Characterization of Pliocene and Miocene Formations in the Wilmington Graben, Offshore Los Angeles, for Large-Scale Geologic Storage of CO_2

Project Number (FE0001922)

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GeoMechanics Technologies

U.S. Department of Energy

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

August 12-14, 2014

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Background and Motivation

- The Los Angeles Basin provides a unique combination of significant need and significant opportunity for large scale CO_2 sequestration
- Has numerous large power plants & oil refineries which produce more than 5 million MT of fossil fuel related CO_2 emissions each year
- Prolific oil & gas producing basin with thick sediments (several billion barrel fields)

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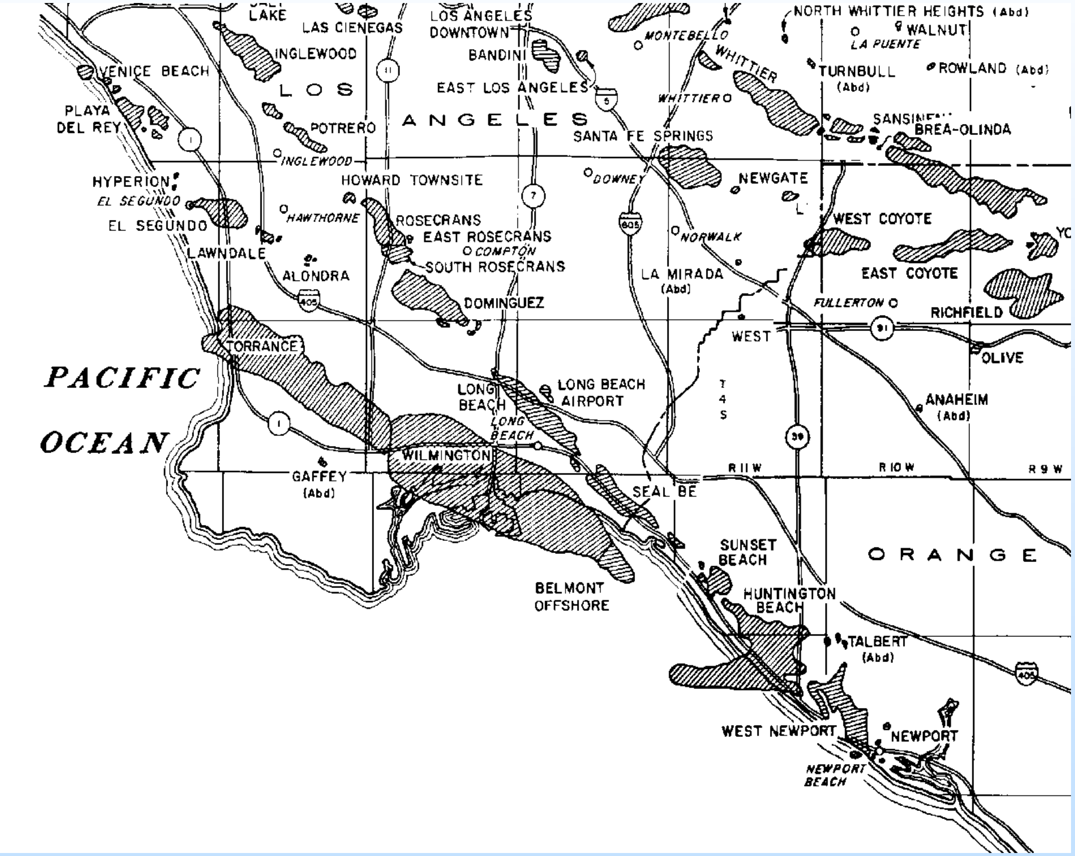
Background and Motivation

- Precedent and history for large scale injection (>3000 injection wells)
- Precedent and history for large scale gas storage (5 fields)
- But, siting large scale CO_2 storage beneath a highly populated area is technically and politically impractical



Oil Fields in LA Basin

Background and Motivation

The offshore Wilmington Graben presents significant advantages, including:

• Geologically isolated, yet accessible from onshore with existing oil and gas infrastructure;

• Very thick sediments nearly identical to those located onshore;

• Fewer existing wells to reduce leakage risk (11 wells).

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Goals and Objectives

The objectives of this research project are to fully characterize Pliocene and Miocene sediments in the Wilmington Graben, offshore Los Angeles, for high volume CO_2 storage, to evaluate risks, and to evaluate logistics for transport from local sources

– The effort contributes to the Carbon Storage Program's goal to develop technologies to predict CO_2 storage capacity in geologic formations to within 30%.

– The effort also contributes to the Program's goal to develop technologies to demonstrate 99% of injected CO_2 remains within the injection zones.

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Goals and Objectives

A key goal is to confirm that more than 100 million metric tons can be safely stored in the Wilmington.

- Contributes to the understanding of injectivity, containment mechanisms, and storage capacity of the Wilmington Graben for large scale CO_2 sequestration.
- One of only two projects focused on offshore storage formations. Only project focused on turbidite geologic settings (common in Western US).

Benefits to the Program

- This project is contributing to the understanding of injectivity, containment mechanisms, and storage capacity of the Wilmington Graben basin.

- Broadens the experimental knowledge base of best practices for site characterization and approving storage site selection with the ultimate goal of developing practical guidelines for future commercially developed CO_2 storage sites.

- This effort contributes to the Carbon Storage Program's effort of conducting field tests to support the development of Best Practices for site selection, characterization, and operations.

- Unique evaluation of offshore storage in a turbidite geologic setting

Project Team and Participants

DOE NETL

California Energy Commission

City of Los Angeles, Department of Public Works

Southern California Gas Company (transport infrastructure)

Cal State Long Beach, Dr. Dan Francis (seismic acquisition)

Legg Geophysics (seismic interpretation)

Don Clarke (geologic evaluation and modeling)

USGS, Dr. Dan Ponti (cores and samples repository)

GeoMechanics Technologies (geology, geomechanics, reservoir engineering and drilling contract management)

Contributors

- Principal Investigator
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- Project Manager & Sr Geologist
  - Jean Young
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- Research Engineer
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- Research Geologist
  - Nicky White
  - Bill Childers
- Contractors
  - Dr. Mark Legg
  - Dr. Dan Francis
  - Don Clarke
  - Drilling crew
  - Logging crew
- Partners
  - City of Los Angeles
  - California Energy Commission
  - CA State University, Long Beach
  - USGS

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Technical Approach/Tasks

1\. Seismic Data Analysis and Acquisition

1\. Well Data Review and Formation Evaluation

2\. New well drilling, logging, core analysis

3\. 3D Geological Model Development

4\. 3D Geomechanical Model Development

5\. 3D Gas Migration Modeling

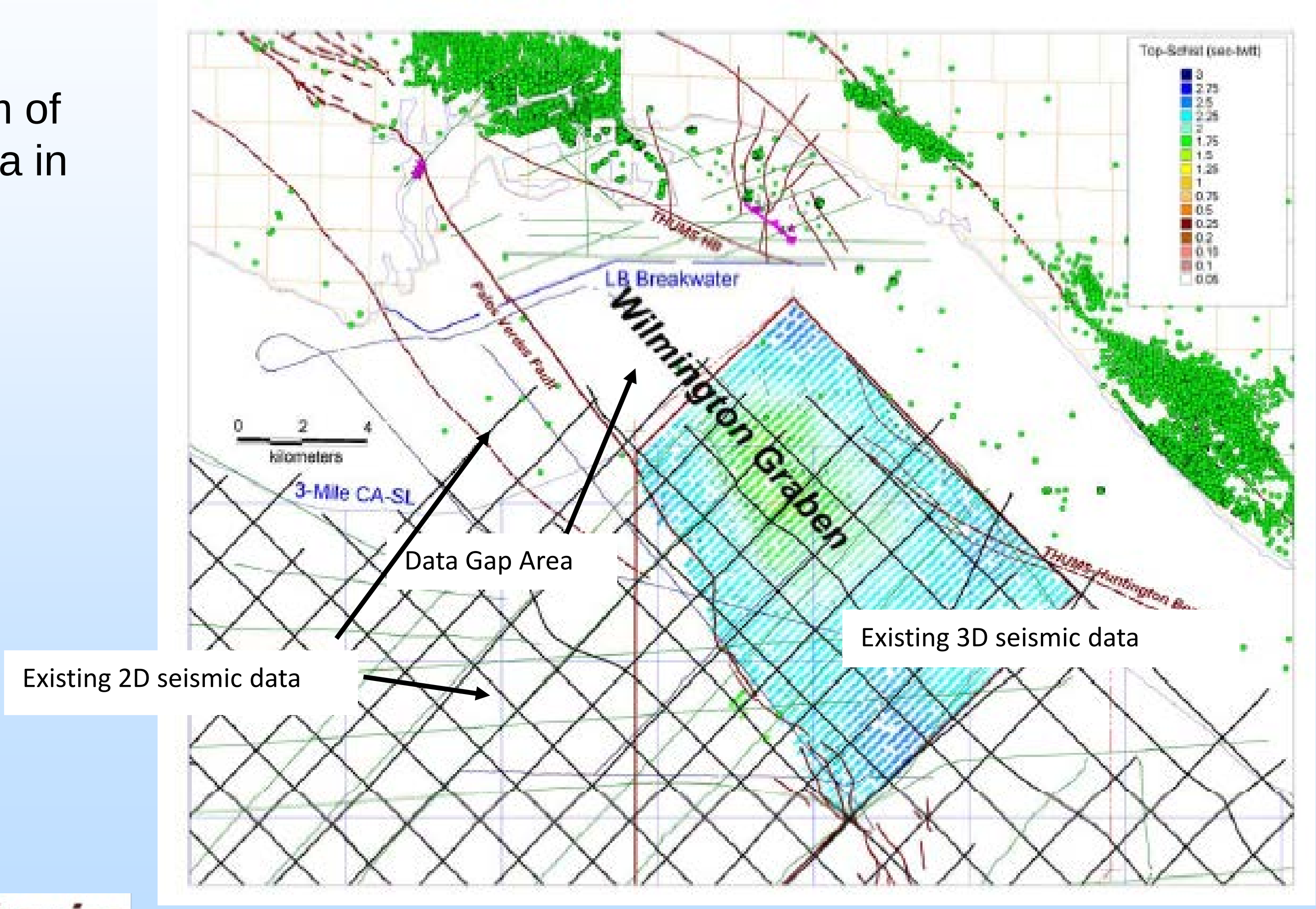
6\. Risk Analysis

Seismic Data Analysis and Acquisition

Collected 175km of new seismic data in "gap area"

Combined and reinterpreted existing data

Established horizons for 3D geologic model



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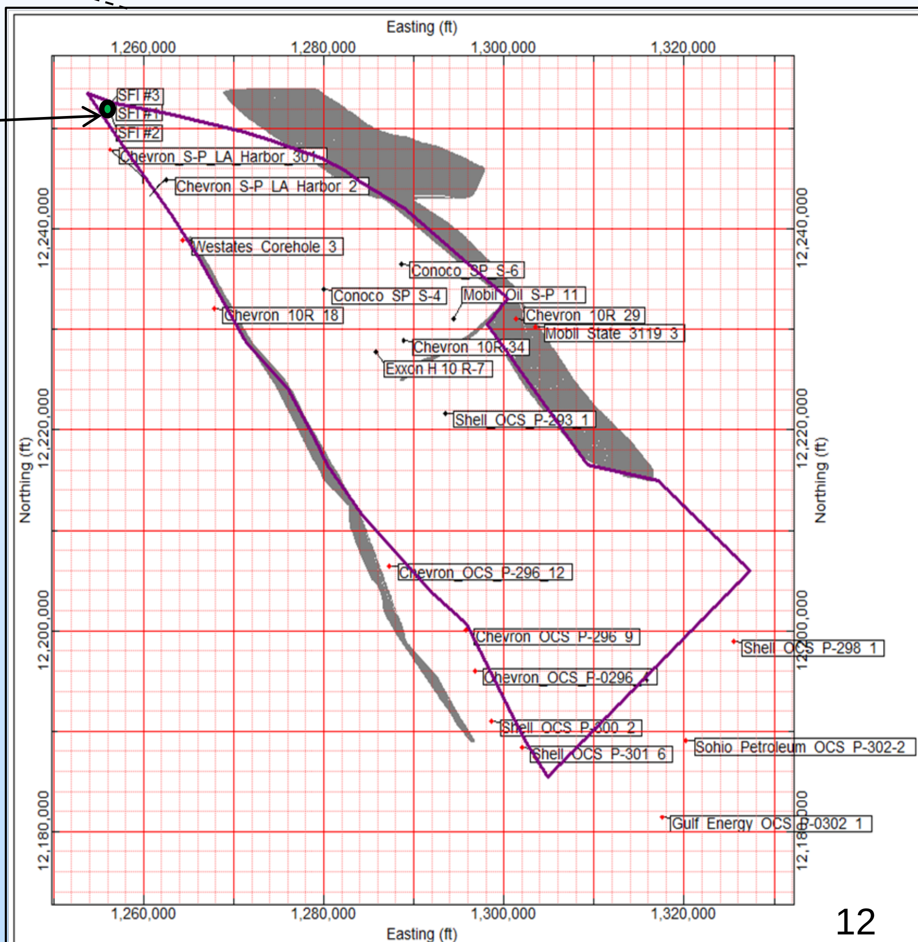
Long Beach

Well Data Review and Formation Evaluation

DOE#1 and DOE#2 wells



Collected log data from 12 exploration wells located in State and Federal waters

Evaluated sand, silty-sand, and shale sequences

Combined into common database

Supplemented with 2 new wells, and planned deepening of 1 existing well

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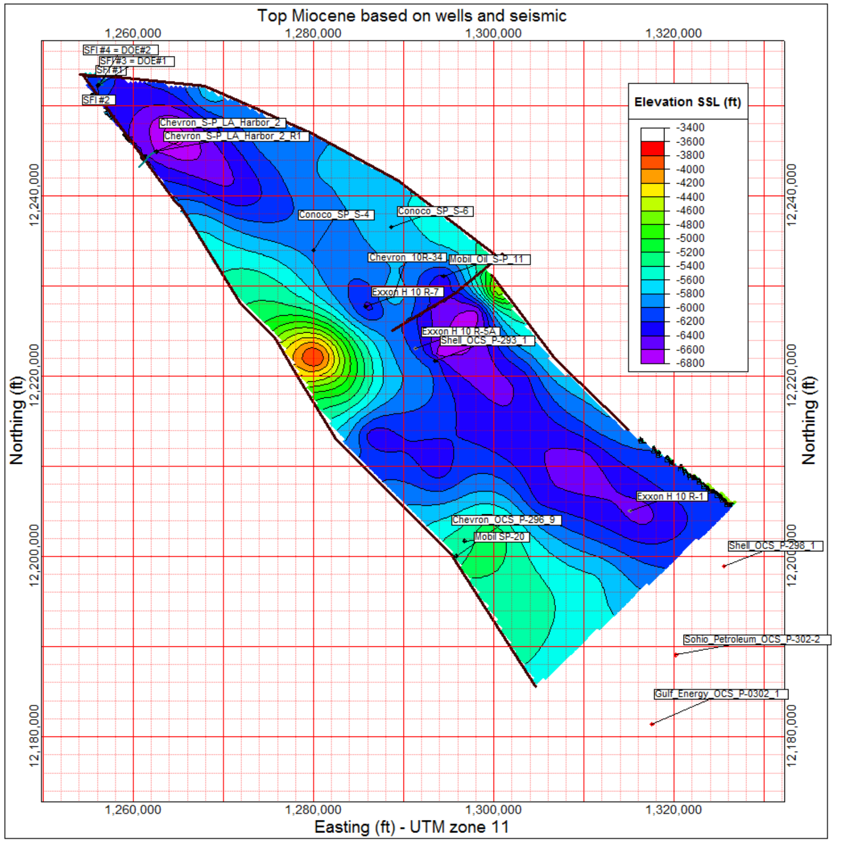
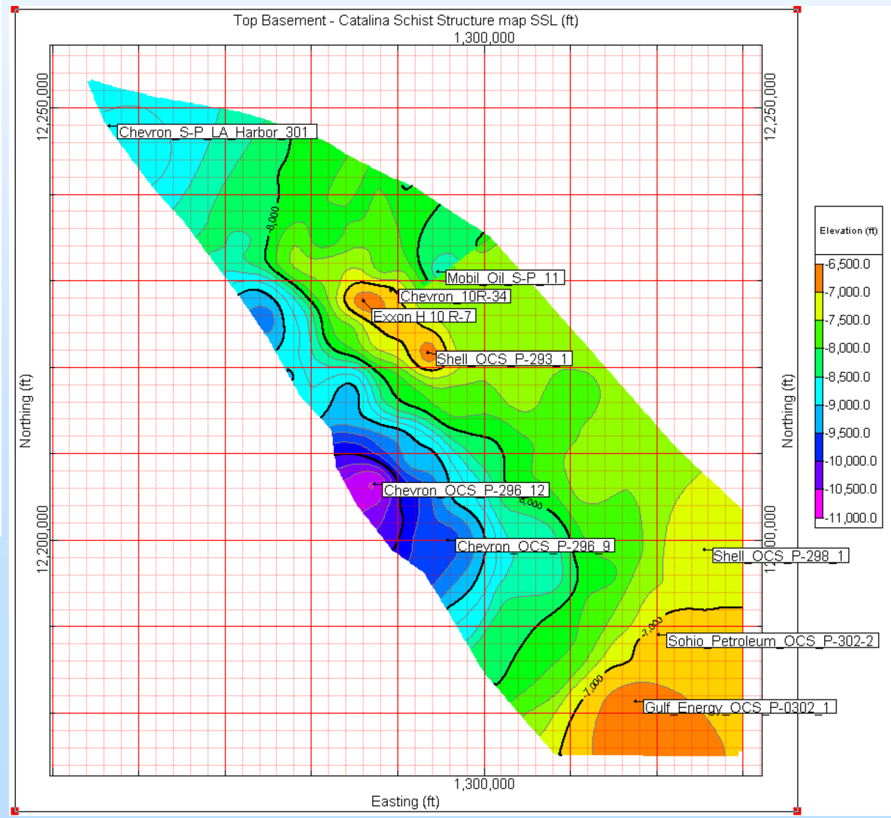
Established Multiple Structure Horizons using Well and Seismic Data





