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Wilmington Graben Project Update and SoCal Carbon Atlas

DOE Carbon Storage Program Annual Meeting

Nov 15 to 17, 2011

Terralog Technologies USA, Inc

1. **Project Background and Motivation**
2. **Project Status and Accomplishments**
3. **Next Steps**

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Project Sponsors 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)

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

Terralog Technologies USA (geology, geomechanics, reservoir eng and drilling contract management)

Why Los Angeles Basin

- Large population
- Prolific oil & gas producing basins
- Has numerous large power plants, oil refineries which produces more than 5 million MT of fossil fuel related CO2 emissions each year
- Great need for large scale geologic storage of CO2

Los Angeles Basin Geology

- Contain massive sand & shale interbeds within the Pliocene and Miocene

- Provide excellent traps for oil & gas

- Contain several billion-barrel oil fields, e.g. Wilmington Oil Field (> 2 billion barrels produced to date)

- Contain 6 large scale underground gas storage fields in the same age sediments (Operated by So Cal Gas Co. for over 50 years).

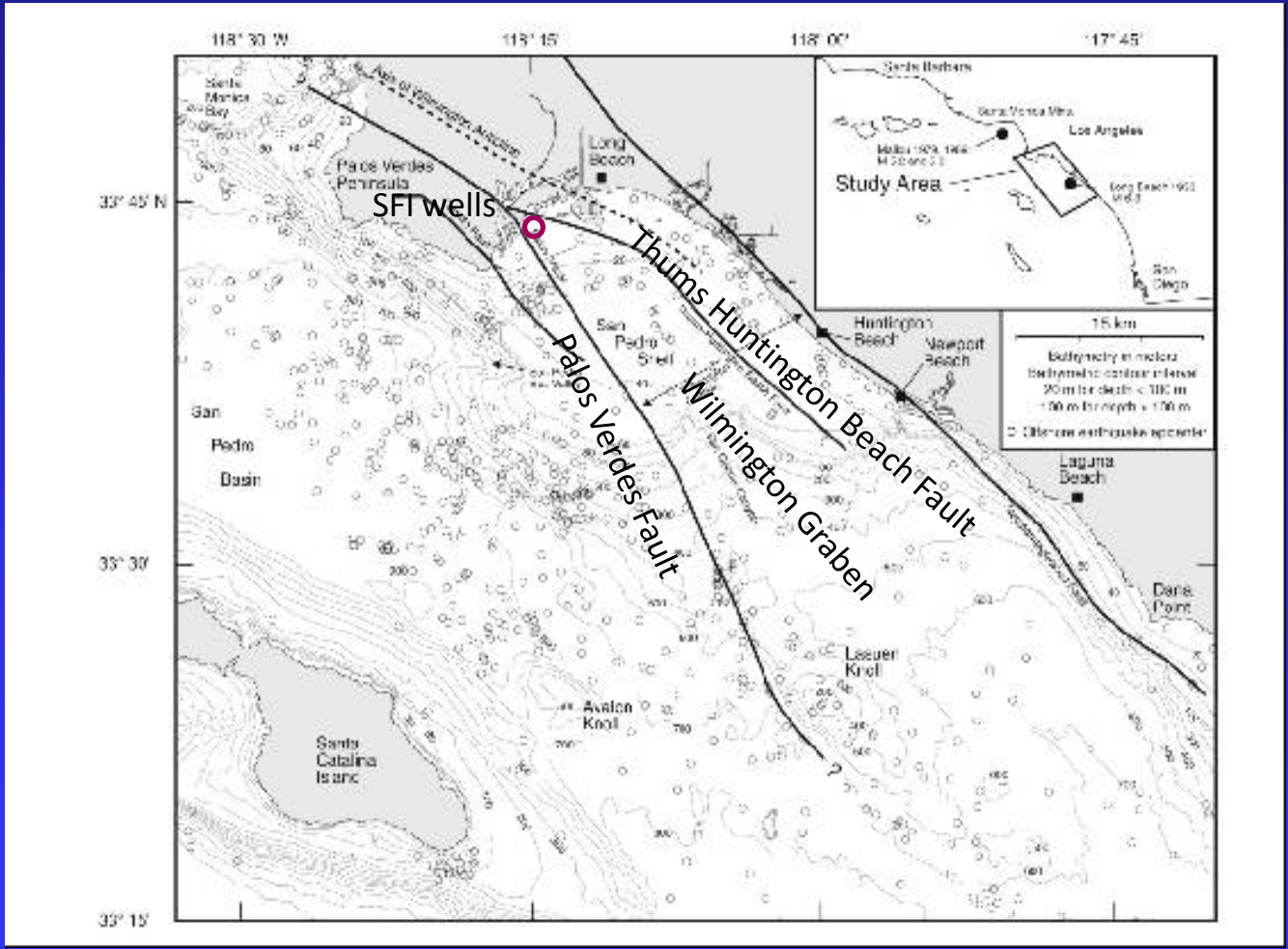
- Demonstrated both the storage potential & security of these formations for CO2 sequestration if properly characterized and selected.

Why Wilmington Graben

- It is impractical to site a large scale CO2 storage project onshore beneath LA due to large population & complex land ownership.

- >3000ft thick of the same Pliocene and Miocene sediments are present in the Wilmington Graben, at appro. 3000-7000ft depth for CO2 sequestration.

- This zone is easily accessible but geologically isolated from the nearby Wilmington Oilfield and the onshore area, thereby reducing communication and public risks.



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Efforts to Better Characterize Pliocene & Miocene for high volume CO2 Storage include

1)Detailed log evaluation of existing exploration wells in the area;

2)Improved evaluation and interpretation of existing 2D and 3D seismic data;

3)Acquisition and interpretation of additional 2D seismic lines;

4)Drilling and coring three new evaluation wells into the Graben (Pliocene and Miocene) and/or on the landward side of the THUMS-HB fault

5)Development of 3D geologic models, geomechanical models, and CO2 injection and migration models for the region.

6)Analysis of industrial sources (top 20 in the LA Basin)

7)Engineering study of existing and new pipeline systems to transport CO2 from significant local sources to sequestration sites (transport infrastructure study)

8)Risk analysis (include well integrity, induced and natural seismicity)

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Project Tasks

- Task 1: Project Management and Planning
- Task 2: Seismic Data and Interpretation
- Task 3: Well Data Review and Formation Evaluation
- Task 4: New Well Drilling, Logging and Core Analysis
- Task 5: Geologic Model Development
- Task 6: Geomechanical Model Development
- Task 7: CO2 Injection and Migration Modeling
- Task 8: Risk Assessment and Characterization
- Task 9: Documentation, Technology Transfer & Reporting

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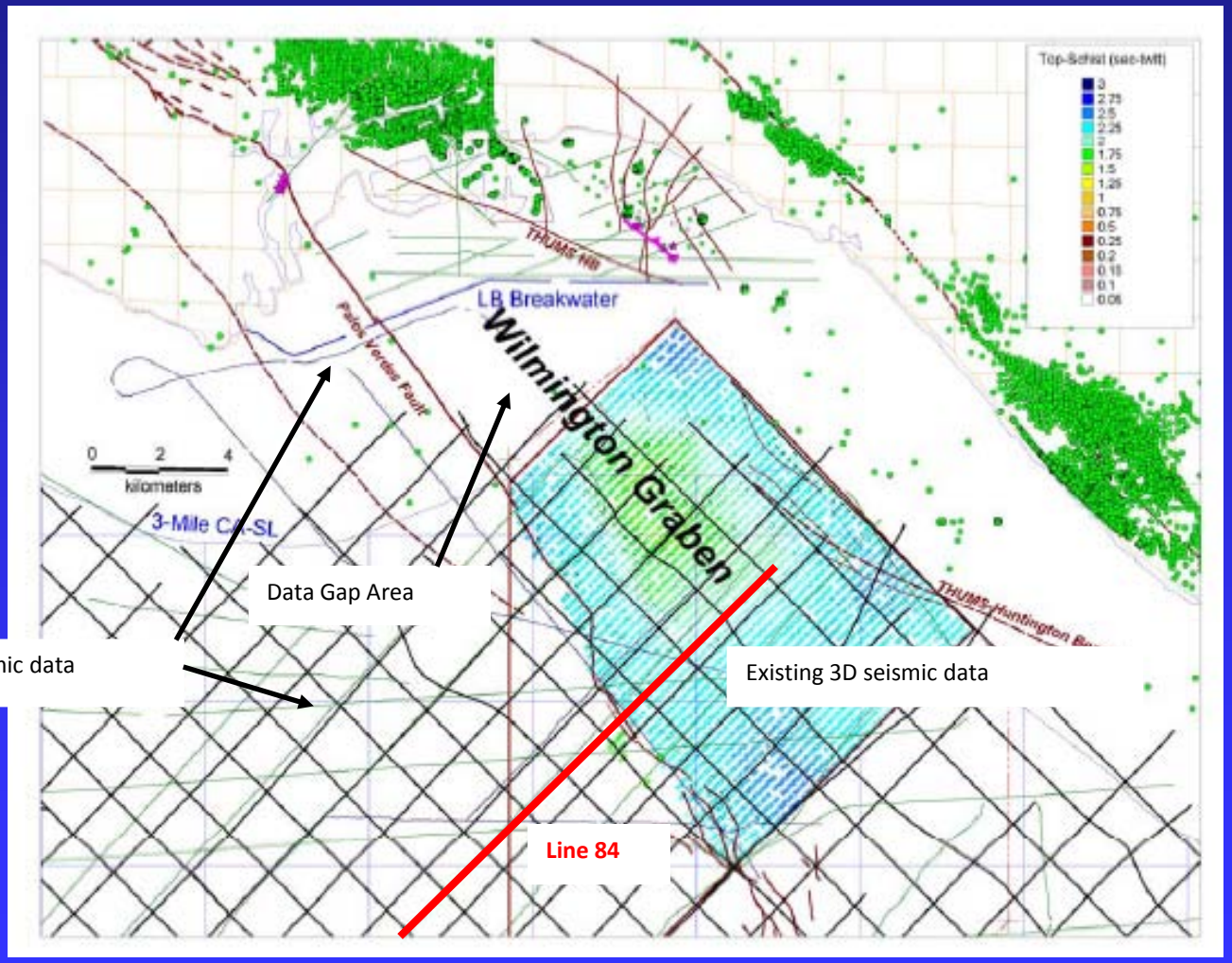
Task 2: Seismic Data and Interpretation

Existing 2D and 3D Seismic Data Prior to Project



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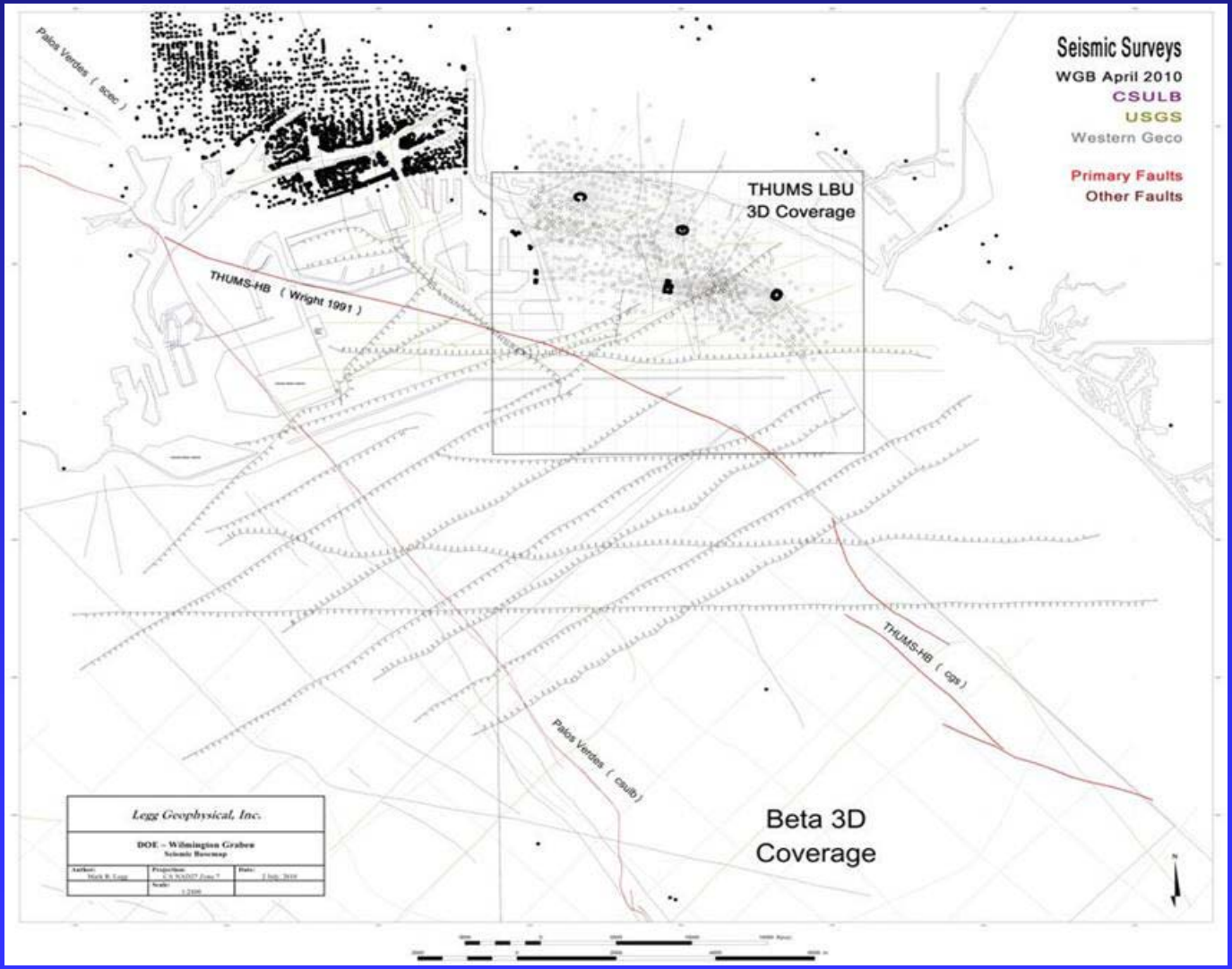
Shot Point Map for 175km of New Seismic Lines



