

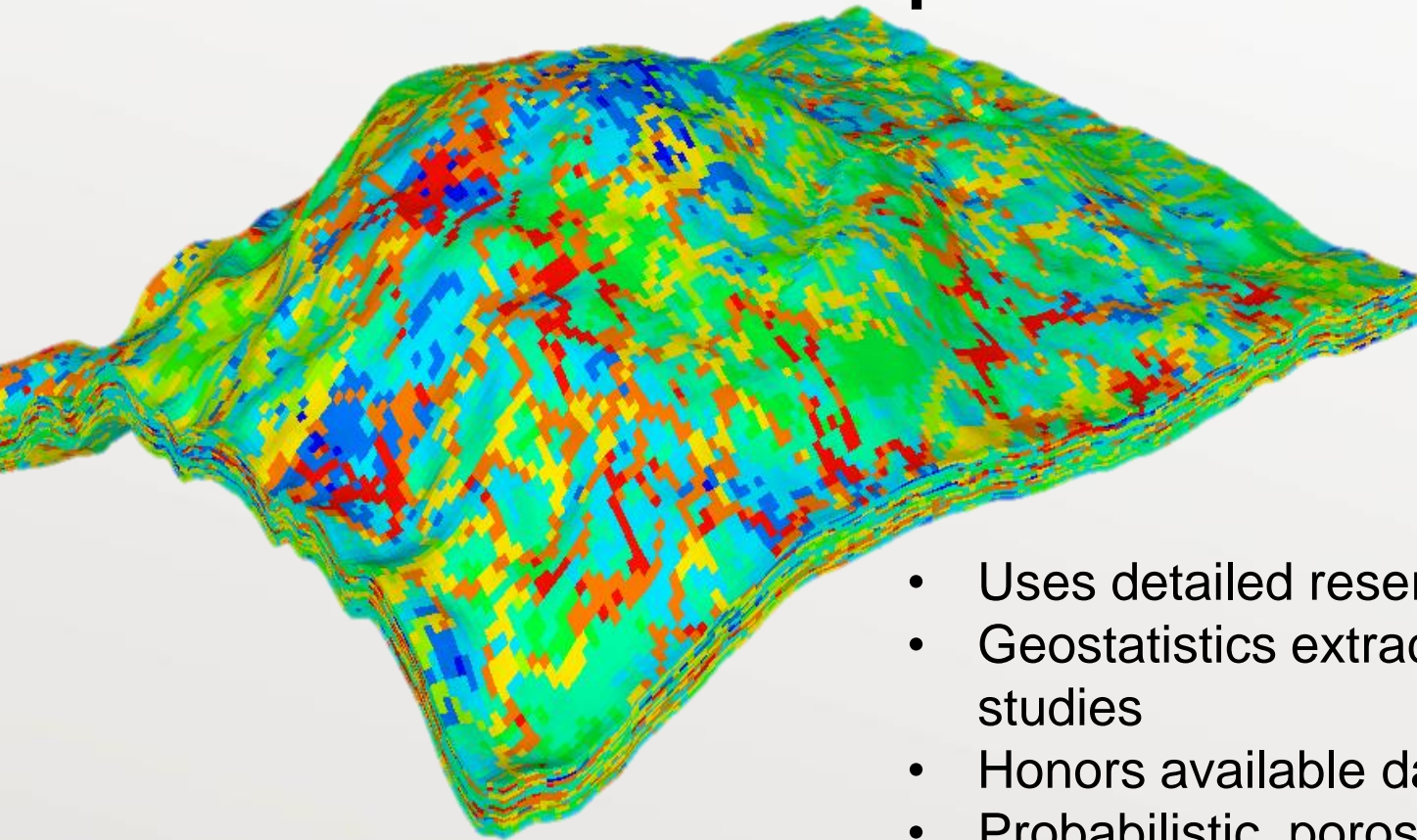
# Update on Reservoir Modeling and Final Testing and P&A underway

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Bureau of Economic Geology  
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March 11, 2013

# Modeling Update (Hossieni)

- Significant progress since last update
  - History matching 1943-1966 production
  - Included oil using black oil simulator
    - Modeling not focused on production but CO<sub>2</sub> tracking
  - Expanded domain modeled to whole field
  - Expanded time frame to current project and model into future
  - Approximate match with time-lapse seismic
- Model can be now used for scenarios