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New well drilling, logging, core analysis

- DOE#1 well TD at 5400ft, penetrating to near base of Pliocene
- DOE#2 well TD at 7647ft; penetrate Miocene at 6600ft
- Deepening SFI#1 to verify continuity of Miocene sands

DOE#1 well spud May 1st, 2010

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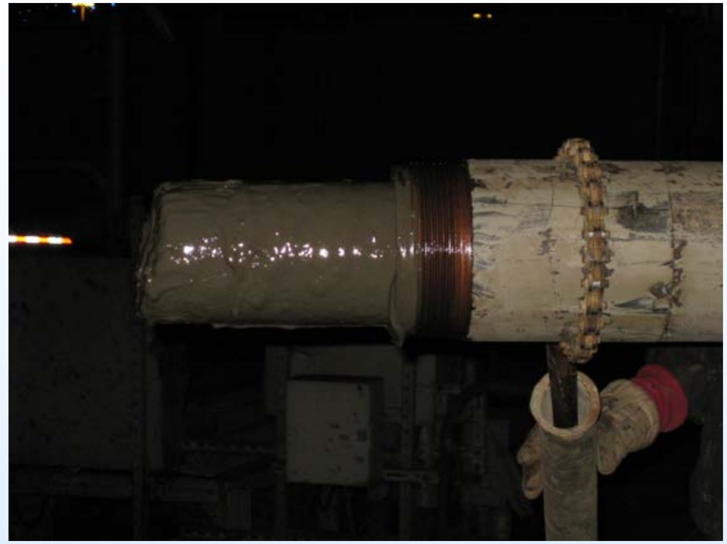
New well drilling, logging, core analysis



Formation evaluation data from new wells used to update geologic, geomechanical and gas migration models.

Results for well 1:

- **200 ft of viable Pliocene age storage formation and 500 ft of caprock identified**
- **Sand porosity 24-31%, permeability 50-353 md.**
- **Shale porosity 23-29%, permeability <2 md**

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Core Analysis from DOE #1 and DOE#2

	Pliocene		Miocene
	DOE#1	***DOE#2***	***DOE#2***
Sand Porosity (%)	24-31	28-37	26-29
Sand Permability (md)	50-353	29-300	4-<100
Shale Porosity (%)	23-29	29	29
Shale Permeability (md)	<2	<2	<5

Found:
>400ft Pliocene sand
>150ft of Miocene sands

DOE# 2 well completed March, 2014

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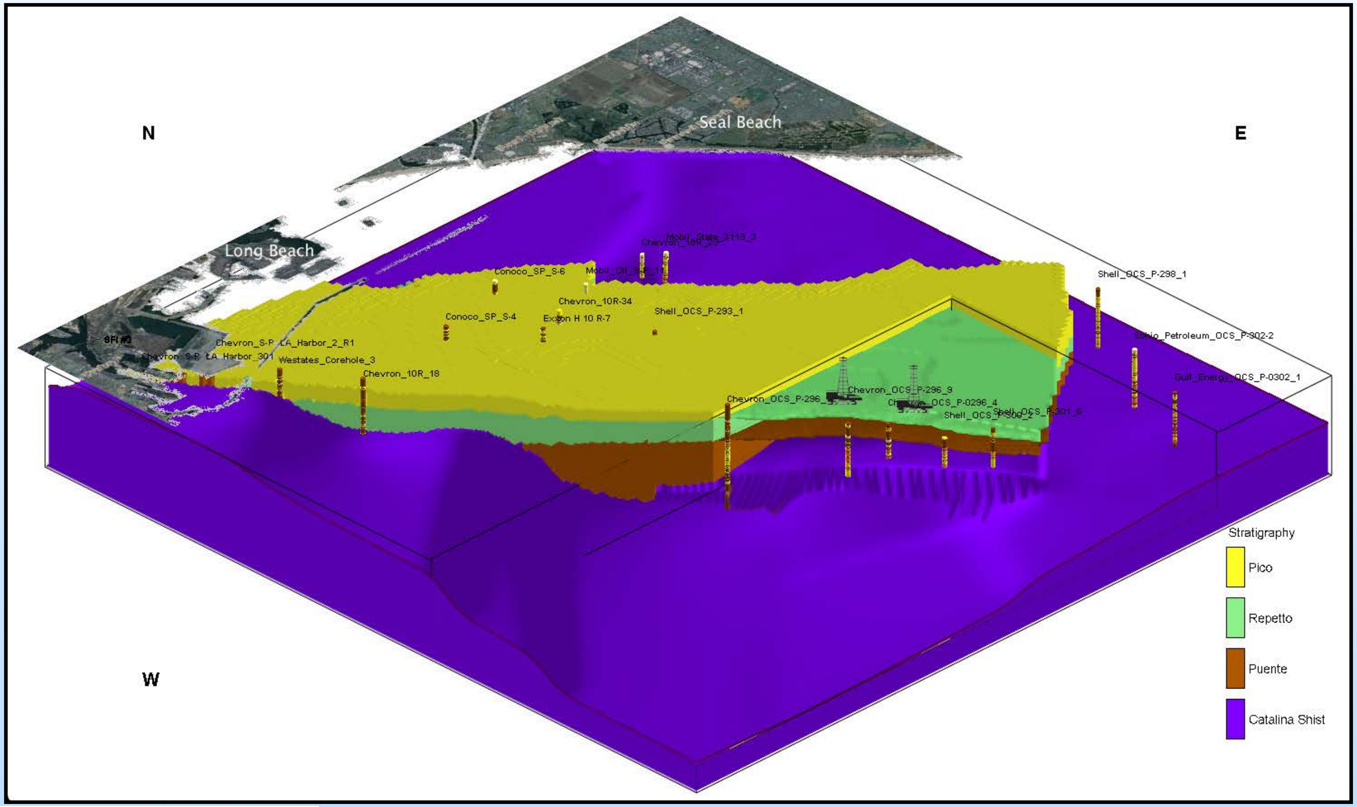
3D Geologic Model Development

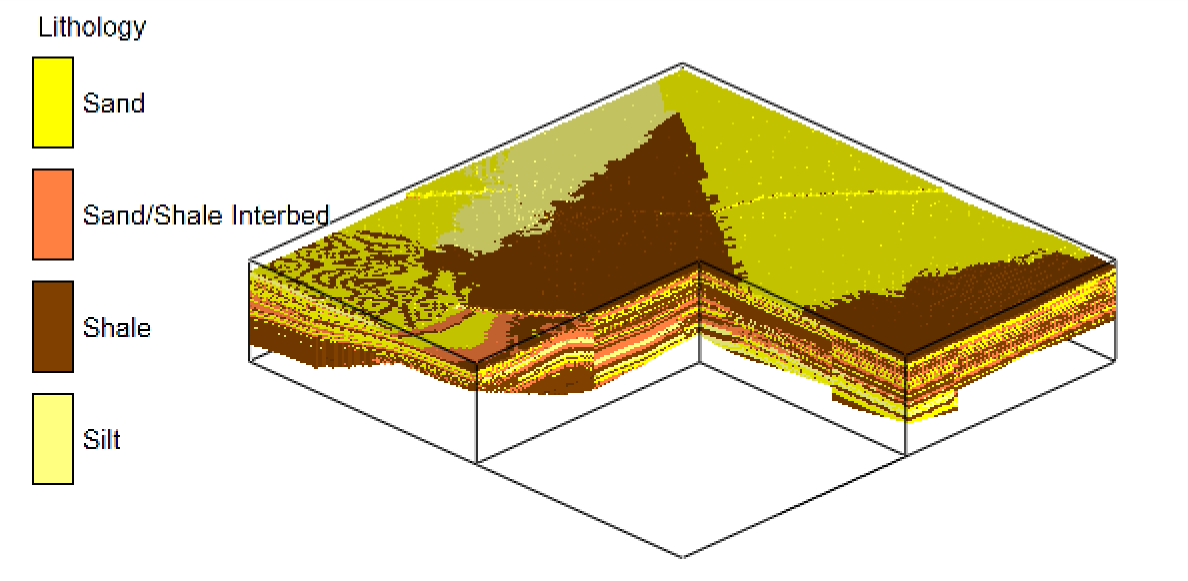
Using acquired seismic data, and well log data, assembled a 3D geologic earth model. Four lithology types: sand, sand-shale, silt, shale identified

Apply geologic model to:

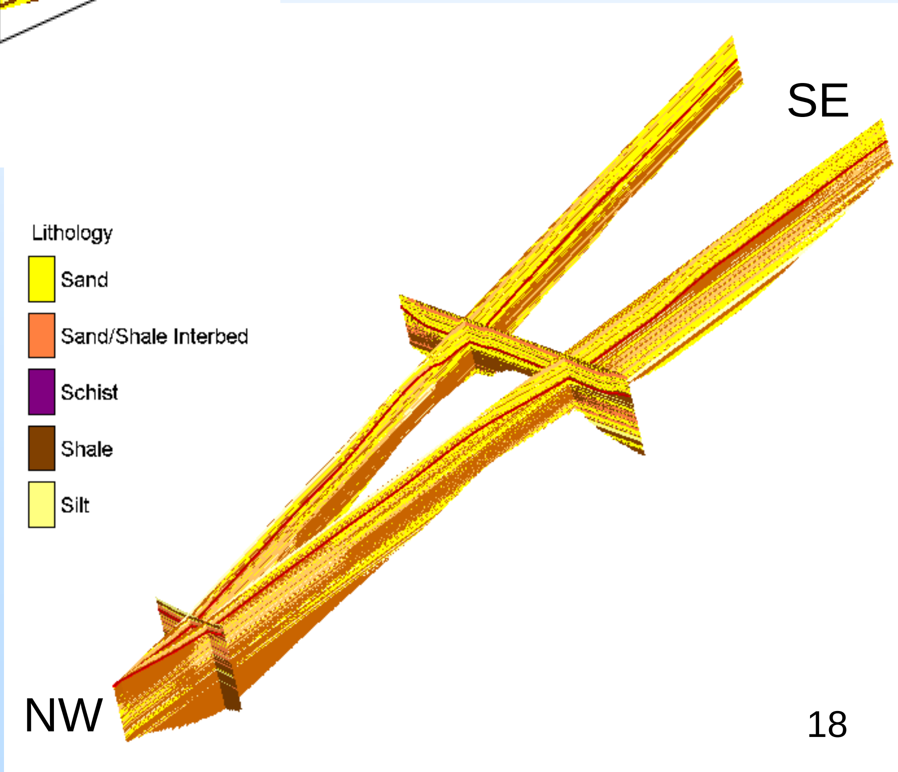
1. **Estimate storage capacity**
2. **Develop geomechanical model and simulation**
3. **Develop CO_2 injection and migration model and simulation**



Geologic Model of Wilmington-Graben



(Top Left) Lithology Model with cut-away view . (Bottom Right) Fence-Diagram.



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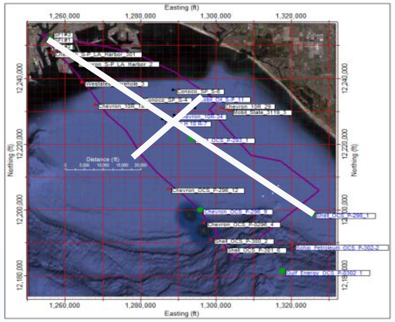
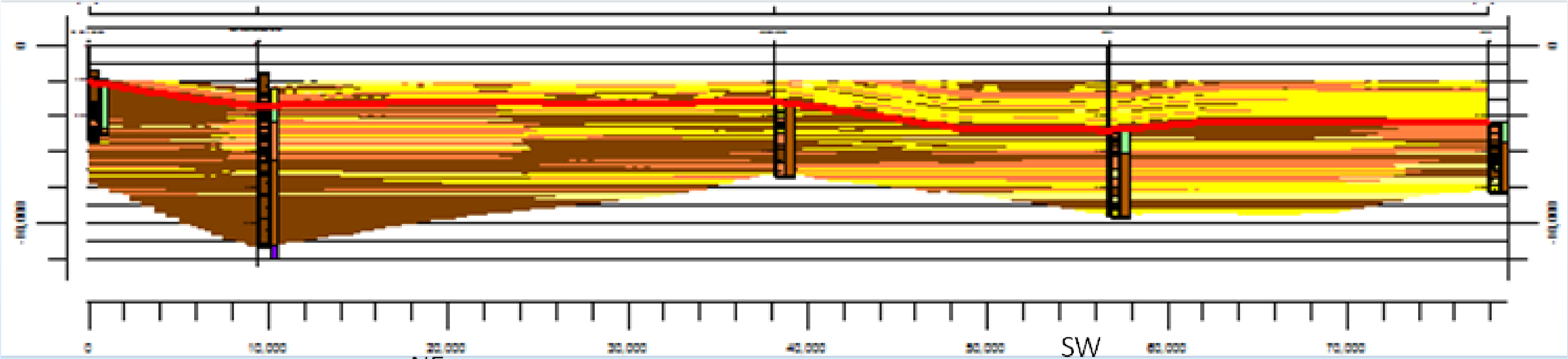


NW-SE and NE-SW Cross Sections

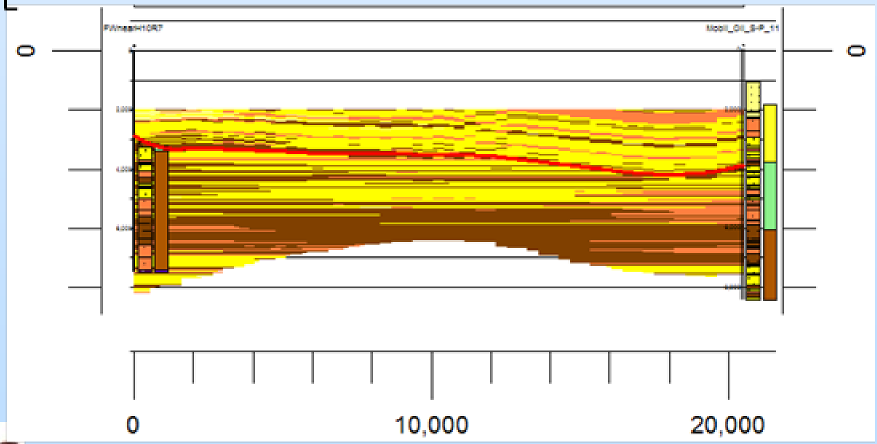
NW

SE



SW

NE



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Red line: Top Repetto Unconformity

Estimated Storage Capacity

Apply geologic model to:

1. **Estimate storage capacity**
2. **Develop geomechanical model and simulation**
3. **Develop CO_2 injection and migration model and simulation**

Storage capacity estimates:

