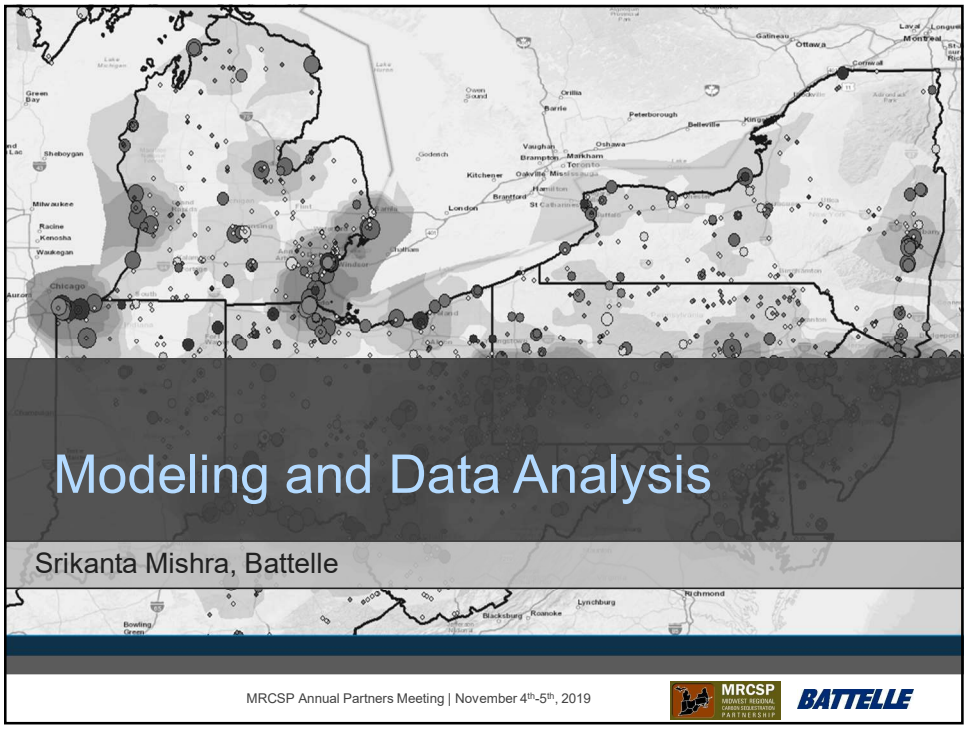


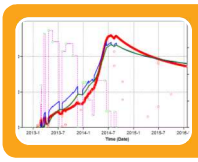
1

MRCSP Modeling & Analysis Team

- Modeling – Autumn Haagsma, Valerie Smith, Joel Main, Samin Razi, Priya Ravi Ganesh, Ashwin Pasumarti
- Analysis – Mark Kelley, Samin Razi, Priya Ravi Ganesh, Manoj Valluri, Andrew Burchwell, Laura Keister, Srikanta Mishra
- Guidance – Srikanta Mishra, Mark Kelley
- External Partners – Prof. Akhil Datta-Gupta's MCERI Group, Texas A&M University

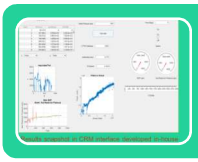
2

Many Types of Models are Used to Infer Reservoir Properties & Evaluate Performance



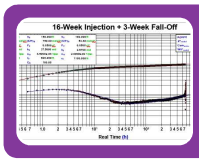
Static and dynamic modeling

- Integrate G&G data; constrain reservoir properties; evaluate reservoir performance for future scenarios
- Dover-33; Chester-16; Bagley; Charlton-19



Capacitance-resistance modeling

- Simplified estimation of reservoir capacity and injectivity; simplified analysis of future scenarios
- Charlton-19; Bagley

