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SHALE RESOURCES ASSESSMENT – A Full Life Cycle Integrated Approach

SPE 2012 -2013 Distinguished Lecturer Series

P. K. Pande

Society of Petroleum Engineers
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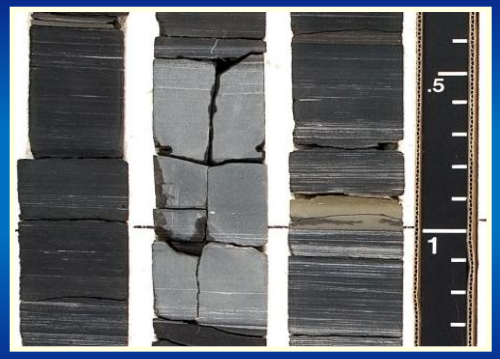
Anadarko Petroleum Corporation

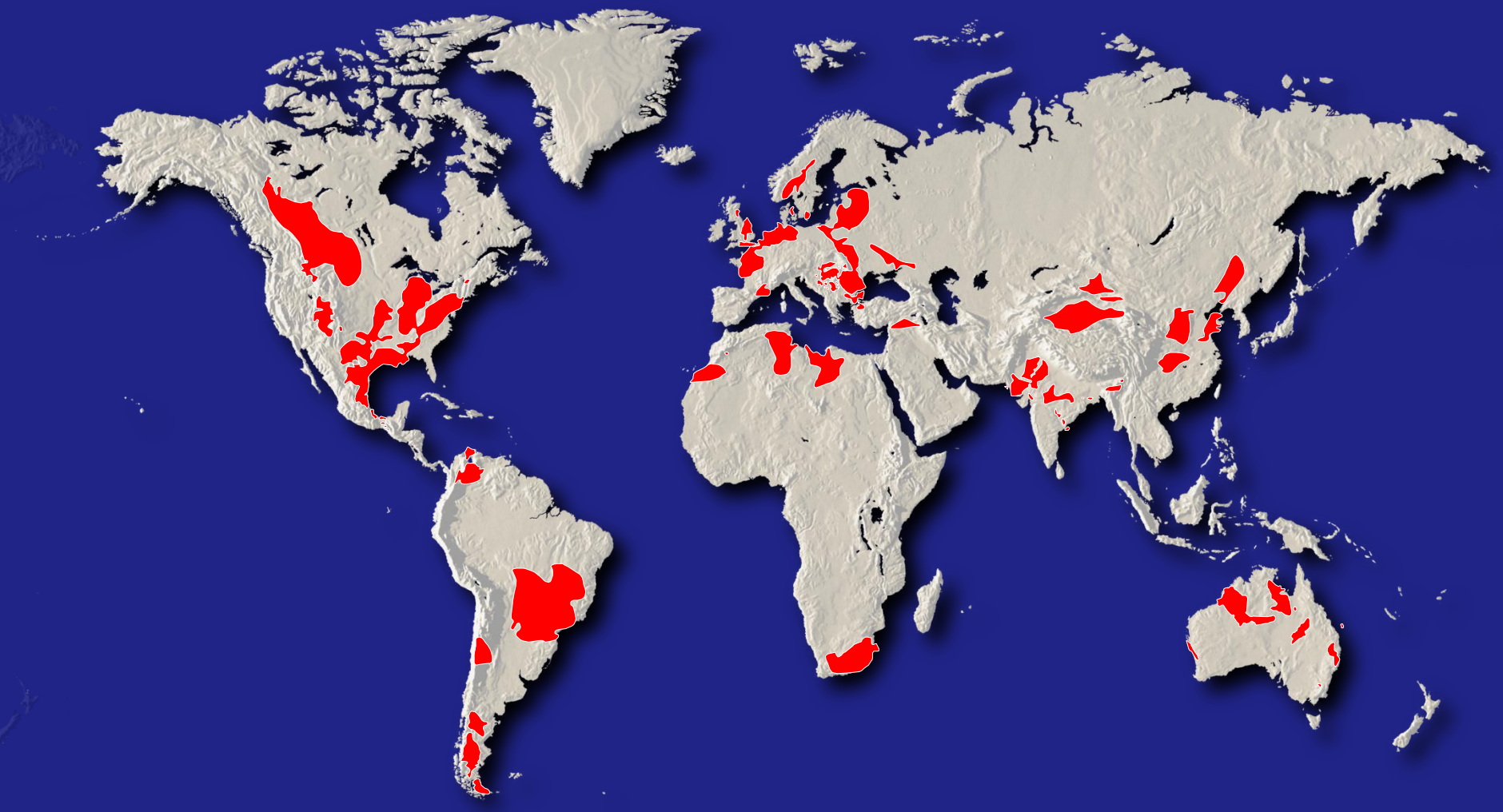
Outline

Full Life Cycle Integrated Approach

- Large Global Resource & Value Drivers
- Key Development Issues & Uncertainties
- Assessment Challenge
- Field Demonstrations & Mechanistic Models
- Conclusions & Key Learnings