Pliocene P10= 2.92E7

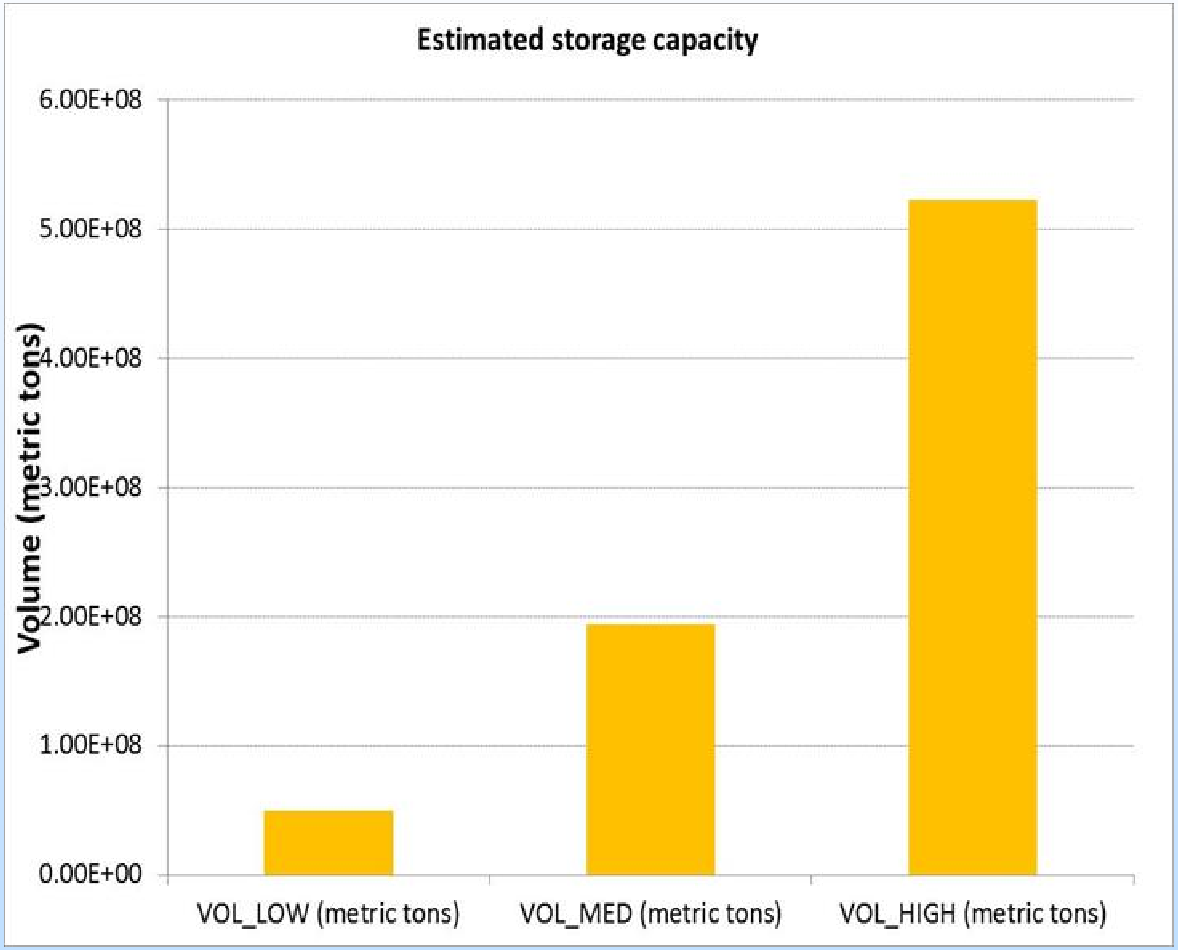
P50=1.15E8

P90=3.09E8

Miocene P10=2.02E7

P50=7.93E7

P90=2.14E8



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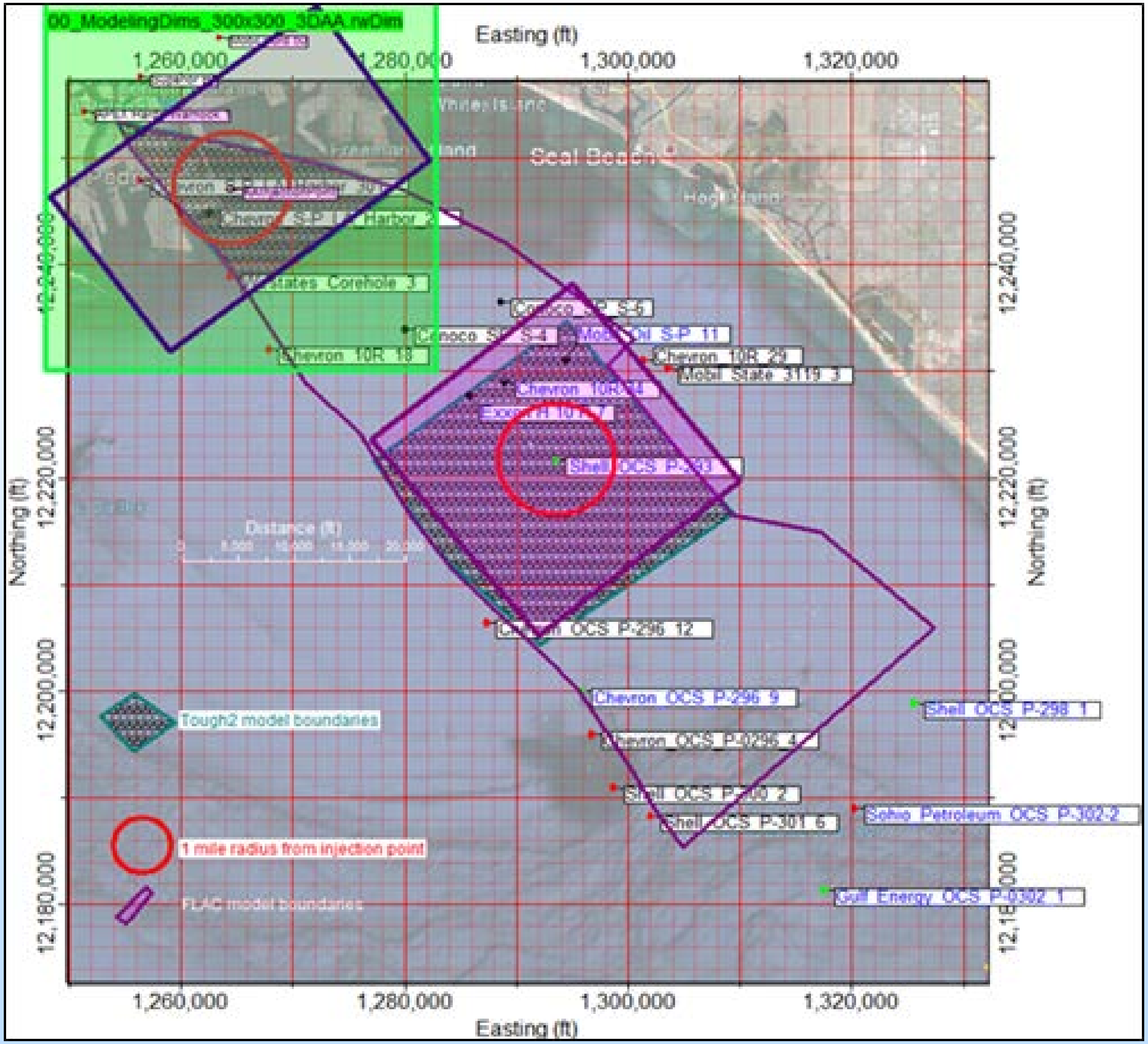
Boundaries for Flow and Geomechanics Models



Develop Flow Models to Assess:

1. **Injectivity per well**
2. **Gas migration vs time**
3. **Pressure change distribution for geomechanical analysis**

Develop Geomechanical Models to Assess:

1. **Induced seafloor deformations**
2. **Induced stresses**
3. **Fault activation risks**

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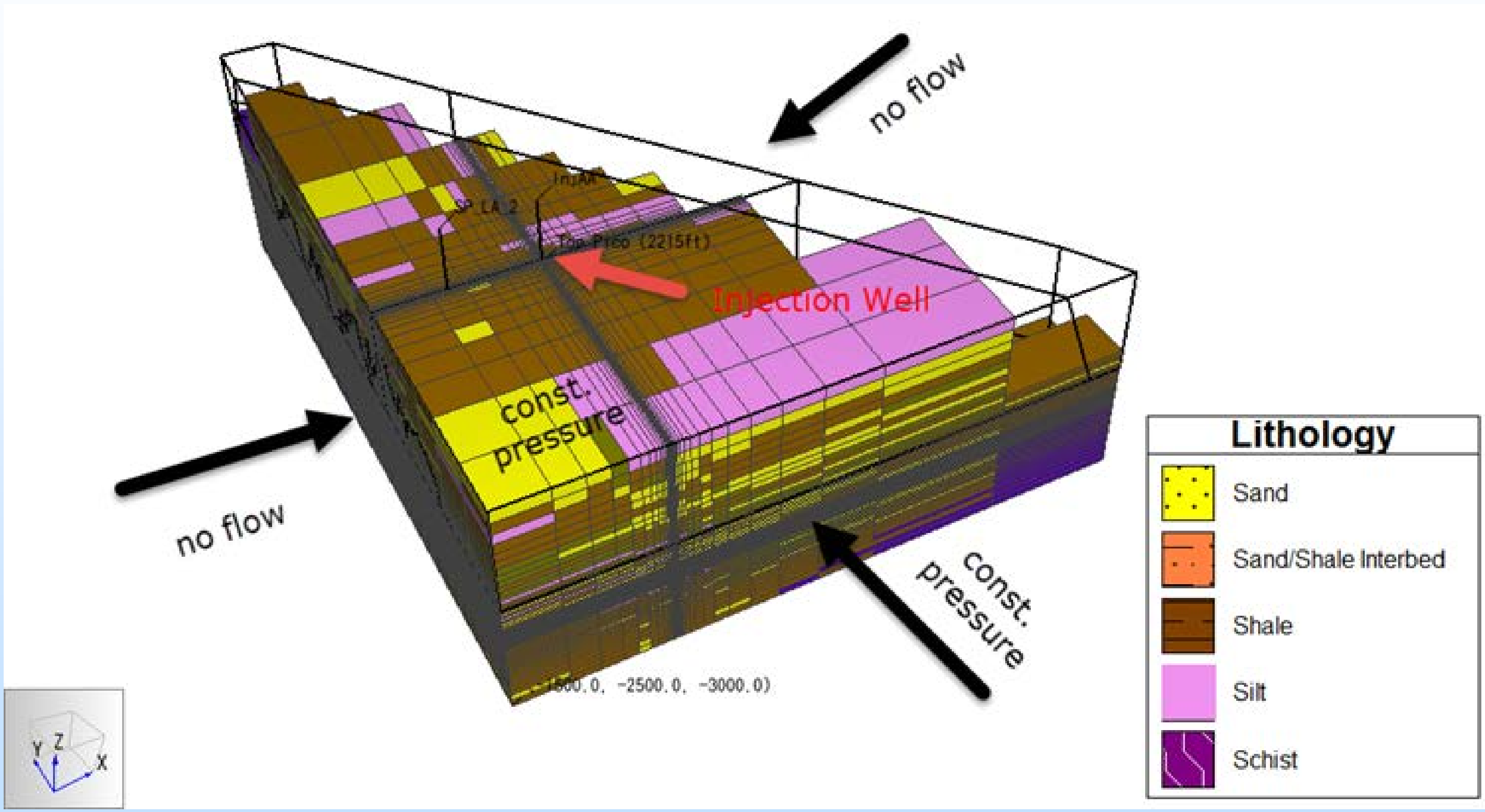
Conceptual fluid flow model NW Graben



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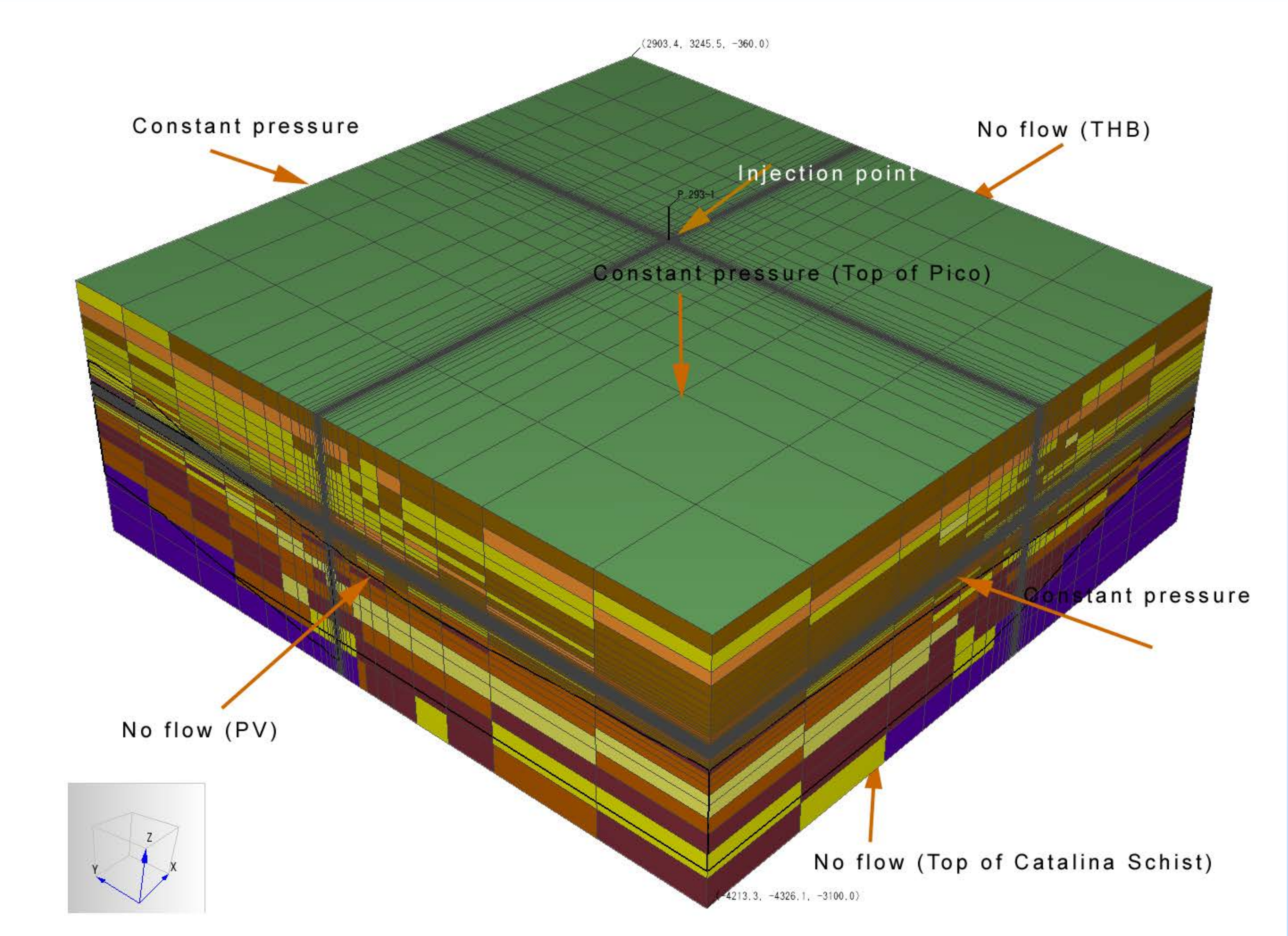
Conceptual Fluid Flow Model mid Graben area