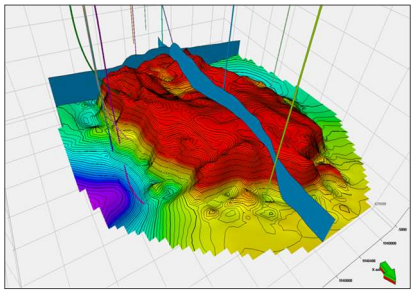


Transient pressure and rate analysis

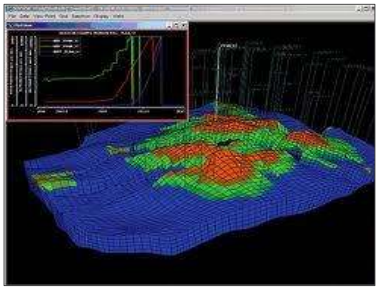
- Estimate reservoir properties; synthesize results from multiple types of analysis; validate dynamic model
- Dover-33; Bagley; Chester-16; Charlton-19

3

Static v/s Dynamic Models



Static Model
Representation of geology and property variations in 3-D



Dynamic Model
Fluid flow modeling on corresponding numerical grid

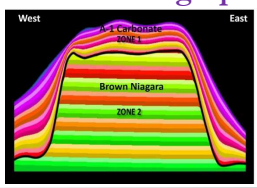
4

Modeling Approaches Evolve with More Data and New Interpretation

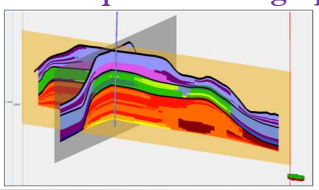
Dover-33 Reef

Increasing Data

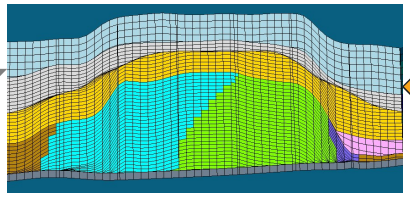
Level 1-Lithostratigraphic



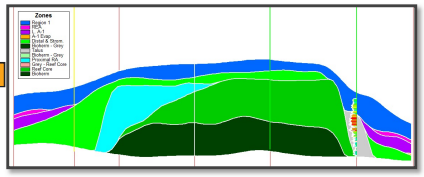
Level 2-Sequence Stratigraphy



Level 3- Simplified Lithology



WMU- Depositional

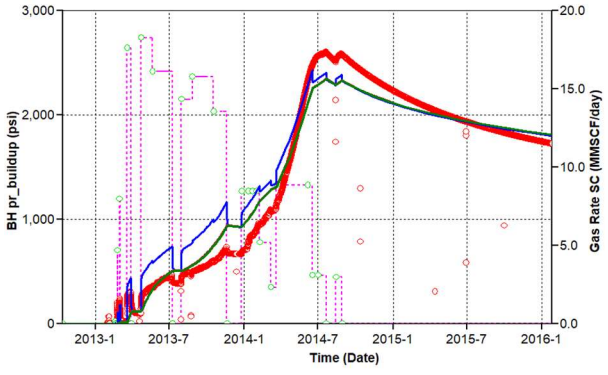


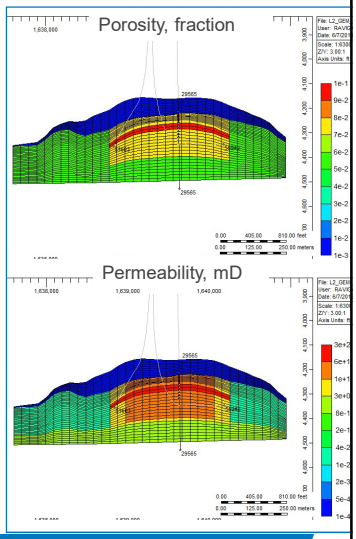
5

History Matched Model Provides Insights Into Reservoir Property Distribution in Space