# Reservoir properties: Porosity input

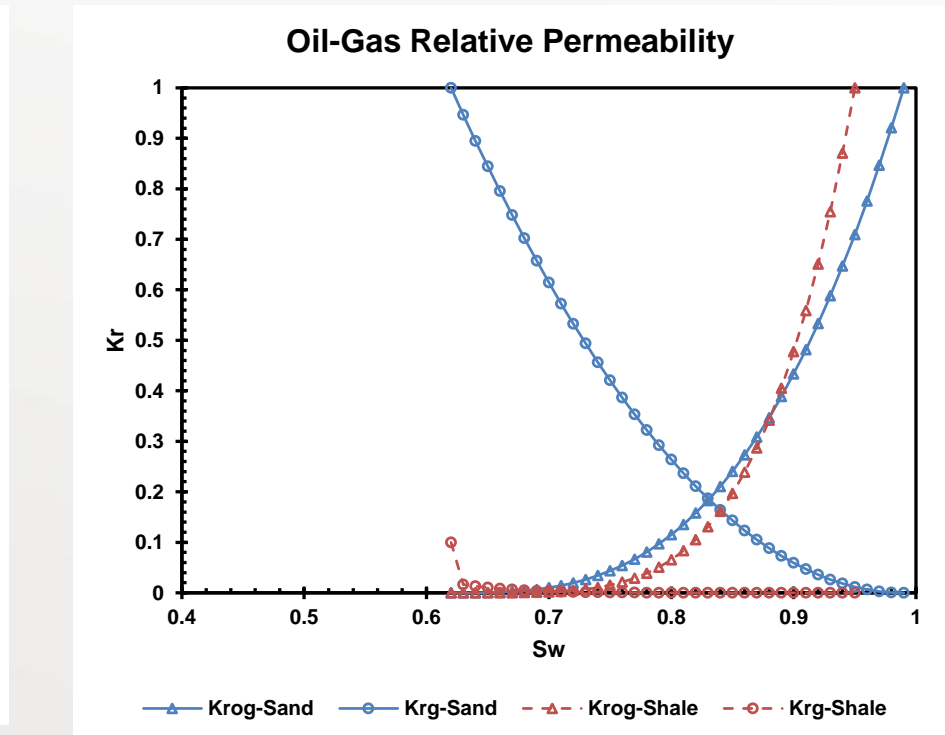
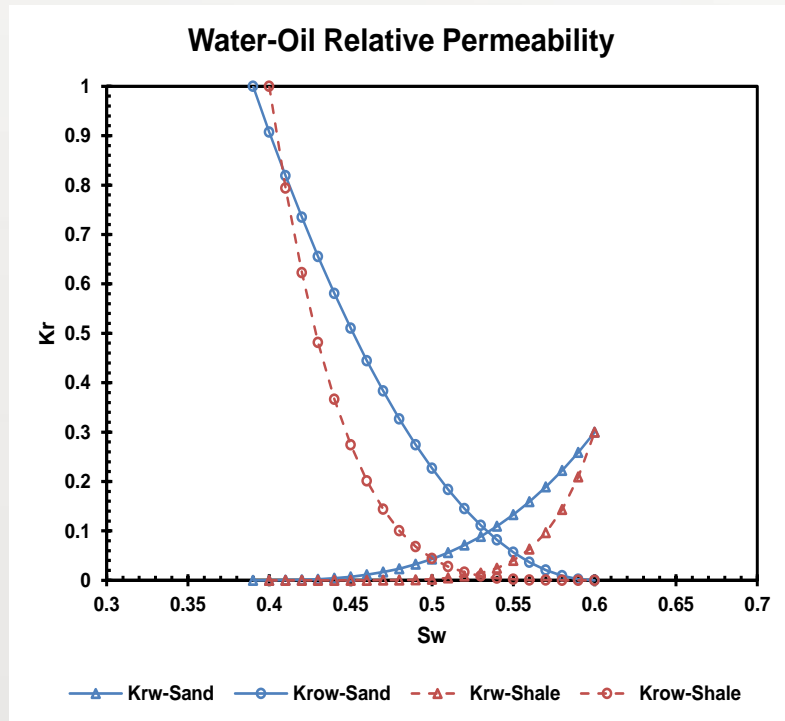


- Uses detailed reservoir geometry
- Geostatistics extracted from detailed studies
- Honors available data
- Probabilistic porosity and permeability

# Reservoir related parameters used in the simulator

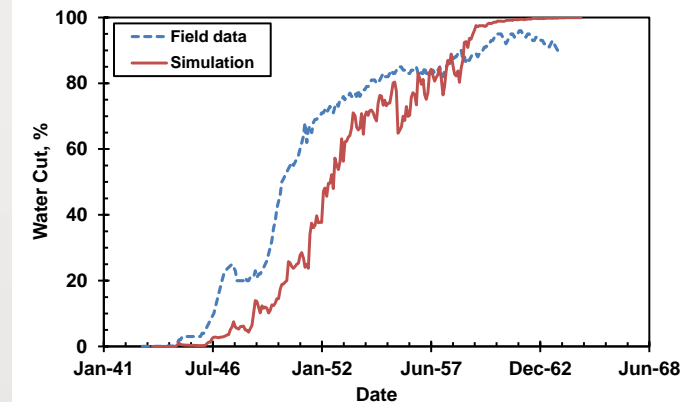
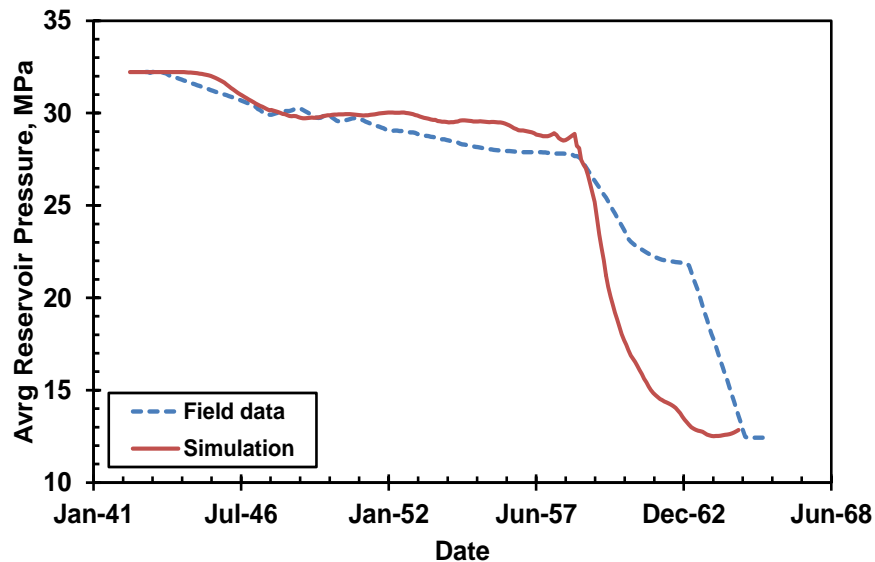
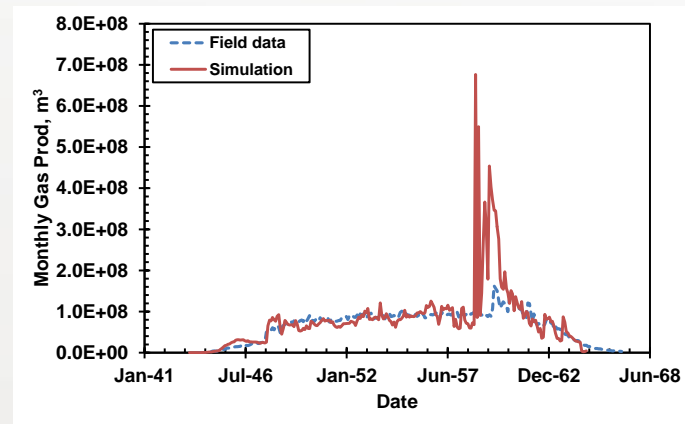