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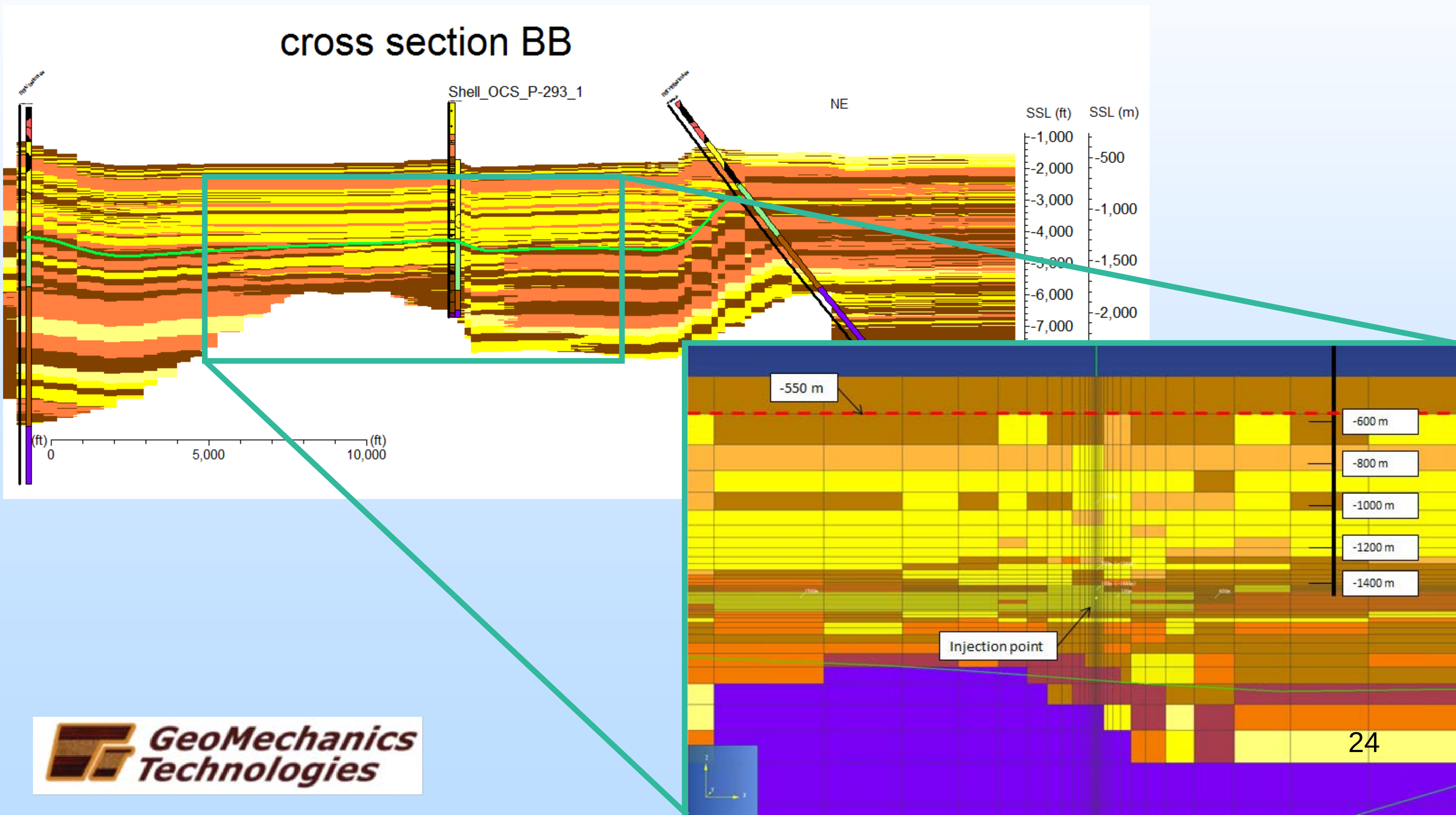
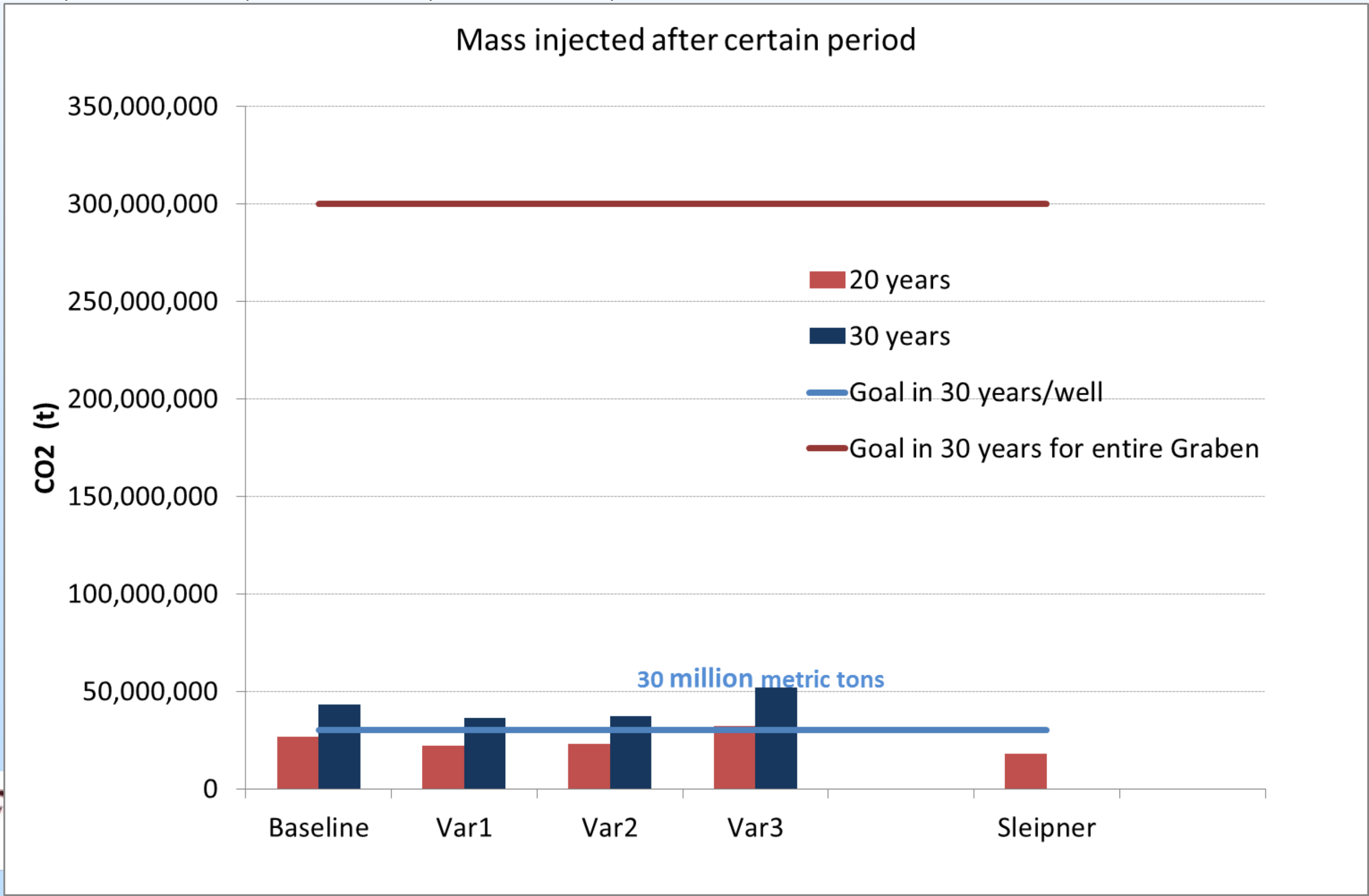
Mapping of lithology from RW to Tough2



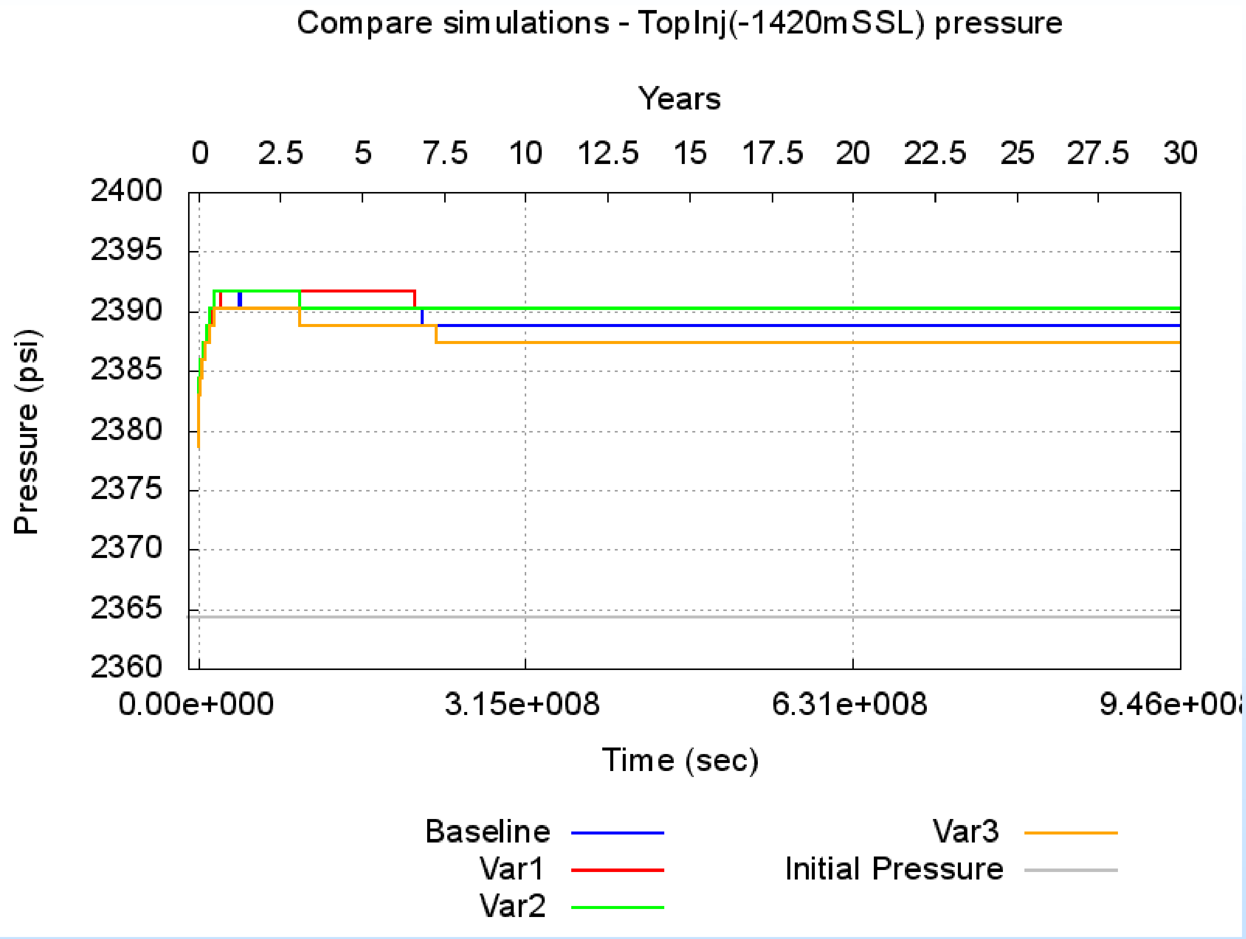
Different Injection Scenarios

Scenarios to be compared, showing volumes after 30 years continuous injection:

	Baseline	Var1	Var2	Var3
Interbed lithology type	sand/shale	shale		
shale z permeability (mD)	6/4		6x10-4/4x10-4	
# of cells	60,690			78,540



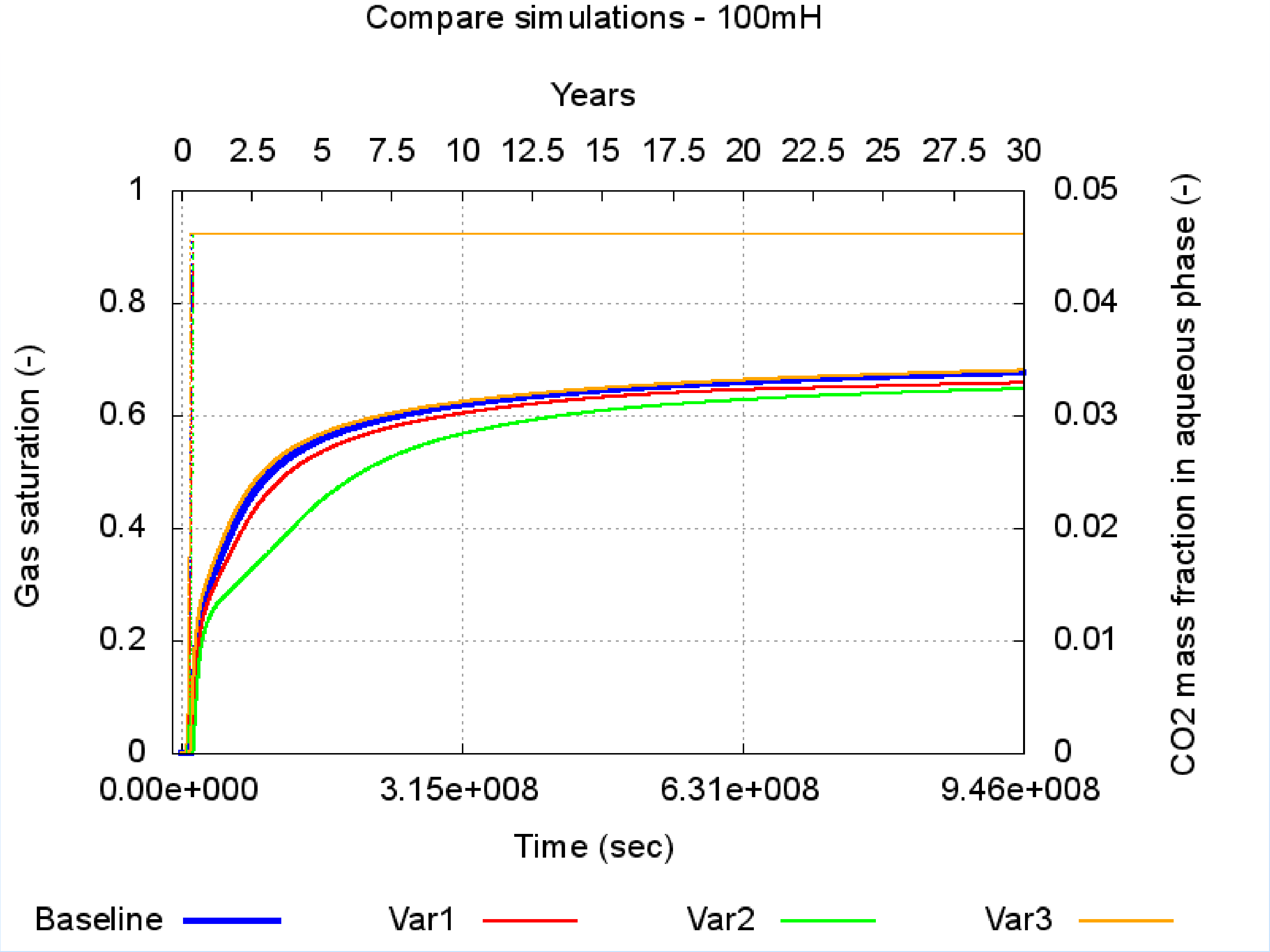
Comparing pressure at different monitoring points



ΔP at injection about 1.3% (30PSI), similar for all variations

	Baseline	Var1	Var2	Var3
Interbed lithology type	sand/shale	shale		
shale z permeability (mD)	6/4		6x10-4/4x10-4	
# of cells	60,690			78,540

Comparing gas saturation & CO2 mass fraction at different points



SC gas phase reaches 100m horizontal from well within 1 year

	Baseline	Var1	Var2	Var3
Interbed lithology type	sand/shale	shale		
shale z permeability (mD)	6/4		6x10-4/4x10-4	
# of cells	60,690			78,540

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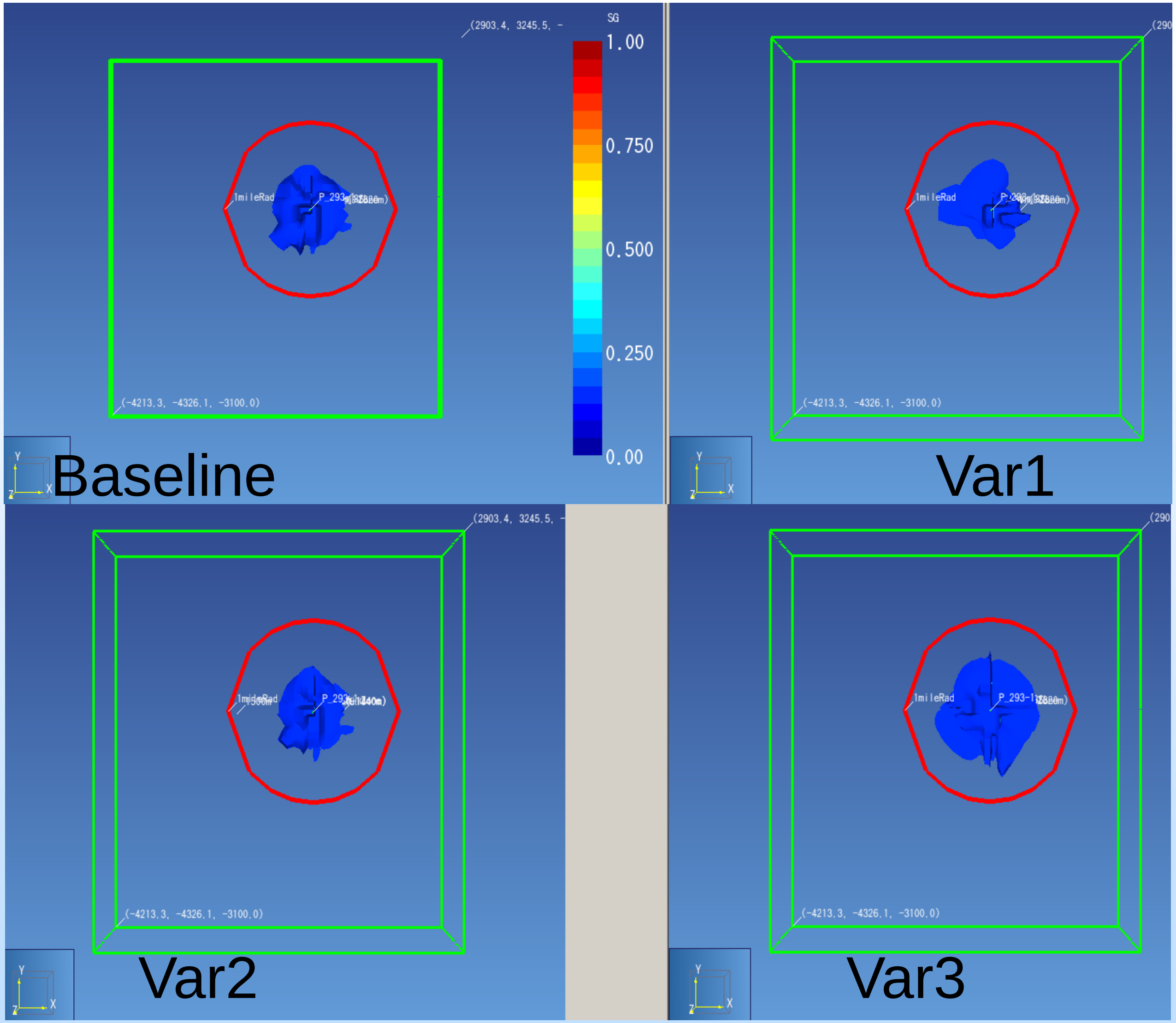
SC Gas saturation after 30 years – top view plume extent