Dover-33 Reef

high-permeability core area
low-permeability flank region

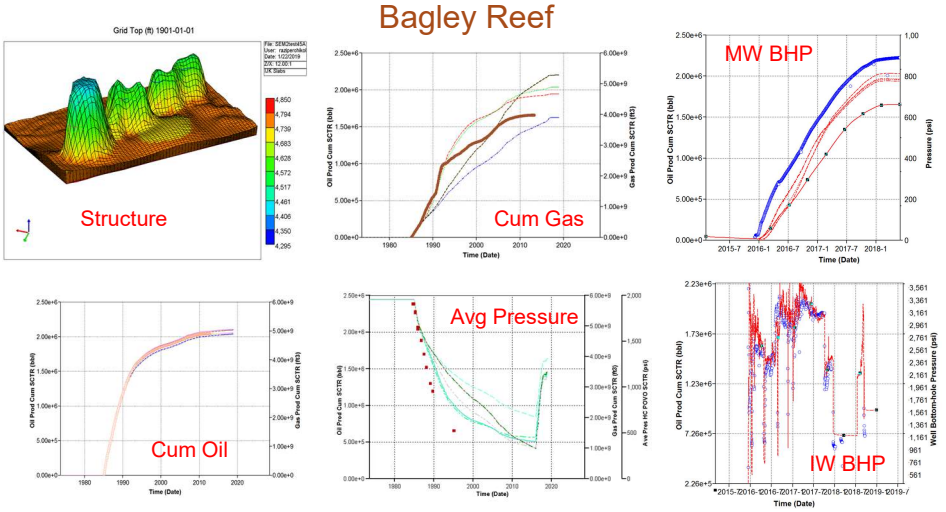




6

History Match Allows Reservoir Properties and Wellbore Anomalies to be Identified

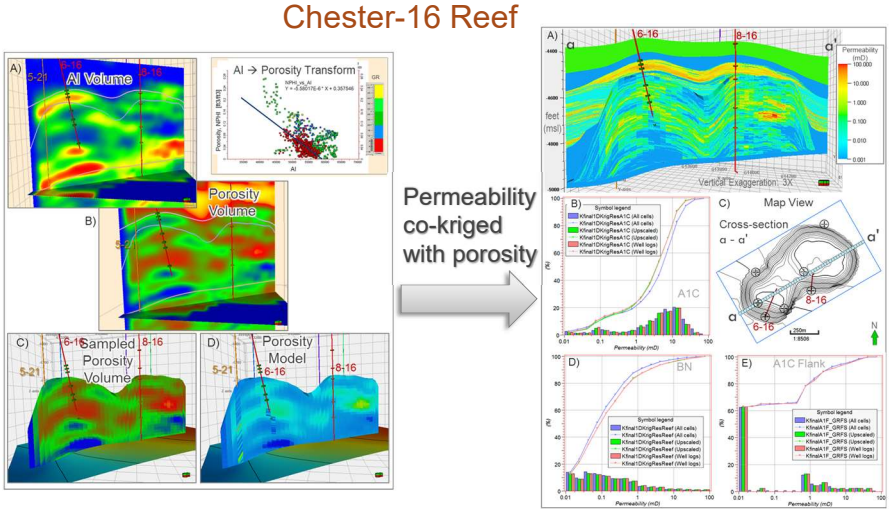
Bagley Reef



7

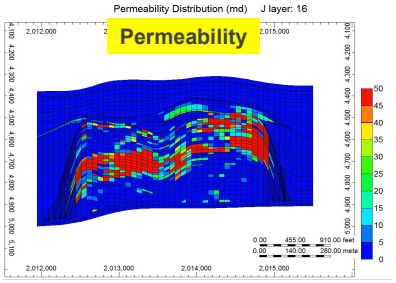
SEM Conditioned to Geologic Trends Deduced From Seismic Data

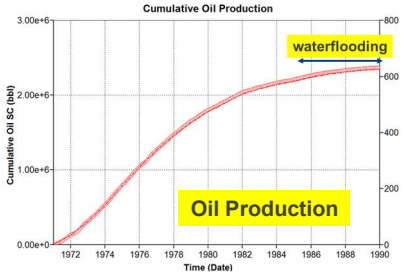
Chester-16 Reef

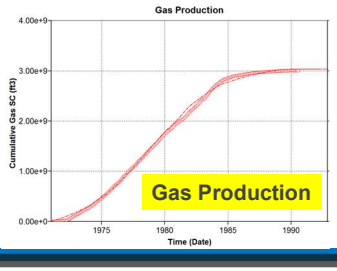


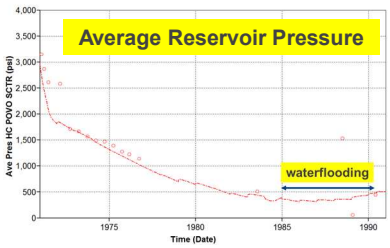
8

Dynamic Model Calibrated to Primary Production and CO_2 Injection (Chester 16)