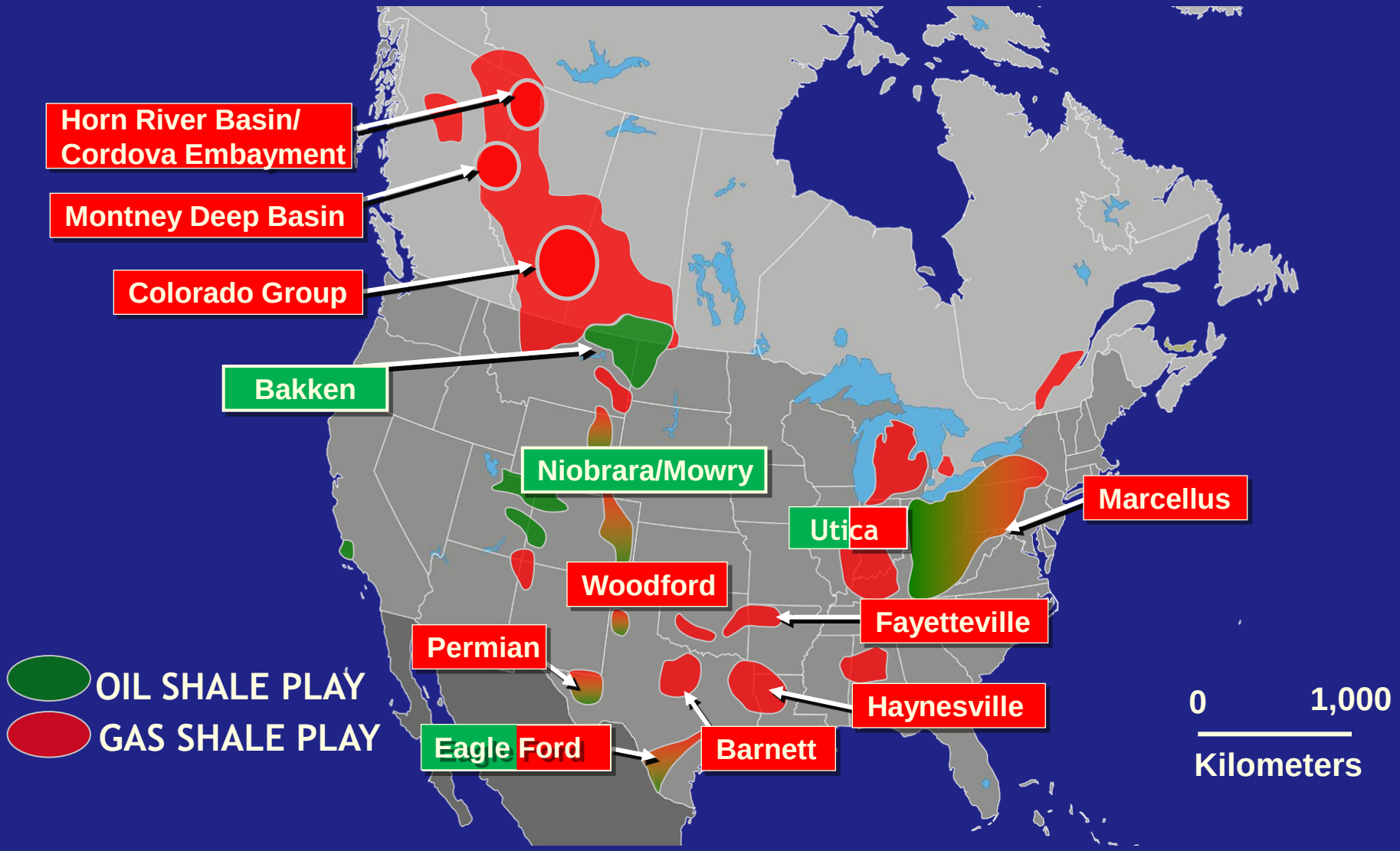


Global Shale Resource: ~6,000 TCF (~170 TCM)



Few Wells Outside North America

North America Resource: ~900 TCF (~25 TCM)

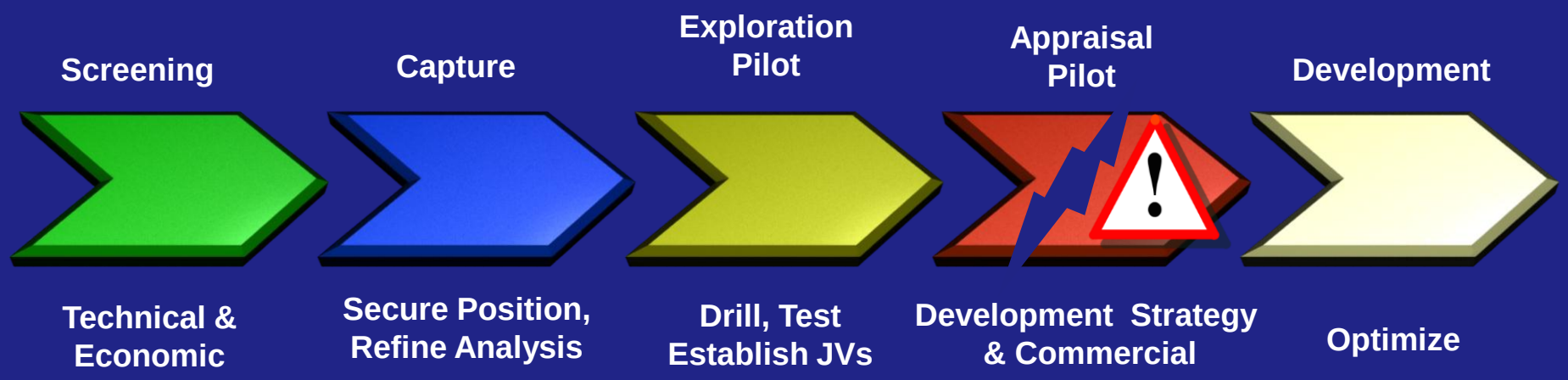


>40,000 wells; ~5000 /year

Key Learnings - Full Life Cycle Value Drivers

Value Driver	--- Value & Resource +++	
Development Approach	Uniform Spacing, Offset Practices	Geologically Targeted Semi-Custom Spacing
Performance Analysis	Type Curves, Arps, Statistical	Advanced Analytical, Numerical, SRV Diagnosis
Data Acquisition	Ad Hoc	Appropriate Combinations & Timing
Subsurface Analysis	Single Domain	Static & Dynamic Data Geology, Geophysics, Petrophysics, Reservoir Eng.

Assessment Challenges



- **Technical**
  - **New Play Types, Low Reservoir Producibility**
  - **Multi-discipline Integration, Subsurface and "Factory Mode Operations"**
- **Commercial**
  - **Highly Competitive, Large Leaseholds**
  - **International Joint Ventures**
  - **Costs & Optimization**

Performance Analysis Tools and Technologies

Performance Prediction Limitations

Shale Performance Forecasting

- Very Low Permeability
- Stress Dependence
- Mechanisms
  - Fractured Horizontal
  - Diffusion
  - Phase Behavior

What is a Field Demonstration?

A Program of Multiple Field Pilots to Address Key Issues and Uncertainties

Learning While Drilling

To Have Value They Must Be:

