

Abstract

The Southwest Regional Partnership on Carbon Sequestration is working closely with Chaparral Energy, LLC to study the effectiveness of large-scale CO₂ injection into the Farnsworth field unit (FWU). The field was discovered in 1955 with an estimated initial oil in place of about 120 MMBO. The target reservoir is the Morrow "B" sandstone. CO₂ flooding was initiated by Chaparral Energy in December 2010.

This poster describes the reservoir compositional fluid flow model of the FWU. A detailed geocellular model constructed from geological, geophysical and engineering data acquired from the FWU was used for the study. A laboratory fluid analysis was tuned to the Peng Robinson equation of state (EOS) for the compositional modeling. Following a suitable match, a slim tube simulation experiment was conducted to analyze the minimum miscible pressure (MMP). The model was then calibrated to reservoir history performance as a baseline for the study. Several models were constructed to study the oil recovery and storage capacity of the FWU.

MMP predicted after the EOS tuning was close to experimental values with errors of less than five percent. Simulation results showed an impressive performance of the CO₂ flood with significant oil production during the tertiary stage attributed to CO₂ injection. Above all, a high percentage of CO₂ has been sequestered within the Morrow formation.

The FWU project will serve as a baseline for future Carbon Capture, Utilization and Storage projects within the Anadarko basin and geologically similar basins throughout the world.

Reservoir Description

- Morrow sandstone deposited in an incised fluvial valley setting
- Diagenetic processes affected primary porosity and permeability
- Trapping mechanism is stratigraphic
- Productive limit extends to ~ 8300 acres
- Maximum pay thickness is 54 ft with an average of 22 ft
- No recorded gas-oil and/or oil-water contacts

Reservoir Production History

- First discovery well drilled by Unocal in October 1955
- Initial reservoir pressure at datum of 4900 ft was 2203 psig
- Original bubble point pressure was 2059 psig
- OOIP ~120 MMSTB
- Secondary recovery started in 1964
- Tertiary recovery started in 2010

Fluid Compositional Modeling

Objective

Tune laboratory PVT data of Farnsworth fluid sample to Equation of State (EOS) for Compositional reservoir simulation

Available Data

- Fluid composition sampled in 1956
- Experimental Data
 - Saturation Pressure Experiment
 - Constant Mass Expansion at 168 °F
 - Differential Liberation 1 at 168 °F
 - Multi Stage Separator Test

Important Initial Information

Reservoir pressure = 2203 psig
 Reservoir Temperature = 168 F
 Saturation Pressure = 2059 psig

Tuning Process

EOS equation - Peng Robinson
 Viscosity equation - Lohrenz-Bray-Clark correlation

Conclusions

- A detailed fluid analysis has been conducted on a FWU fluid sample for compositional modeling.
- A detailed history matching model for the FWU has been completed. This included primary production, waterflood and the first four years of CO₂ injection.
- Over 93% of purchased CO₂ has been stored as of June 2015.

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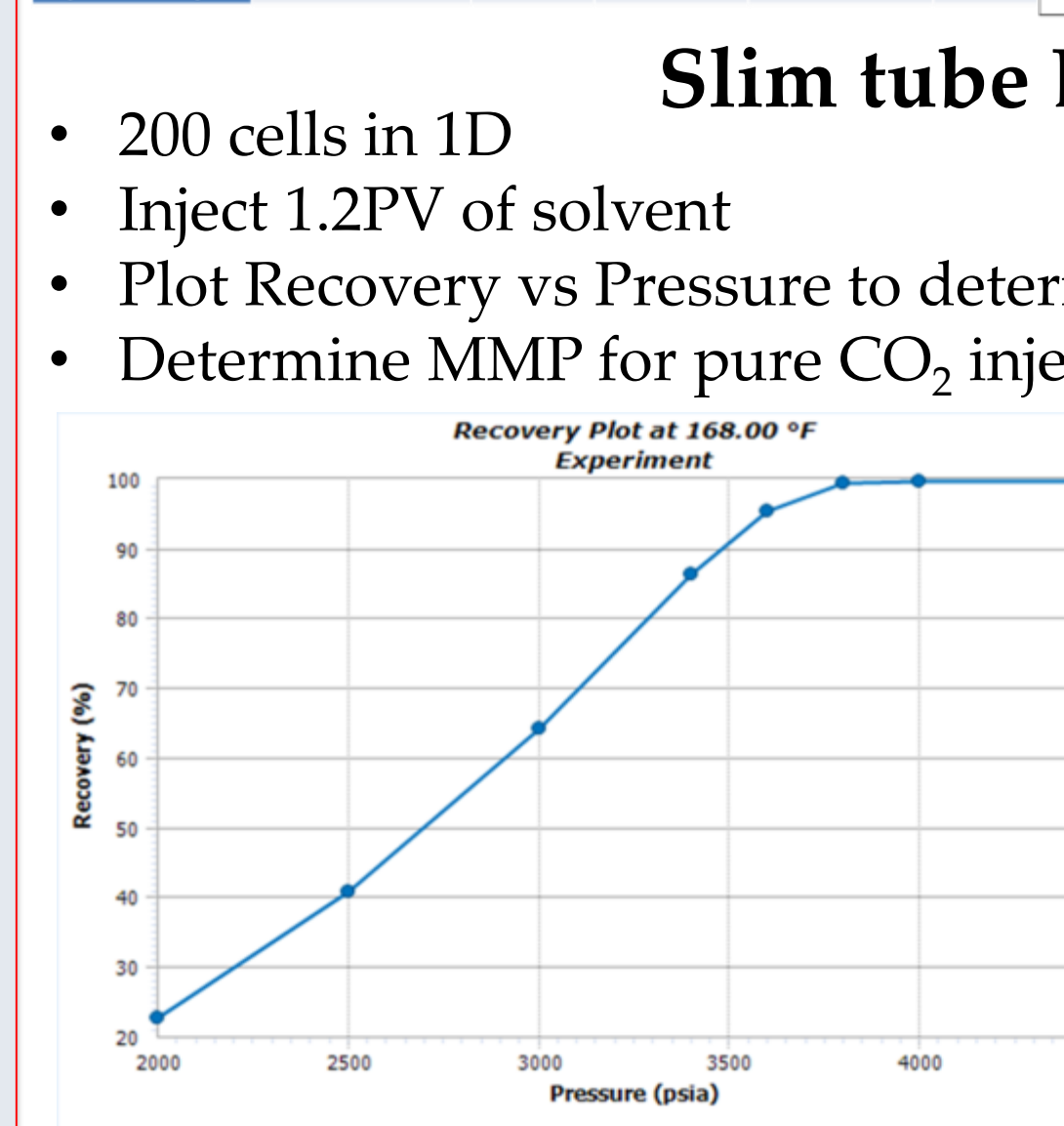
Petroleum Recovery Research Center,
 New Mexico Institute of Mining and Technology

Component	Weight %	Mol%	Density	API	Molecular weight
C1	3.98	38.44			
C2	0.75	3.85			
C3	0.7	2.46			
IC4	0.11	0.29			
NC4	0.62	1.66			
IC5	0.25	0.53			
NC5	0.59	1.26			
C6	1.57	2.83			
C7+	91.43	48.68	0.8477	35.3	291
Total	100	100			