→ Containment within 1 mile radius

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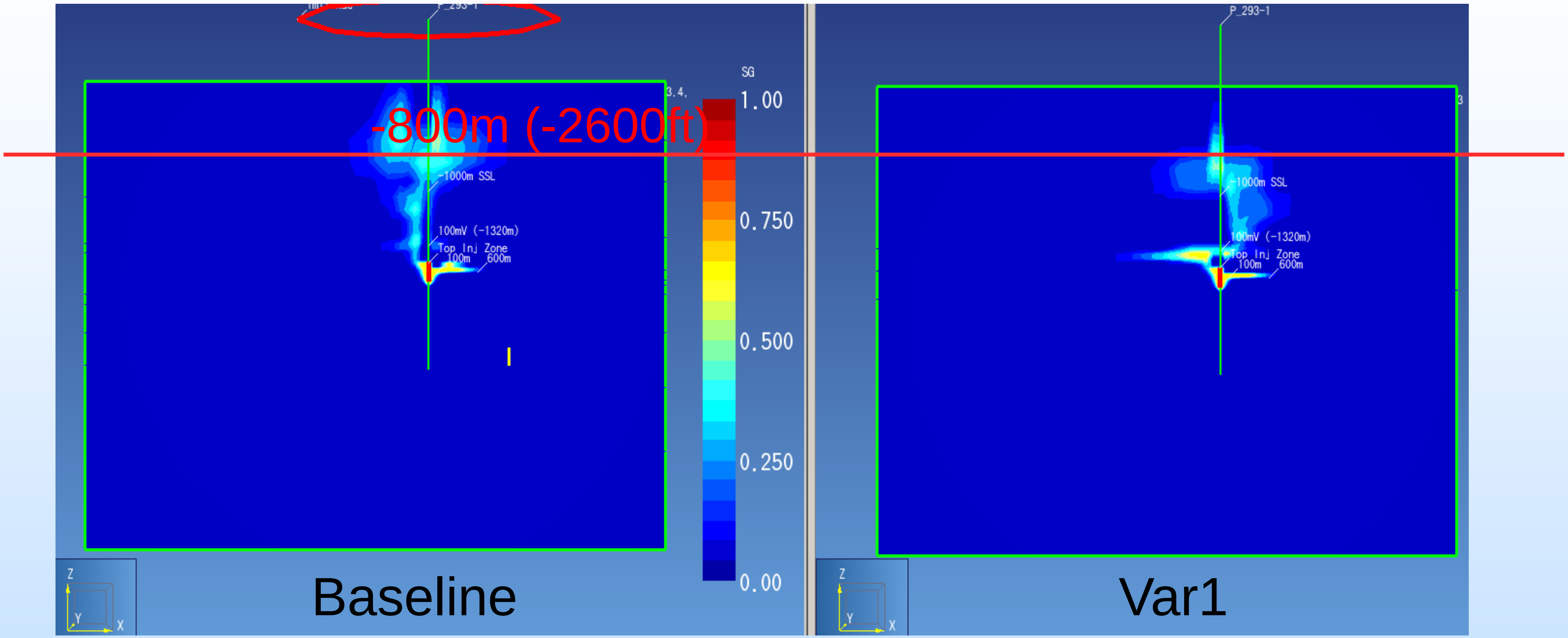
Gas saturation after 30 years –SW-NE cross section



→Assuming more shale than anticipated does not ensure containment.

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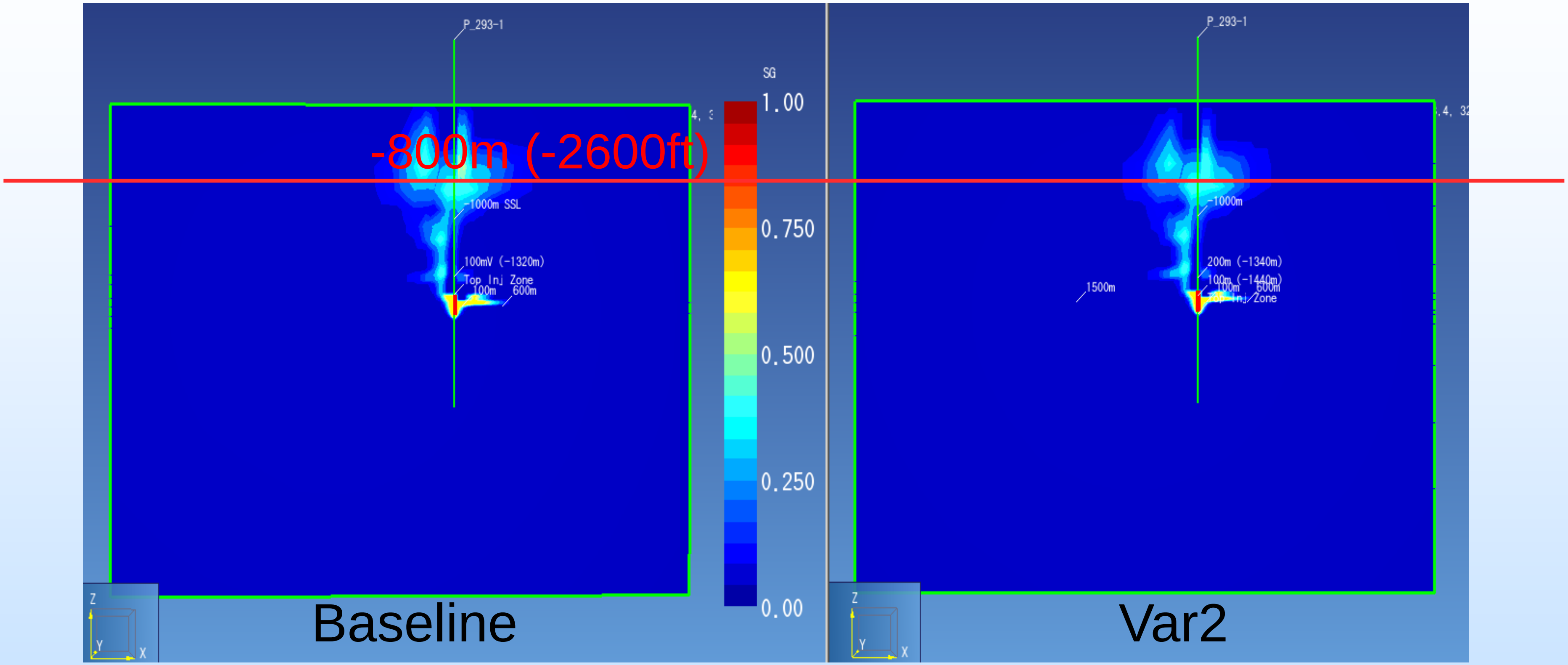
Gas saturation after 30 years –SW-NE cross section



→Assuming lower shale perm. than anticipated does not ensure containment.

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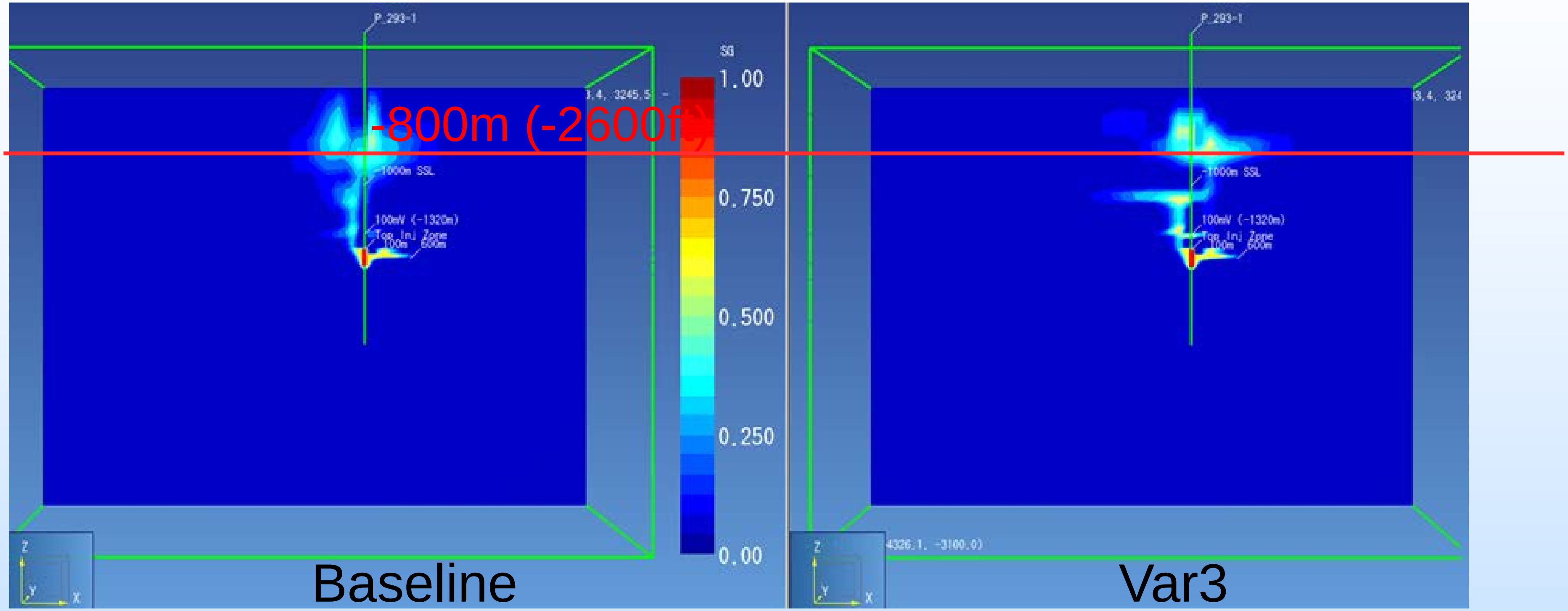
Gas saturation after 30 years –SW-NE cross section



→Refinement in vertical grid to catch various layers better does not ensure containment.

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Initial Simulation Implications

1. Sufficient volumes (100 million tons) can be injected into 3 or 4 wells while avoiding lateral migration to poorly cemented existing wells, by maintaining ½ mile offset distance.
2. Pressure change and stress changes are very modest.
3. For injection at depths shallower than about 6000 ft, however, vertical containment can not be assured for a range of geologic scenarios consistent with available data. Injection volumes would need to be restricted.
4. In summary, we do not recommend the relatively shallow Pliocene be considered further for large scale CO2 injection.

Appropriate Next step is to characterize the deeper Miocene Formation.

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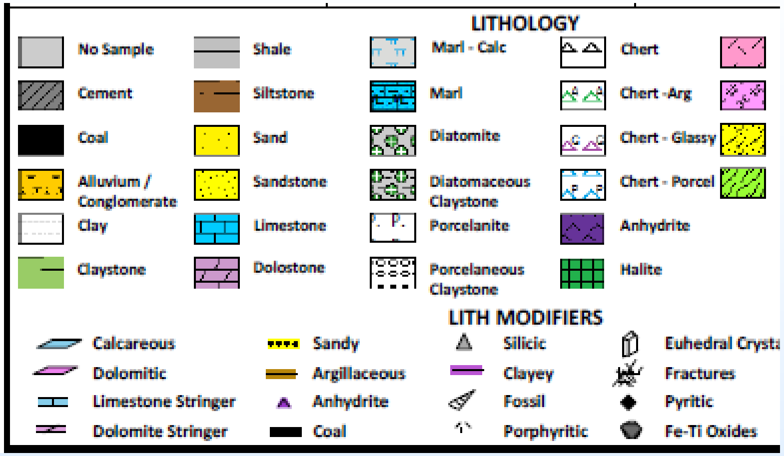
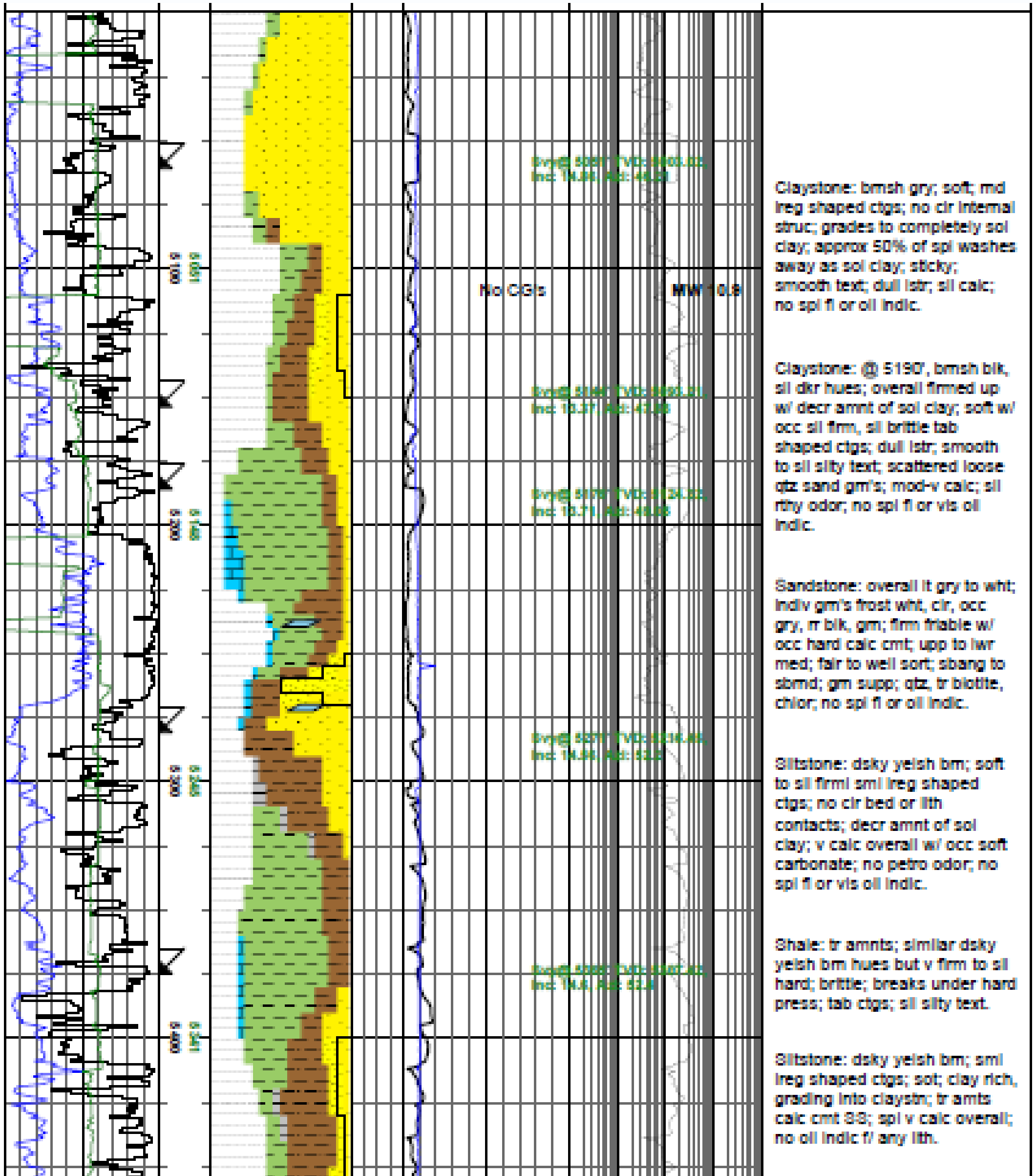
DOE# 2 spudded Feb 27, 2014