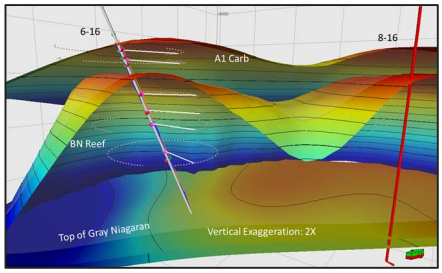
9

Calibrated Model Used To Evaluate Alternative Scenarios for Improved Performance

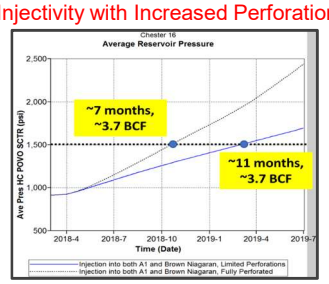
Chester-16 Reef

- Increasing the number of perforations provides only marginal improvement
- Drilling radial "tunnels" is more effective; performs similar to a horizontal well

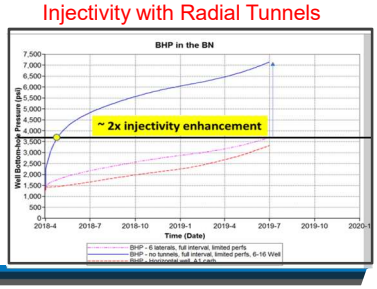
Radial Tunnels are small open boreholes drilled laterally from existing well



Injectivity with Increased Perforations

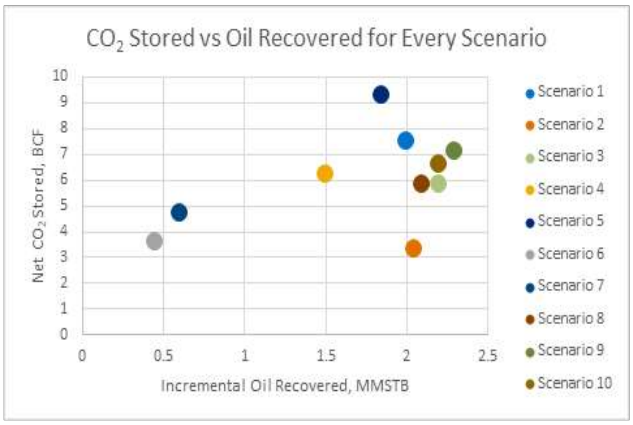


Injectivity with Radial Tunnels



10

Forecasting CO_2-EOR in Chester 16



11

Capacitance Resistance Model Helps Estimate Reservoir Capacity & Injectivity (Charlton-19)

- Simplified (tank) model with two "lumped" parameters
  - Total compressibility * Pore volume, C_t.PV
  - Injectivity index, $J = q/\Delta p$
- Balances cumulative CO_2 injected with BHP data
- Applied to many O&G waterflooding project
- Here, first application for history matching to CO_2 injection data
- Allows rapid prediction of pressure buildup for given injection rate (& vice versa)

- C_t*PV = 3423 bbl/psi (calc)
- PV = 4.38e6 MM bbl (from SEM)
- C_t = 7.8e-4 1/psi (reasonable for typical oil and gas systems)

- J = 7.58 MT/day/psi (calc)
- J = 7.38 MT/day/psi (from flowing material balance)