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California State University, Long Beach provided the Seismic Boat and Equipment

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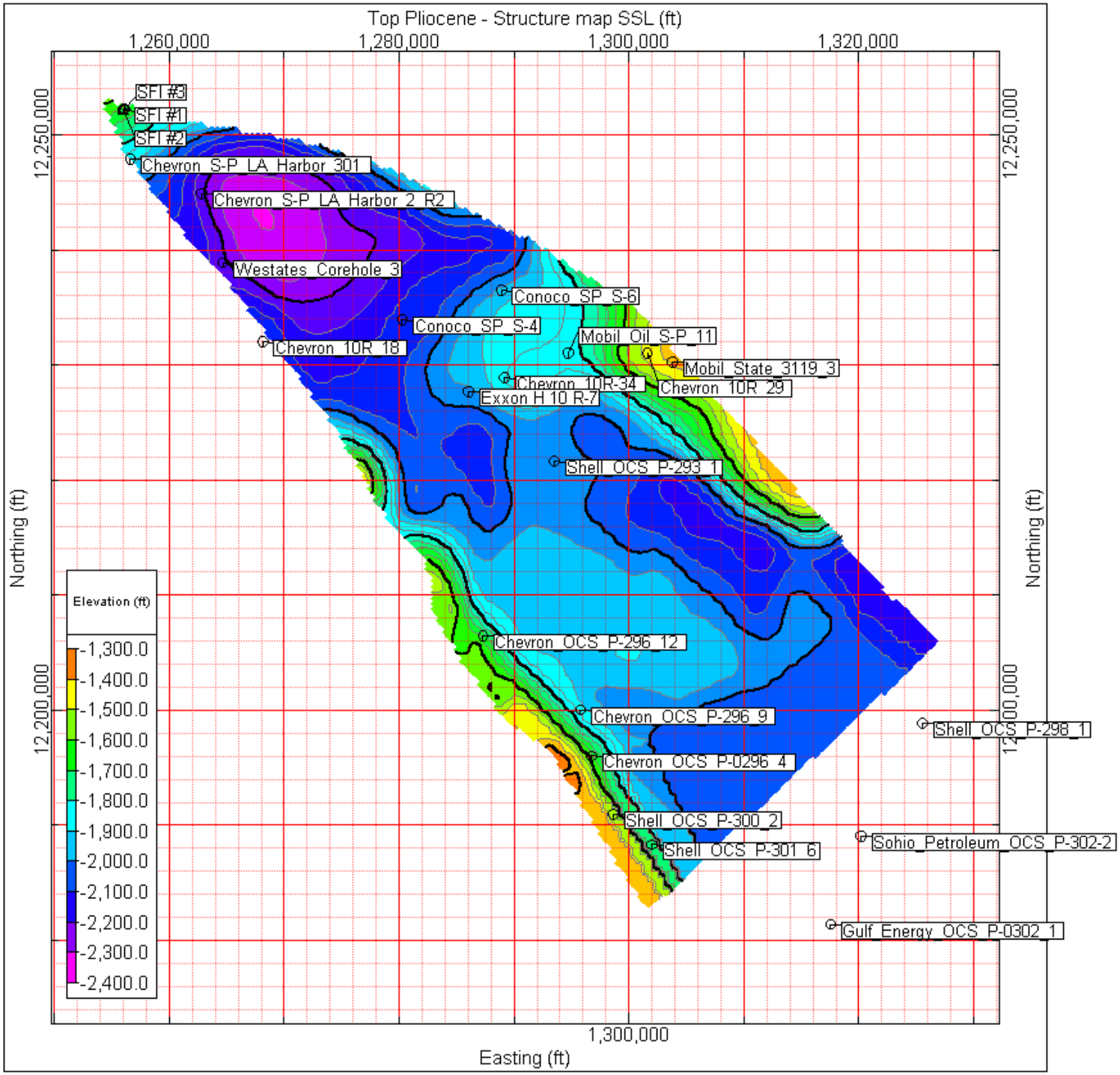
Top Pliocene, Mid Pico structure map



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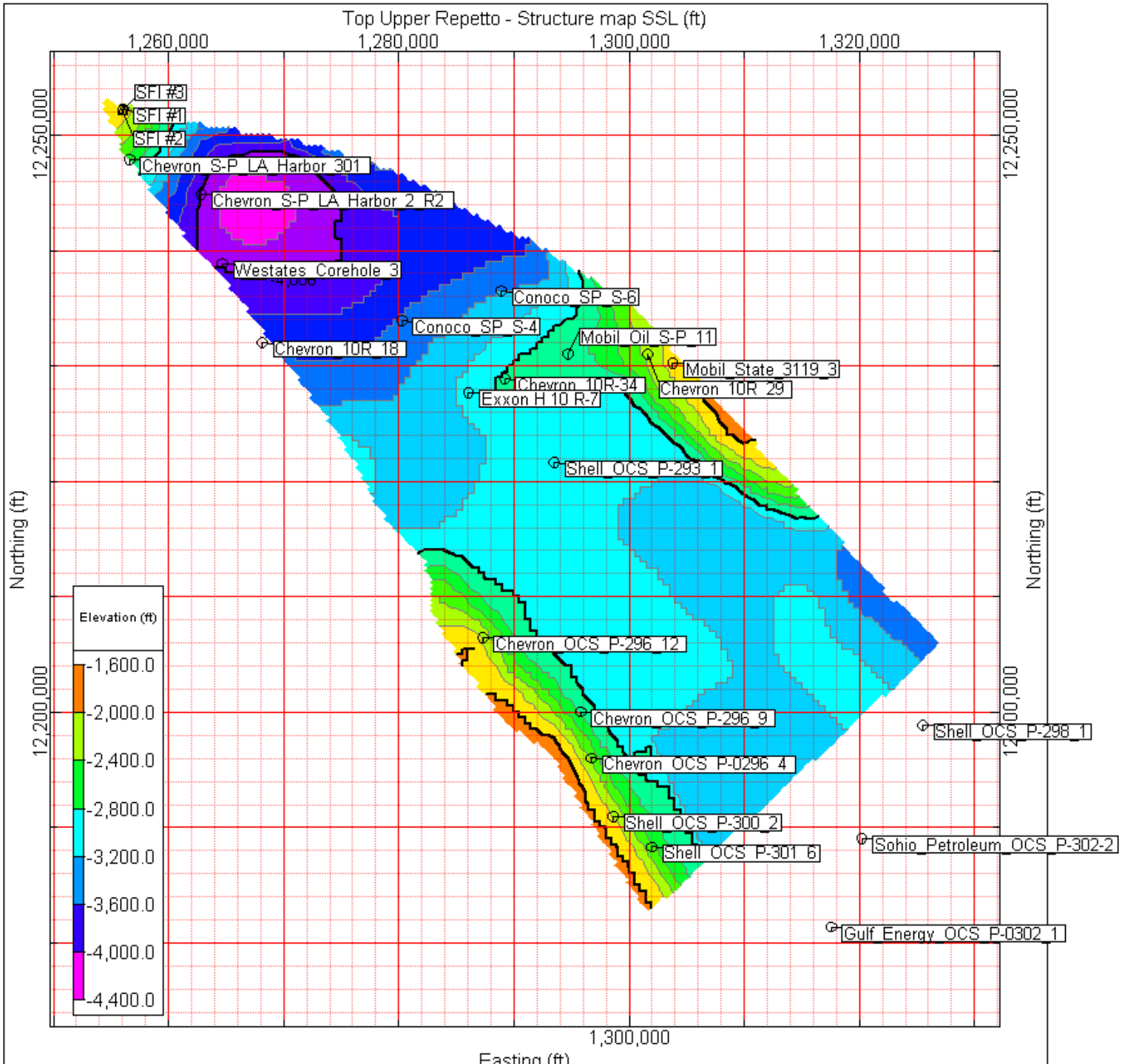
Top Upper Repetto, structure map



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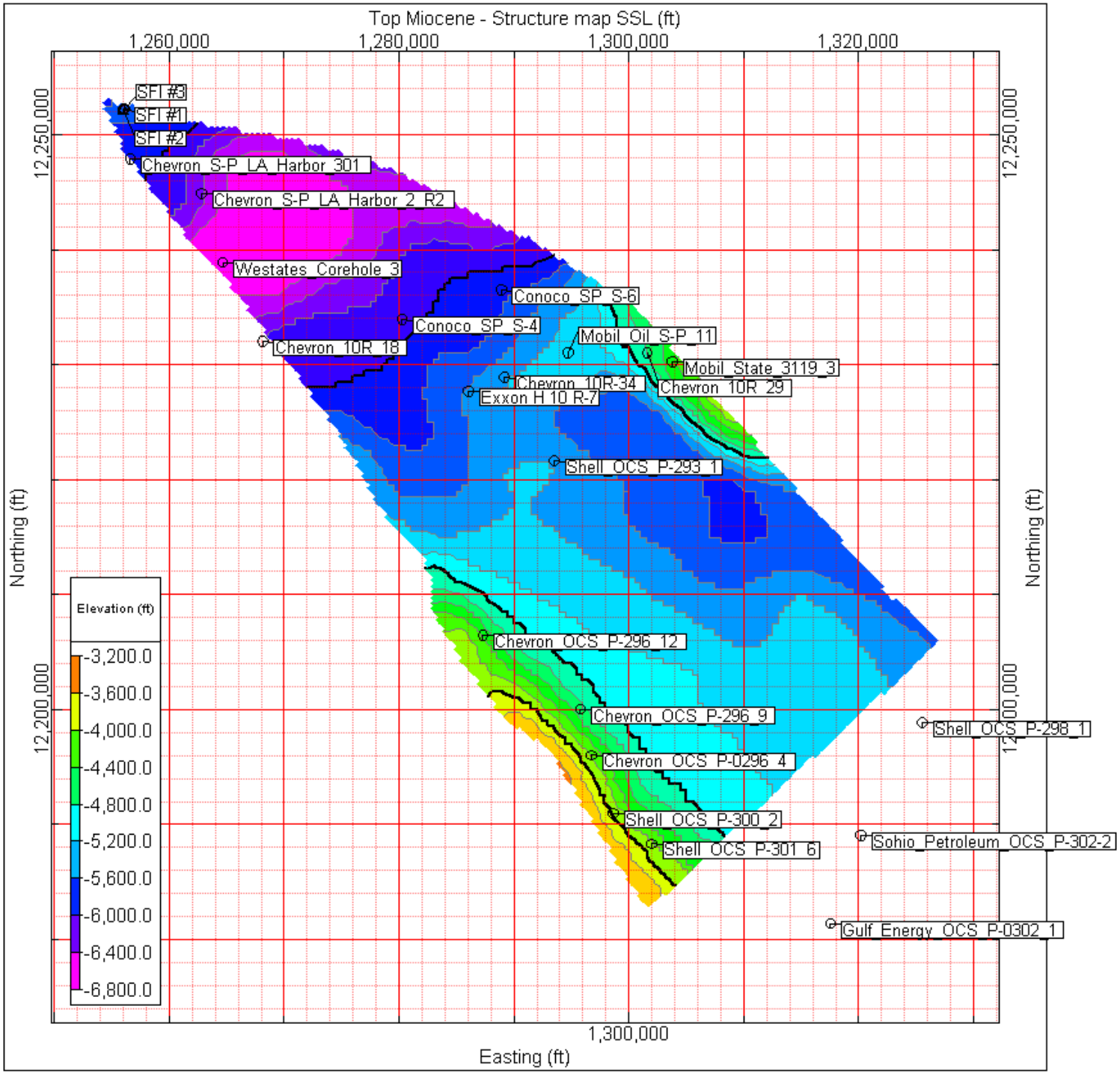
Top Miocene, structure map



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Task 3: Well Data Review and Formation Evaluation