DOE# 2 well completed Mar 18, 2014

Key Findings From Drilling DOE #2





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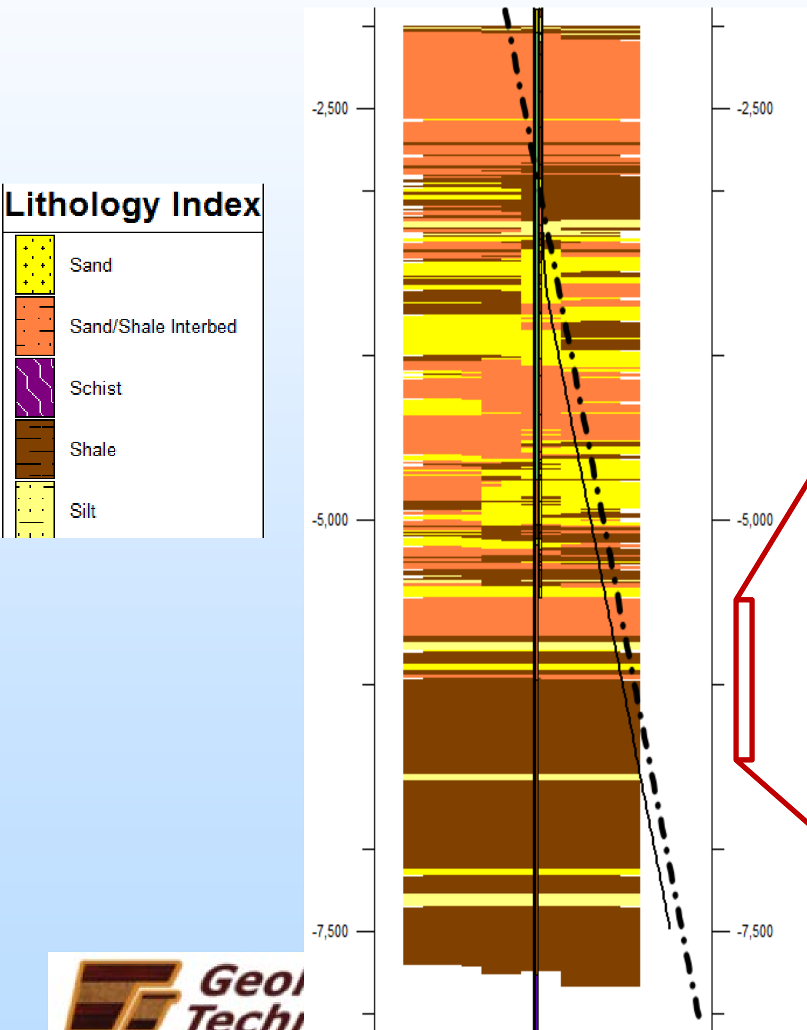
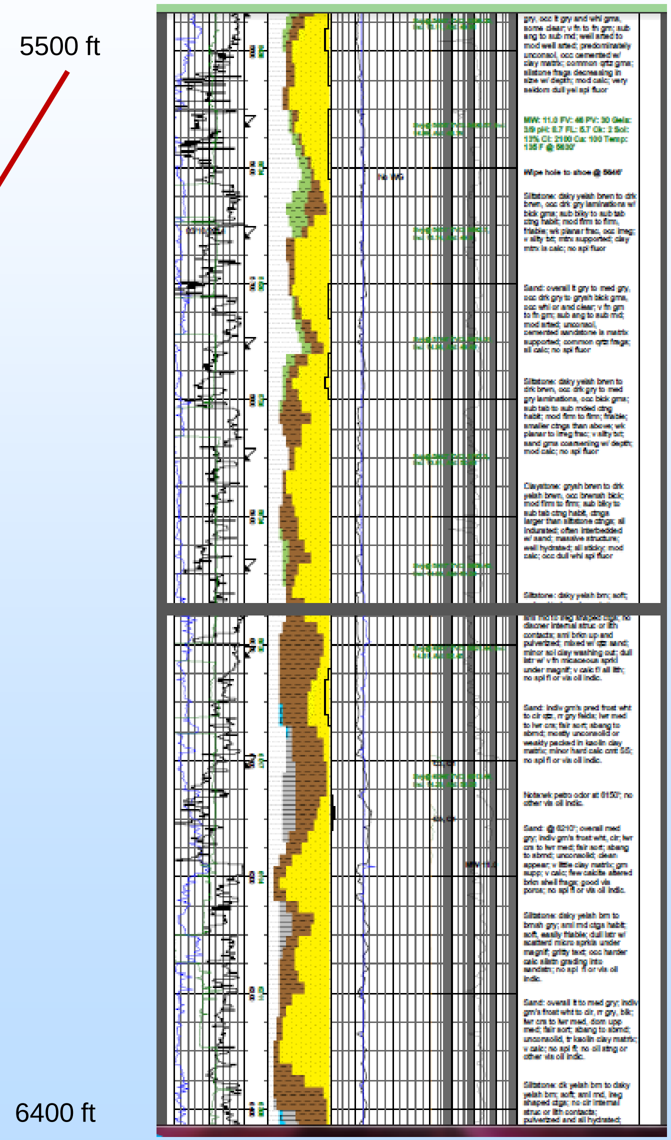
Key Findings From Drilling DOE #2

Initial model estimate at DOE2





Key Findings From Drilling DOE #2

- More sand within Lower Pliocene and Upper Miocene than previously anticipated
- Several good injection intervals, with one strong (200ft) shale cap
- Good correlation in sand intervals from Offset well SFI1 to DOE2
- Validation and good correlation for assumed faults and dip reversals, confirming updated geologic model for upper section
- Revisions required to Northern Graben geologic model for Miocene
- Motivation and justification for project to complete additional deep characterization in Northern Graben

Risk Assessment Includes:

- Lateral Migration to Poorly Cemented Offset Wells
  - ➢ Detailed well record review
  - ➢ Reservoir scale fluid and migration modeling

- Injection Well Failure and Transmission
  - ➢ Stress analysis, near-well migration modeling

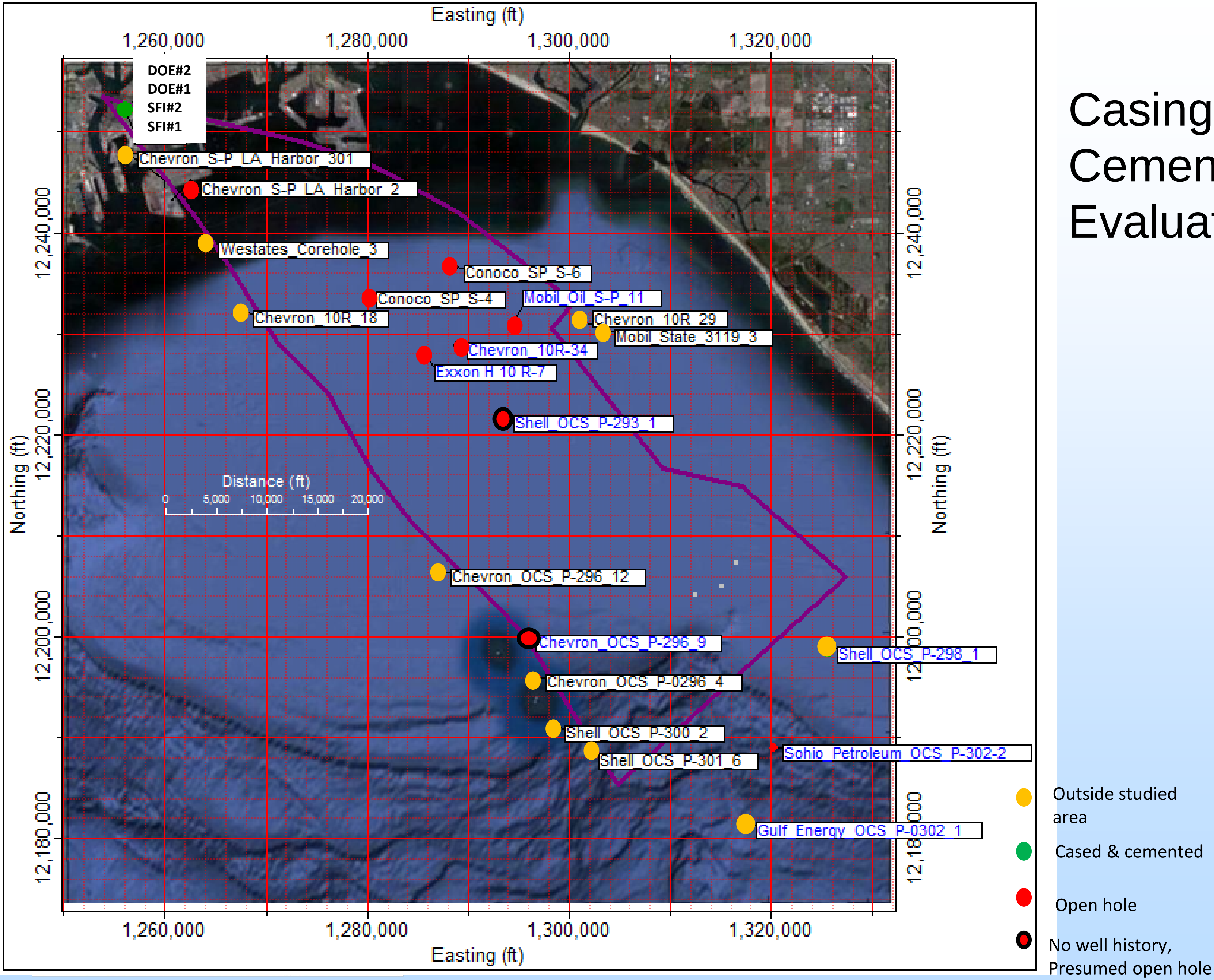
- Caprock Integrity Study
  - ➢ Geomechanical analysis of fracture and fault activation risk

- Natural Seismicity Risks
  - ➢ Historical review of impacts on O&G and Gas Storage operations

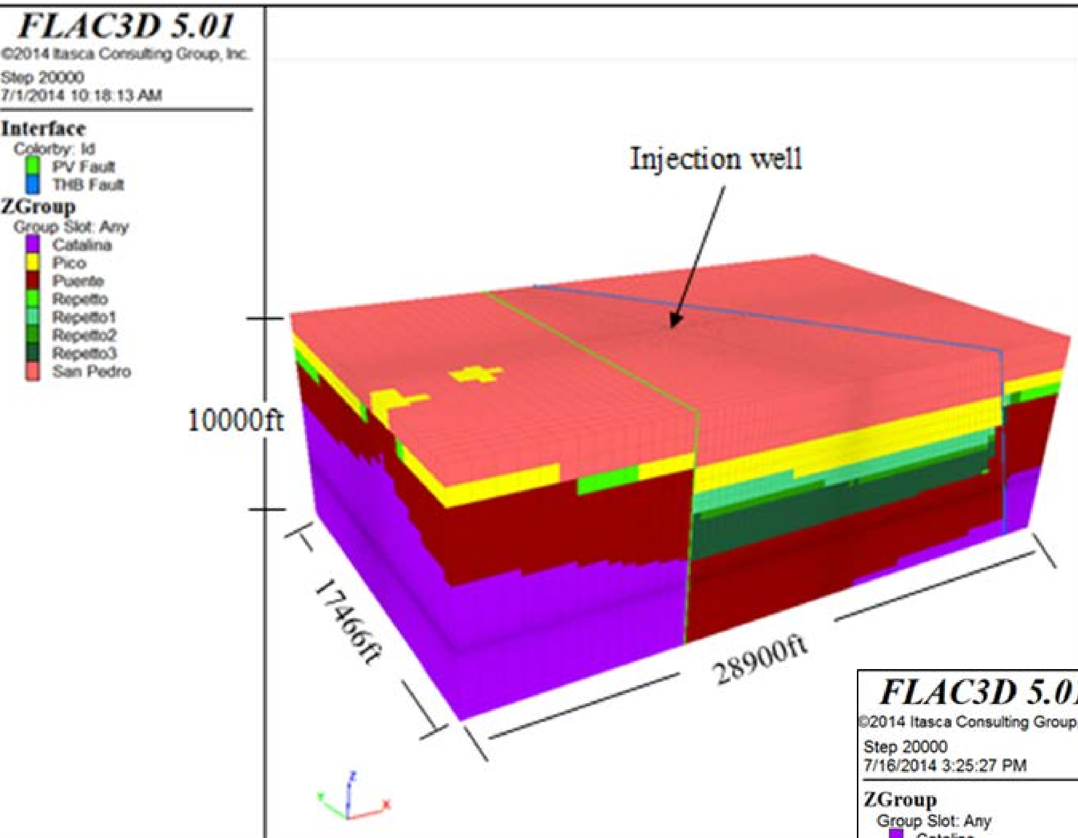
- Induced Seismicity Risks
  - ➢ Analog review, geomechanical analysis, microseismic monitoring

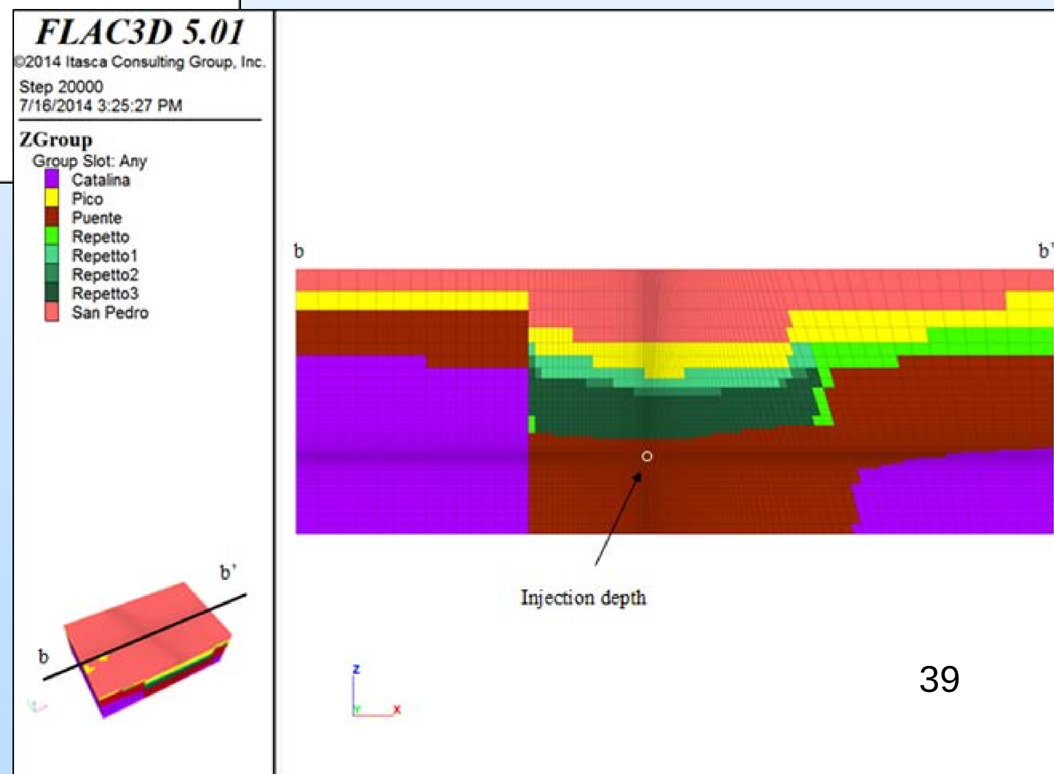
- CO2 Migration to Sea Floor
  - ➢ Analog review, rate assessment, and biologic impact estimate

Casing and Cement Evaluation



Geomechanical Model
--- Northern Graben





Dimension:
28900ft in x-direction
17466ft in y-direction
10000ft in z-direction
Total: 572,000 elements