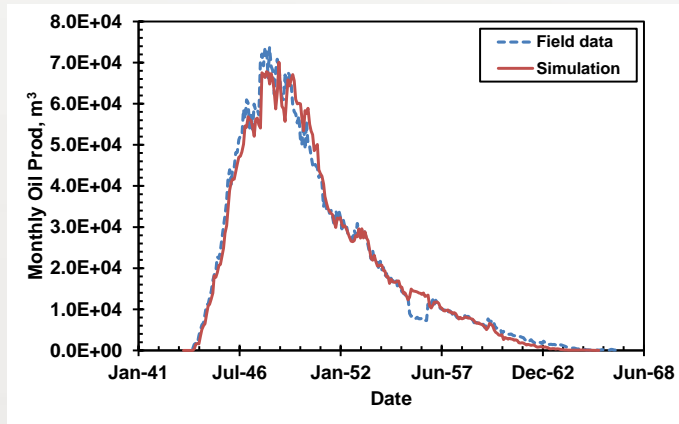
Parameter	Value
Stock tank oil density	873 kg/m <sup>3</sup>
Gas density SC	0.942 kg/m <sup>3</sup>
Water density	1108 kg/m <sup>3</sup>
Solvent (CO <sub>2</sub> ) density	1.8 kg/m <sup>3</sup>
Oil compressibility above pb	1.98E-9 Pa <sup>-1</sup>
Initial Pb	31.06 MPa
Original water oil contact depth	3064 m
Original gas oil contact depth	3008 m
Pressure at ref depth of 3048 m	32.03 MPa