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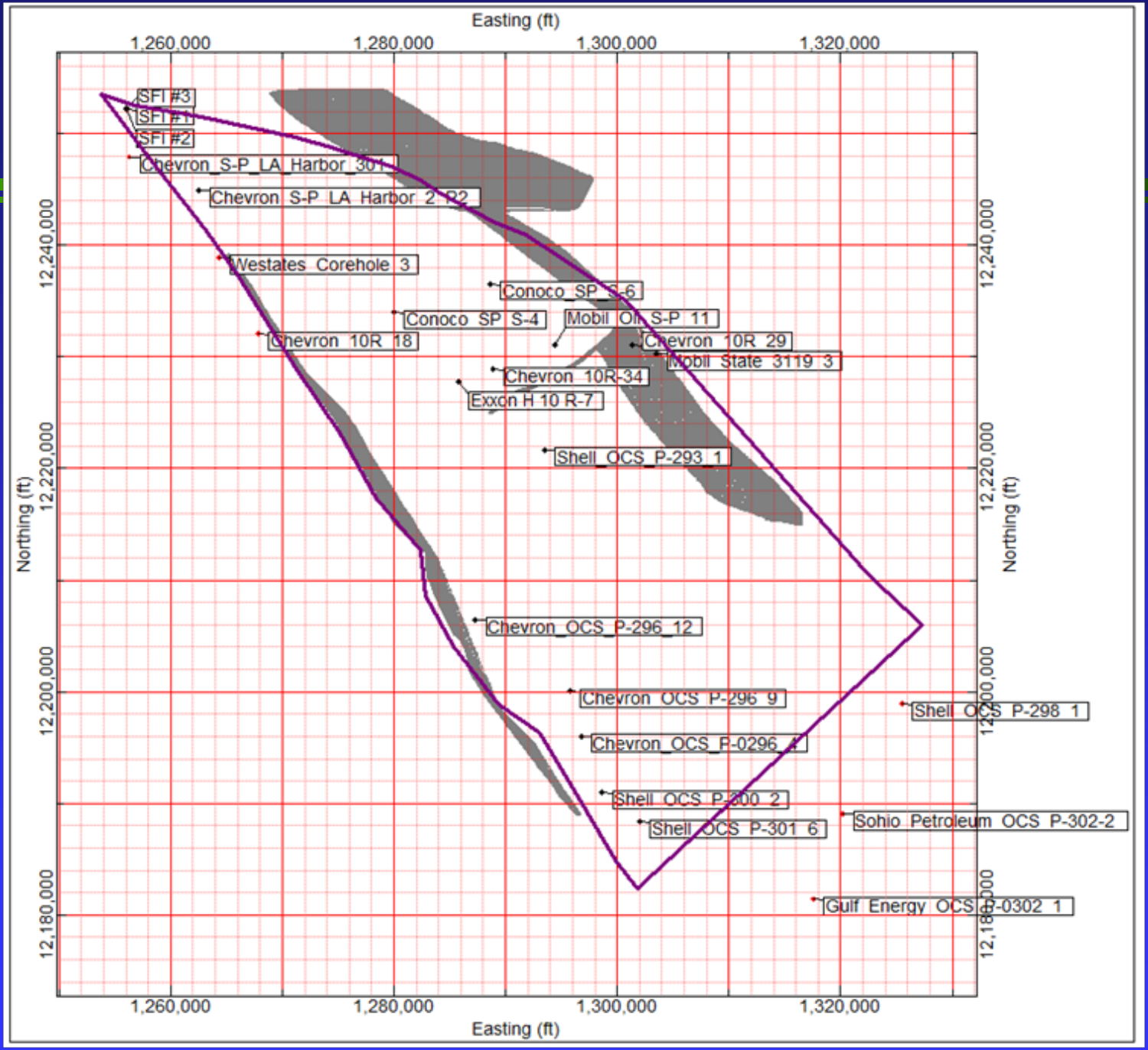
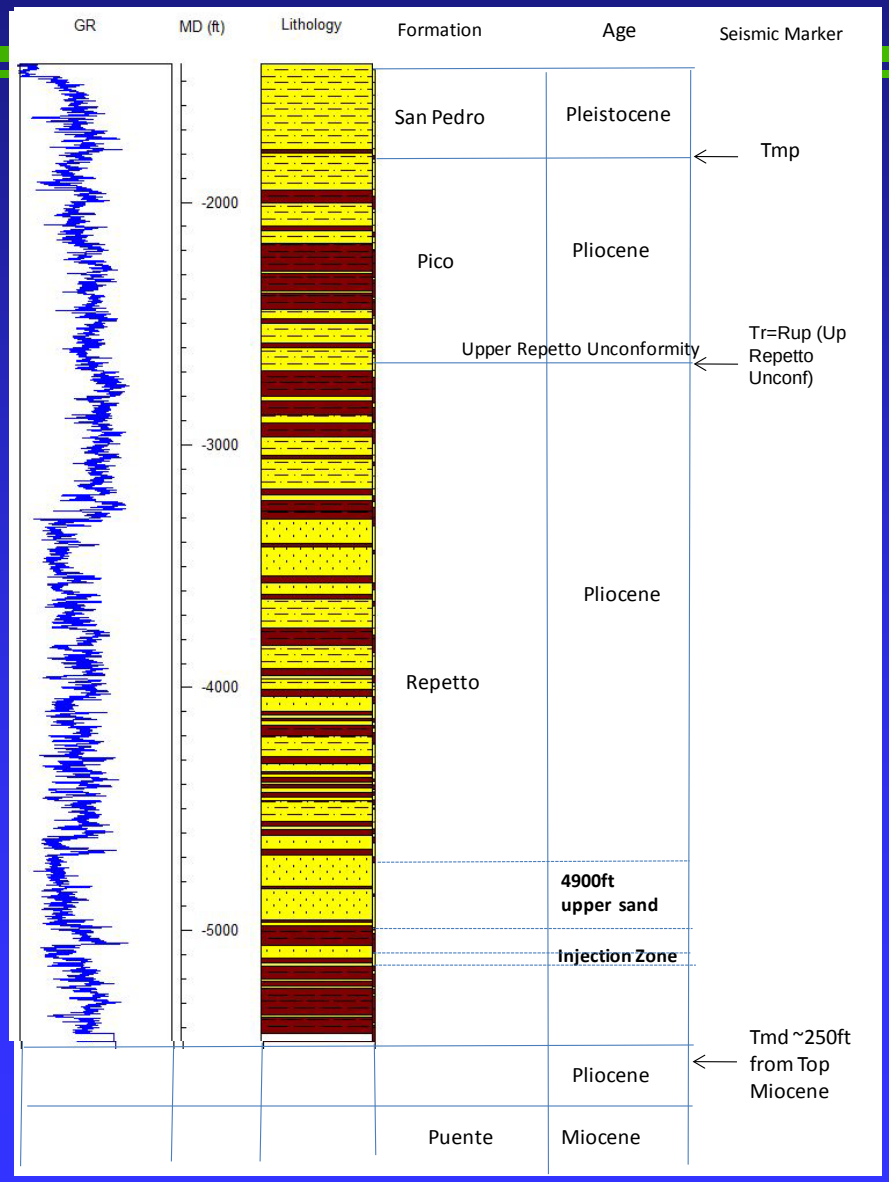
Exploratory Wells Location



DOE#1 Well Stratigraphic Column



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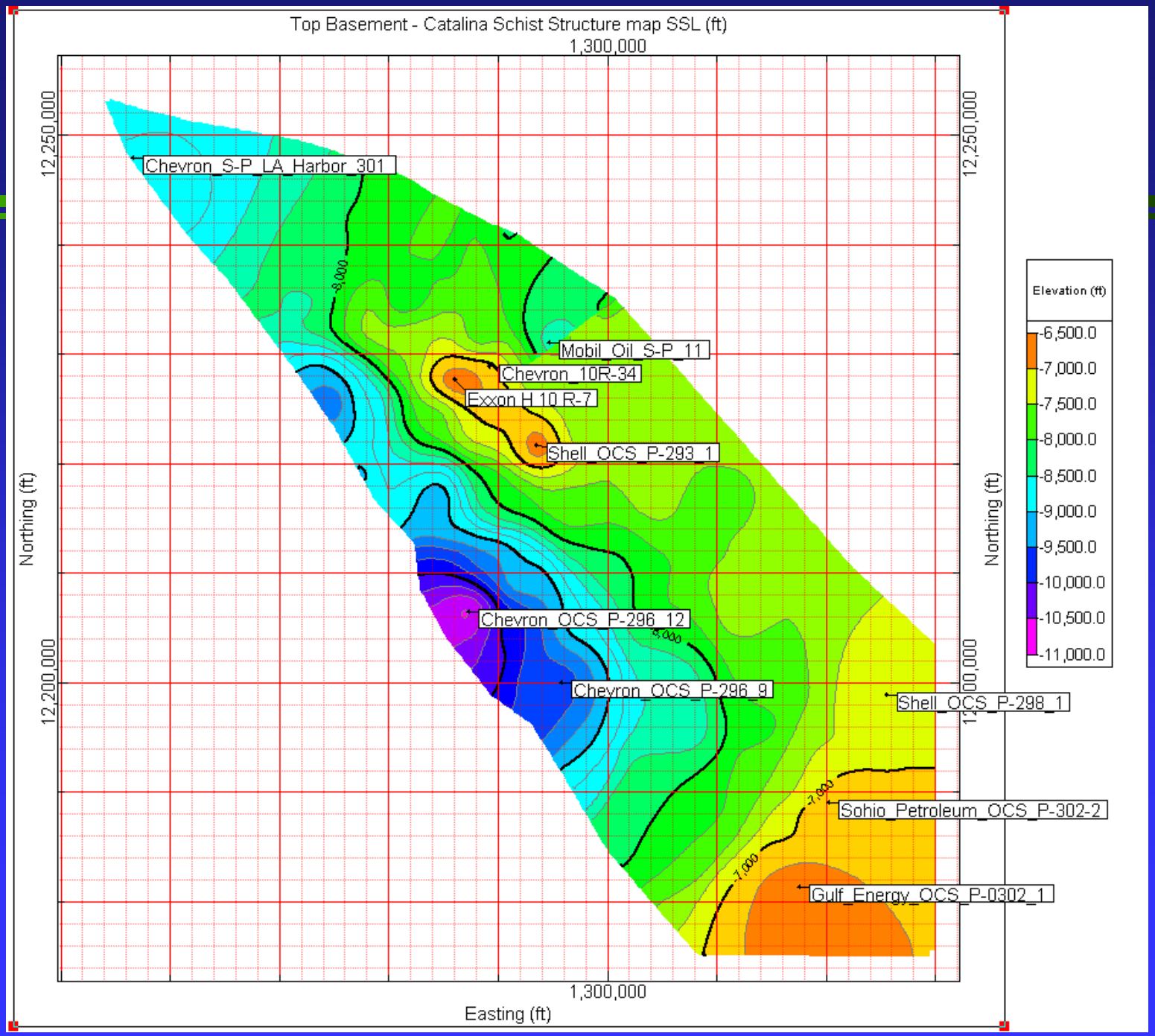
Top Basement Structure Map



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DOE#1 well Sidewall Cores

SFI#3 Sidewall Core Samples

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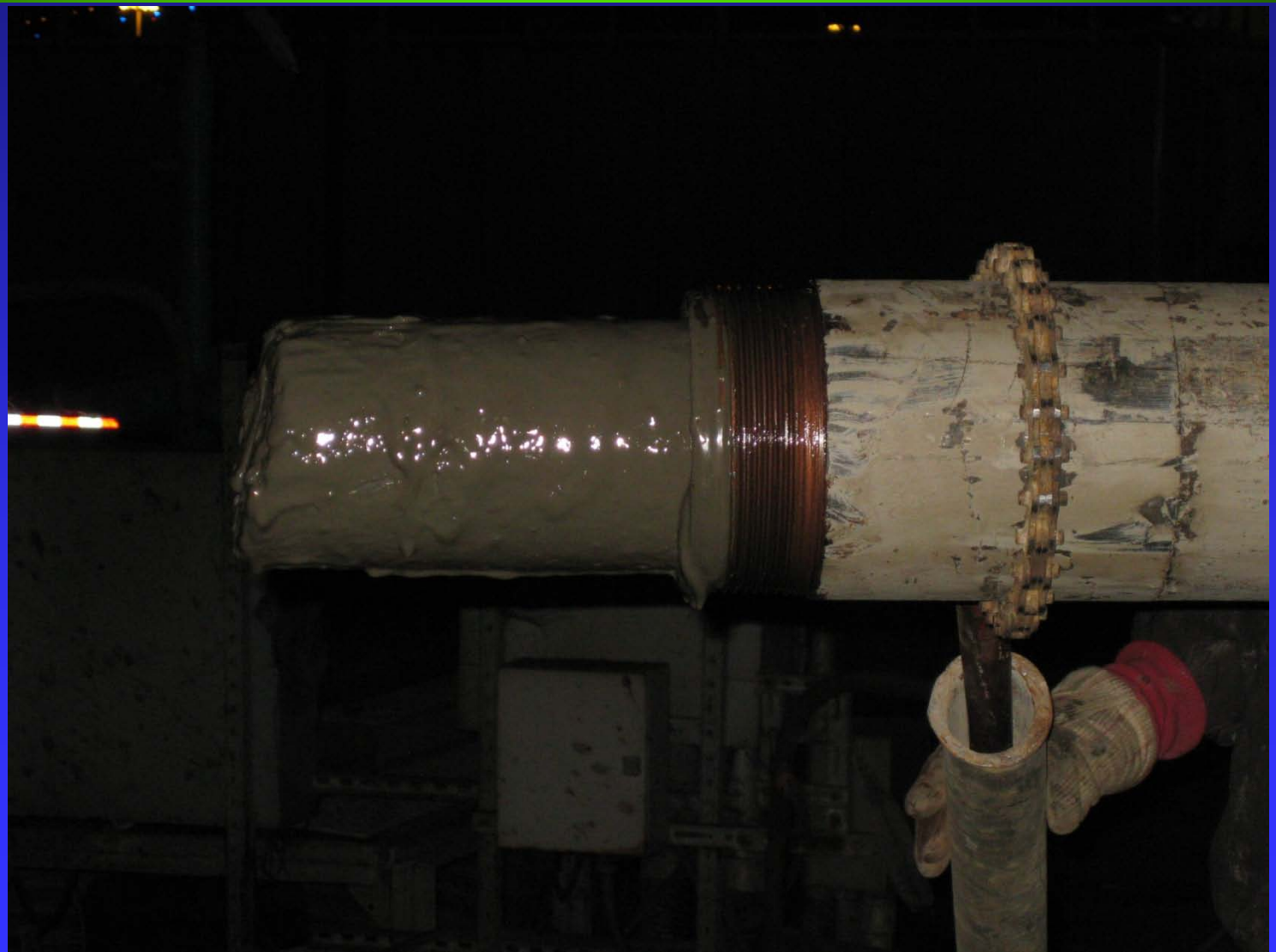
Conventional Core fresh out of hole (DOE#1 Well)



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Northern Wilmington Graben Pliocene Characterization from DOE#1 Well

- Recovered 29 SWC and 9.5ft conventional core
- Correlated well with SFI#1 and SFI#2 wells
- Well TD in Pliocene based on micropaleontology correlation from SFI#2 well
- Sand porosities – 24-31%
- Sand permeabilities – 50-353md
- Shale porosities – 23-29%
- Shale permeabilities – <1-2md
- Pliocene sand thickness – 3000-3500ft

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Task 4: New Well Drilling, Logging and Core Analysis