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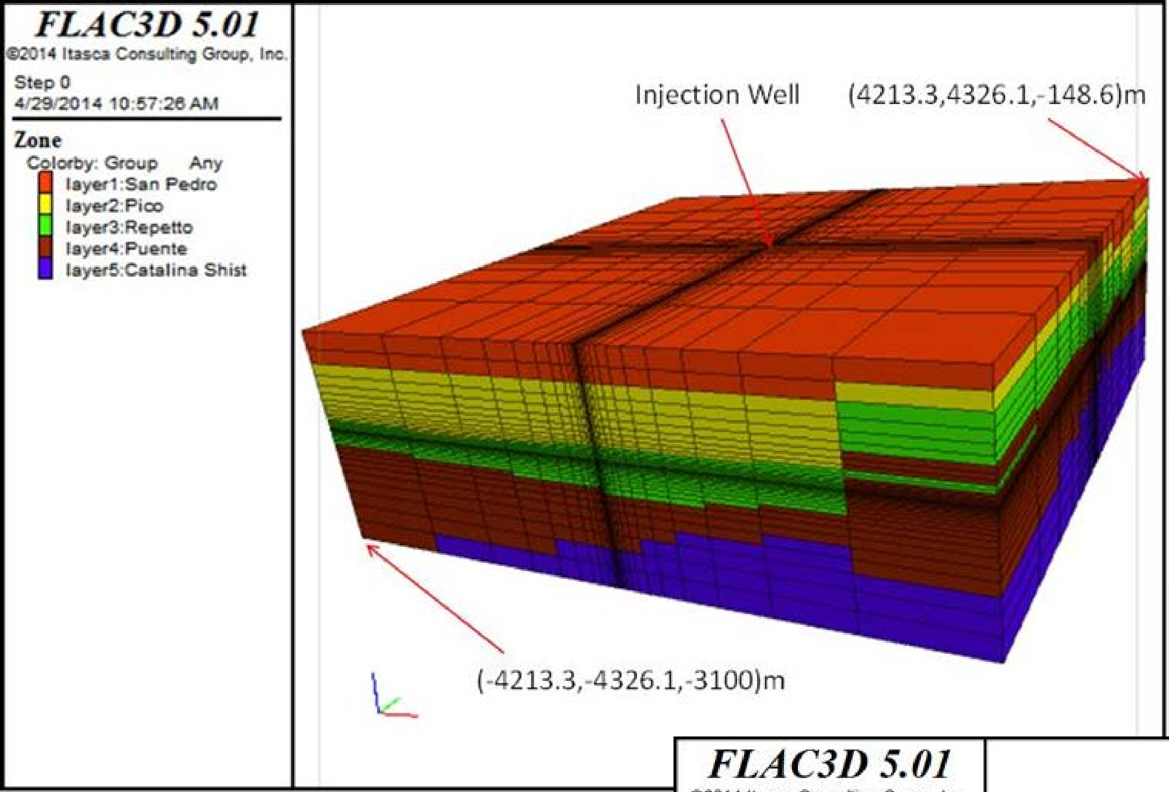
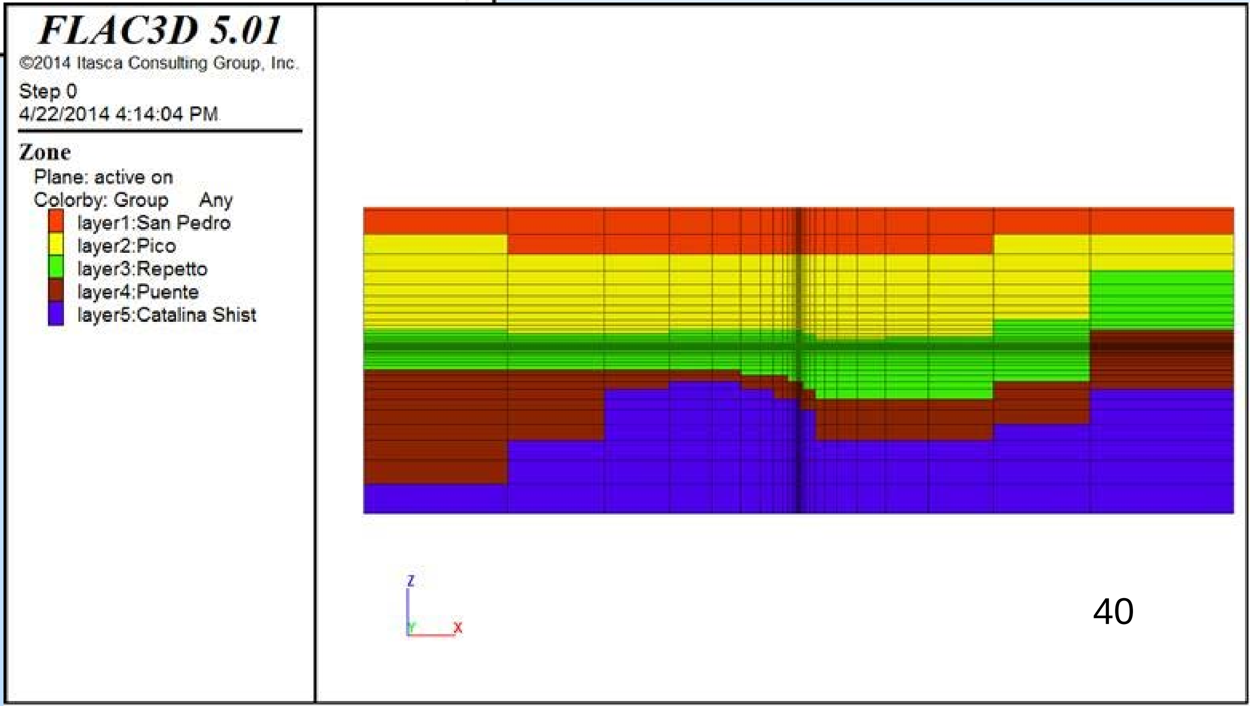
Geomechanical Model --- Central Graben



Dimension:
~ 28000ft in x & y direction
9678ft in z-direction
Total: 35,100 elements



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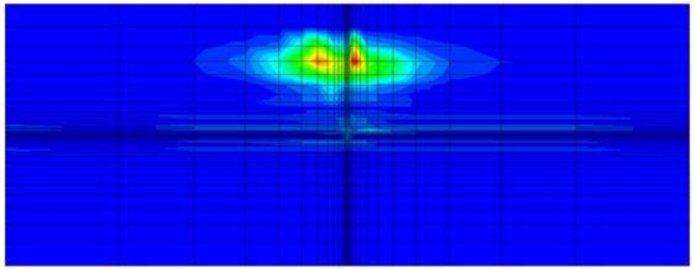
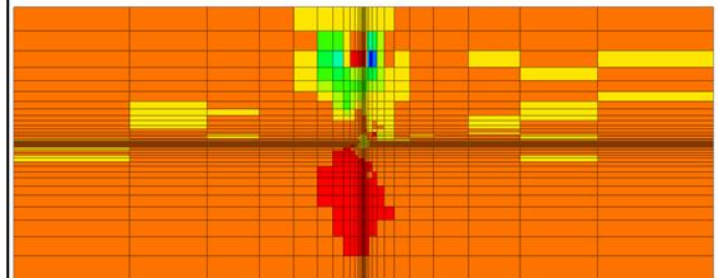
30 years delta pressure distribution – baseline (Pa)

NE-SW



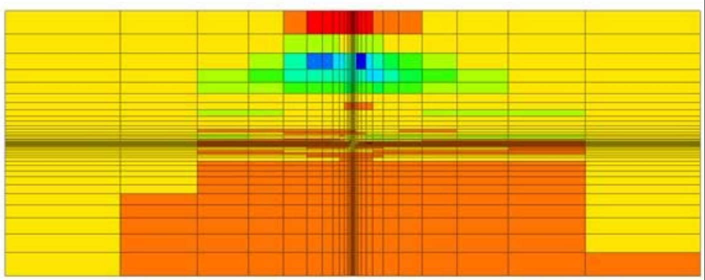
highest pressure above the injection interval, max magnitude of 9.7E5 Pa

Induced ZZ stress in NE-SW



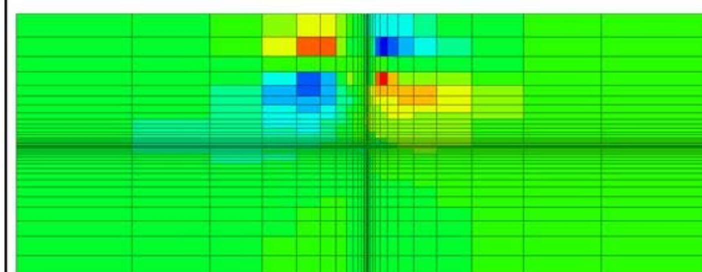
max compressive & tensile stresses above & below injection point -- 3.8E5 Pa and 9.8E4 Pa

Induced XX stress in NE-SW



max compressive stress 7.7E5 Pa, max tensile stress 1.7E5 Pa above & below pressure concentration area

Induced XZ stress in NE-SW



max shear stresses 1.0E5 Pa

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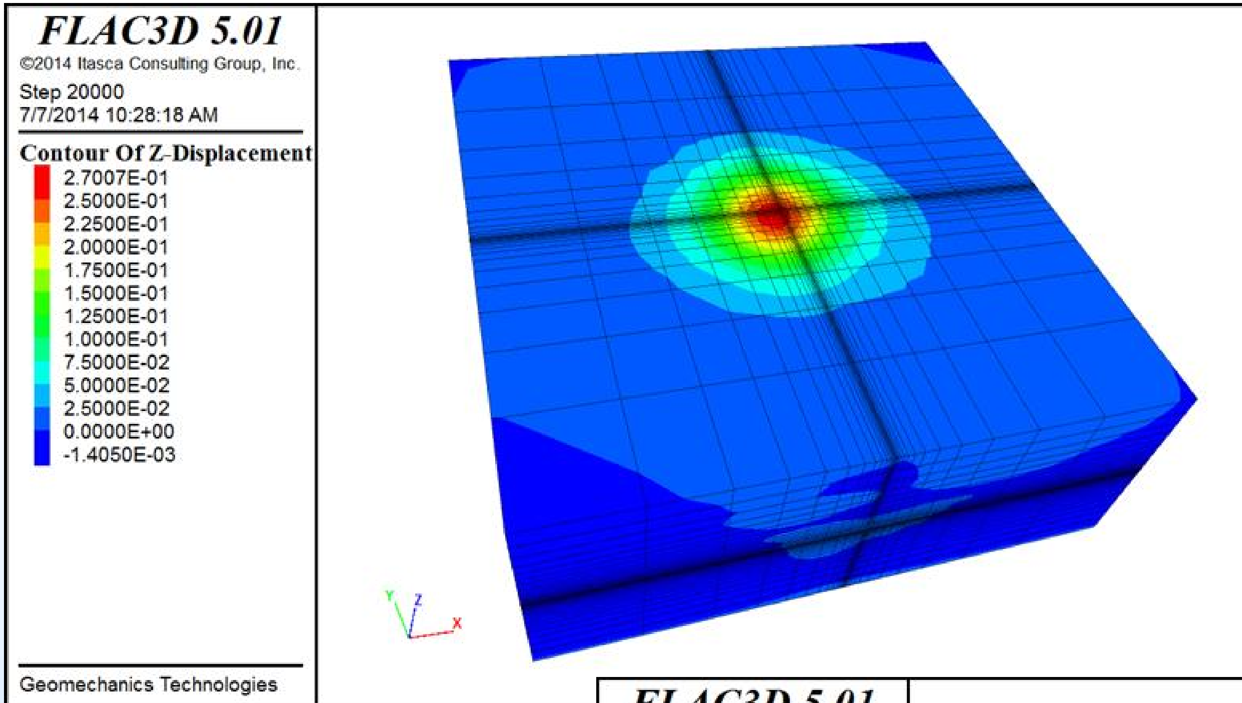
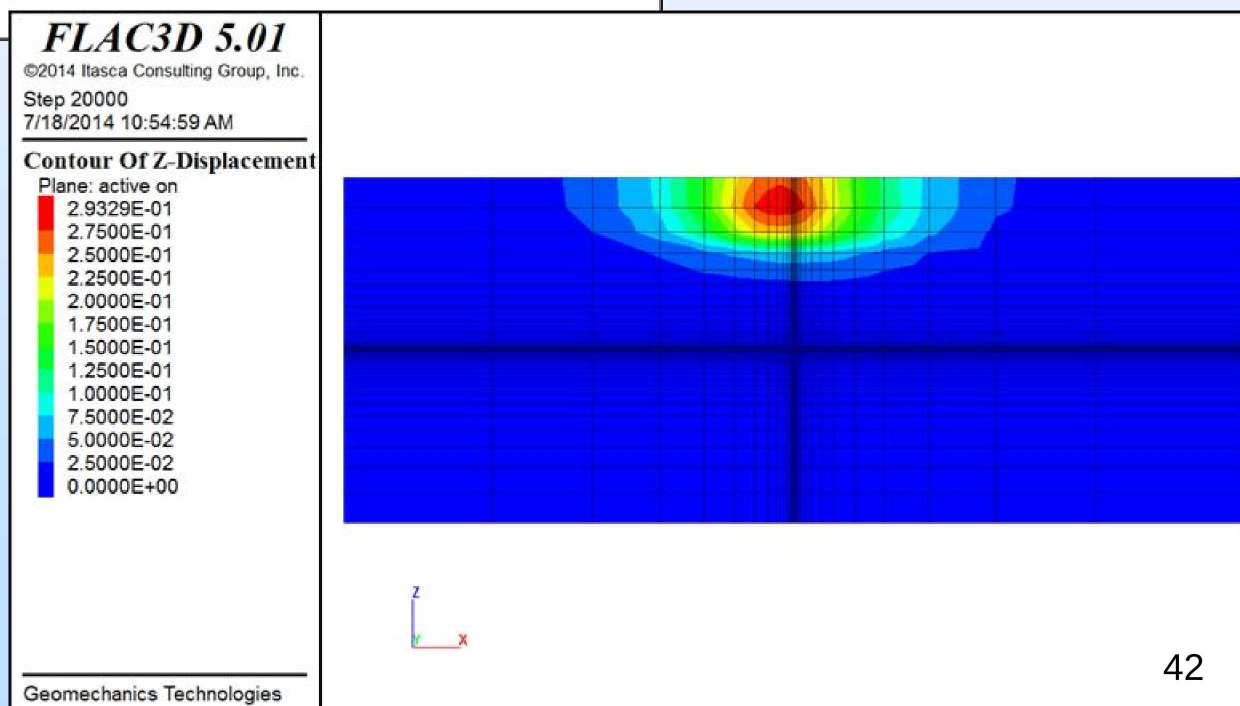
Induced seafloor deformation: 3D view & NE-SW direction across injection well





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Risk Matrix Evaluation Tool

CO_2 injection Risk Analysis Tool Wilmington Graben

MECHANICAL STATE

	tens frac		fault reac		well fail	
1. STRESS						
Max P/min princ stress						
a. ≥ 0,75	0	100	0	100	0	100
b. 0,5-0,75	1	10	1	10	1	10
c. ≤ 0,5	0	1	0	1	0	1
Stress regime						
a. Compressional	1	100	1	100	1	100
b. Transform	0	10	0	10	0	10
c. Extensional	0	1	0	1	0	1
Shmin/Sv						
a. < 0.55	0	1	0	100	0	100
b. 0.55-0.65	0	1	0	10	0	10
c. > 0.65	1	1	1	1	1	1
2. PRESSURE						
Desired Max P/Discovery P						
a. ≥ 1.5	0	100	0	100	0	100
b. 1.25-1.5	0	10	0	10	0	10
c. ≤ 1.25	1	1	1	1	1	1
Max P/formation depth						
a. ≥ 0.75	0	100	0	100	0	100
b. 0.625-0.75	0	10	0	10	0	10
c. ≤ 0.625	1	1	1	1	1	1
3. FAULTS						
Fault boundaries						
a. Multiple bounding faults	1	1	1	100	1	100
b. One bounding fault	0	1	0	10	0	10
c. None	0	1	0	1	0	1
Natural seismicity						
a. High	1	100	1	100	1	100
b. Moderate	0	10	0	10	0	10
c. Low	0	1	0	1	0	1
Category Score	214		313		313	
Category Total Score	840	*1902*				
TOTAL SCORE	1839	*4314*				

CAPROCK-STORAGE ZONE SYSTEM

	tens frac		fault reac		well fail	
4. STORAGE ZONE SPECIFIC						
Lateral extent/storage zone depth						
a. <25	1	100	1	100	1	100
b. 25-100	0	10	0	10	0	10
c. >100	0	1	0	1	0	1
Storage zone thickness/storage zone depth						
a. > 0.5	0	100	0	100	0	1
b. 0.1-0.5	0	10	0	10	0	1
c. < 0.1	1	1	1	1	1	1
5. CAPROCK SPECIFIC						
Caprock heterogeneity						
a. Significant	1	100	1	100	1	1
b. Moderate	0	10	0	10	0	1
c. Low	0	1	0	1	0	1
Caprock strength						
a. Weak	0	100	0	100	0	100
b. Moderate	1	10	1	10	1	10
c. Strong	0	1	0	1	0	1
Caprock thickness						
a. ≤ 3m	0	100	0	100	0	1
b. 3-30 m	1	10	1	10	1	1
c. ≥ 30 m	0	1	0	1	0	1
Caprock lateral extent/caprock thickness						
a. <25	1	100	1	100	1	100
b. 25-100	0	10	0	10	0	10
c. >100	0	1	0	1	0	1
Caprock permeability						
a. k > 1E-15 m2	0	100	0	1	0	1
b. 1E-18 m2 ≤ k ≤ 1E-15 m2	1	10	1	1	1	1
c. k < 1E-18 m2	0	1	0	1	0	1
Number of caprocks						
a. Single	0	100	0	100	0	100
b. Double	0	10	0	10	0	10
c. Multiple	1	1	1	1	1	1
Caprock dip						
a. γ ≥ 8°	1	1	1	100	1	1
b. 2°≤γ≤8°	0	1	0	10	0	1
c. γ ≤ 2°	0	1	0	1	0	1
Category Score	333		423		216	
Category Total Score	972	*2007*				