# Model using black oil simulator CMG-IMEX

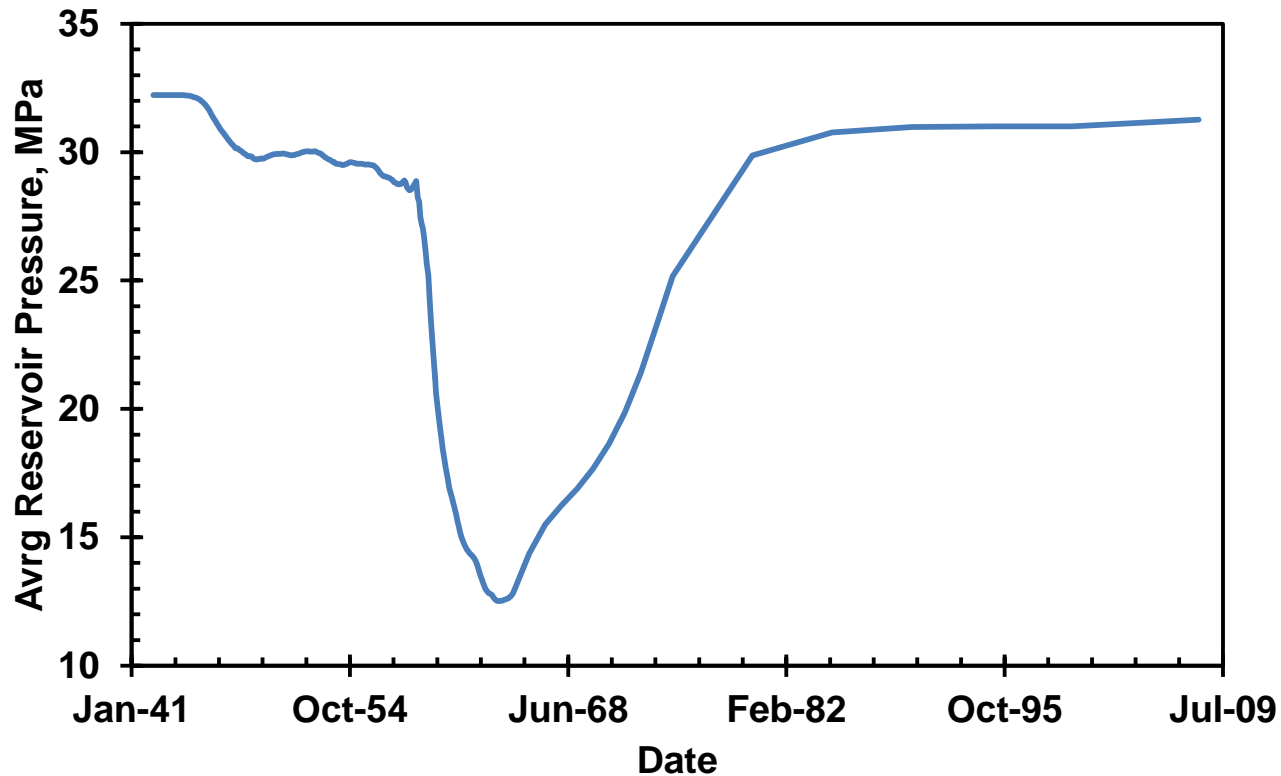


Pseudo-miscible model, Todd and Longstaff 1972

# Historic data history matching

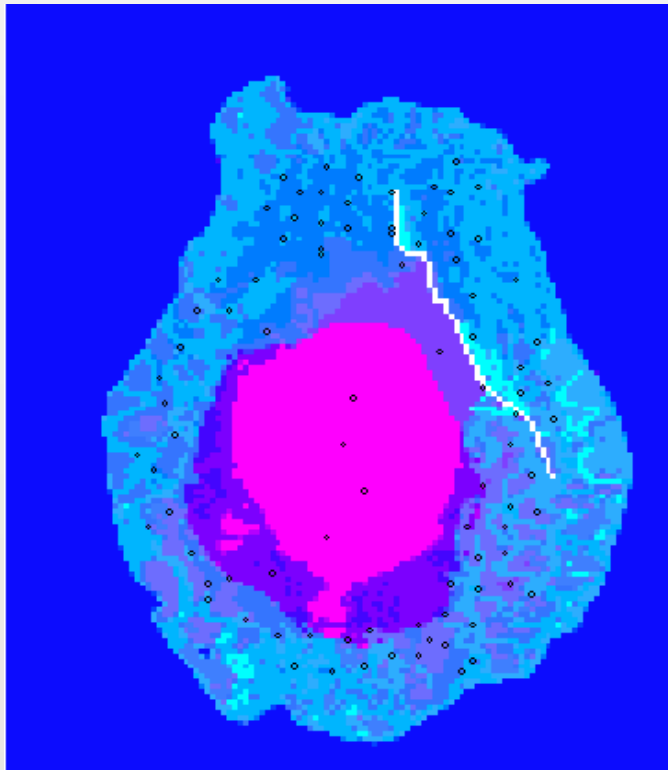


# Preinjection Pressure history

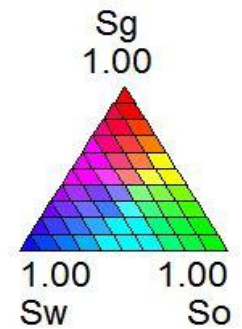
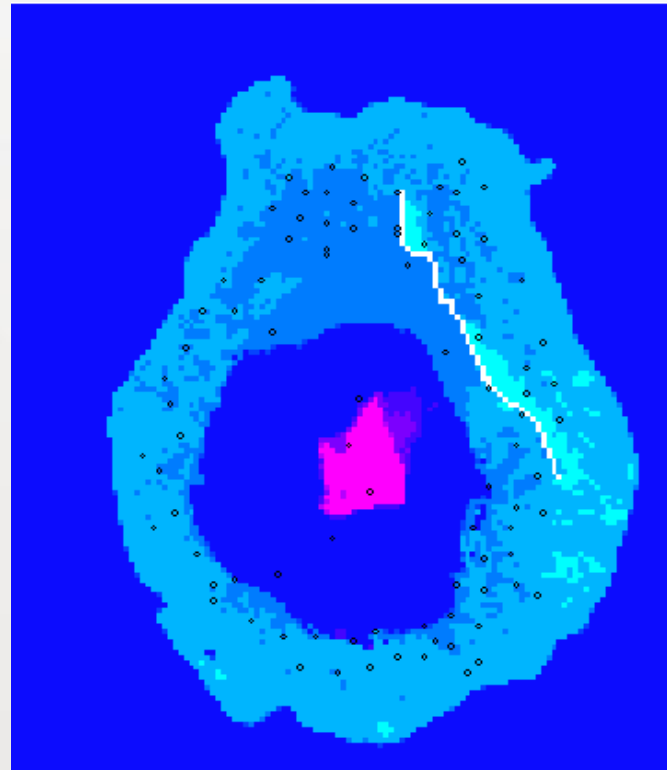


# Initial Conditions to EOR

1966



2008



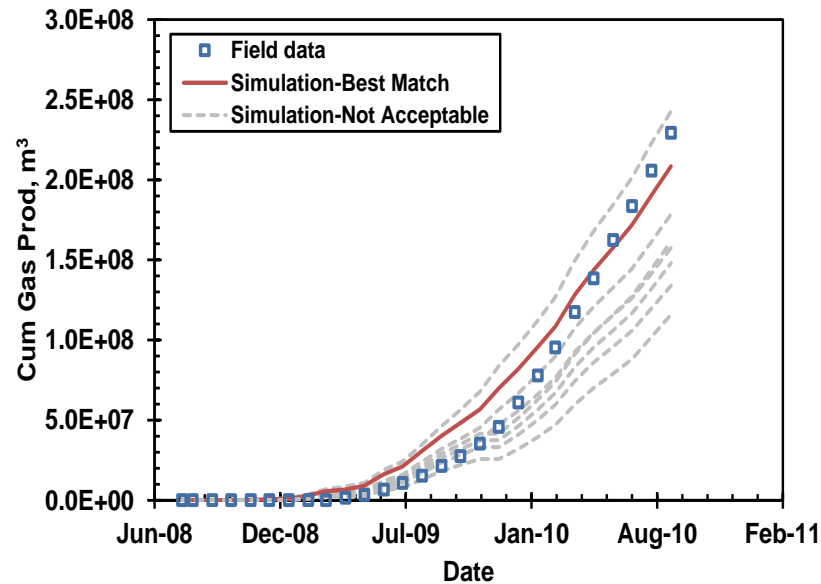
Min Values:  
 $S_w = 0.000$   
 $S_o = 0.000$   
 $S_g = 0.000$