DOE#1 well schematic

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Terminal Island Facility

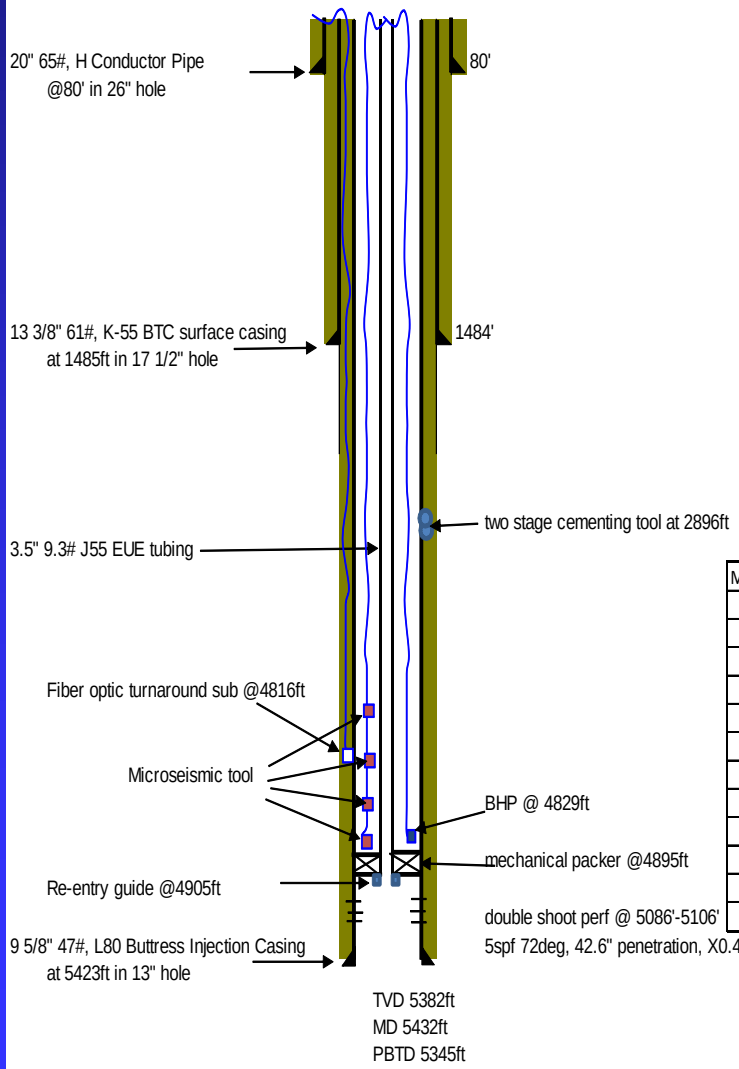
DOE#1 (aka SFI # 3)

Section 8 - T5S - R13W

Slurry Injector

Deviated Well	KOP 1600ft, build angle 1degree/100ft	
Surface:		Bottom:
Lat: (NAD83)	33.74399	33.74405
Long: (NAD83)	-118.26465	-118.26281

KB (above sea level) 30ft
GL (above sea level) 10ft



MD	TVD (from deviation survey)
1604	1604
2076	2075
2554	2550
3002	2990
3512	3492
3956	3930
4399	4367
4872	4833
5430	5382

Microseismic Sensor	TVDss
1	-4215.1
2	-4264.4
3	-4313.6
4	-4362.9
5	-4412.2
6	-4461.5
7	-4510.8
8	-4560.0
9	-4609.1
10	-4658.3
11	-4707.5
12	-4756.7

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Status on Next Well

- We have submitted an EPA permit for DOE#2 well this past July

- CEQA for DOE#2 well is currently at the 30-days Public Comment period. We anticipate approval of the CEQA before Dec. 2011

- We probably will also pull a DOGGR permit for DOE#2 well. This well will be permitted as a stratigraphic well. For DOGGR permit an approved CEQA is required

- We are proceeding with multiple options to obtain a drilling permit for DOE#2 well

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Task 5: Geologic Model Development

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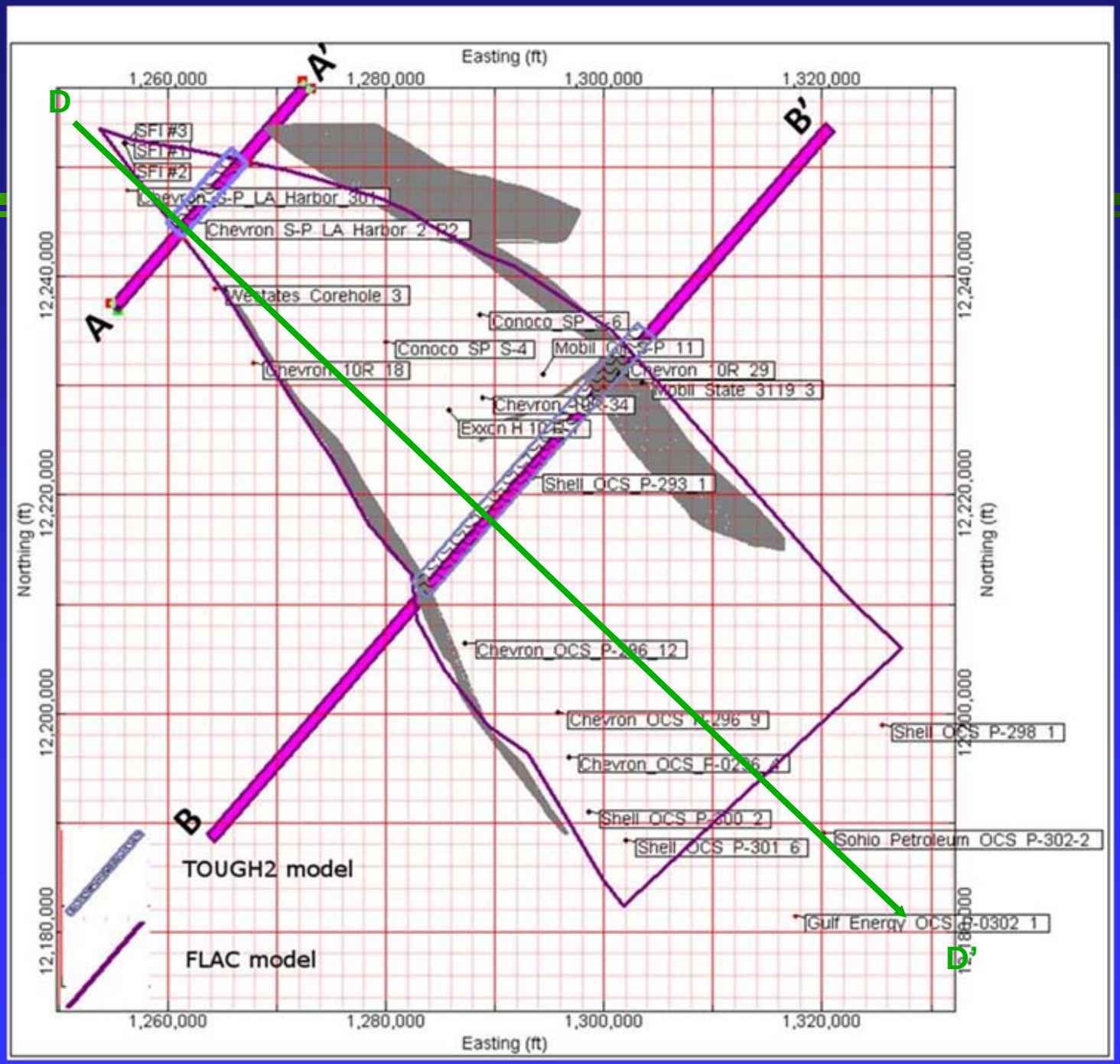
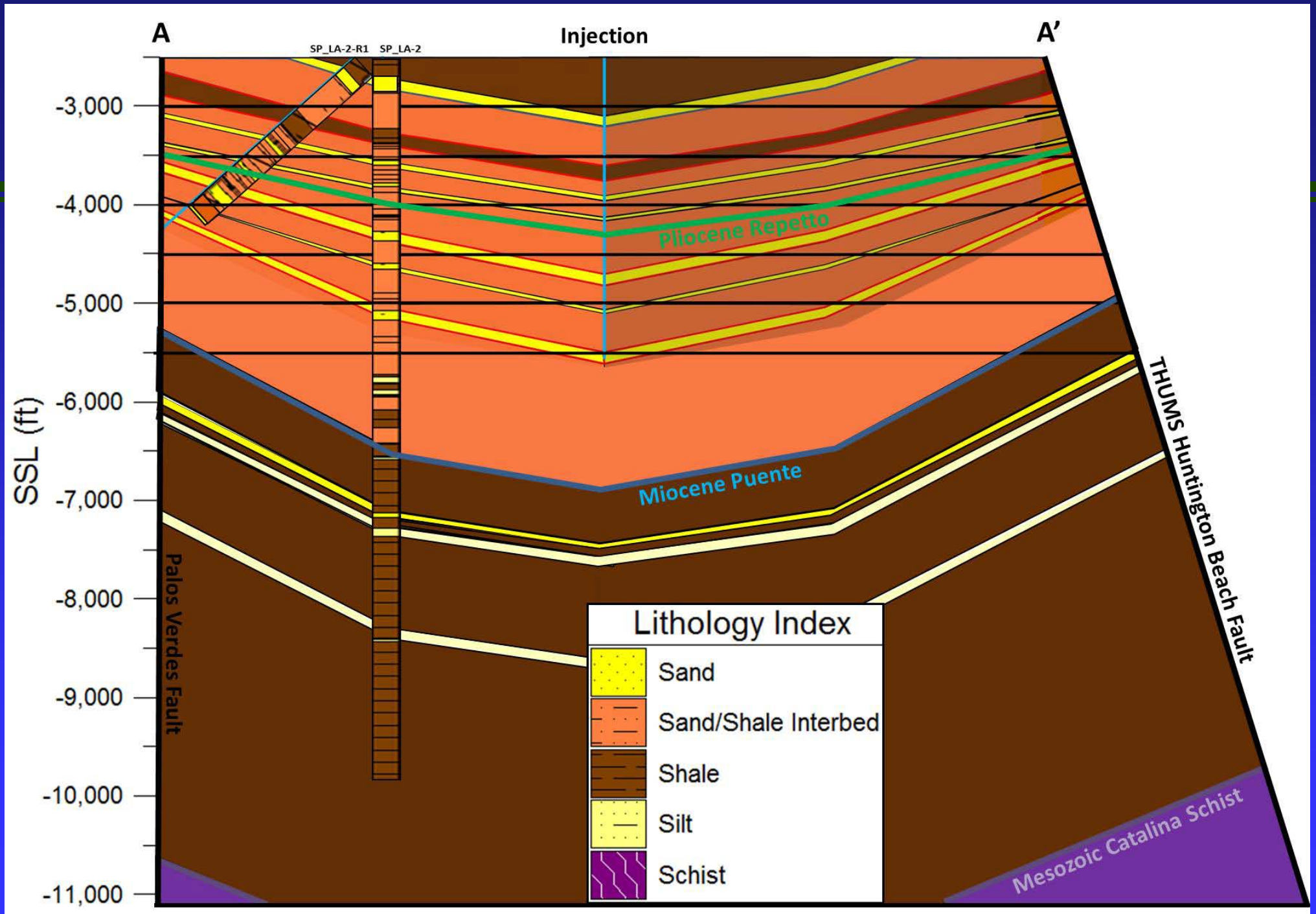
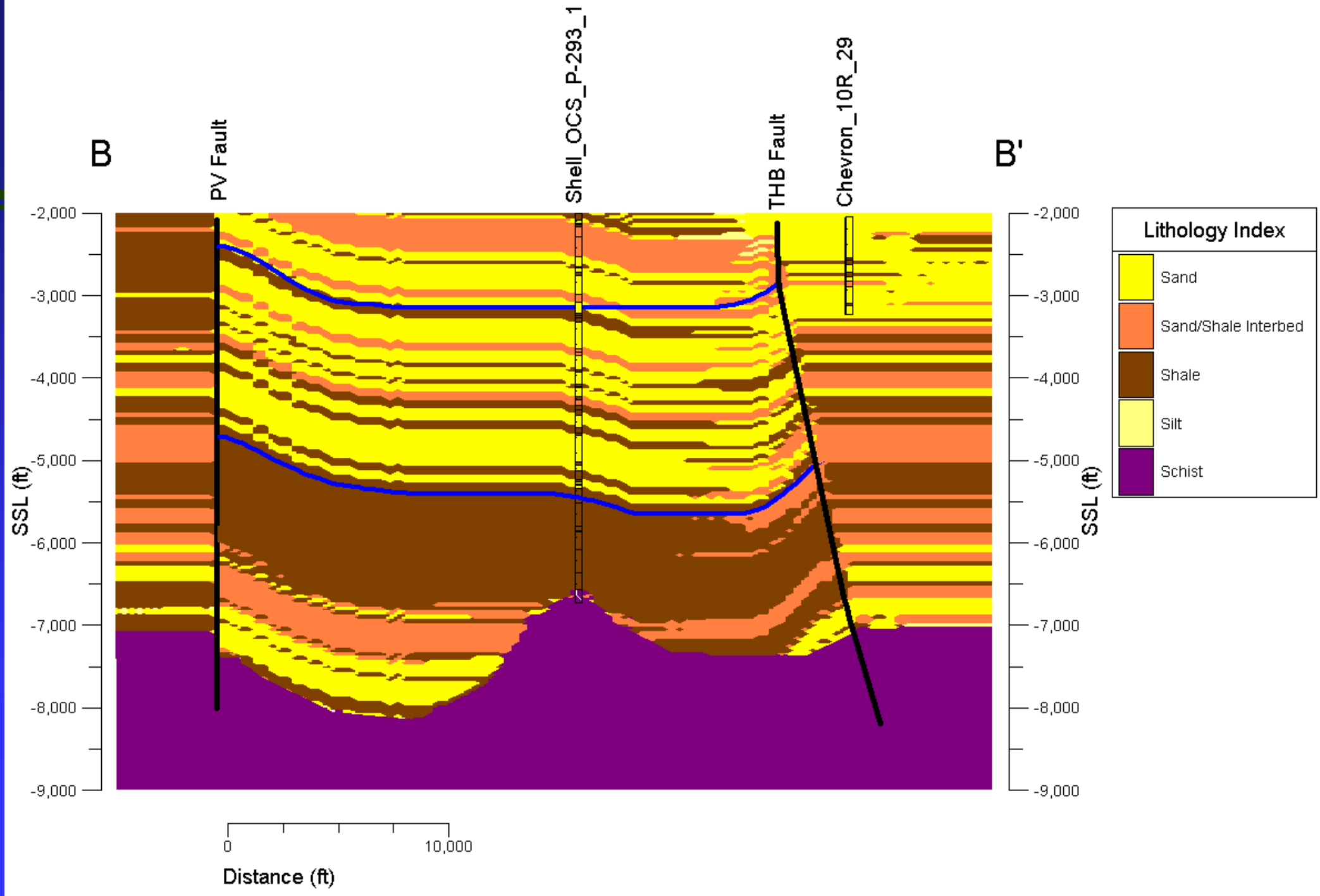
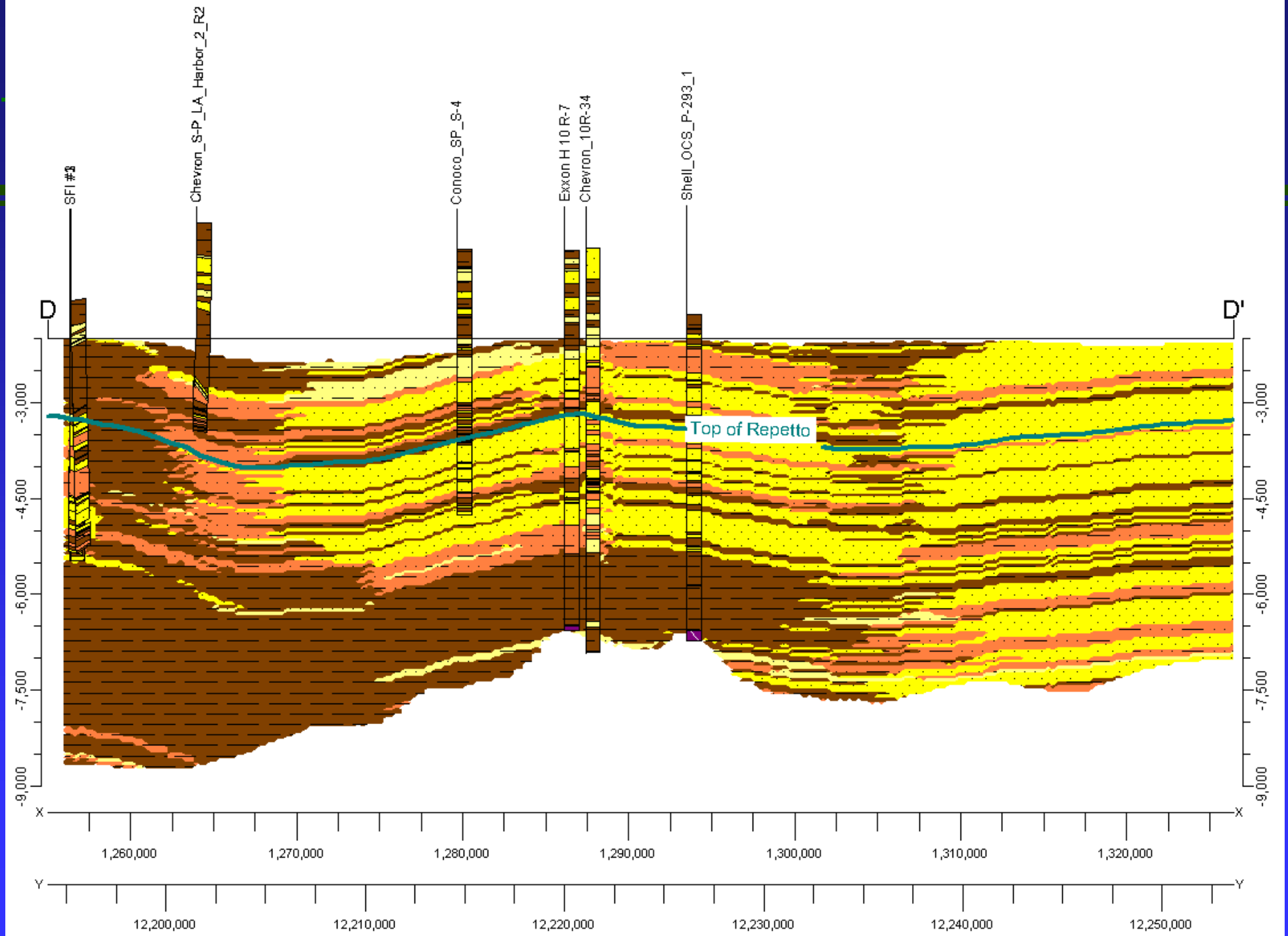
Location Map for modeling