OPERATIONS

	tens frac		fault reac		well fail	
6. OPERATIONS						
Well density						
a. > 15 km-2	0	1	0	1	0	100
b. 5-15 km-2	0	1	0	1	0	10
c. < 5 km-2	1	1	1	1	1	1
No. of uncased wells/total no. of wells						
a. > 0.6	0	1	0	1	0	100
b. 0.2-0.6	0	1	0	1	0	10
c. < 0.2	1	1	1	1	1	1
ΔT between CO_2 and storage zone						
a. ≥ 60 °C	0	100	0	100	0	1
b. 30 °C - 60 °C	1	10	1	10	1	1
c. ≤ 30 °C	0	1	0	1	0	1
Category Score	12		12		3	
Category Total Score	27	*405*				

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Absolute risk scores for the different example cases

Category	Range of risk scores	Kevin Dome	Loudon	Wilmington Graben	Sleipner	In Salah
Mechanical state	21-1902	345	660	840	102	390
Caprock-Storage Zone system	27-2007	27	45	972	342	27
Operations	9-405	9	27	27	9	27
TOTAL	57-4314	381	732	1839	453	444

The relative risk ranking based on three types of risk factors

Category	Range of risk scores	Kevin Dome	Loudon	Wilmington Graben	Sleipner	In Salah
Tensile fracturing	19-1405	127	235	559	154	145
Fault (re)activation	19-1603	127	244	748	154	154
Wellbore failure	19-1306	127	253	532	145	145
TOTAL	57-4314	381	732	1839	453	444

The relative risk ranking based on failure type

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Risk Analysis and Practical Logistics

Logistics Evaluation Includes:

1. Identify and characterize top 20 sources in LA Basin
   - Include on Interactive Google Earth Map
   - Contribute to NATCARB Atlas and Database

2. Evaluate pipeline and storage field infrastructure in LA Basin
   - Location and design of existing oil and gas lines
   - Location of existing storage fields
   - Requirements for transport from major sources to Graben area
   - Typical design and cost for CO_2 transmission lines

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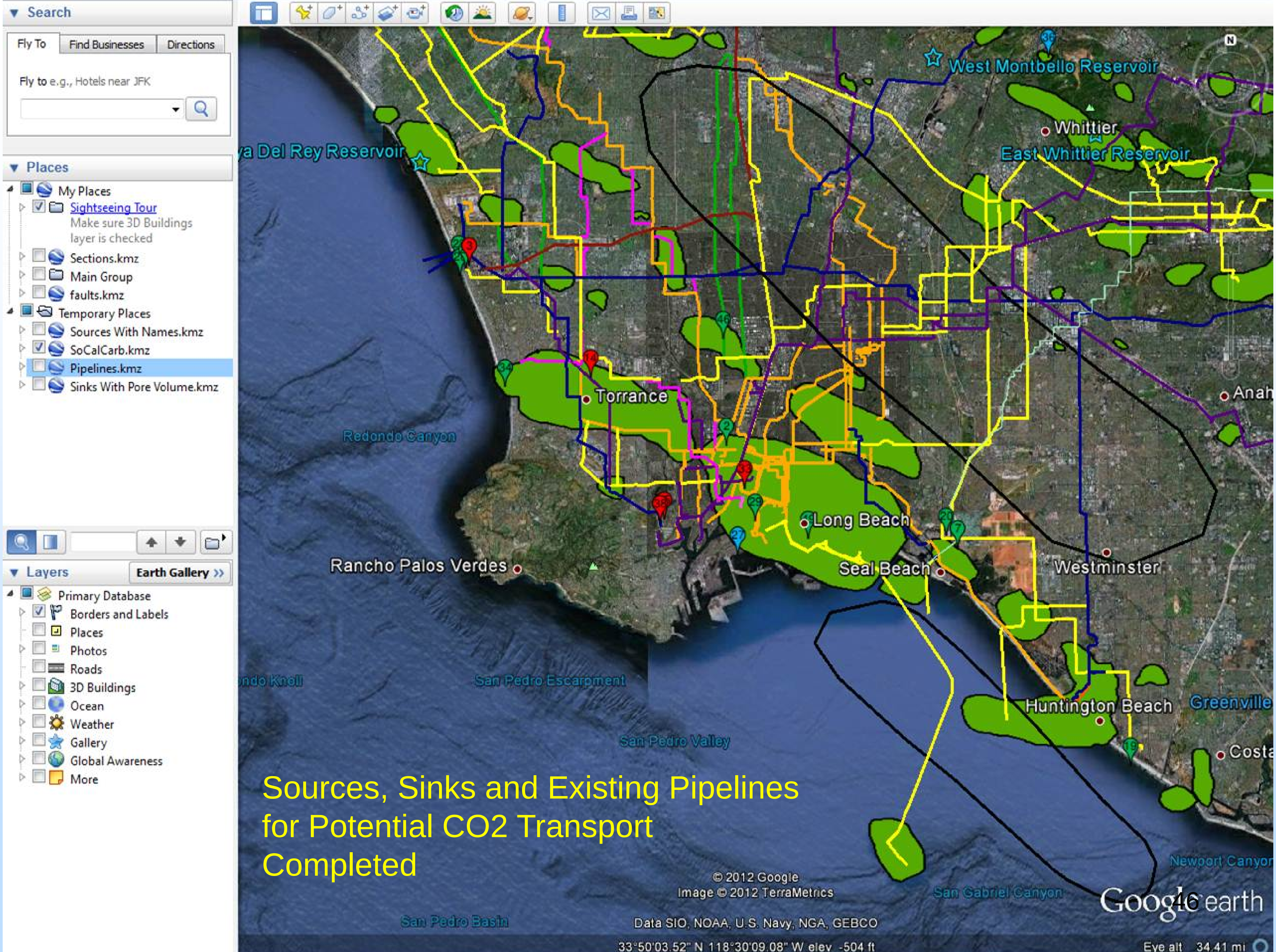

Sources, Sinks and Existing Pipelines for Potential CO2 Transport Completed
Search
Fly To
Find Businesses
Directions
Fly to e.g., Hotels near JFK
Places
My Places
Sightseeing Tour
Make sure 3D Buildings layer is checked
Sections.kmz
Main Group
faults.kmz
Temporary Places
Sources With Names.kmz
SoCalCarb.kmz
Pipelines.kmz
Sinks With Pore Volume.kmz
Layers
Earth Gallery
Primary Database
Borders and Labels
Places
Photos
Roads
3D Buildings
Ocean
Weather
Gallery
Global Awareness
More
West Montbello Reservoir
Whittier
East Whittier Reservoir
a Del Rey Reservoir
Torrance
Redondo Canyon
Long Beach
Seal Beach
Westminster
Rancho Palos Verdes
Anah
ndo Knoll
San Pedro Escarpment
San Pedro Valley
Huntington Beach
Greenville
Costa
Newport Canyon
San Gabriel Canyon
San Pedro Basin
© 2012 Google
Image © 2012 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
33°50'03.52" N 118°30'09.08" W elev -504 ft
Eye alt 34.41 mi
Google earth

Accomplishments to Date

- Detailed log evaluation of existing exploration wells in the area
- Improved evaluation and interpretation of existing 2D and 3D seismic data
- Acquisition and interpretation of additional 175 km of 2D seismic lines
- DOE#1 (onshore Pliocene) well drilled and analyzed
- DOE#2 well drilled March, 2014. Core data being analyzed
- Completed development of 3D geologic models, geomechanical and CO_2 injection and migration models. Re-running models based on new data obtained from DOE#2 well.
- Completed analysis of top 20 industrial sources in the LA Basin and transportation infrastructure. Developed interactive map/atlas (www.socalcarb.org)
- Completed quantitative risk analysis for Wilmington Graben

Summary

- Identified >400ft of Pliocene and >150ft of Miocene sands
- Interactive map of sources, sinks, pipeline completed
- Simulation models indicate that for long-term injection into relative shallow Pliocene Formation (about 5000ft), vertical containment can not be assured. Deeper characterization required.
- Additional simulations are being completed to evaluate deeper injection options within the Miocene Formation (6500 to 7500 ft depth).
- Geomechanical analysis indicates little risk for surface deformation, induced stresses, and induced seismicity
- Qualitative risk analysis and ranking indicates Wilmington Graben storage relatively higher risk than other potential storage sites within the US.

Next Steps:

- Perform microseismic monitoring to better assess induced seismicity risks
- Deepen offset well to 7500 ft, updating storage and viability recommendations
- Complete and submit technical report to DOE

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Appendix

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

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Organization Chart

- Principal Investigator
  - Dr. Mike Bruno
- Project Manager & Sr Geologist
  - Jean Young
- Sr Research Engineer
  - Julia Diessl
  - Kang Lao
  - Juan Ramos
- Research Engineer
  - Jing Xiang
- Research Geologist
  - Nicky White
  - Bill Childers
- Contractors
  - Dr. Mark Legg
  - Dr. Dan Francis
  - Don Clarke
  - Drilling crew
  - Logging crew
- Partners
  - City of Los Angeles
  - California Energy Commission
  - CA State University, Long Beach
  - USGS

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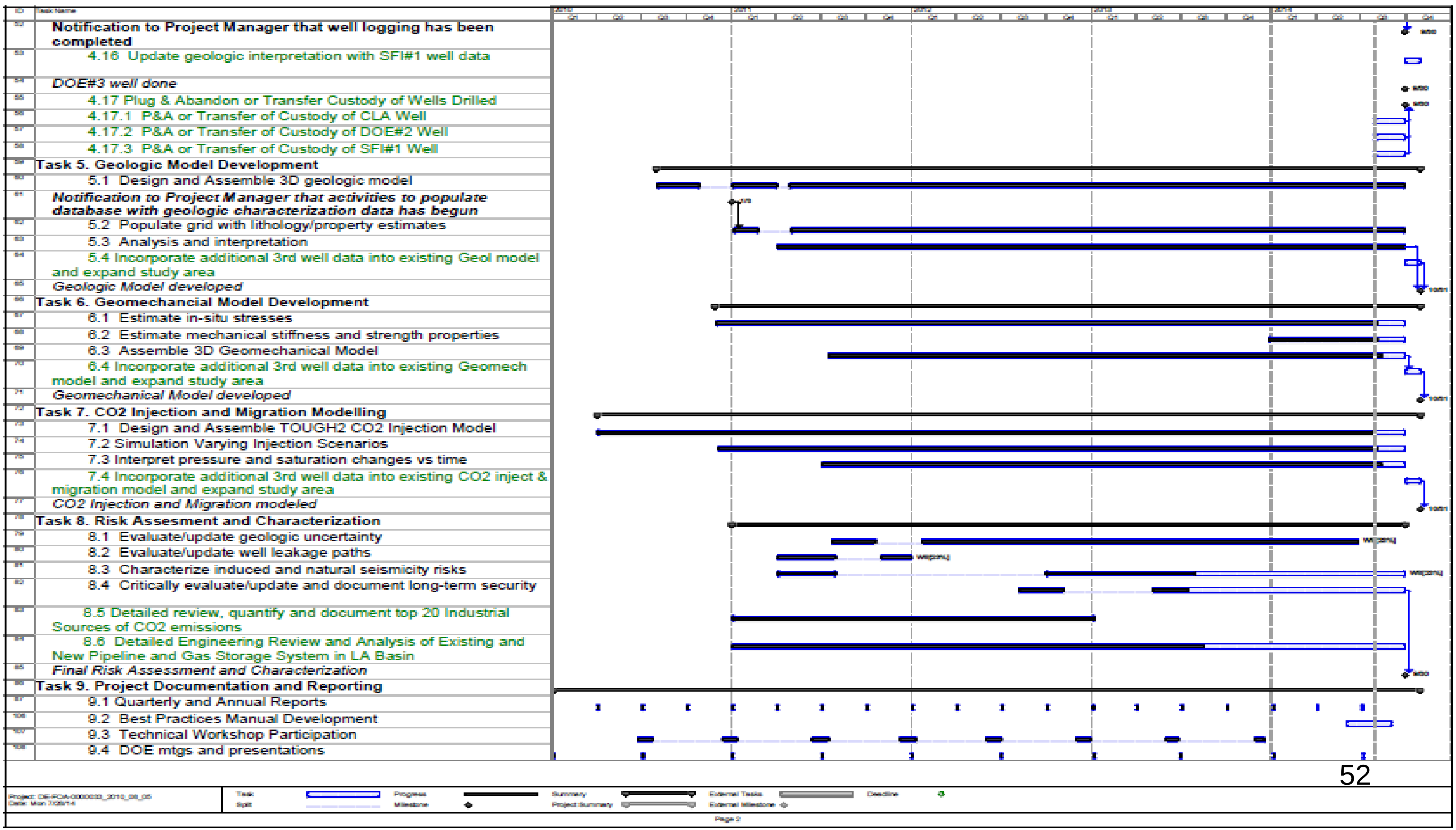
Gantt Chart

Task 1. Project Mgmt & Planning
1.1 Kickoff mtgs and planning discussions w/ DOE
Document links between project and RCSPs and
1.2 RCSP and NATCARB Coordination and Data Sharing
1.3 Project Management and Oversight
1.4 Coordinate, communication, participation w/CEC
Updated Project Management Plan
Submit Site Characterization Plan
Task 2. Seismic Data Analysis and Interpretation
Task 3. Well Data Review and Formation Evaluation
3.1 Data sharing & collaboration /USGS and CSLB
Notification to Project Manager that reservoir data collection has been initiated
3.2 Existing offshore well data assembly and review
3.3 Tie-in to seismic data and Wilmington field data
3.4 Analysis and Interpretation
3.5 Quantify Pliocene and Miocene targets and seals
3.6 Additional wells & saline fms evaluation surrounding Wilmington Graben
Well Data Reviewed and Formation Evaluated
Task 4. New well drilling, logging, and core analysis
DOE#1 well completed
Preliminary Estimate of Storage Vollume, Seals Risks: GO-NO-GO decision point
4.6 DOE#2 well design and drilling contractor selection
Notification to Project Manager that subcontractors have been identified for drilling/field service operations
Notification to Project Manager that field service operations have begun at the project site
4.7 Drill, log and core DOE#2 well (engineering oversight)
Notification to Project Manager that characterization wells have
4.8 DOE#2 well Log analysis and Core analysis
Notification to Project Manager that well logging has been completed
4.9 DOE#2 well injection testing and interpretation
4.9.1 Comprehensive fluid and gas sampling and analysis
4.10 Update geologic interpretation with DOE#2 well data
4.11 Depth Extension to DOE#2 well to identify more CO2 storage capacity
DOE#2 well done
4.12 Deepening SFI#1 well design and drilling contractor selection
Notification to Project Manager that subcontractors have been identified for drilling/field service operations
Notification to Project Manager that field service operations have begun at the project site
4.13 Deepen, log and core SFI#1 well (engineering oversight)
Notification to Project Manager that characterization wells have
4.14 SFI#1 well Log analysis and Core analysis

Gantt Chart



Notification to Project Manager that well logging has been completed
4.16 Update geologic interpretation with SFI#1 well data
DOE#3 well done
4.17 Plug & Abandon or Transfer Custody of Wells Drilled
4.17.1 P&A or Transfer of Custody of CLA Well
4.17.2 P&A or Transfer of Custody of DOE#2 Well
4.17.3 P&A or Transfer of Custody of SFI#1 Well
Task 5. Geologic Model Development
5.1 Design and Assemble 3D geologic model
Notification to Project Manager that activities to populate database with geologic characterization data has begun
5.2 Populate grid with lithology/property estimates
5.3 Analysis and interpretation
5.4 Incorporate additional 3rd well data into existing Geol model and expand study area
Geologic Model developed
Task 6. Geomechancial Model Development
6.1 Estimate in-situ stresses
6.2 Estimate mechanical stiffness and strength properties
6.3 Assemble 3D Geomechanical Model
6.4 Incorporate additional 3rd well data into existing Geomech model and expand study area
Geomechanical Model developed
Task 7. CO2 Injection and Migration Modelling
7.1 Design and Assemble TOUGH2 CO2 Injection Model
7.2 Simulation Varying Injection Scenarios
7.3 Interpret pressure and saturation changes vs time
7.4 Incorporate additional 3rd well data into existing CO2 inject & migration model and expand study area
CO2 Injection and Migration modeled
Task 8. Risk Assesment and Characterization
8.1 Evaluate/update geologic uncertainty
8.2 Evaluate/update well leakage paths
8.3 Characterize induced and natural seismicity risks
8.4 Critically evaluate/update and document long-term security
8.5 Detailed review, quantify and document top 20 Industrial Sources of CO2 emissions
8.6 Detailed Engineering Review and Analysis of Existing and New Pipeline and Gas Storage System in LA Basin
Final Risk Assessment and Characterization
Task 9. Project Documentation and Reporting
9.1 Quarterly and Annual Reports
9.2 Best Practices Manual Development
9.3 Technical Workshop Participation
9.4 DOE mtgs and presentations