0.00 1.00 2.00 km

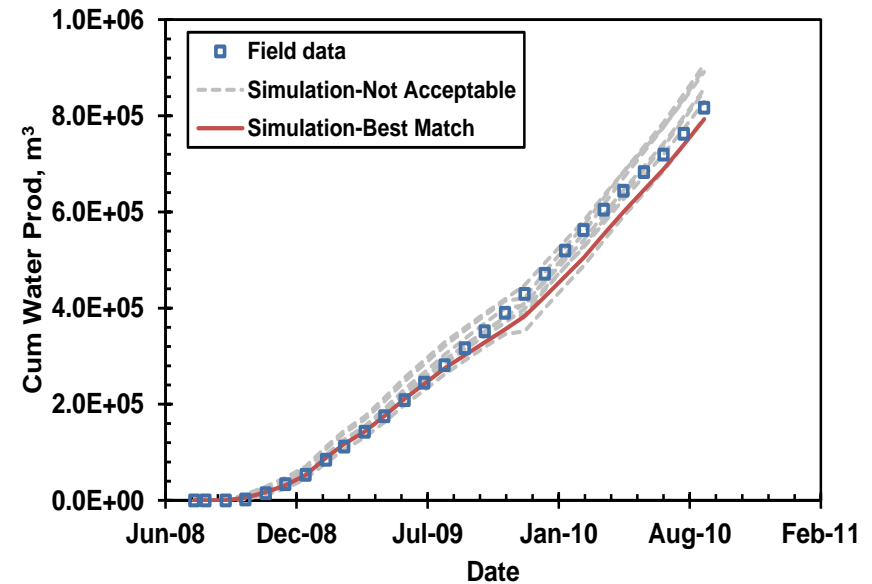


# EOR flood history match

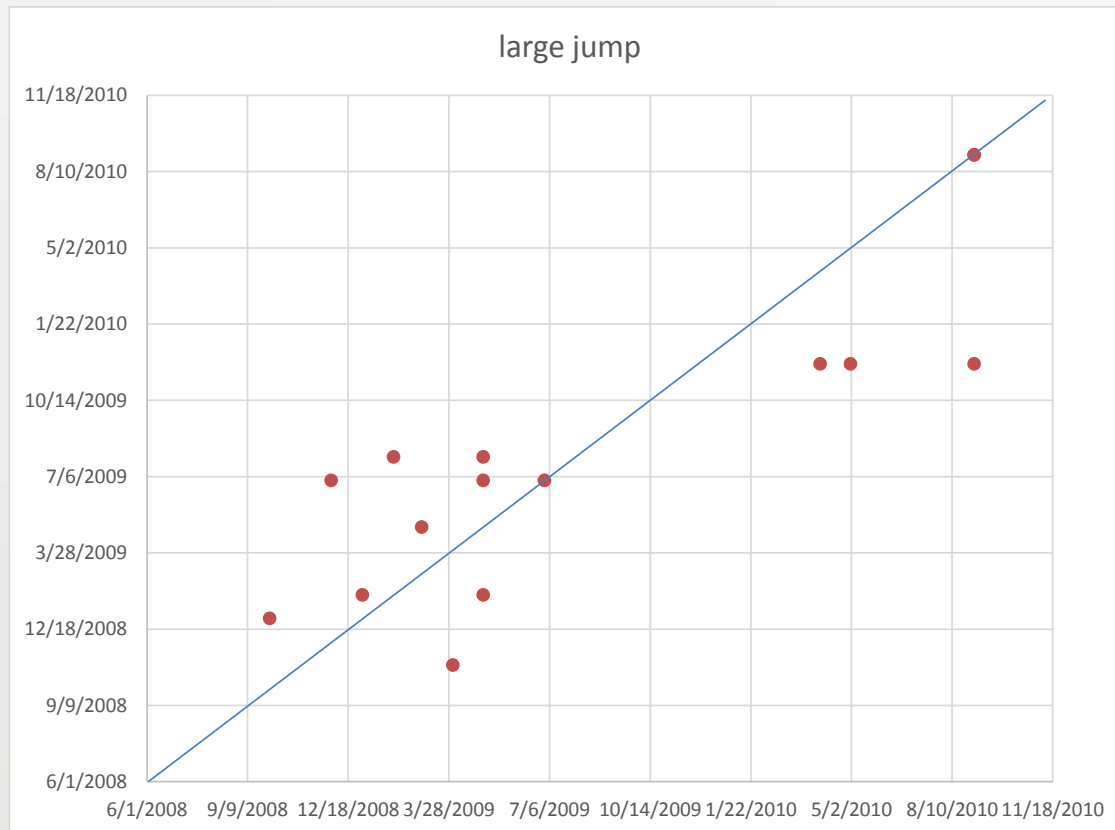
Cumulative Gas production



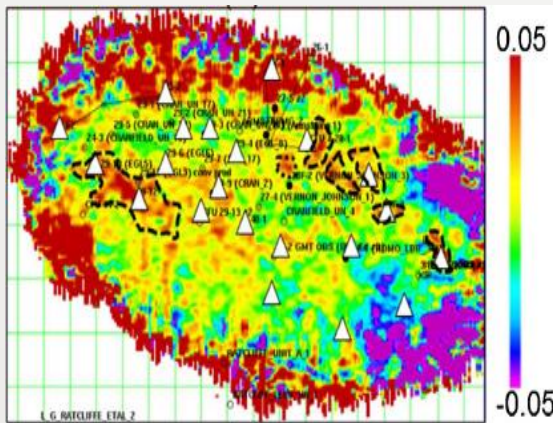
Cumulative water production



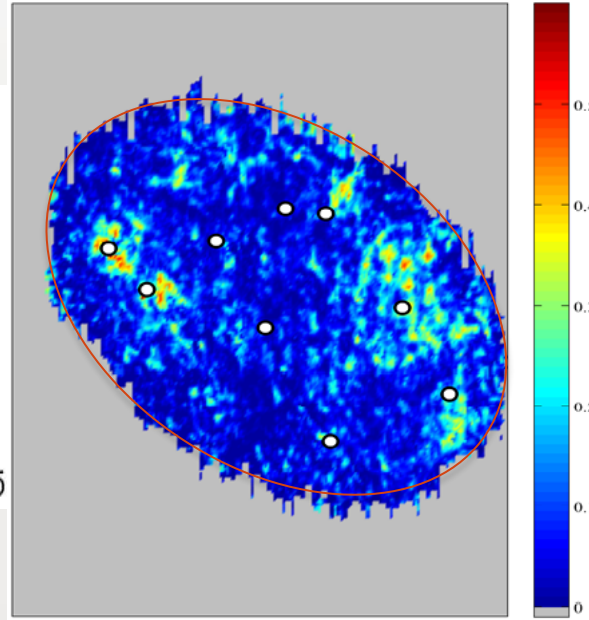
# History Match Modeled and measured