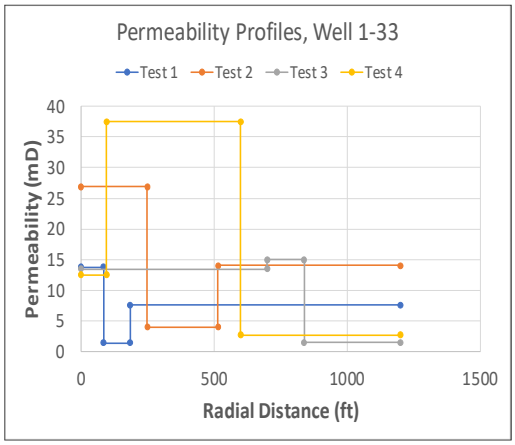
q = 1000 MT/d
=> Δp = 1000/7.5 = 133 psi

12

Multiple Techniques Used for Transient Pressure and Rate Analyses (1)

- Analytical modeling of injection-falloff response (using IHS WELLTEST)
- Radial-composite model
- Specialized (log-log) plots for estimating formation characteristics
- Cartesian plots of complete sequence for validation
- Consistency check across multiple sequences

Dover 33 Reef



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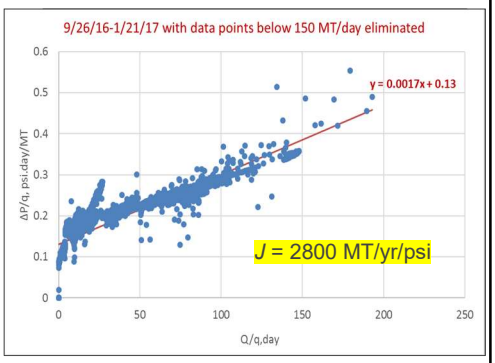
Multiple Techniques Used for Transient Pressure and Rate Analyses (2)

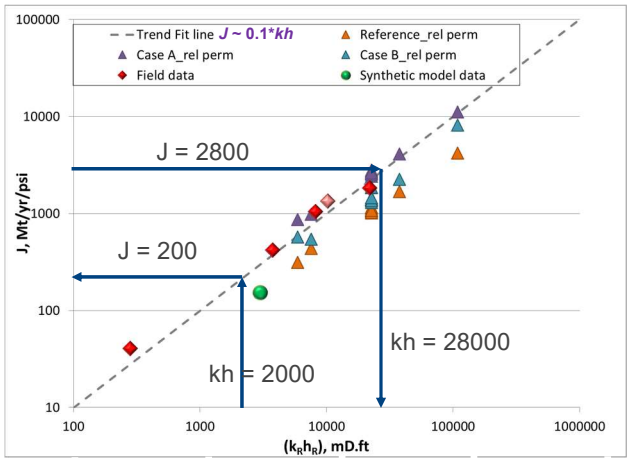
- Flowing material balance analysis
- Plot of $\Delta p/q$ v/s Q/q linear with intercept $1/J$ – reflects boundary dominated flow
- Consistency check across multiple injection sequences
- Validates analytical injection-falloff analysis
- J can be correlated to kh product (screening model)

Charlton-19 Reef



14

Analysis of Well Injectivity
Injection [ΔP v/s q] Correlated to Permeability



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Key Takeaways

- Models serve multiple purposes
  - Details of subsurface fluid distribution
  - Evaluation of design options
  - Regulatory/stakeholder communication
- Static and dynamic models allow varieties of data types to be integrated
- Calibrated models allow “what-if” questions to be answered without running new field experiments
- Other models (analytical or lumped parameter) provide additional insights and cross-validation of results

16

Lessons Learned for CCUS Projects

- Fundamental tools for building dynamic reservoir models to understand impacts of CO_2 injection (containment, hazards) currently in place (and tested in field settings)
- Dealing with data sparsity is a challenge
- Active integration of multi-physics data (e.g., seismic, ERT, pressure, temperature) continues to be aspirational
- Forecasting for stakeholder interaction and decision-making remains computation-intensive
- Machine learning based workflows to assist physics-based models are under-utilized

SMART
(Science Informed Machine Learning for Accelerating Real-Time Decisions in the Subsurface)