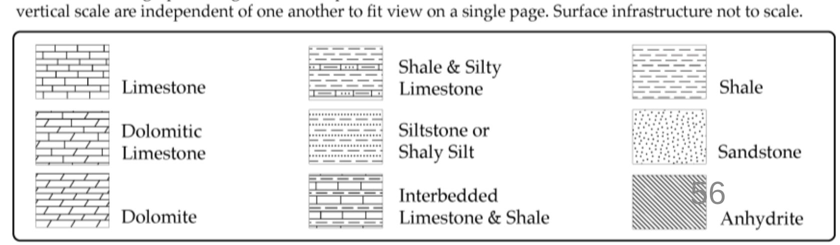
Nisku Formation
Lithology: limestone
Thickness: ~ 50-75 ft
Porosity: 10-25 ft thick porosity zone
Importance: potential storage resource

Duperow Formation
Lithology: primarily limestone and dolostone, with mixed anhydrite in the upper zone
Thickness: ~700 ft total, 300 ft of Upper Duperow cap rock, 200 ft injection zone
Total Dissolved Solids: >100,000
Porosity: 10-15% in injection zone, interbedded low porosity anhydrites in upper zone
Importance: the formation is a naturally occuring CO_2 trap with the potential to store >1GT of additional CO_2.

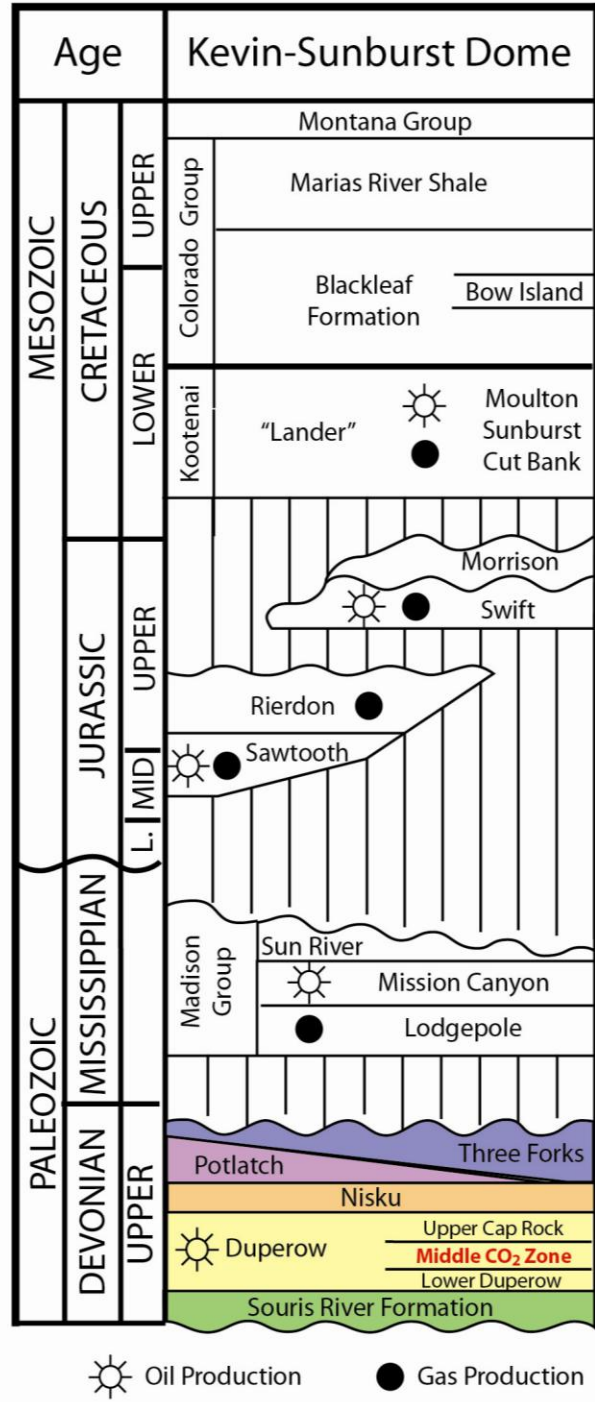
Souris River Formation
Lithology: carbonates
Importance: potential CO_2 storage resource