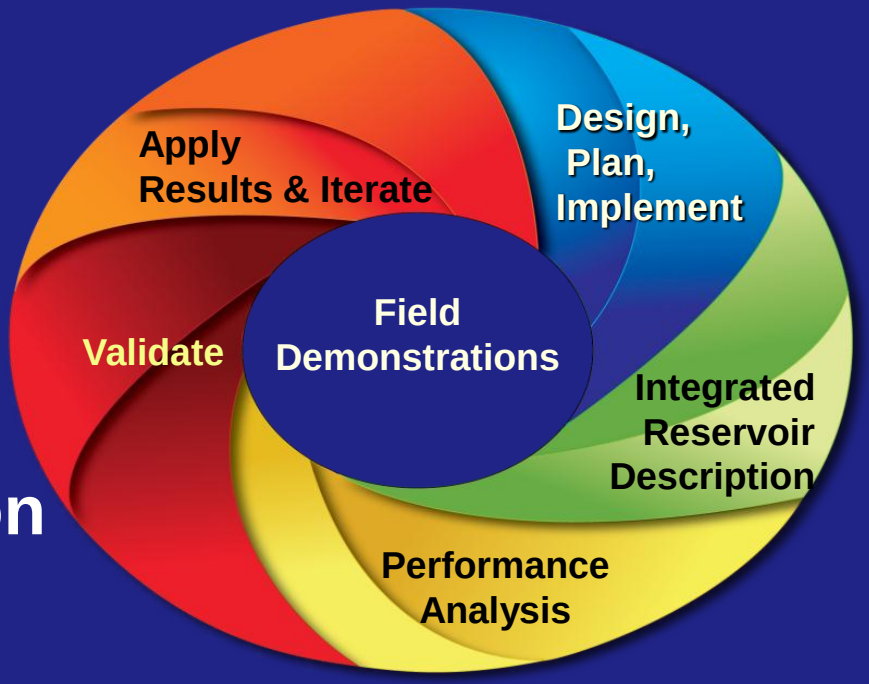
- Systematic
- Statistically Valid
- Scalable

General Shale Play Application

- Build Database of Analogs

Goal

- Capital Investment Efficiency



What is a Field Demonstration?

A Program of Multiple Field Pilots to Address Key Issues and Uncertainties

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General Shale Play Application

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Goal

- Capital Investment Efficiency

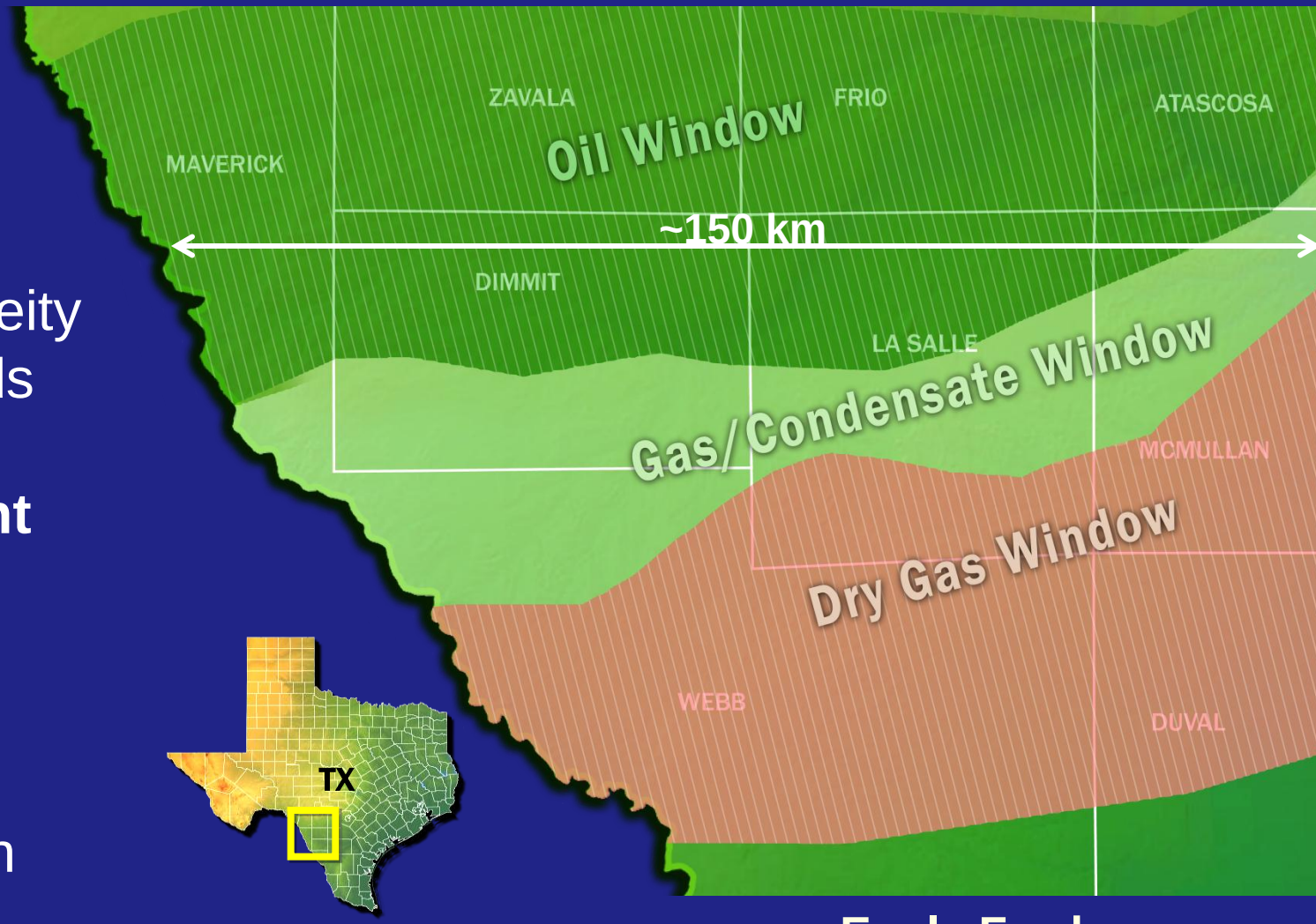
“Learning While Drilling”