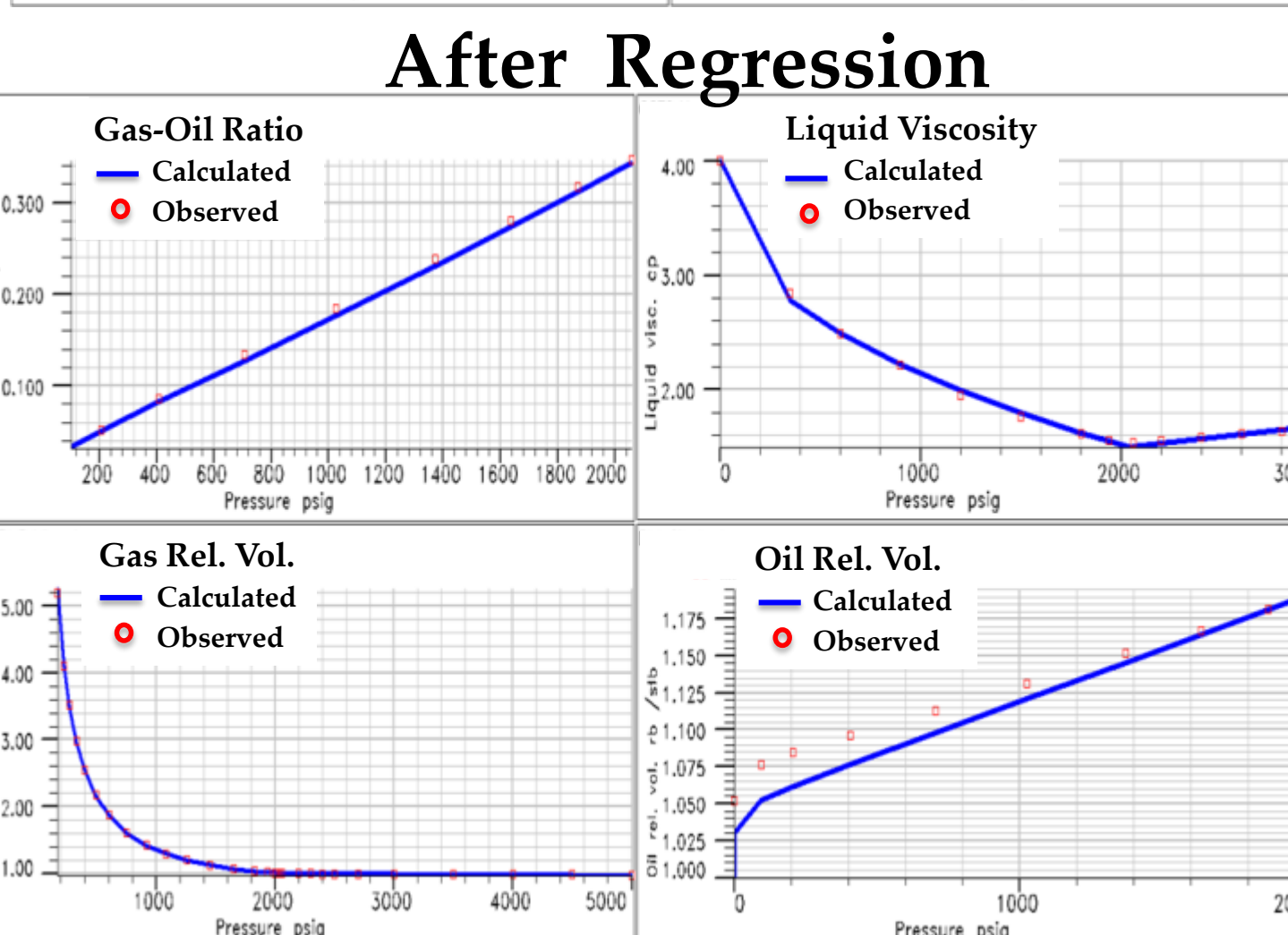
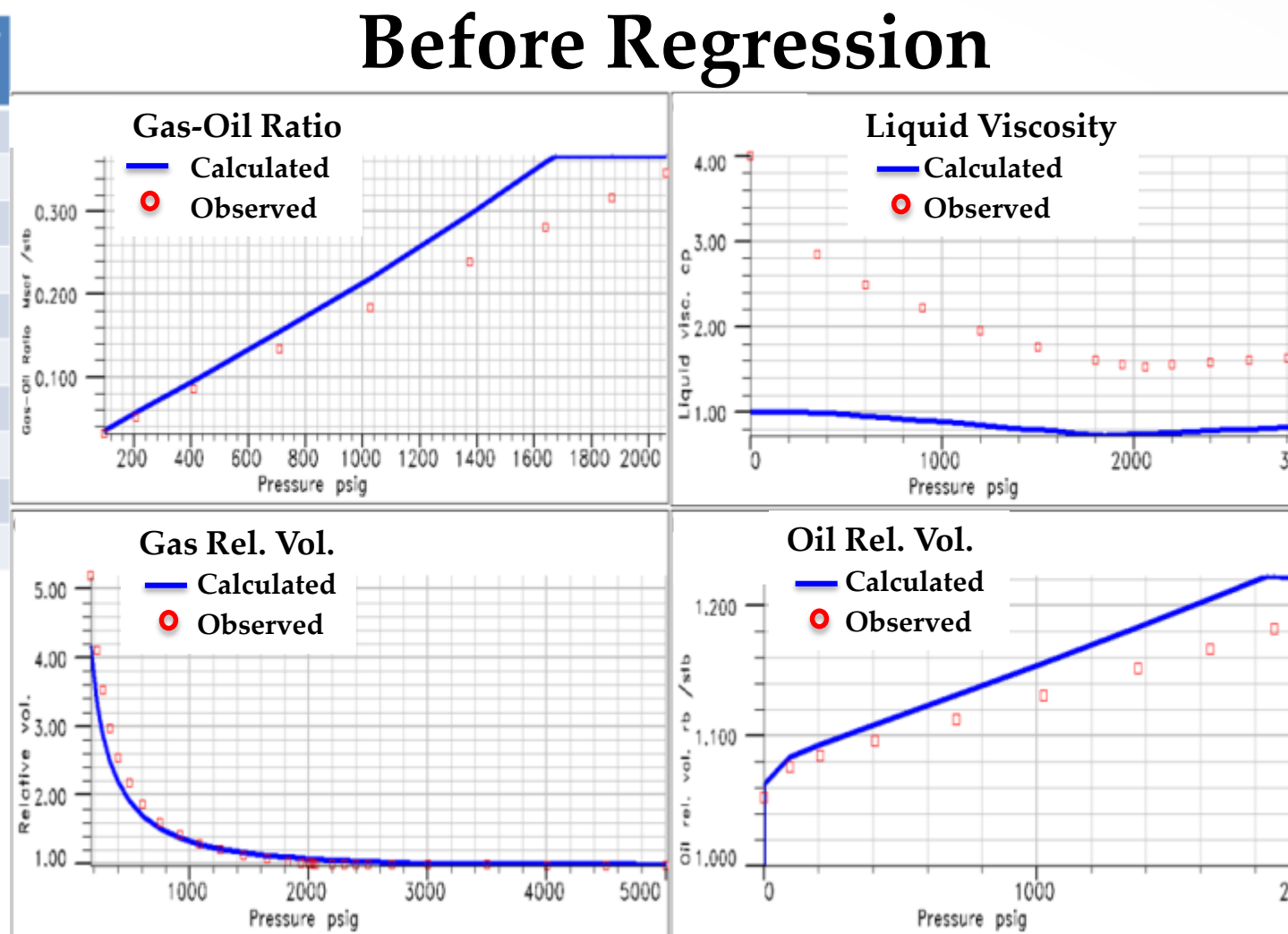
Properties	Units	Observed	Calculated	Reference Pressure	%Error
Saturation Pressure	psig	2059	1674		18.71
Oil FVF	RB/STB	1.192	1.2264	Observed Pb	2.89
Vapor Z-factor		0.906	0.898	1372	0.88
GOR	MSCF/STB	0.347	0.3576	Observed Pb	5.94
Gas Gravity		0.627	0.6153	1372	1.87
Liquid Viscosity	CP	1.536	1.0801	Observed Pb	29.68