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



Stratigraphy



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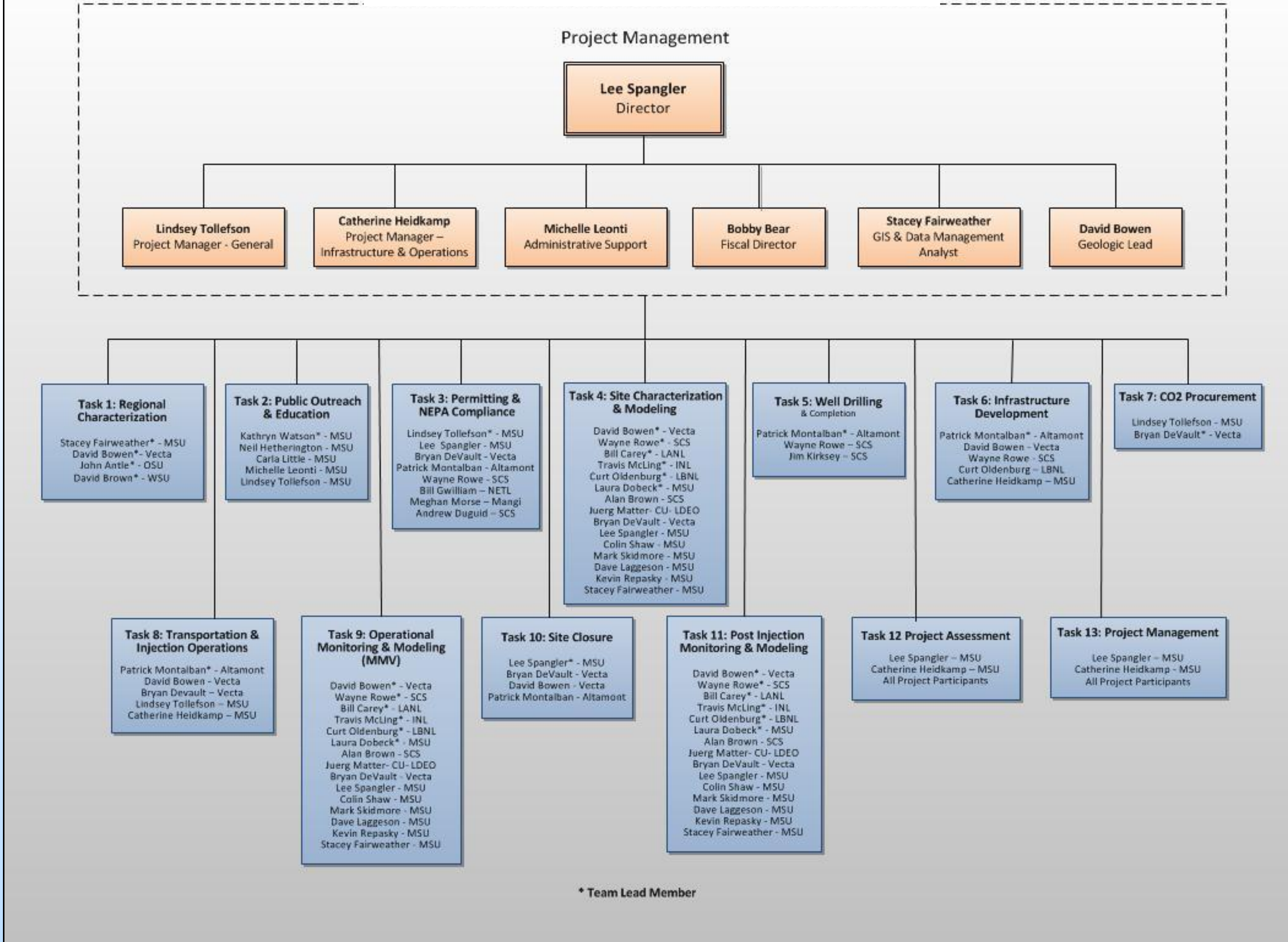
BIG SKY CARBON
SEQUESTRATION PARTNERSHIP