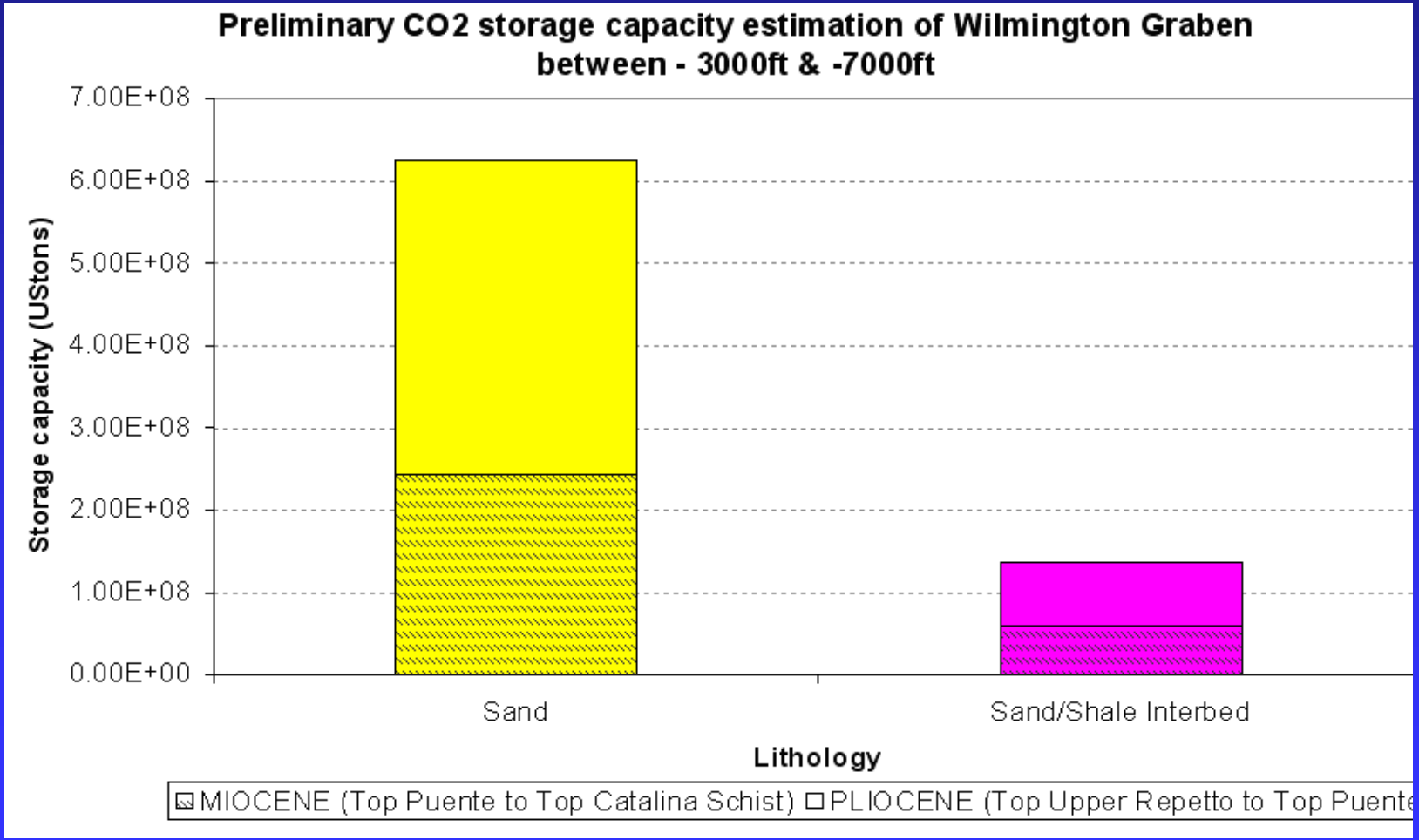



A
A'
Injection
SP_LA-2-R1
SP_LA-2
SSL (ft)
-3,000
-4,000
-5,000
-6,000
-7,000
-8,000
-9,000
-10,000
-11,000
Pliocene Repetto
Miocene Puente
Palos Verdes Fault
THUMS Huntington Beach Fault
Mesozoic Catalina Schist
Lithology Index
Sand
Sand/Shale Interbed
Shale
Silt
Schist


B
B'
PV Fault
Shell_OCS_P-293_1
THB Fault
Chevron_10R_29
SSL (ft)
-2,000
-3,000
-4,000
-5,000
-6,000
-7,000
-8,000
-9,000
Lithology Index
Sand
Sand/Shale Interbed
Shale
Silt
Schist
0
10,000
Distance (ft)


SFI #3
Chevron_S-P_LA_Harbor_2_R2
Conoco_SP_S-4
Exxon H 10 R-7
Chevron_10R-34
Shell_OCS_P-293_1
D
D'
Top of Repetto
-3,000
-4,500
-6,000
-7,500
-9,000
X
1,260,000
1,270,000
1,280,000
1,290,000
1,300,000
1,310,000
1,320,000
Y
12,200,000
12,210,000
12,220,000
12,230,000
12,240,000
12,250,000

Preliminary CO2 Storage Capacity Estimate, between -3000ft and -7000ft



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Task 6: Geomechanical Model Development

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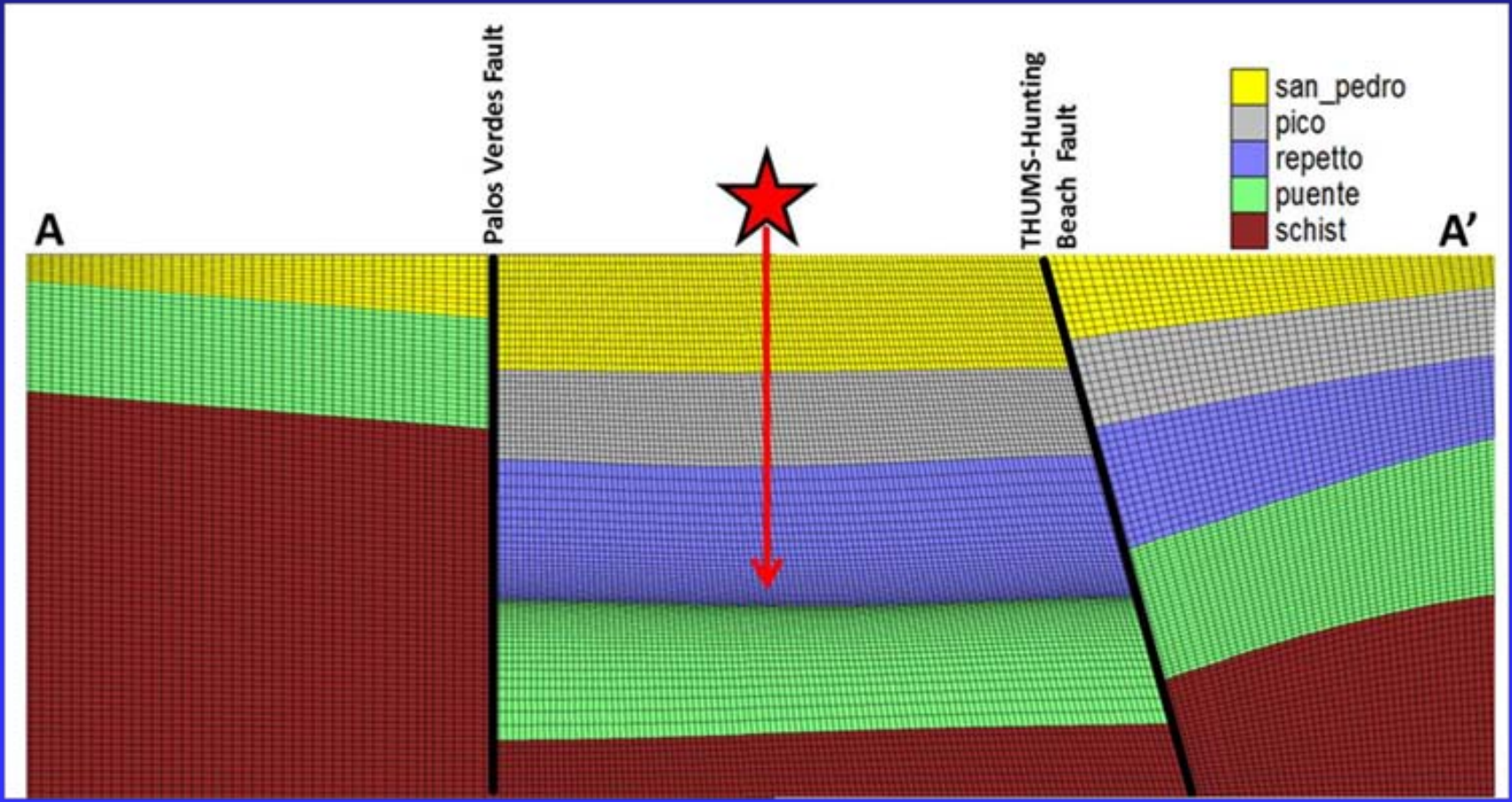
FLAC 3D Geomechanical Model through DOE#1 Well