Components	Zi	Weight fraction	Mol Weight
CO2	0.000	0.000	44.010
C1	38.491	3.873	16.043
C2	3.855	0.727	30.070
C3	2.463	0.681	44.097
C4+	1.952	0.712	58.124
C5+	1.793	0.811	72.151
C6	2.834	1.532	86.178
HC1	33.484	39.891	189.952
HC2	15.128	51.773	545.650

Properties	Units	Observed	Calculated	Reference Pressure	%Error
Saturation Pressure	psig	2059	2053		0.29
Oil FVF	RB/STB	1.192	1.1947	Observed Pb	0.23
Vapor Z-factor		0.906	0.8957	1372	1.14
GOR	MSCF/STB	0.347	0.347	Observed Pb	0.03
Gas Gravity		0.627	0.6192	1372	1.24
Liquid Viscosity	CP	1.536	1.5128	Observed Pb	1.51



Properties	Units	Observed	Before Regression	After Regression	%Error
MMP	psia	4200	3038.4	4008.8	4.5

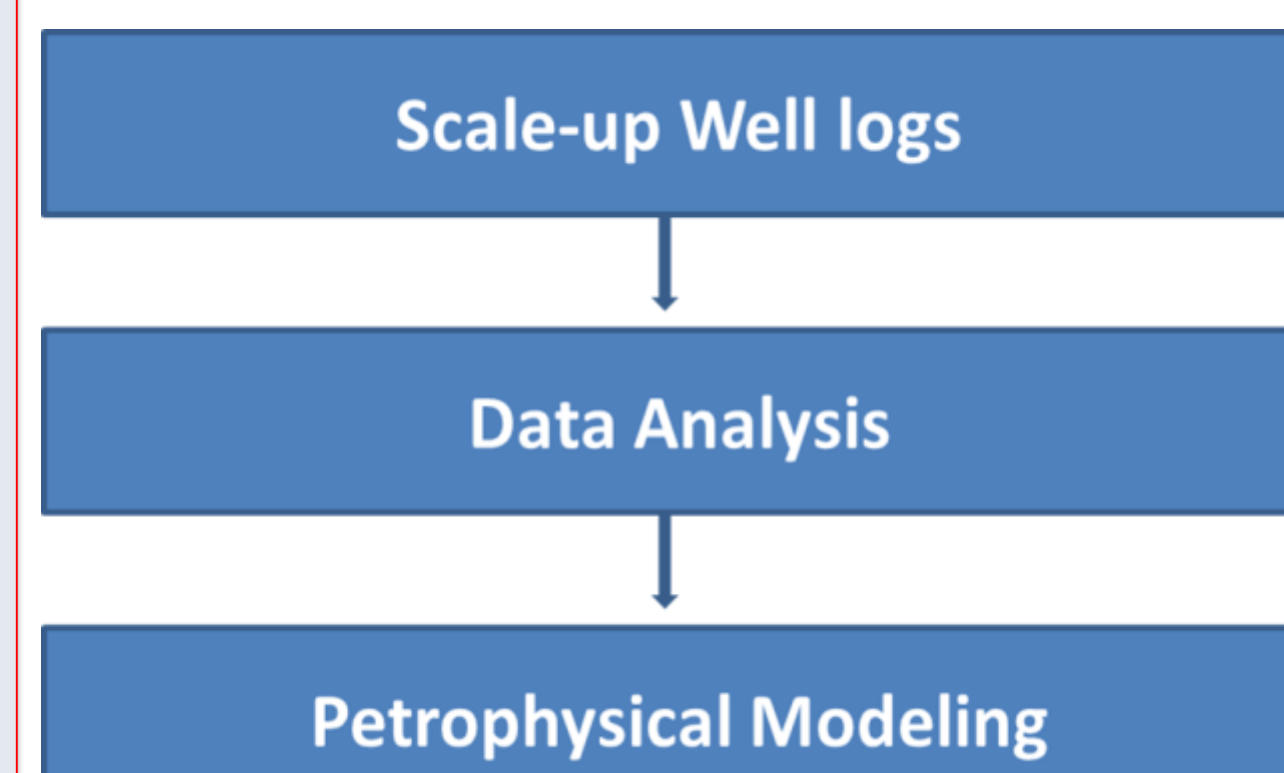


Slim tube Experiment

- 200 cells in 1D
- Inject 1.2PV of solvent
- Plot Recovery vs Pressure to determine MMP
- Determine MMP for pure CO₂ injection and with different impurities.