Field Demonstration Types

Strategic
- Spacing
- Early EUR
- Heterogeneity
- PVT/Liquids

Development
- Seismic
- Azimuth

Operational
- Completion

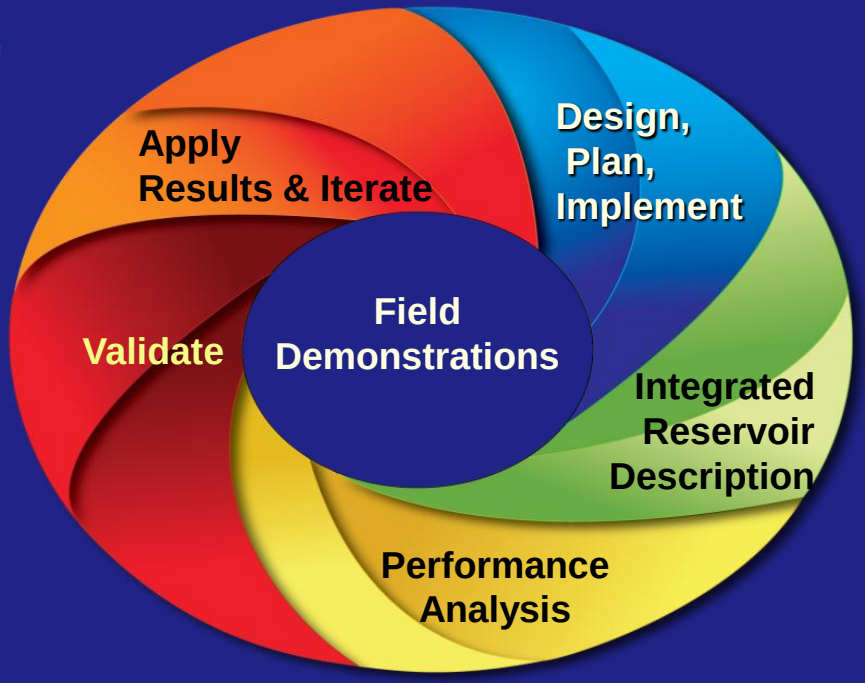


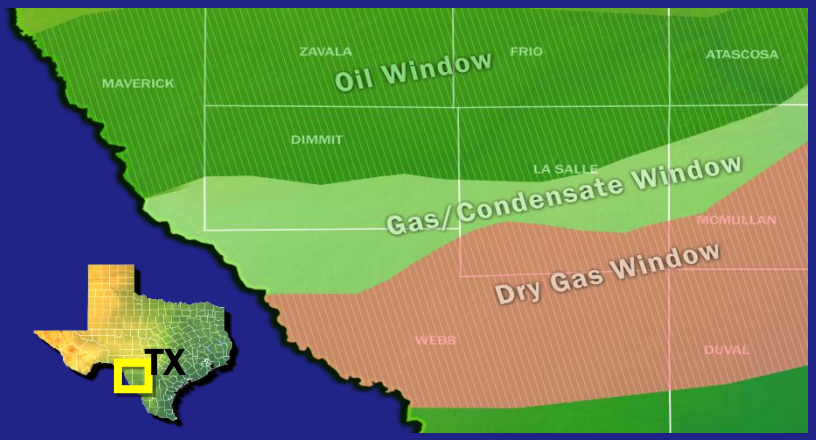
Eagle Ford

Eagle Ford Well Spacing Field Demonstration

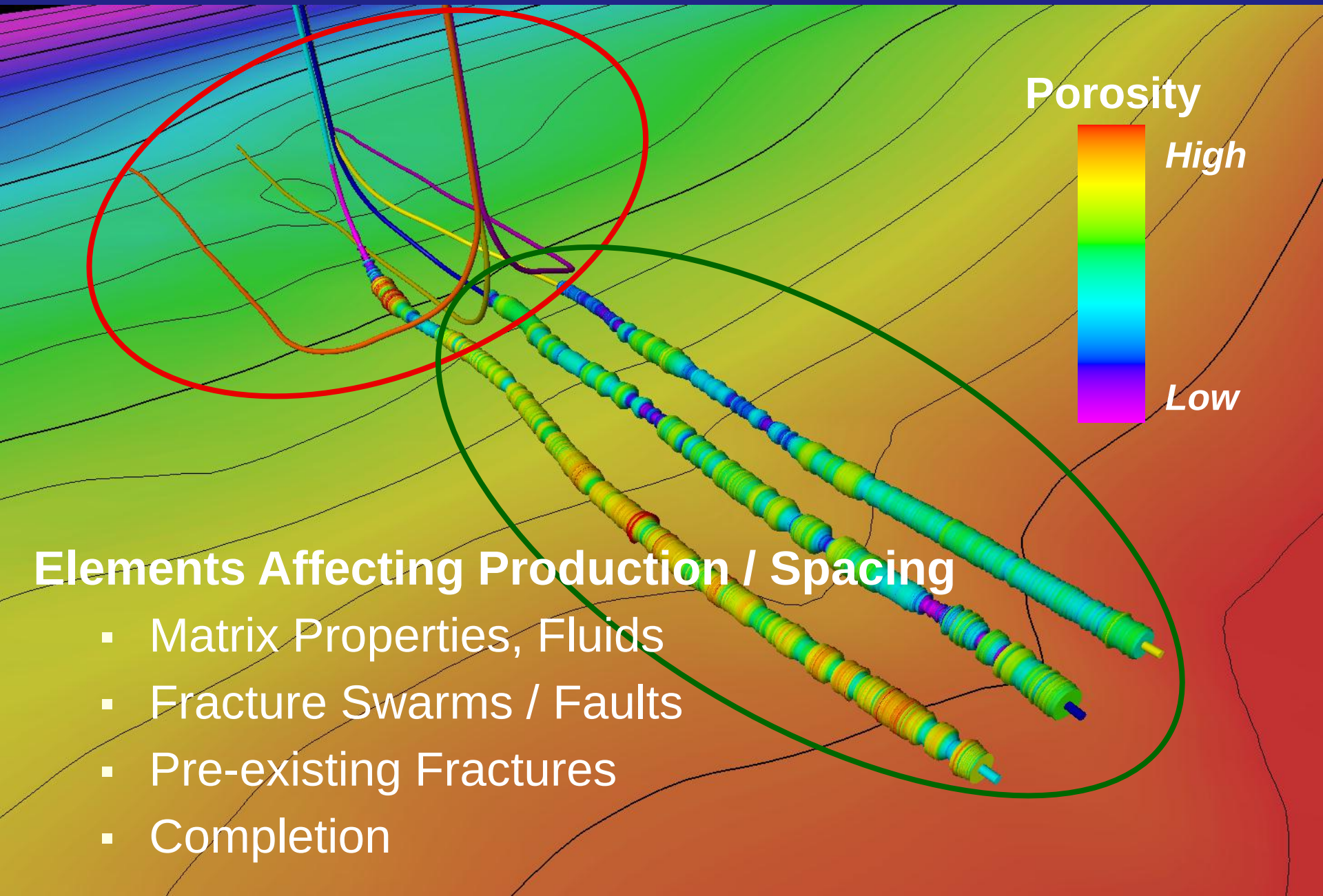
"Learning While Drilling"