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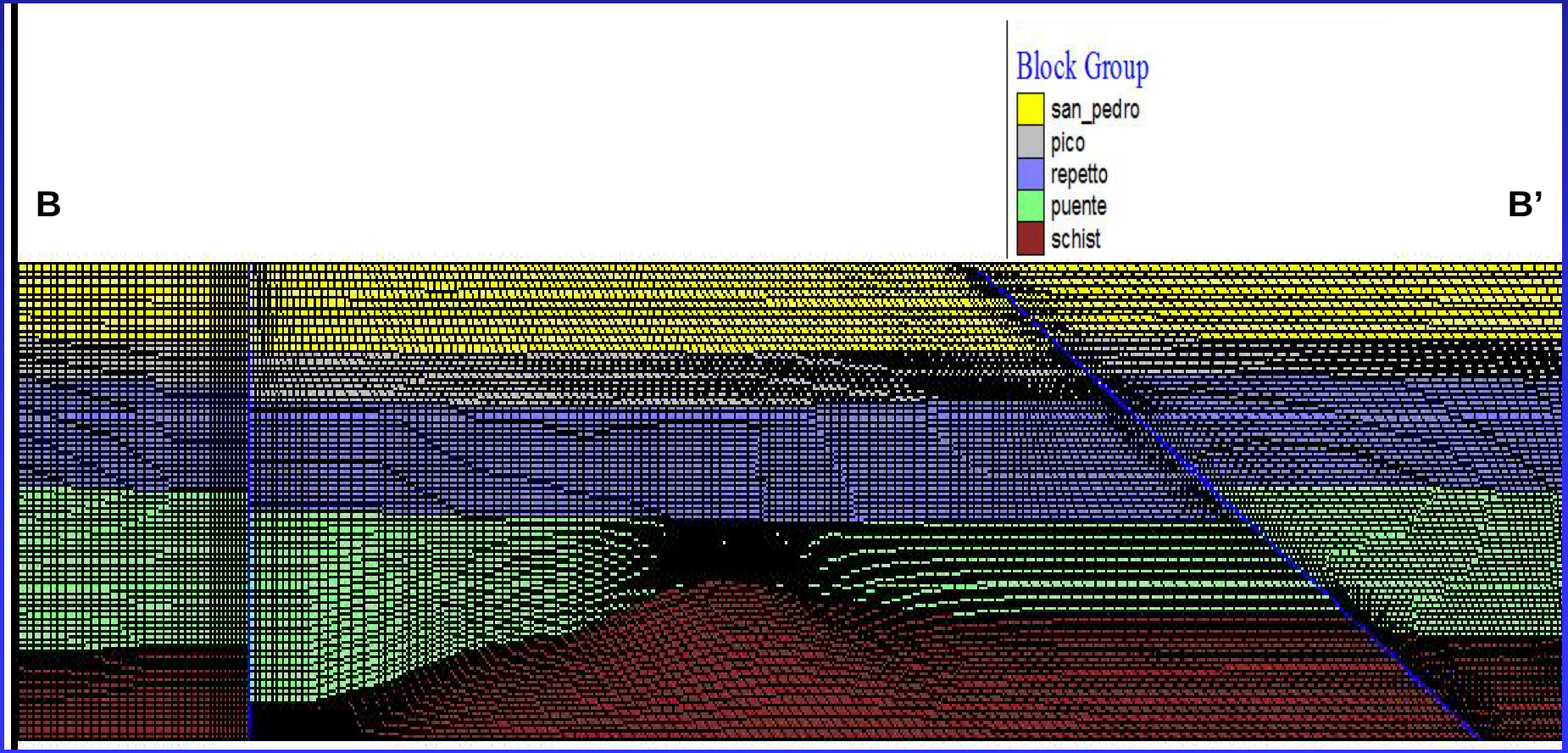
FLAC 3D Geomechanical Model through B-B’



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Task 7: CO2 Injection and Migration Modeling

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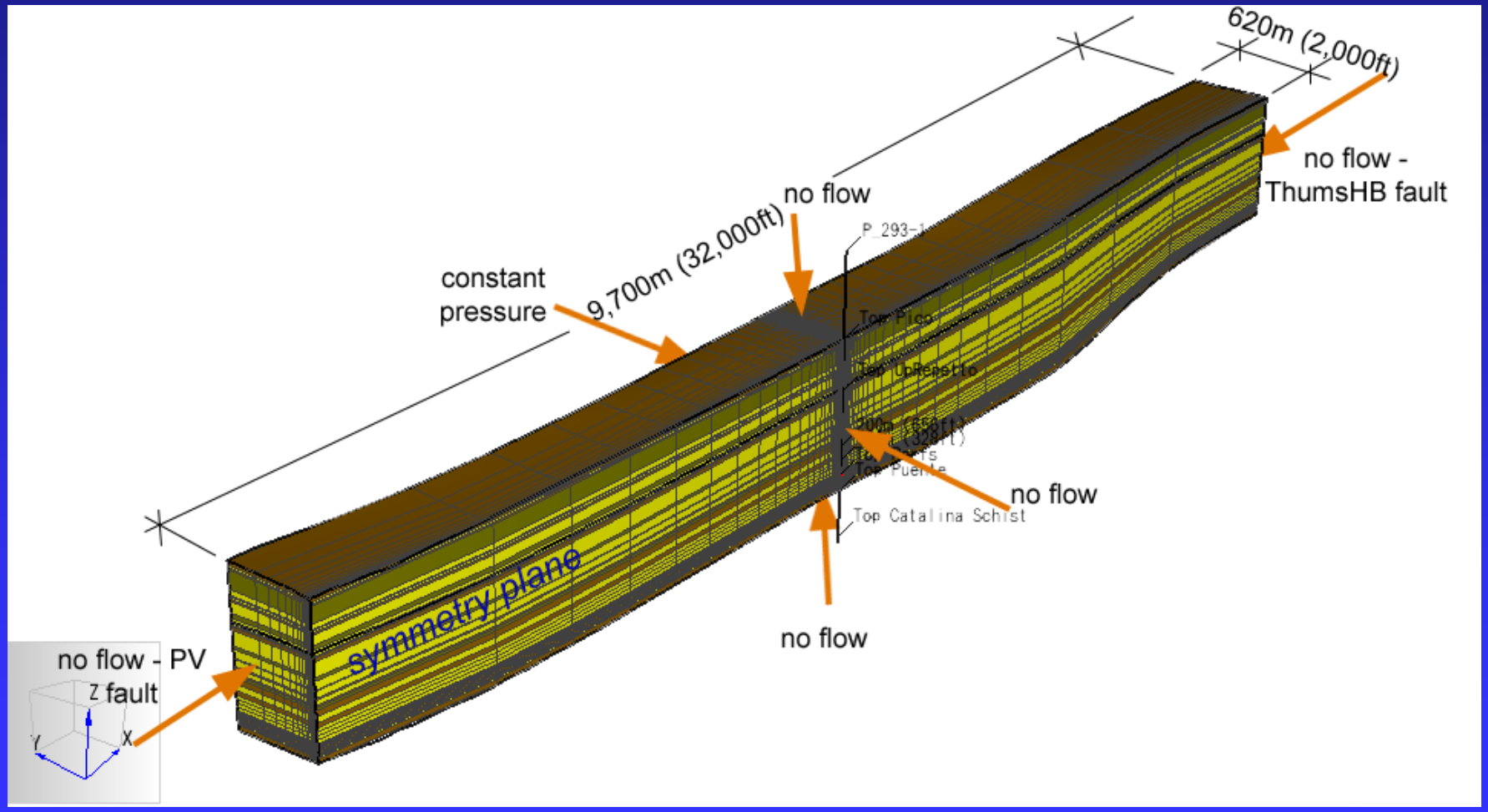
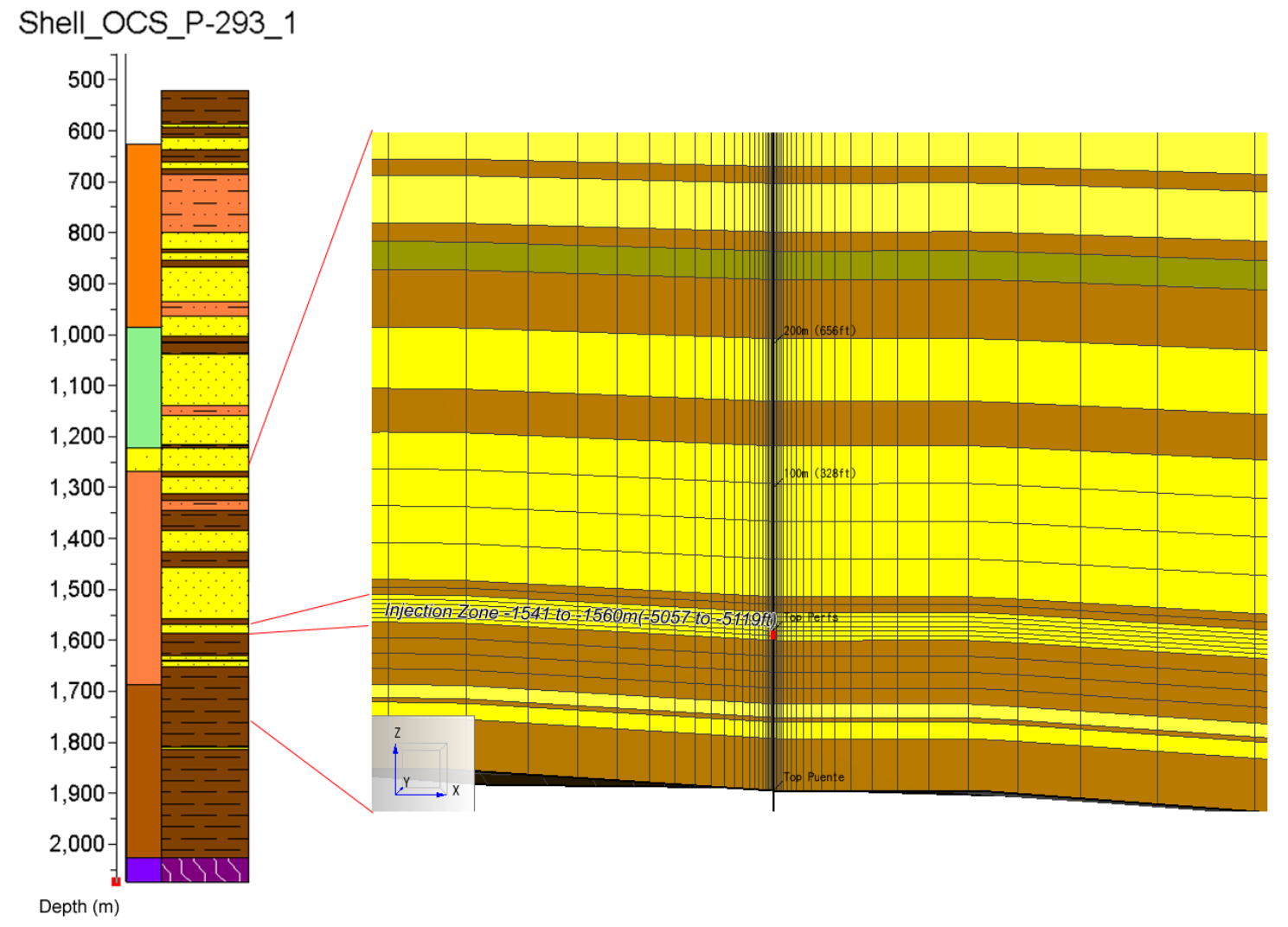
Lithology and Boundary conditions of Tough2 model