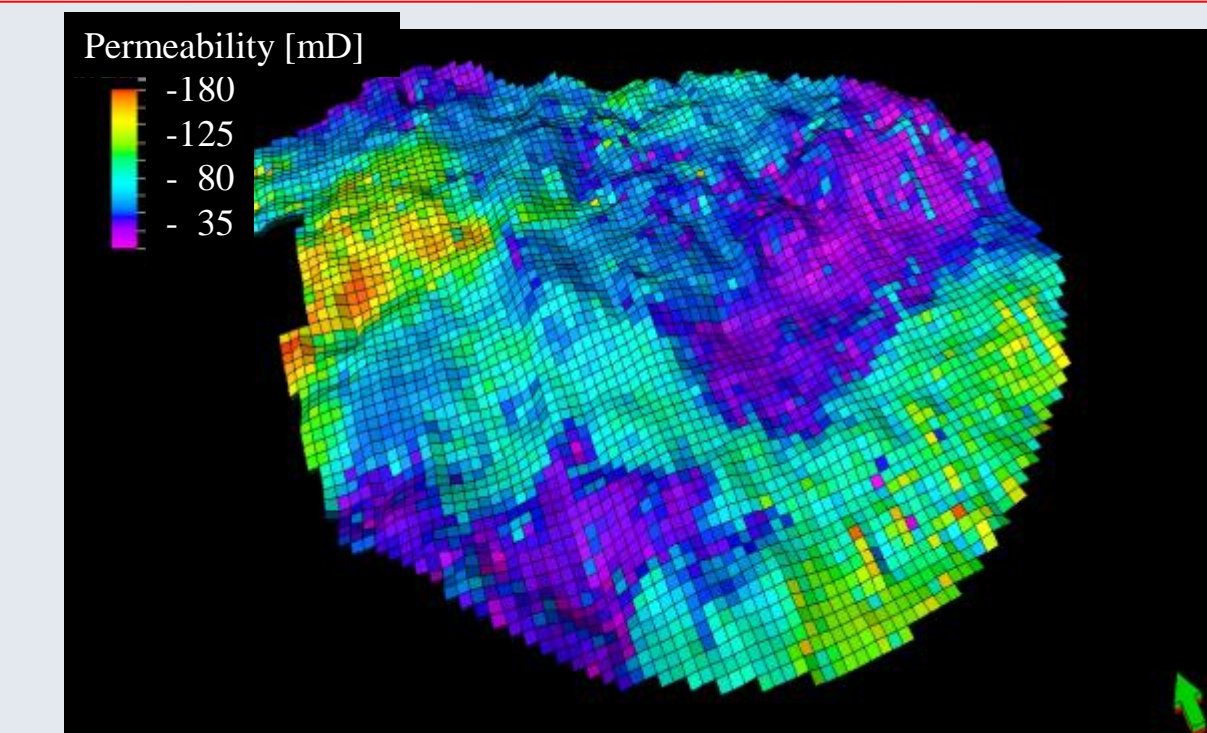
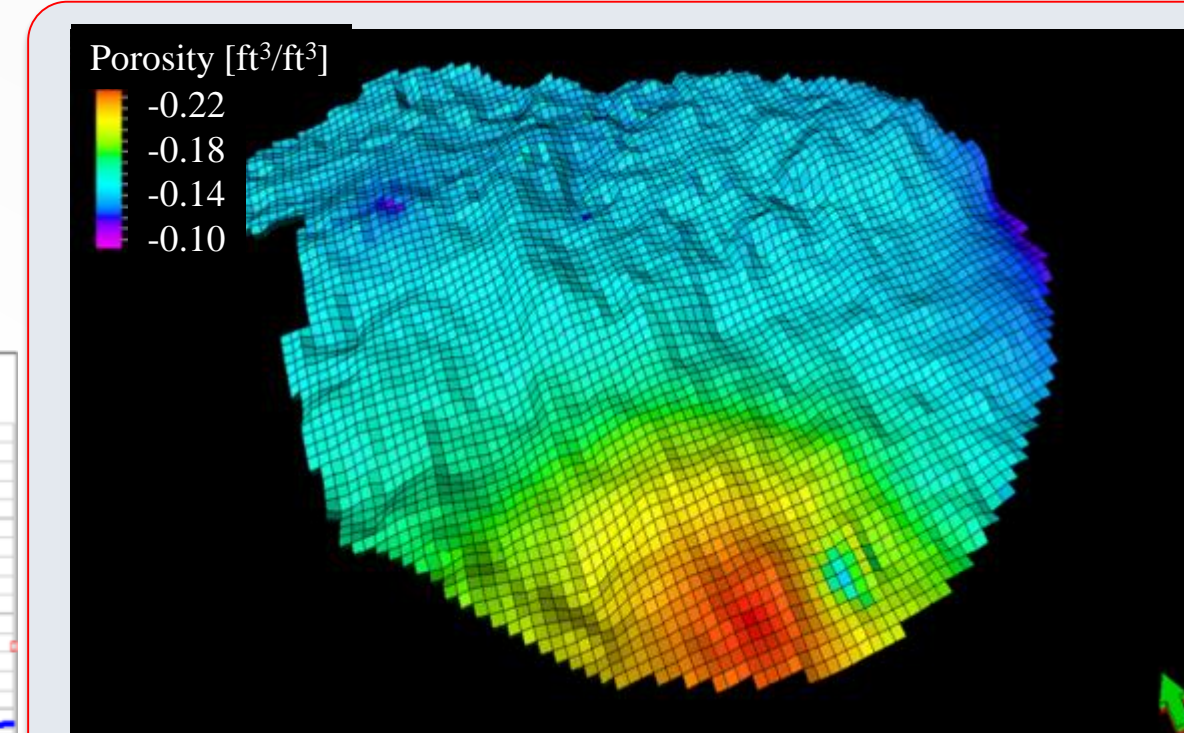
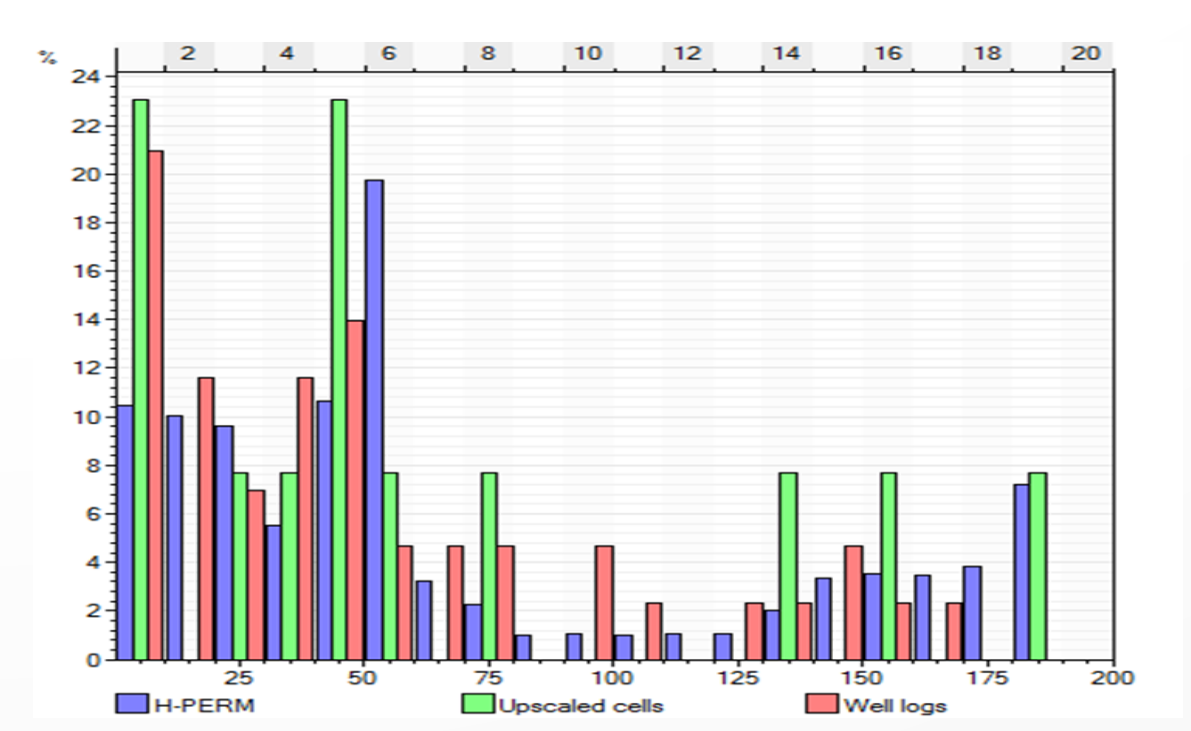
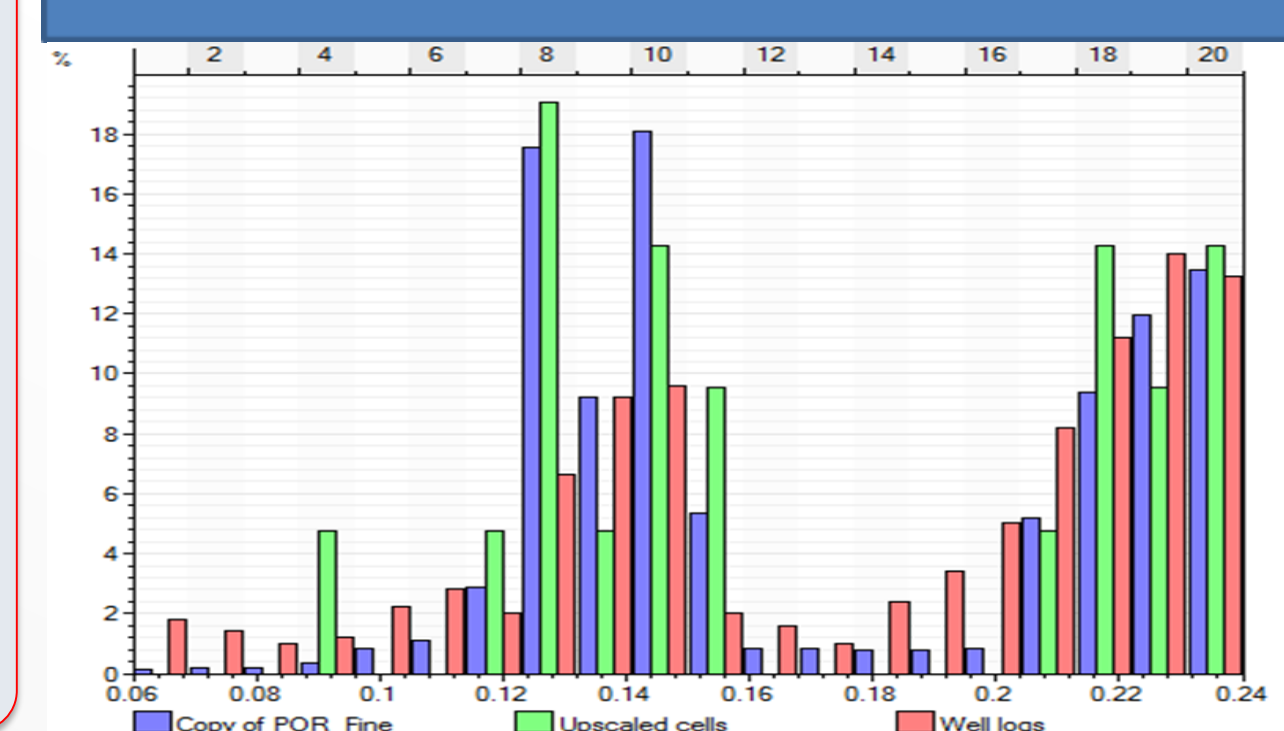
S.No	CH4 (%)	CO2 (%)	C2H6 (%)	N2 (%)	MMP(psia)
1	0	100	0	0	4008.8
2	5	95	0	0	4025.6
3	10	90	0	0	4094.6
4	15	85	0	0	4196.6
5	20	80	0	0	4321.4
6	0	95	5	0	3635
7	0	90	10	0	3389.9
8	0	85	15	0	3211.3
9	0	80	20	0	3070.5
10	0	95	0	5	4641.5
11	0	90	0	10	5336.1
12	0	85	0	15	6102.3
13	0	80	0	20	6952