- 12 Million Acres
- Production
  > ~2+ BCFD
  > ~500+ MBOPD
- 7,000+ Wells





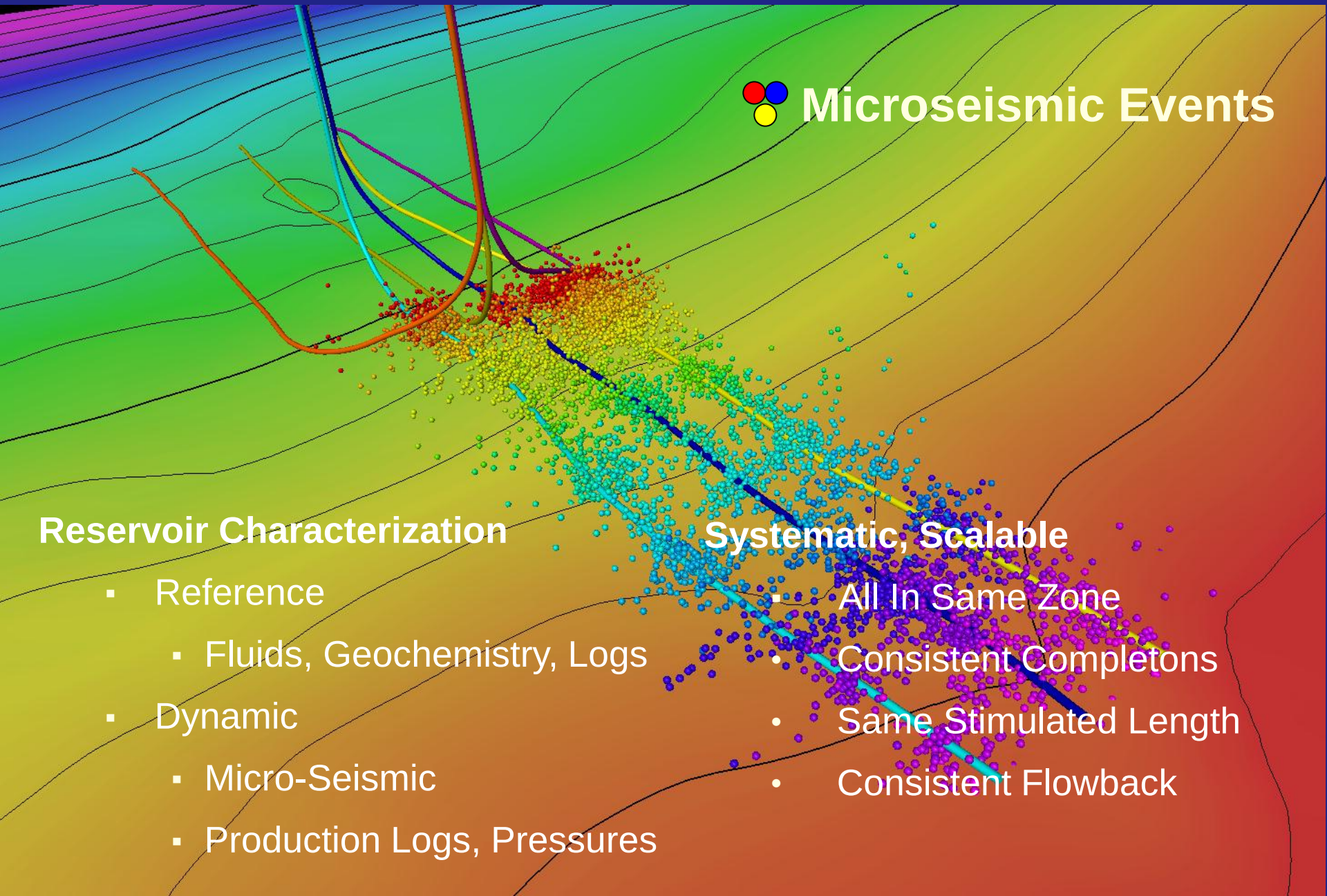
Well Spacing Field Demo - Early vs. New Practices



Elements Affecting Production / Spacing

- Matrix Properties, Fluids
- Fracture Swarms / Faults
- Pre-existing Fractures
- Completion

Field Demo – Data Acquisition Design & Planning



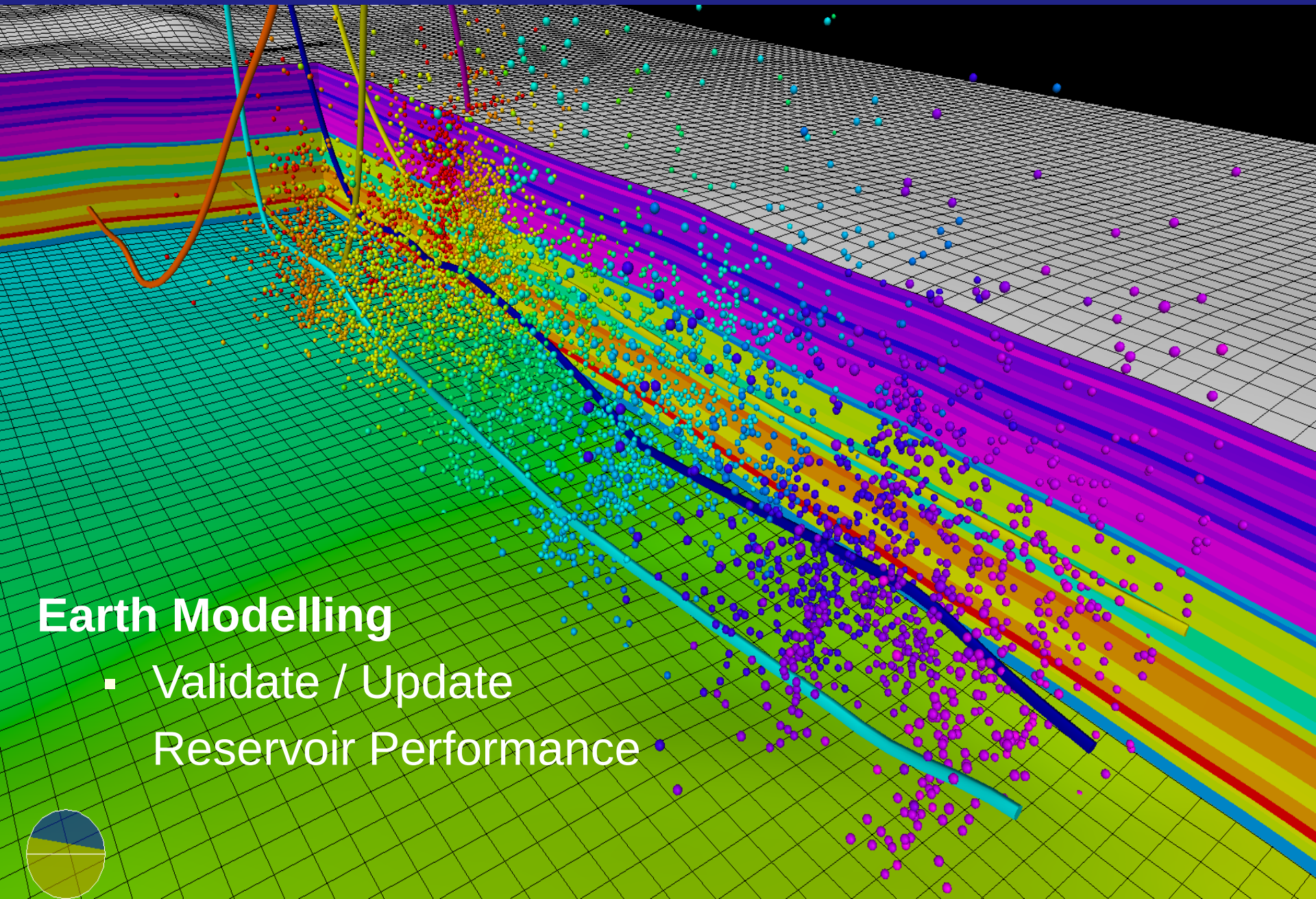
Reservoir Characterization

- Reference
  - Fluids, Geochemistry, Logs
- Dynamic
  - Micro-Seismic
  - Production Logs, Pressures