Tough2 Injection Well Grid based on Lithology from Shell_OCS_P-293_1



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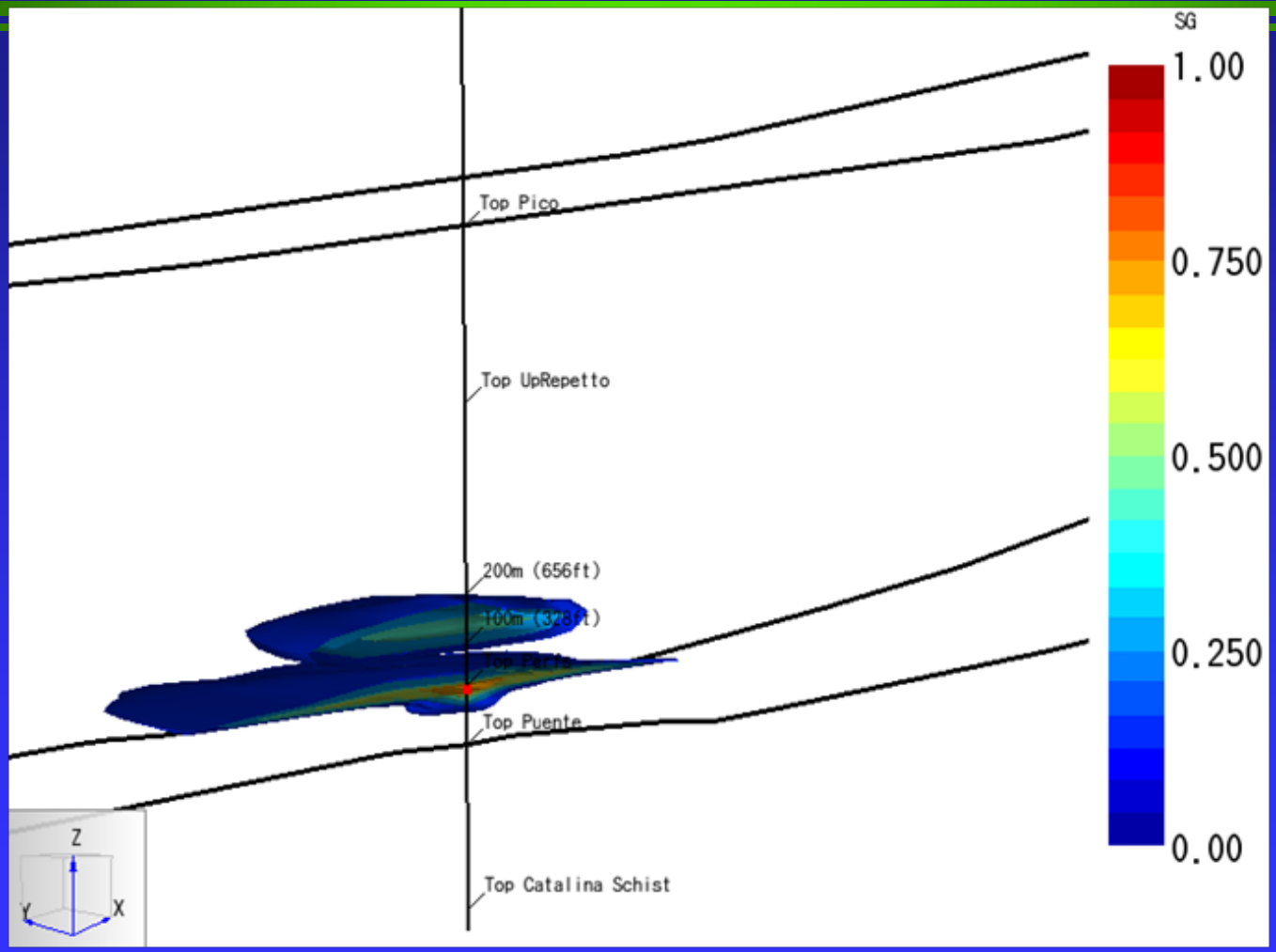
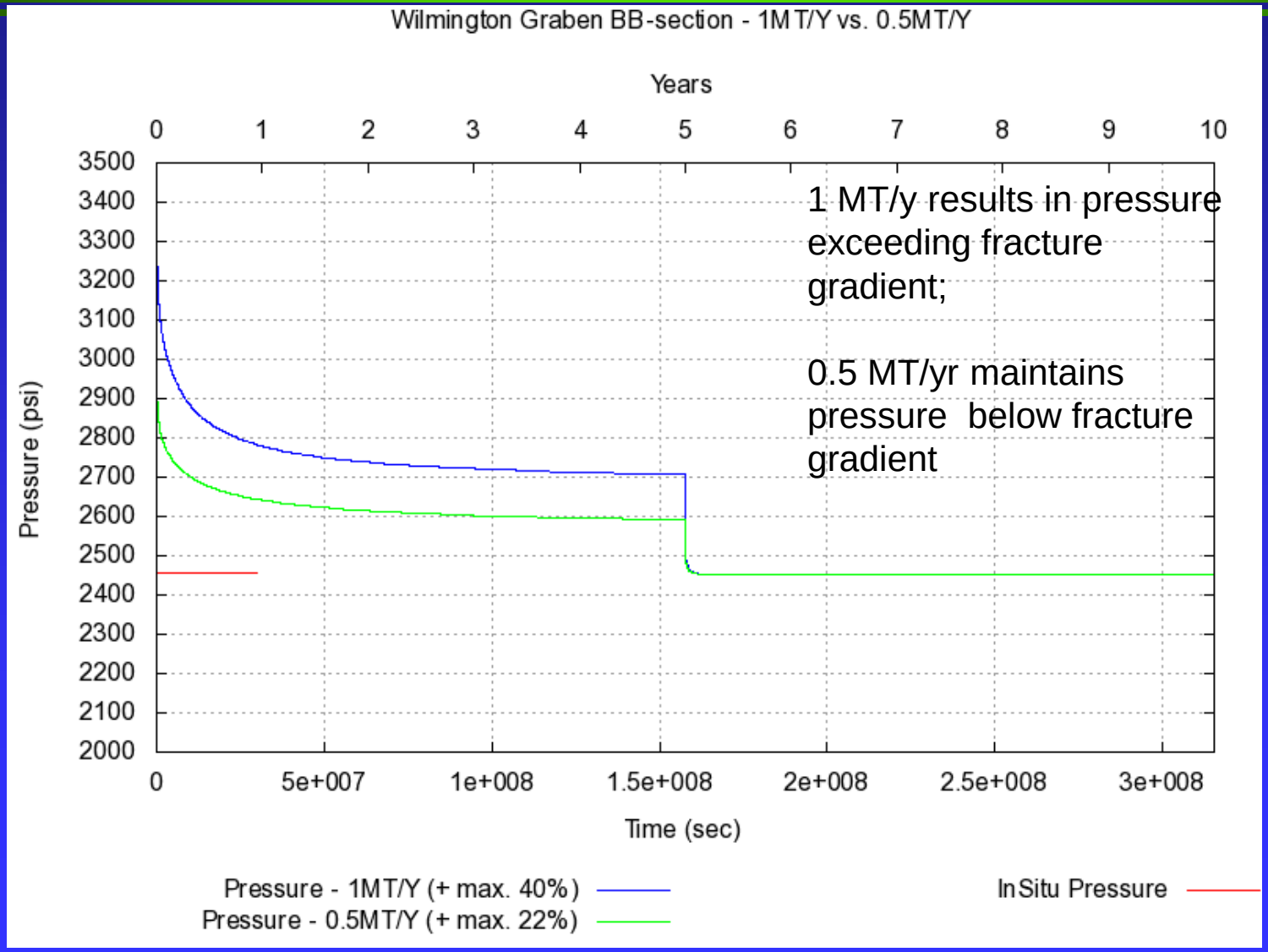
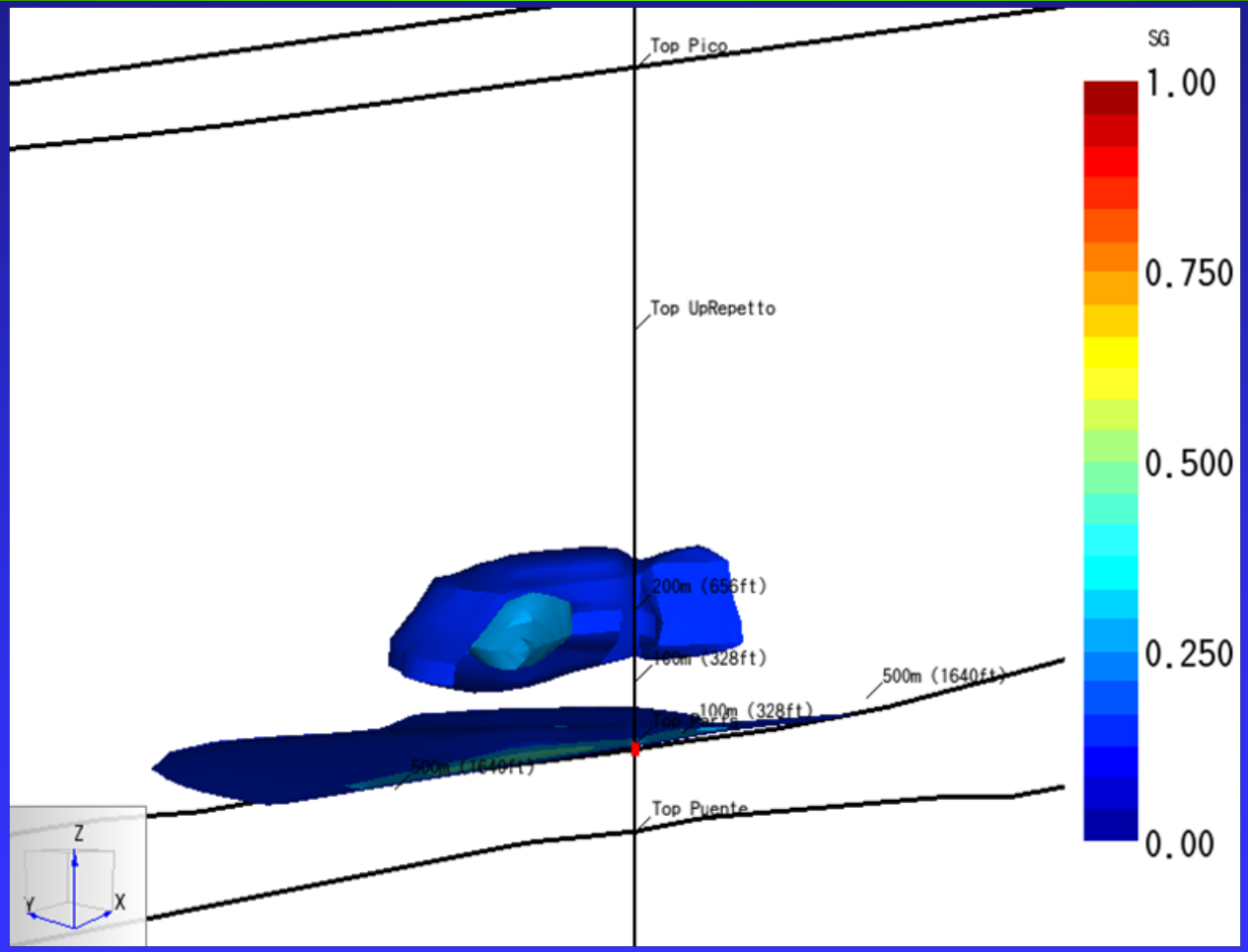
Gas saturation of baseline after 10 years of simulation (5 years injection, 5 years observation, 1MT/year



Pressure Comparison at Injection Cell for 1 MT/Yr and 0.5 MT/Yr Injection for 5 years



Gas saturation of baseline after 25 years of simulation (5 years injection, 20 years observation, 0.5MT/year)



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Task 8: Risk Assessment and Characterization

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Terminal Island Facility

DOE#1 (aka SFI # 3)

Section 8 - T5S - R13W

Slurry Injector

Deviated Well	KOP 1600ft, build angle 1degree/100ft	
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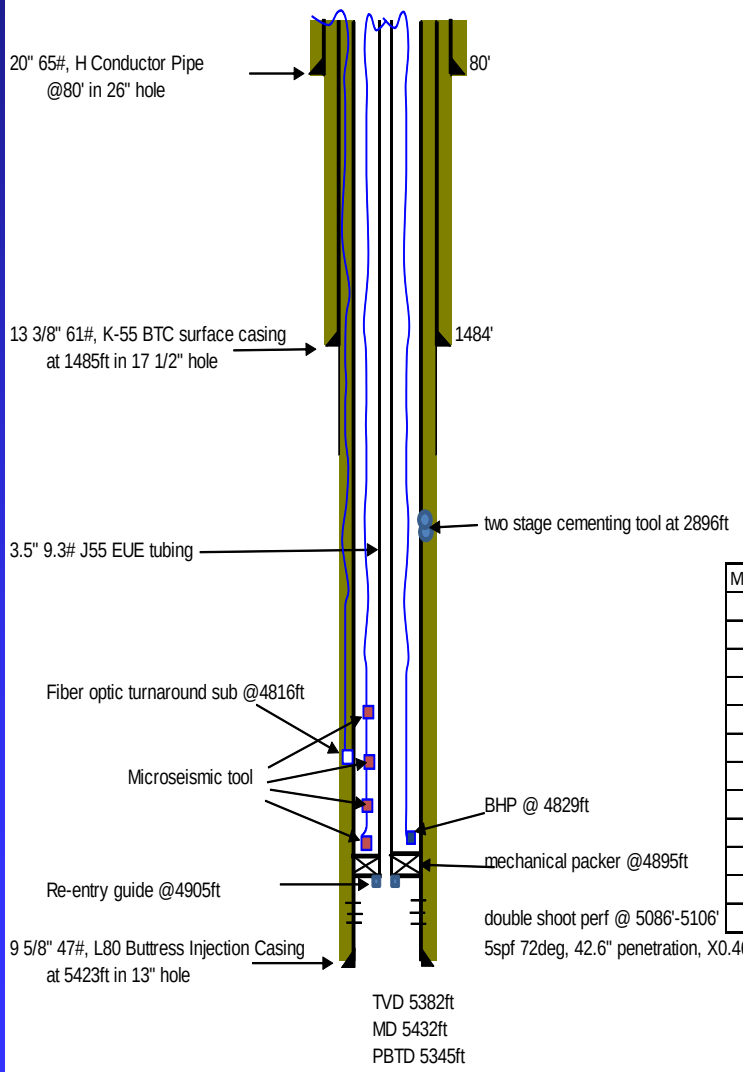

MD
1604
2076
2554
3002
3512
3956
4399
4872
5430

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1	-4215.1
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7	-4510.8
8	-4560.0
9	-4609.1
10	-4658.3
11	-4707.5
12	-4756.7

Wilmington Summary of Microseismic Activity Nov 4 - Nov 10, 2011

Date	# Triggers	# of Events	# Auto triggers	# Single Phase	# Noise	# Electrical Spikes
04-Nov-11	57	0	24	33	0	0
05-Nov-11	49	1	24	24	0	0
06-Nov-11	46	0	24	21	1	0
07-Nov-11	50	0	24	26	0	0
08-Nov-11	38	0	24	13	1	0
09-Nov-11	56	0	24	32	0	0
10-Nov-11	58	0	24	33	1	0
Nov04-Nov10	**354**	**1**	**168**	**182**	**3**	**0**

Microseismic Monitoring

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SoCalCarb - Home - Internet Explorer provided by Dell

http://socalcarb.org/

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SoCalCarb

Southern California Carbon Sequestration Research Consortium

Home | Sponsors & Participants | What is CO2 Sequestration | SoCal Carbon Atlas | Wilmington Graben Project | Other California Sequestration Projects

Sponsors & Participants

GeoEnvironment Technologies

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Home

Southern California Map (NASA JPL Shuttle Radar Topography Mission (SRTM))

The Southern California Carbon Sequestration Research Consortium (SoCalCarb) is a collaborative research group bringing together scientists and engineers from more than 10 public agencies, private companies, and universities to identify and validate the best regional opportunities for keeping CO_2 out of the atmosphere, thereby reducing our anthropogenic impact on the climate.