Geological Model



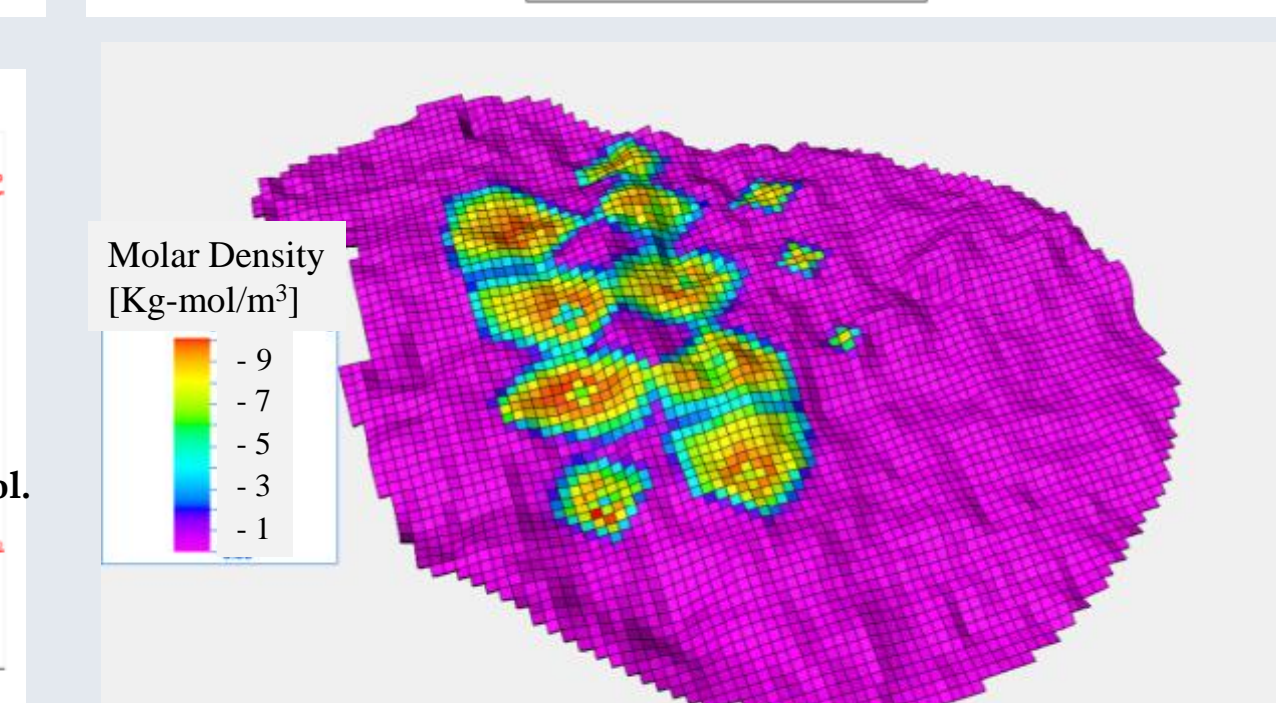
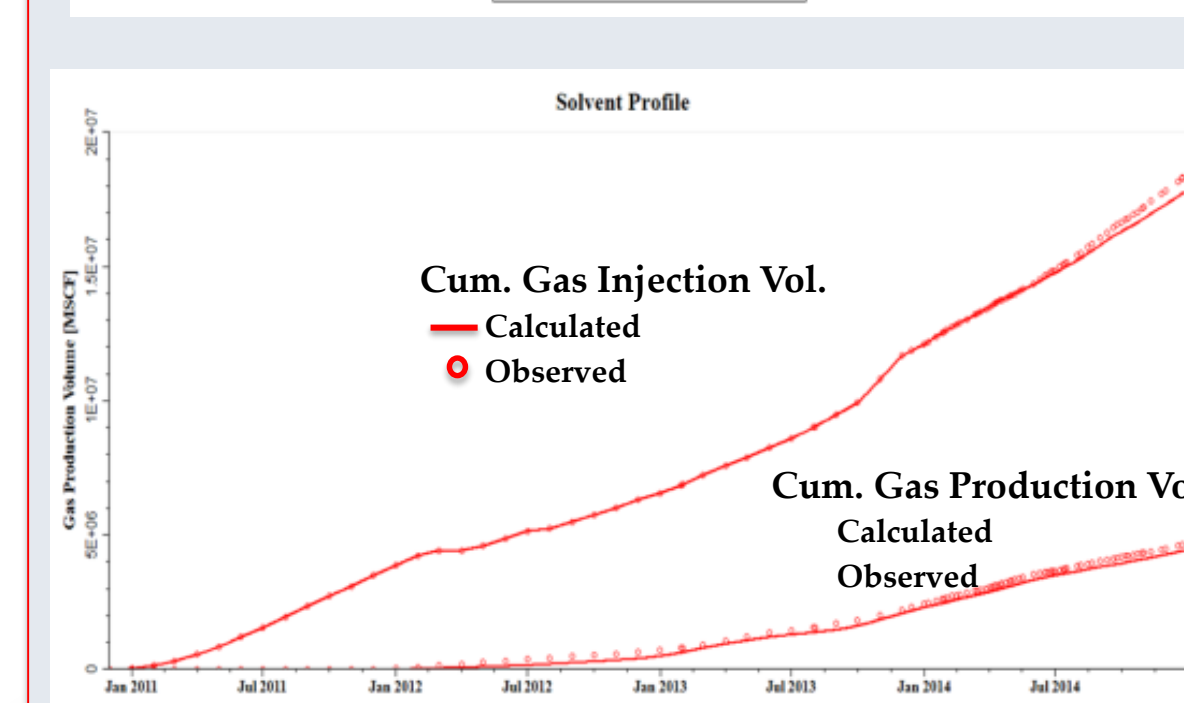
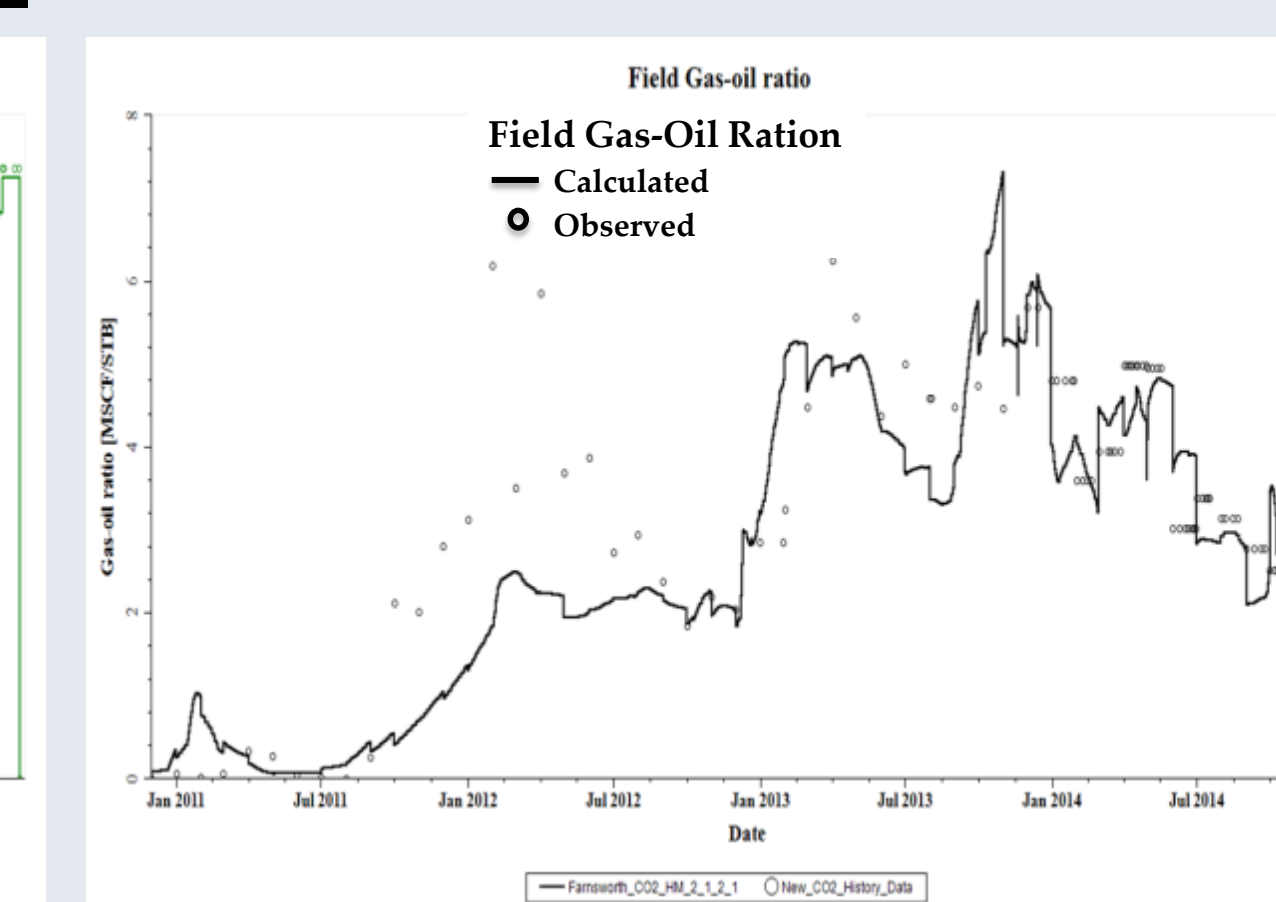
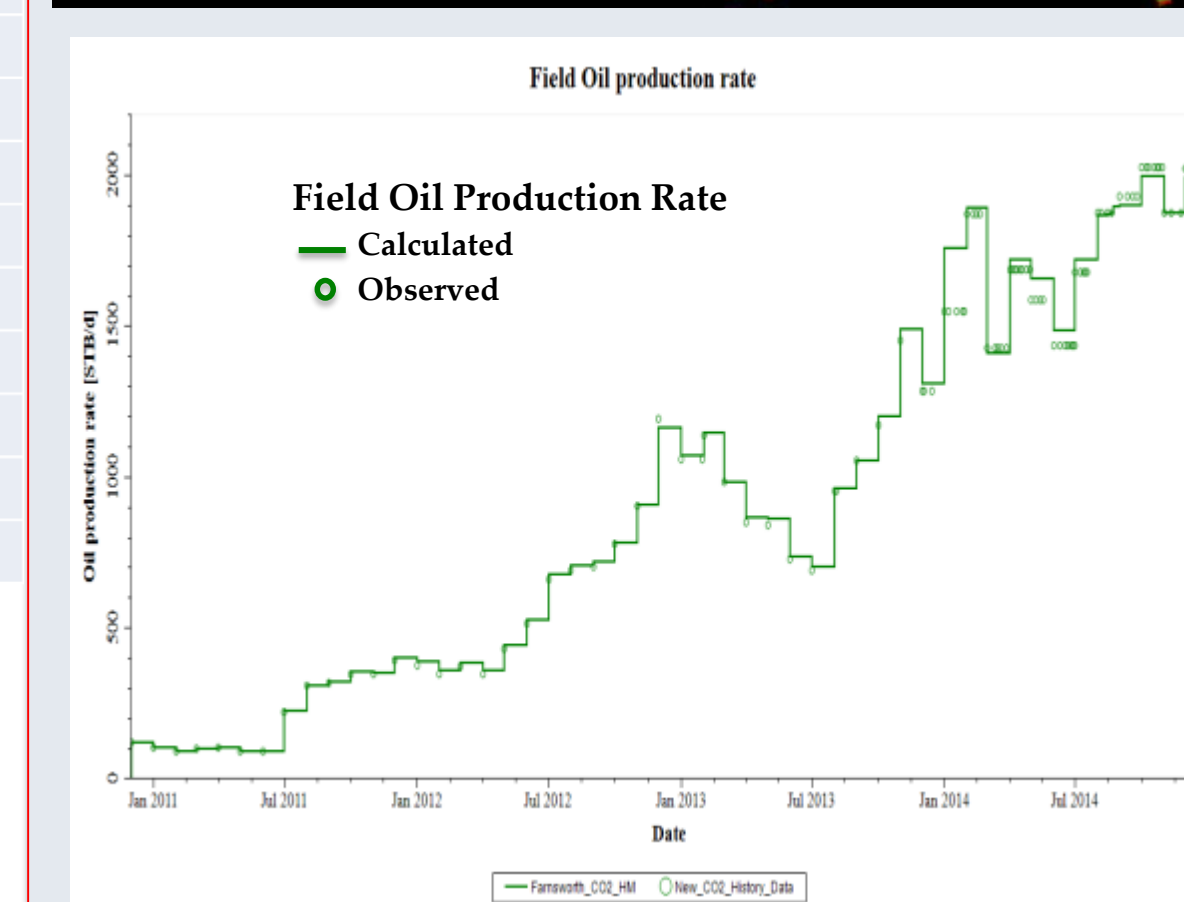
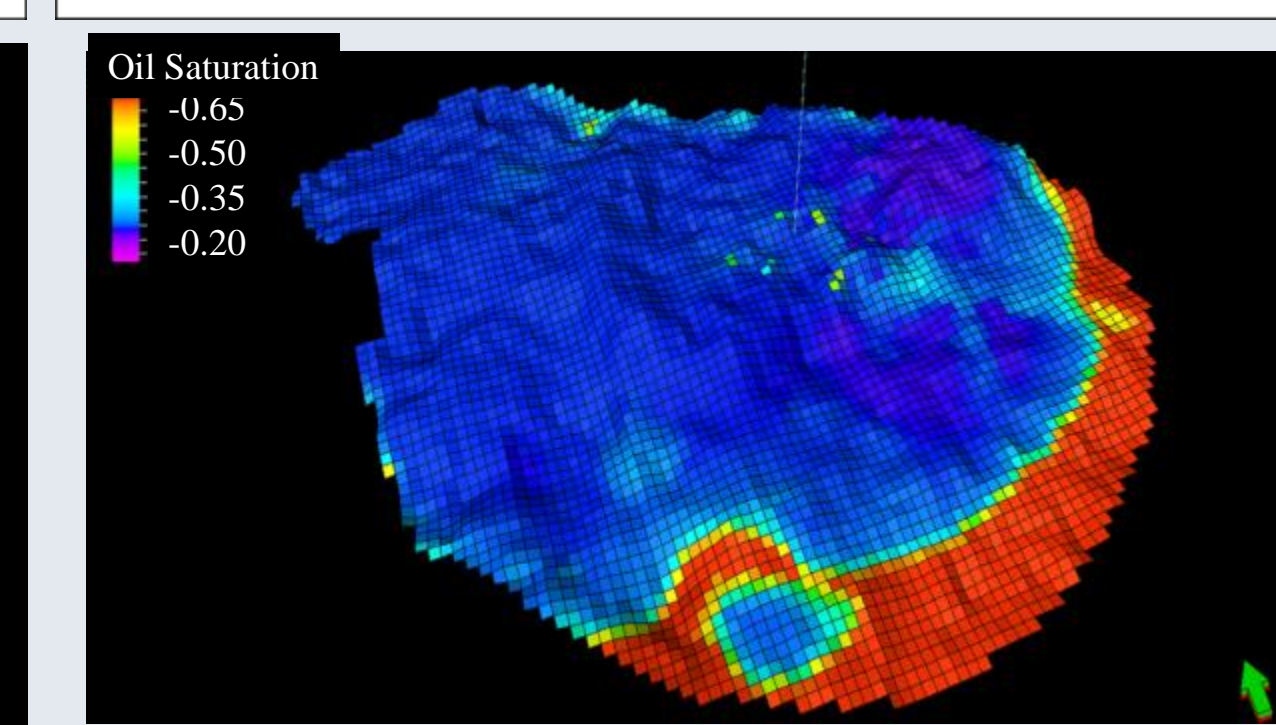
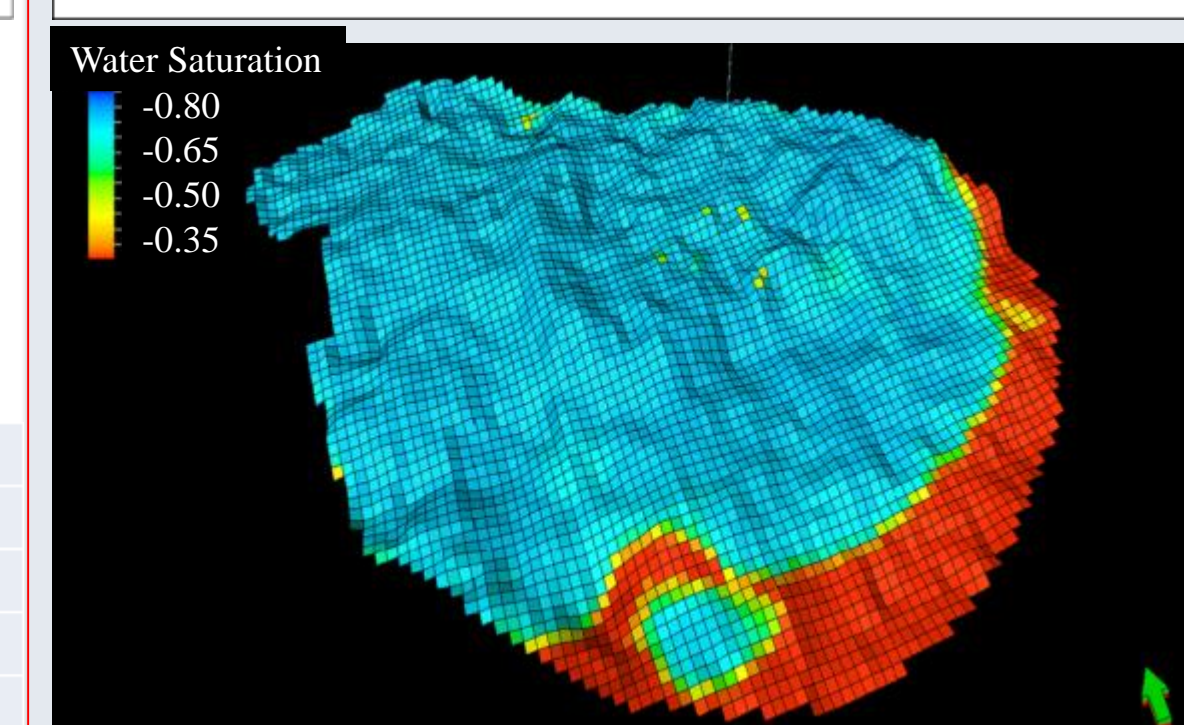
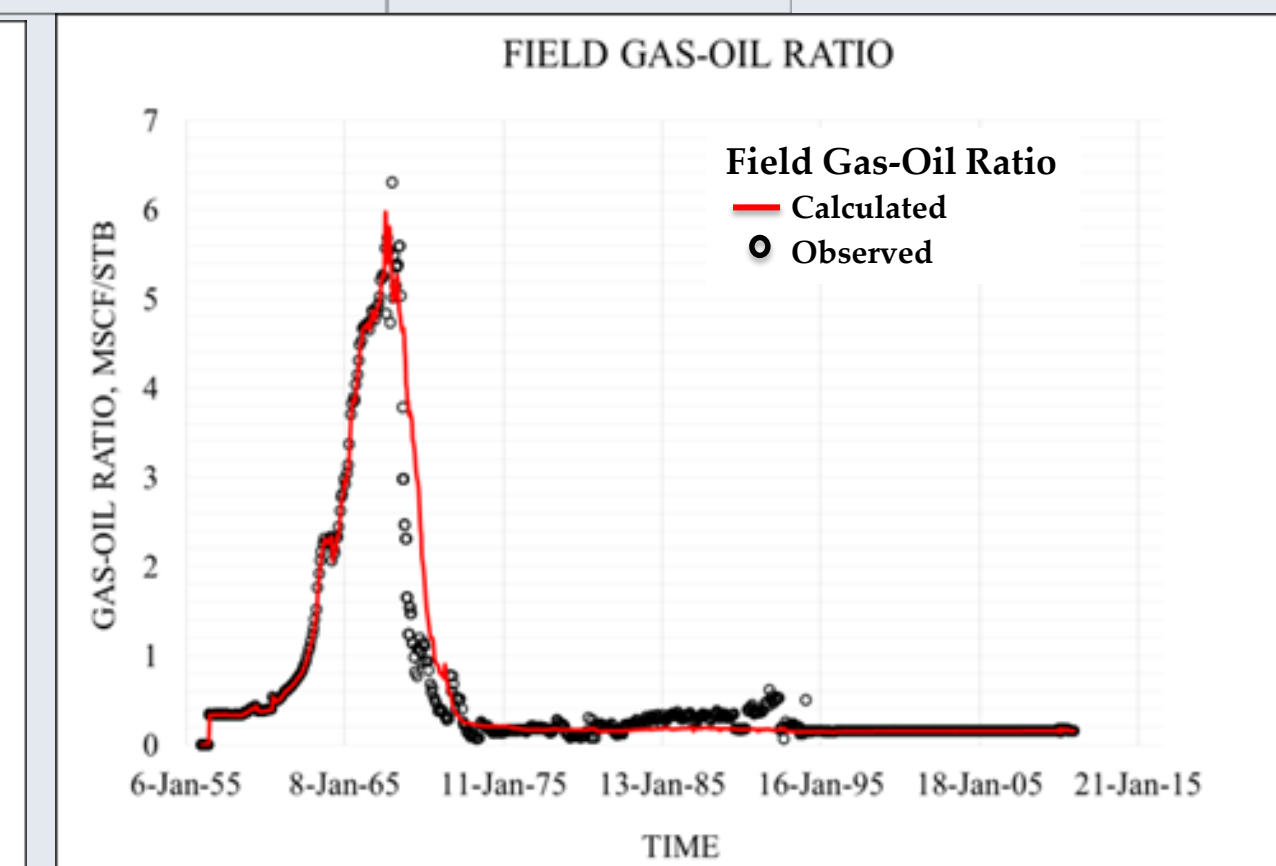
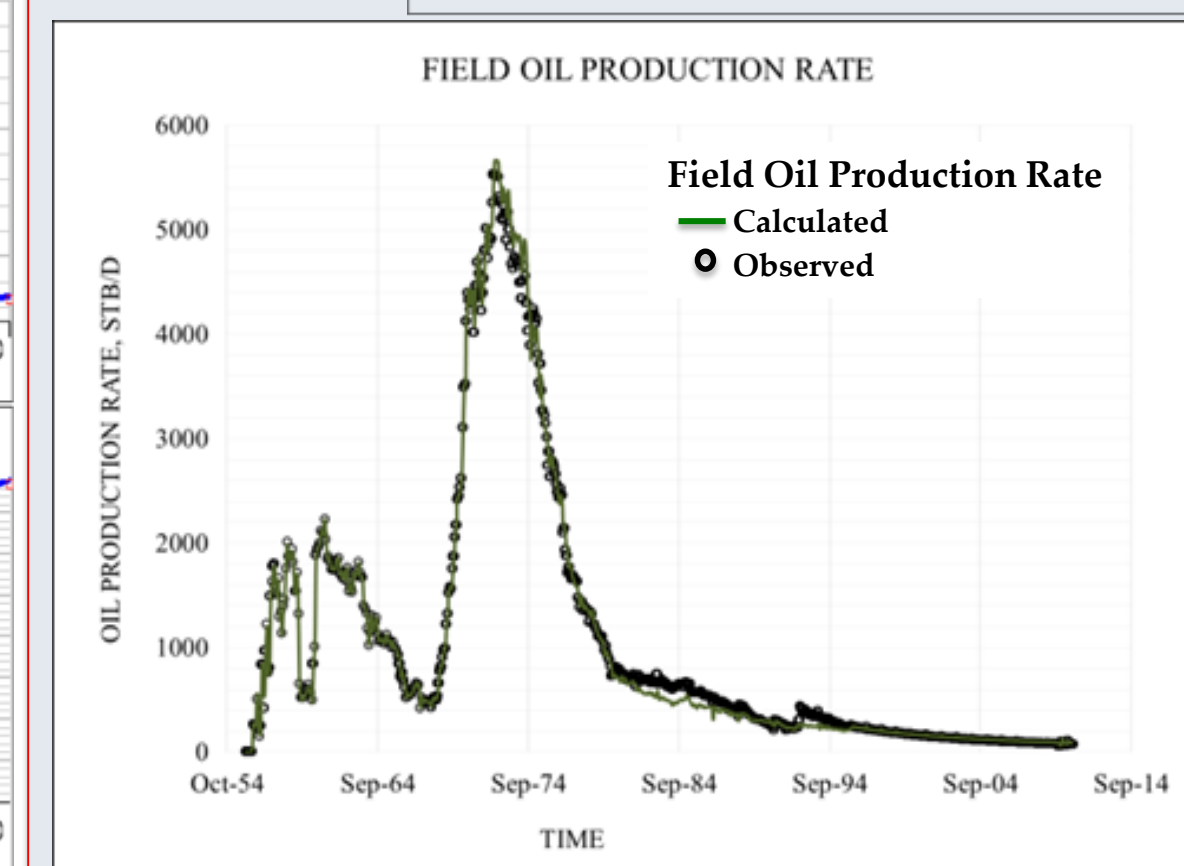
- 55 Wells have Porosity logs
- Source: Core and interpretation
- Scale up using Arithmetic Averaging

- 48 Permeability logs
- Source: Core data
- Scale up using Geometric Averaging



Simulation Model

P _{init} , psig @ Datum Depth	2203
P _{bubble} , psig @ Datum Depth	2059
Datum Depth(subsea), ft	4900
GOR, Mscf/stb	0.345
Temperature, °F	168
Initial Water saturation	0.31



Acknowledgement

"Funding for this project is provided by the U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) through the Southwest Partnership on Carbon Sequestration (SWP) under Award No. DE-FC26-05NT42591. Additional support has been provided by site operator Chaparral Energy, L.L.C. and Schlumberger Carbon Services."