Systematic, Scalable

- All In Same Zone
- Consistent Completons
- Same Stimulated Length
- Consistent Flowback

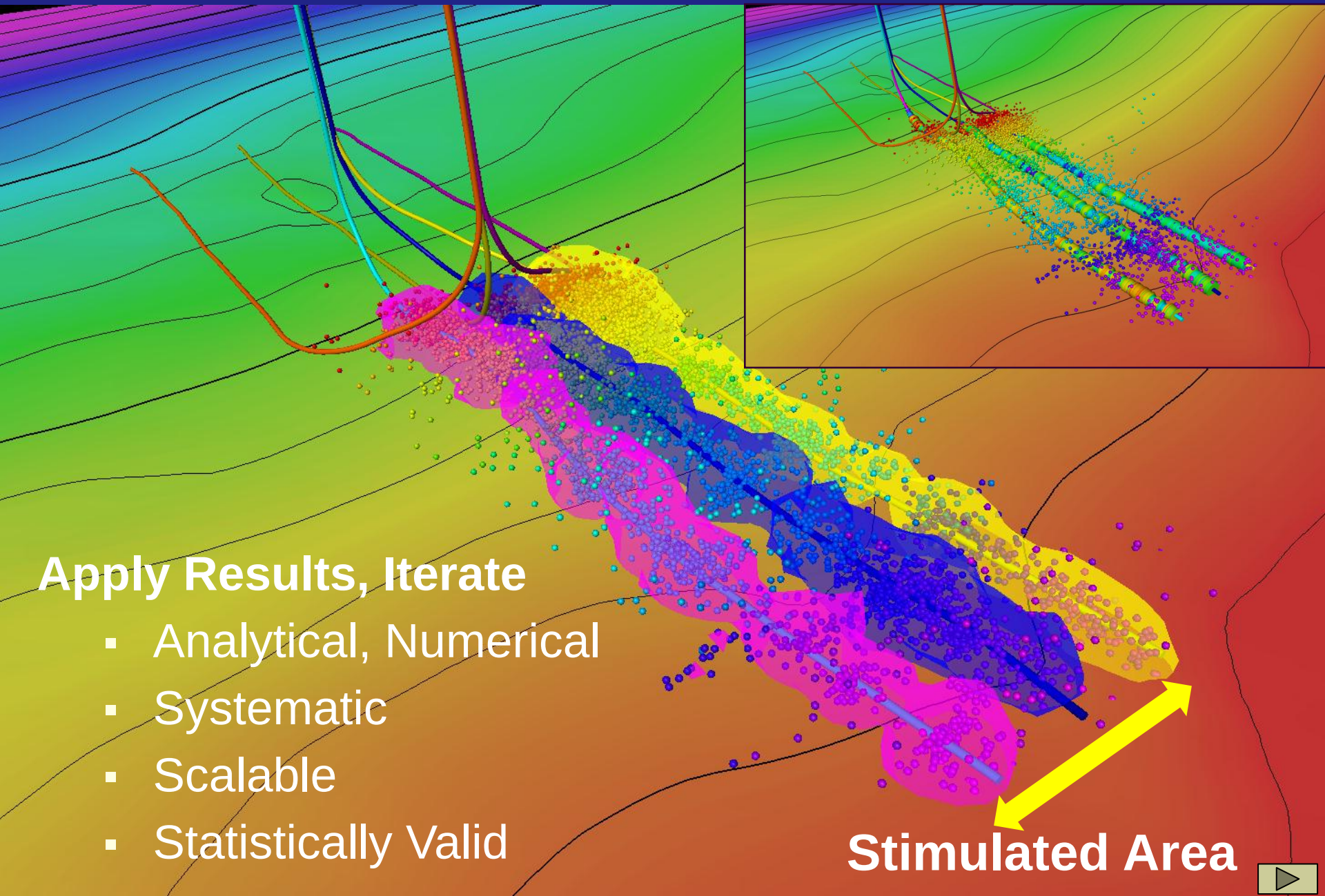
Field Demo – Integrated Reservoir Description



Earth Modelling

- Validate / Update Reservoir Performance

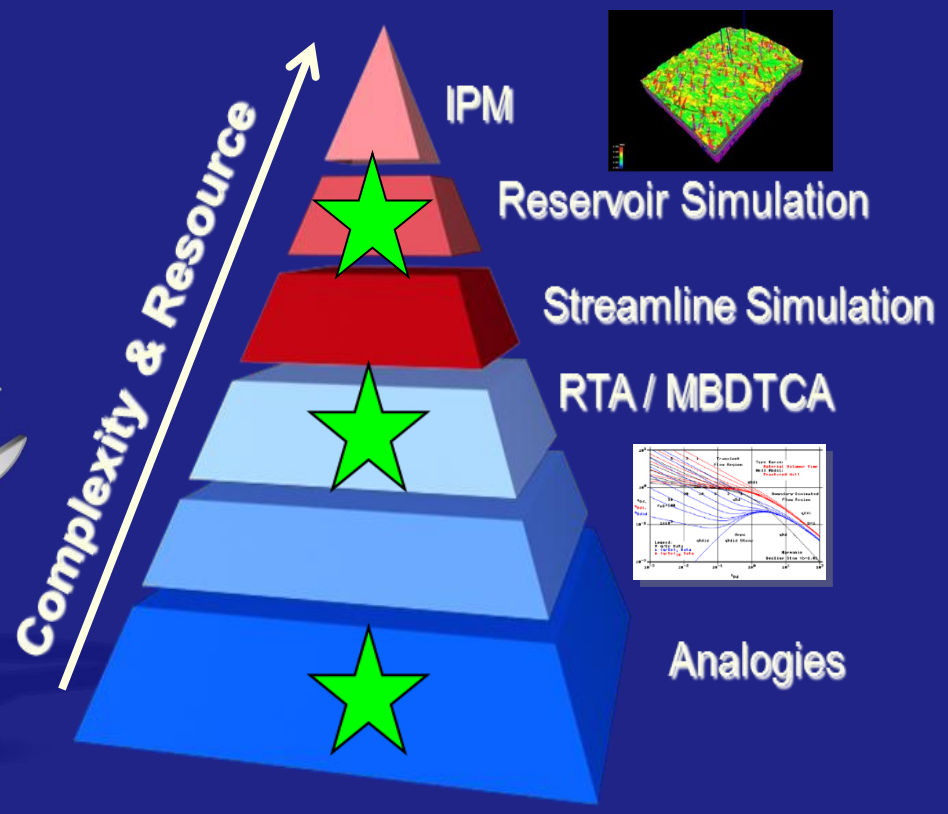
Field Demo – Performance Analysis, Validation