Appendix

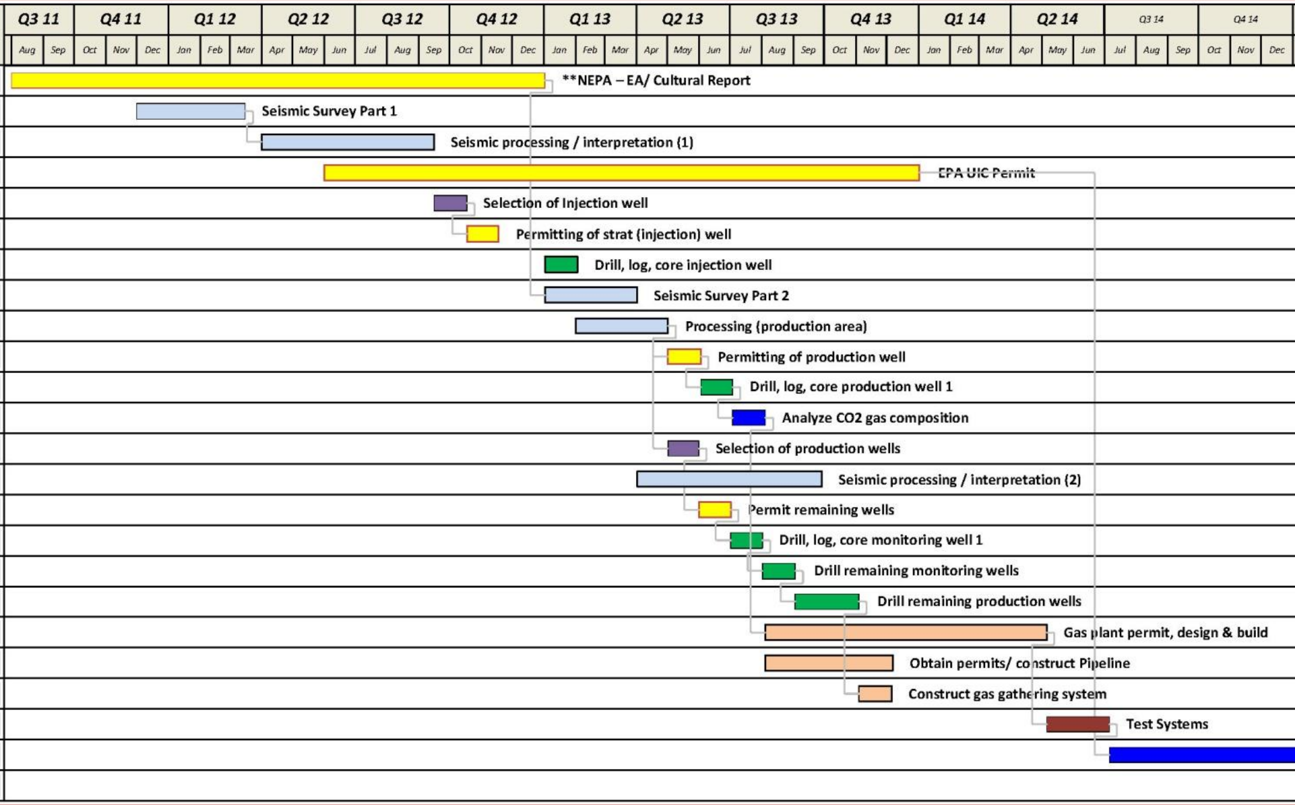
– These slides will not be discussed during the presentation, **but are mandatory**

Organization Chart



Gantt Chart

Task Name	Start	Finish	Duration
**NEPA – EA/ Cultural Report	8/1/2011	1/1/2013	520d
Seismic Survey Part 1	12/1/2011	3/15/2012	106d
Seismic processing / interpretation (1)	4/1/2012	9/15/2012	168d
EPA UIC Permit	6/1/2012	1/1/2014	580d
Selection of Injection well	9/16/2012	10/17/2012	32d
Permitting of strat (injection) well	10/18/2012	11/17/2012	31d
Drill, log, core injection well	1/2/2013	2/2/2013	32d
Seismic Survey Part 2	1/2/2013	4/1/2013	90d
Processing (production area)	2/1/2013	5/1/2013	90d
Permitting of production well	5/2/2013	6/2/2013	32d
Drill, log, core production well 1	6/3/2013	7/3/2013	31d
Analyze CO2 gas composition	7/4/2013	8/4/2013	32d
Selection of production wells	5/2/2013	5/31/2013	30d
Seismic processing / interpretation (2)	4/2/2013	9/28/2013	180d
Permit remaining wells	6/1/2013	7/1/2013	31d
Drill, log, core monitoring well 1	7/2/2013	8/1/2013	31d
Drill remaining monitoring wells	8/2/2013	9/2/2013	32d
Drill remaining production wells	9/3/2013	11/3/2013	62d
Gas plant permit, design & build	8/5/2013	5/5/2014	274d
Obtain permits/ construct Pipeline	8/5/2013	12/6/2013	124d
Construct gas gathering system	11/4/2013	12/5/2013	32d
Test Systems	5/6/2014	7/5/2014	61d
Begin CO2 Injection	7/6/2014	7/5/2018	1461d
Post-injection work	7/6/2018	7/4/2020	730d