CO<sub>2</sub> breakthrough



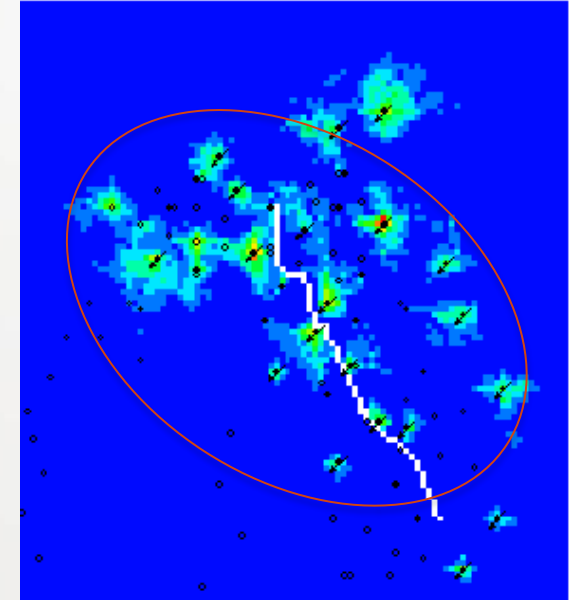
# Approximate match with time-lapse seismic 2008-2010



$v_p - v_s$  ratio difference  
Zhang et al. (2014)

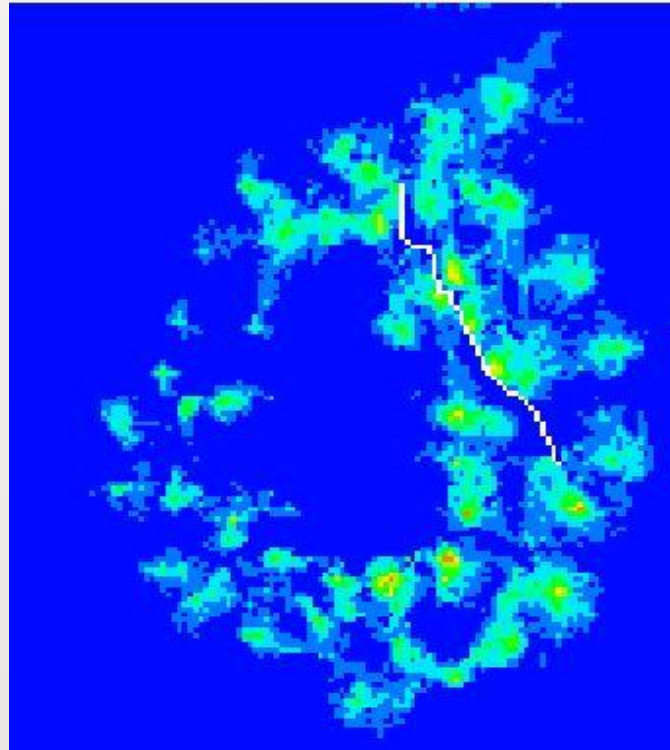


$\text{CO}_2$  saturation distribution  
estimate using rock  
physics 2010 from 3D  
seismic data (Carter 2014)