Led by Terralog Technologies USA, with funding support by the US Department of Energy and the California Energy Commission, SoCalCarb is pursuing characterization studies for large scale CO_2 sequestration both onshore and offshore Southern California.

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www.socalcarb.org

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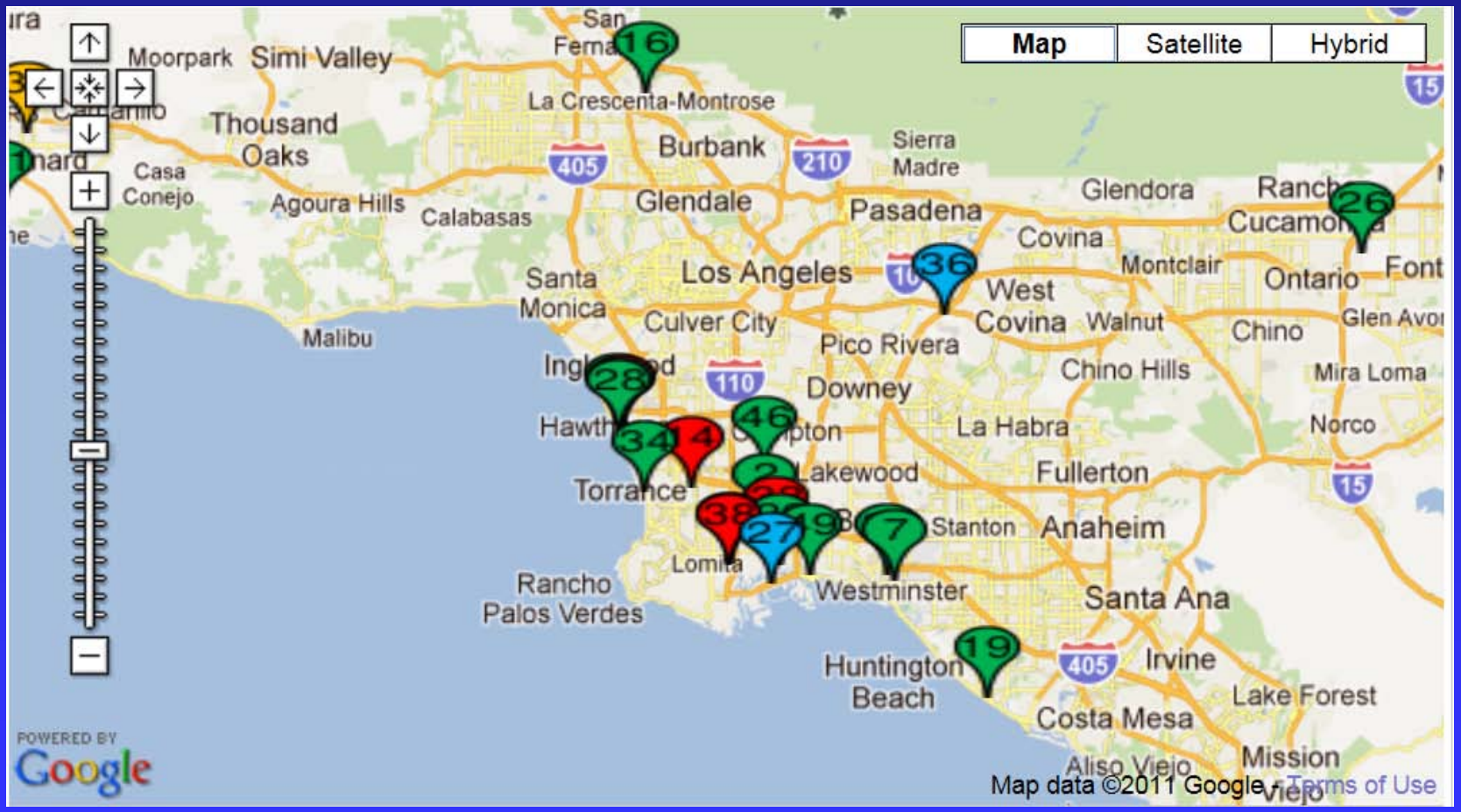
CO2 Sources



www.socalcarb.org

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Legend for Southern California CO2 Atlas

Pipelines: hide show

Sources: hide show

Sinks: hide show

LEGEND

Sources:

- Refuse-to-Energy Facility
- Mine
- Refinery
- Power Plant
- Cement
- Paper Factory

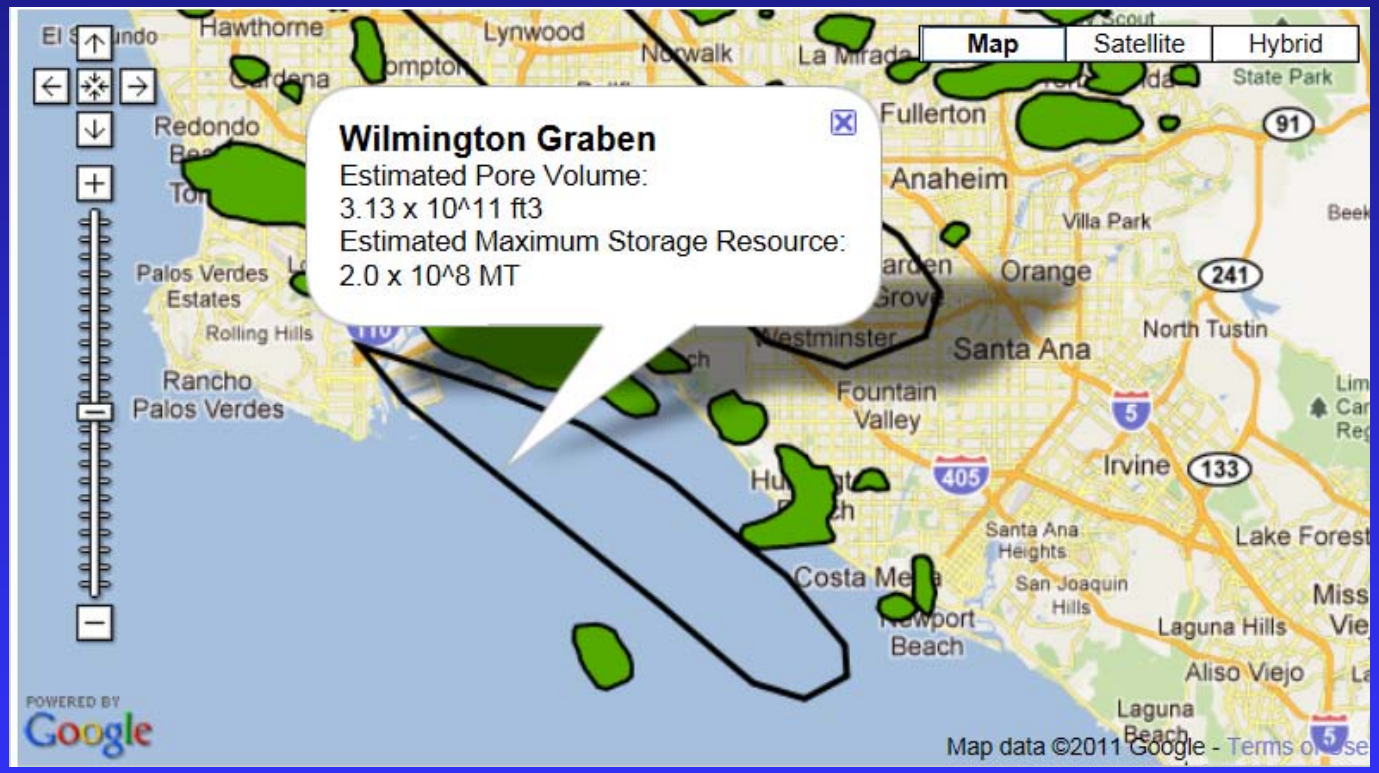
Sinks:

- Oil Field
- Natural Gas Storage
- Gas Field
- Saline Aquifer

Pipelines:

- BP/Arco
- Chevron
- Shell
- Kinder Morgan
- Pacific Pipelines
- Huntington Beach Gath
- All Other Pipelines

CO2 sinks



G_{CO2} – Estimated Mass
A - Area
H – Height
Φ – Porosity
ρ_{CO2} - Density at supercritical state
E - Efficiency Factor
B – Fluid formation volume factor
Sw - Water Saturation

$$G_{CO2} = (60\%\ A)*h*\Phi*\rho_{CO2}*X$$

$$X = (1-Sw)*B*E = 0.05$$

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Potential Pipelines for CO2 Transport

Location of pipelines are strictly estimated

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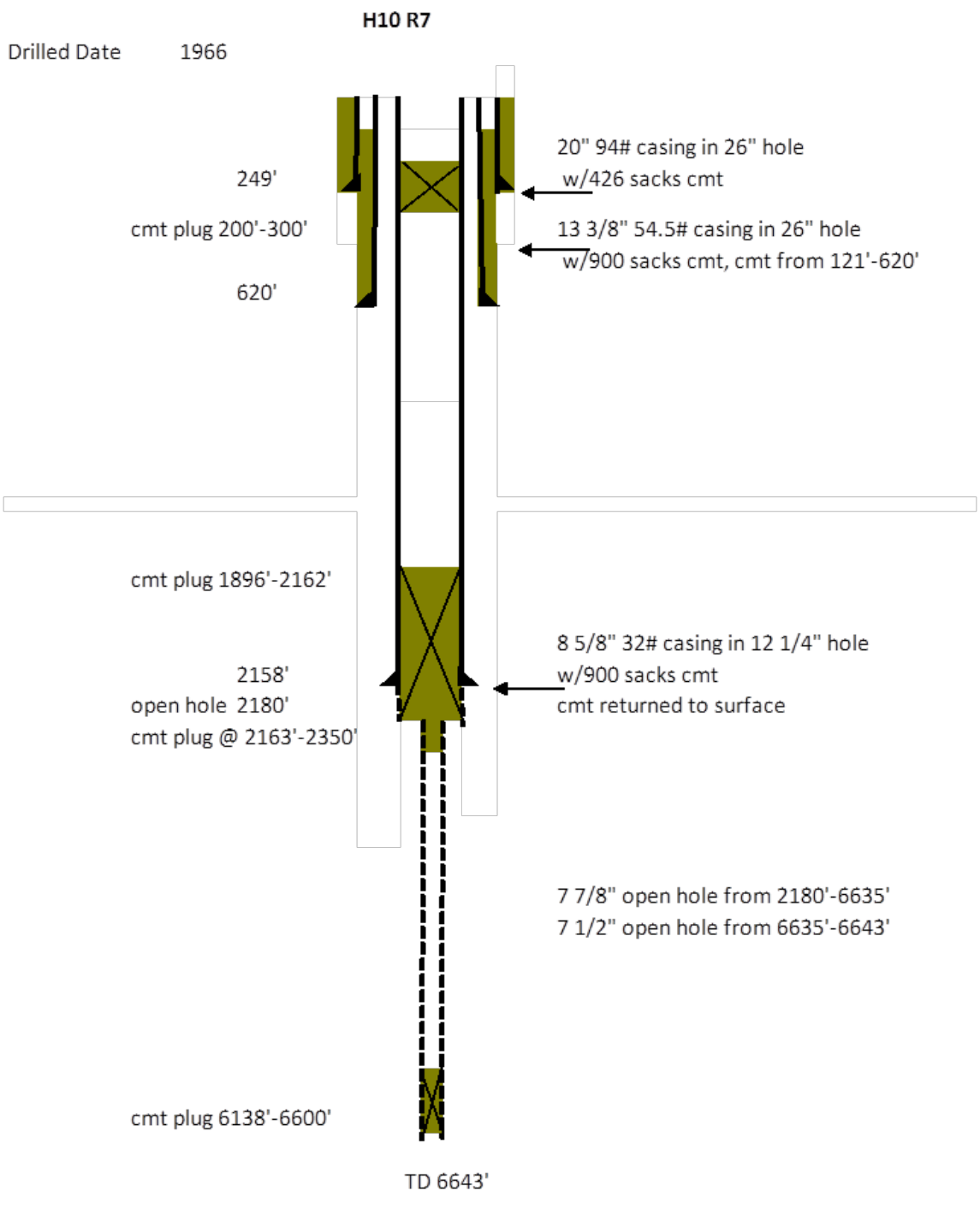
Well Schematic for 1960's era well



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Well Leakage Risks

All 9 DOGGR 1960's wells open hole below surface casing.

All 6 Federal 1970's offshore wells no well history data

3 New wells drilled in 2007 and 2010 all cased and cemented. No well leakage risk.

Problem wells will either need to be sealed or (preferably) those areas must be avoided completely.

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Summaries

- Acquired 175km of new seismic lines
- Drilled 1st characterization well into Pliocene
- Structure maps constructed for 4 horizons
- initiated geologic simulation
- Initiated CO2 migration modeling (TOUGH2): injecting 1 MT/yr results in pressure exceeding fracture gradient; 0.5 MT/yr maintains pressure below fracture gradient
- Initiated geomechanical modeling (FLAC3D)
- Preliminary storage estimates >100MT
- Old well path may need to be sealed or avoided for large scale CO2 storage
- Source, sinks and pipeline interactive maps available online

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Next Steps

- Improve 3D geologic model,
- Explore all options to obtain drilling well permits for 2 characterization wells
- Run geomechanical model for the northern and central areas
- Expand gas migration modeling to 50 years
- Complete engineering studies of LA Basin sources and transportation systems
- Risk characterization and documentation