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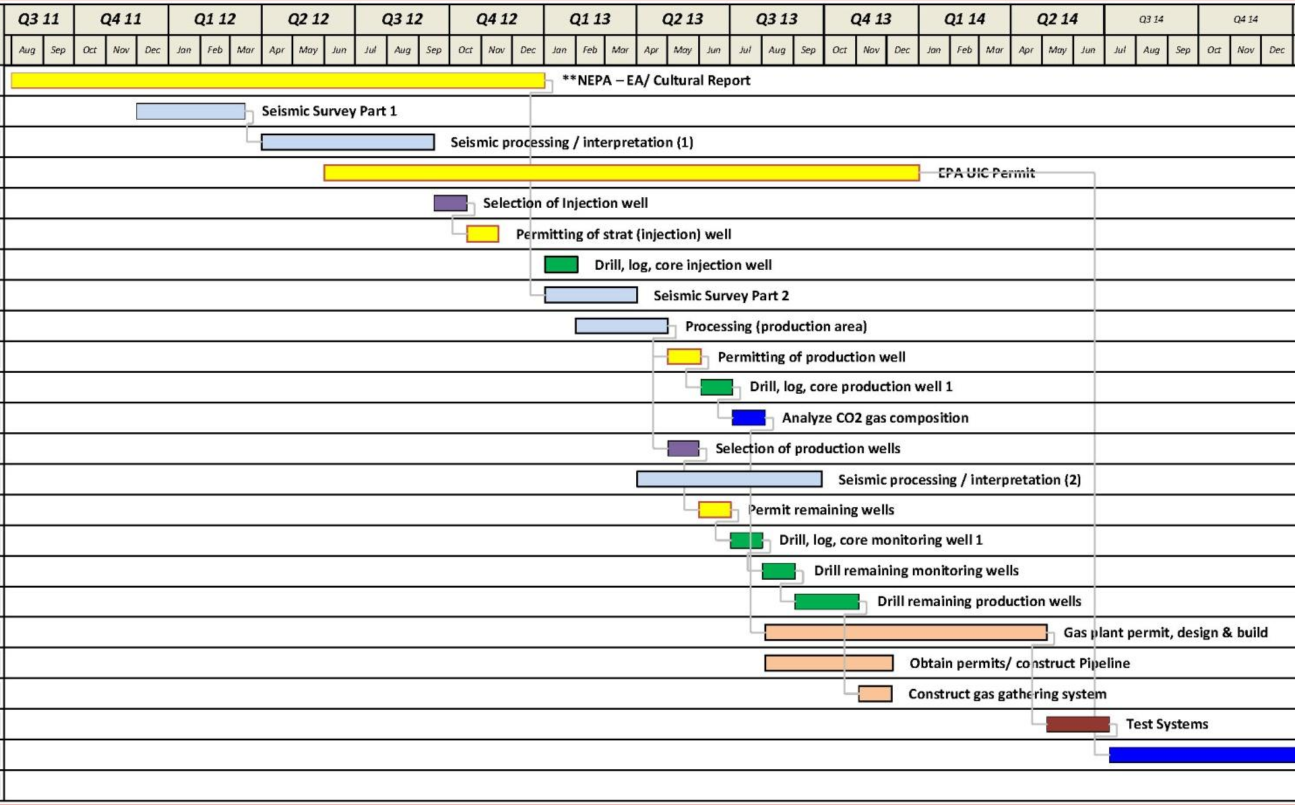

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List **peer reviewed publications** generated from project per the format of the examples below

- Hudak, A., Strand, E., Vierling, L., Byrne, J., Eitel, J., Martinuzzi, S., and Falkowski, M. 2012. *Quantifying aboveground forest carbon pools and fluxes from repeat LiDAR surveys*. Remote Sensing of Environment. v. 123, p. 25-40.
- Brinklemeyer, R., Brown, D., Barefield, J. and Clegg, S. 2011. *Improving intact soil core carbon measurement with full spectrum LIBS*. European Journal of Soil Science.
- McGrail, P., Spane, A., Sullivan, C., Bacon, H., and Hund, G. 2011. *The Wallula Basalt Sequestration Pilot Project.* Energy Procedia. V. 4, p. 5653-5660.
- Bricklemyer, R. and Brown ,D. 2009. *On-the-go VisNIR: Potential and limitations for mapping soil clay and organic carbon.* Computers and Electronics in Agriculture. V. 70, Issue 1. p, 209-16.
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- Derner, J., and Hart, R. 2007. *Grazing-Induced Modifications to Peak Standing Crop in Northern Mixed-Grass Prairie*. Rangeland Ecological Management. V. 60, Issue 3. p, 270-76.