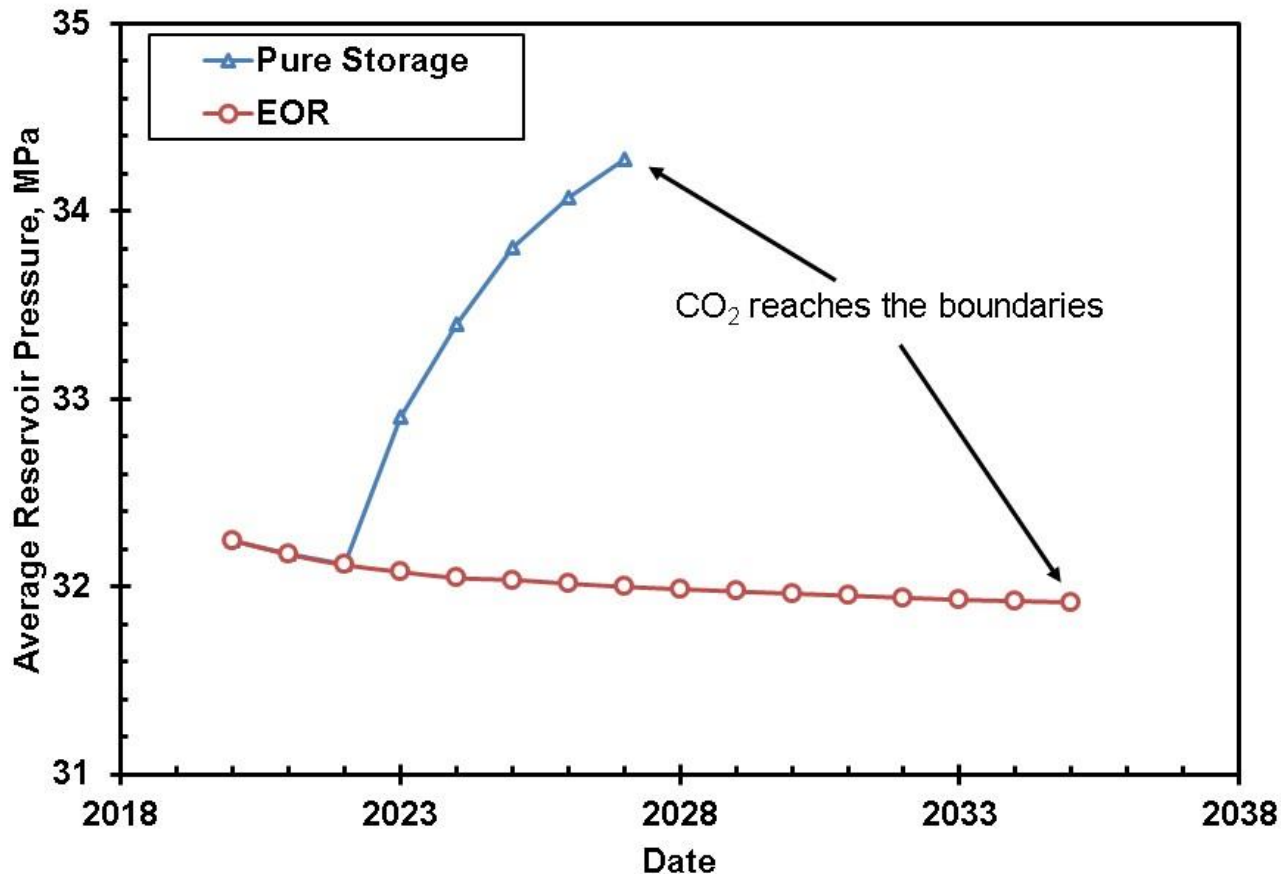


Modeled  $\text{CO}_2$   
distribution

# Theoretical 2018 CO<sub>2</sub> distribution based on continued same build-out process



# Theoretical Scenarios



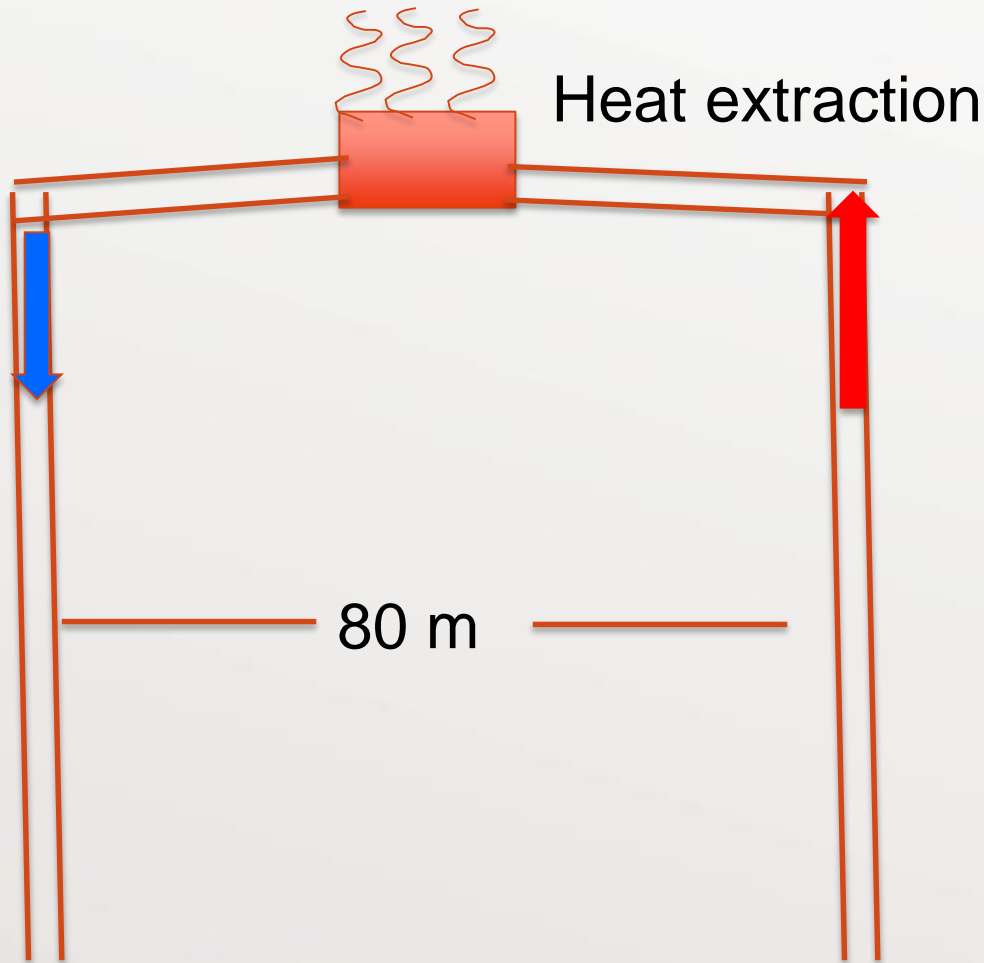
## Summary

- A black-oil simulation of the whole field has been developed based on characterization and history-matched to past production
- Model was successfully history matched to EOR development using produced fluids and this matched CO<sub>2</sub> breakthrough times (as a population)
- Reasonable match between modeled CO<sub>2</sub> saturation and that estimated from time lapse seismic, limitations noted
- Limitations also observed to pressure match
- Can use calibrated model for scenarios