Apply Results, Iterate

- Analytical, Numerical
- Systematic
- Scalable
- Statistically Valid

Performance Analysis Tools and Technologies



What Are Mechanistic Studies?

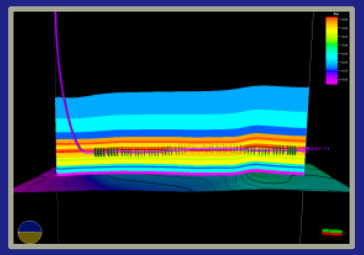
Thorough, Integrated Process to Investigate Key Performance and Production Drivers

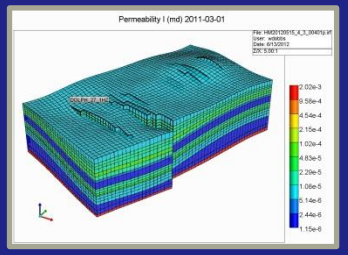
- Historical Context
- Development and Operational Guidance
  - Selecting Well Targets
  - Performance Improvement Characteristics
- Framework for Interpreting “Field Demonstration” Results
  - Strategic, Development, Operational
- Develop Analogs
  - For New Play / Development Applications

Mechanistic Evaluation Workflow

Integrate Subsurface, Well, & Completion Data

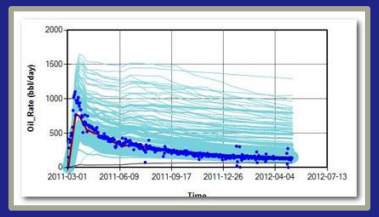
Key Data
Fluids | Matrix | Fractures

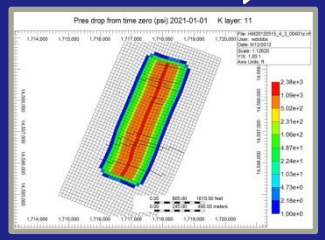