# Final Testing and P&A

- Last two stages of project:
  - Pulse testing and thermosyphon completed in January 2015
  - P&A and final data collection to be completed in April, 2015
- This will conclude field phase of Early Test
  - Denbury commercial EOR will continue
  - DOE program work will extract lessons learned and conduct technologies transfer

# Thermosyphon (Barry Freifeld)

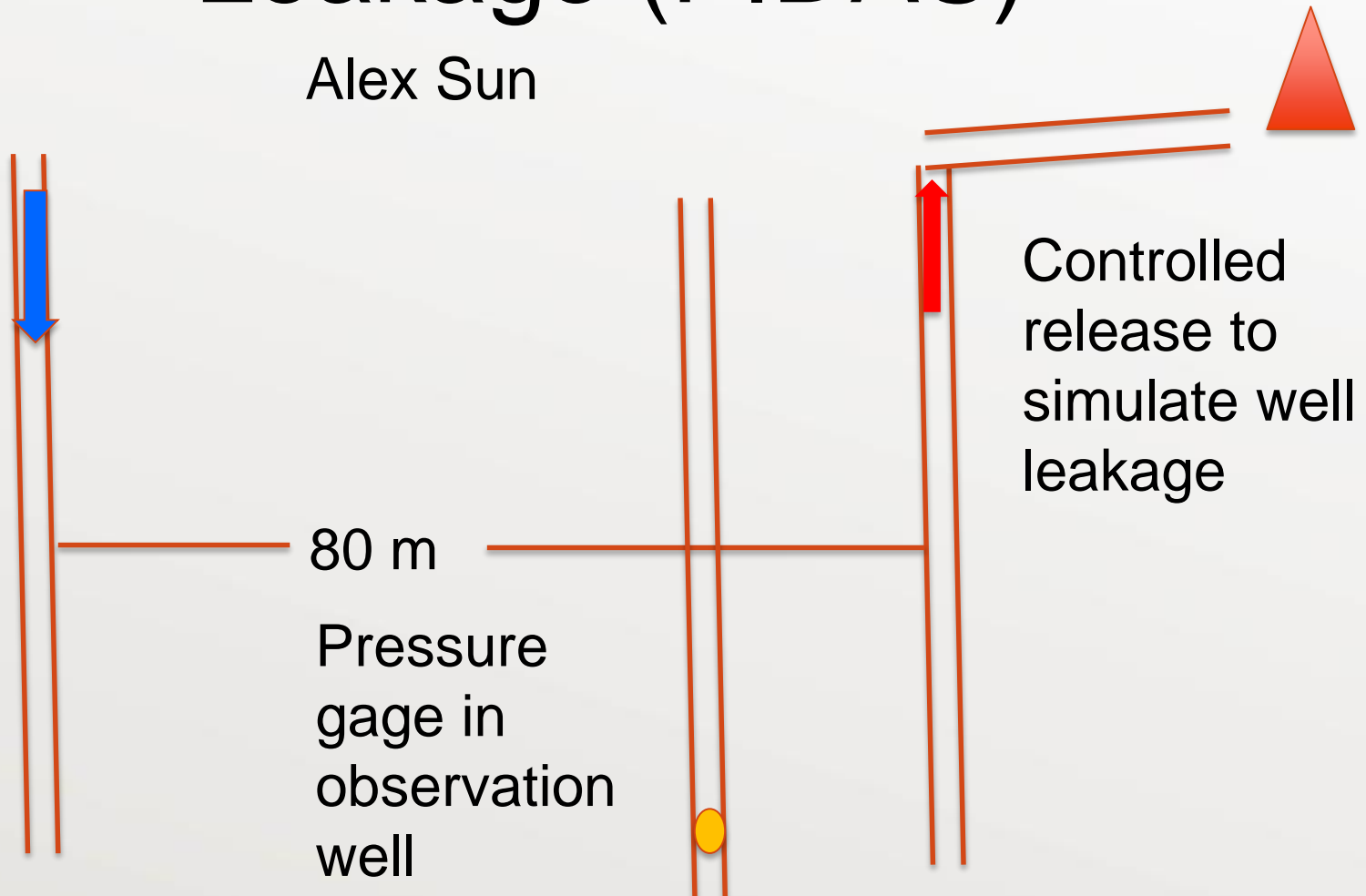


DOE  
program  
combining  
CCUS and  
geothermal;  
LBNL lead



# Harmonic Pulse testing for Leakage (PIDAS)

Alex Sun





Heat exchanger



Vent system

Photos by Lu

# Plugging Procedure Overview

- Final Repeat RST
- “Kill” F2 and F3 wells
- Remove packers
- Squeeze Tuscaloosa perforations, test
- Logging, Sonic, USIT, Cross-well, sidewall cores, gyro
- Fluid sampling and hydro tests in AZMI
- Squeeze perforations
- Cement and abandon according to MO&G Board rules

# Next steps

- Analysis of data collected – value and best practices to commercial CCUS monitoring
  - Publications
- Technology transfer
  - Current commercial projects
  - International collaborators

## Summary

- Monitored >5 million metric tons CO<sub>2</sub> stored in EOR + saline setting 2008-2014
  - Monitoring tool performance
  - History matching
  - “learn by doing” best practices development
- Technology transfer
  - Projects
  - Protocols
  - publications

Thanks for your attention!