History-Match Multiple Geologic Scenarios

Reservoir Sensitivity Analysis & Diagnosis





Performance Predictions

Well Spacing/ Interference

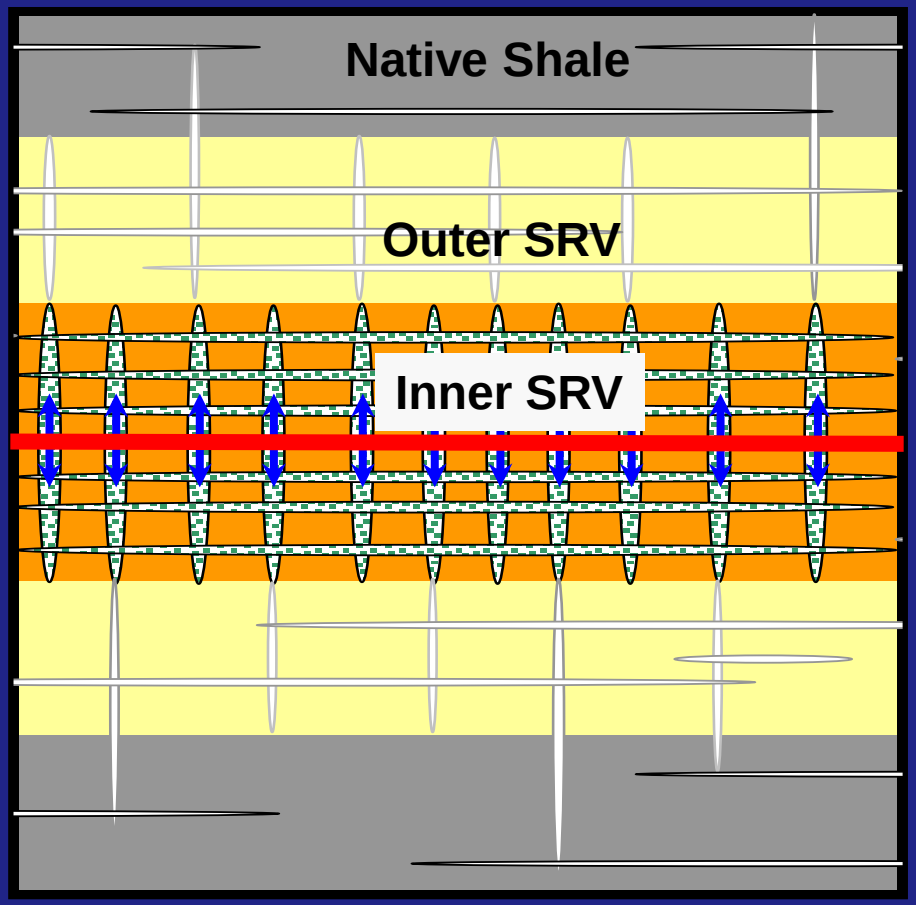
Well Performance Drivers

EUR + GIP + Drainage Estimate

Impact of Key Uncertainties

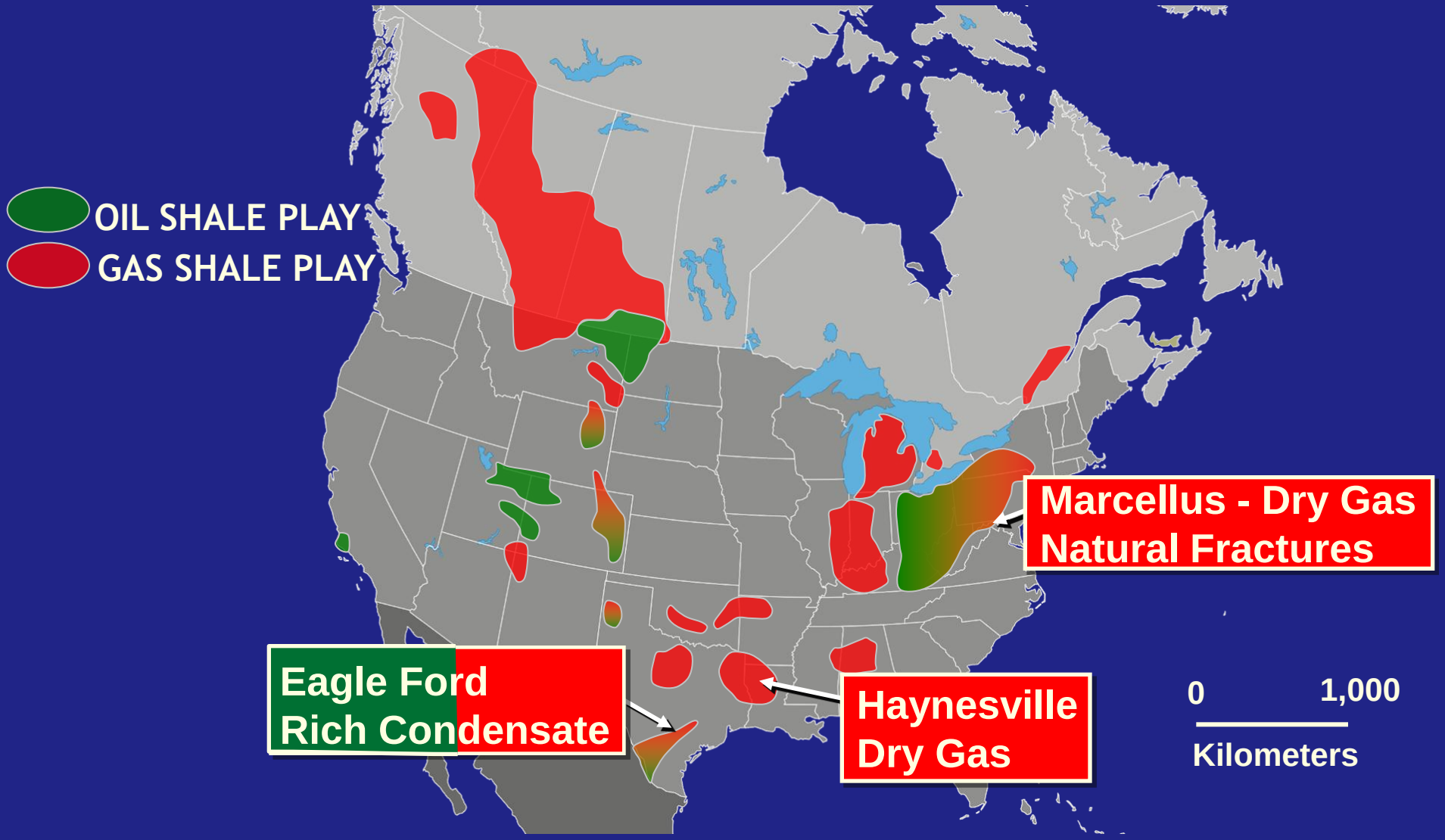
Mechanistic Studies – What Can be Inferred?

- Completion
  - Stimulated Rock Volume (SRV) and Fracture Conductivity
- Phase Behavior
  - Dry Gas, Liquid Rich Systems
- Reservoir Characterization
  - Open Natural Fractures Impact
- Development Planning
  - Well Spacing



Stimulated Rock Volume (SRV)

Mechanistic Studies In Action



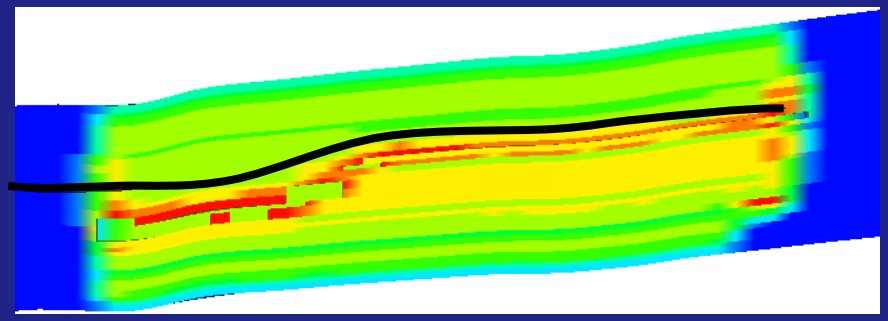
Skip Examples

Eagle Ford Rich Gas Condensate Performance

(30 Years)

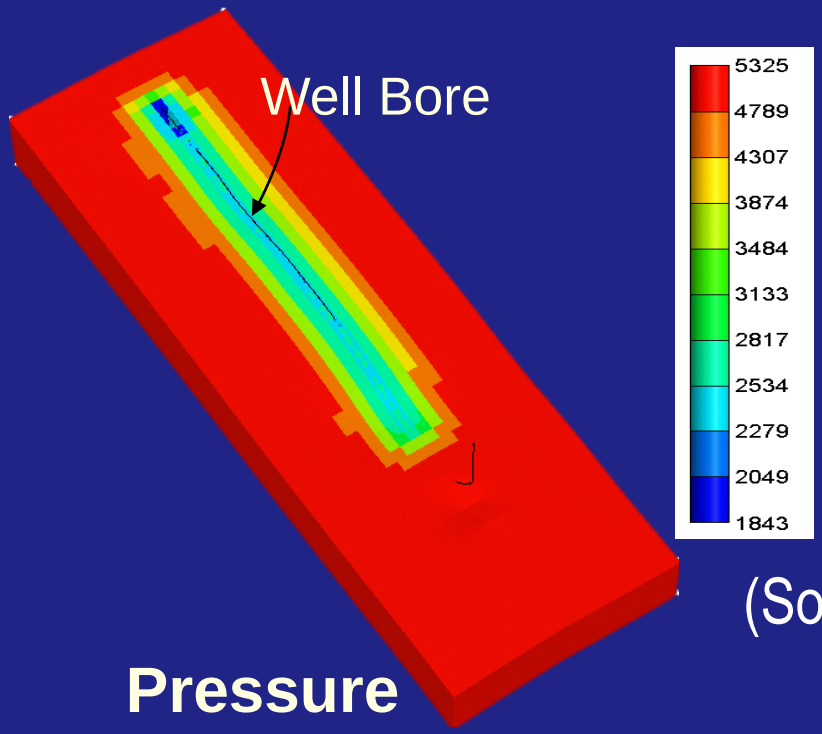
Pressure Distribution

Condensate Distribution



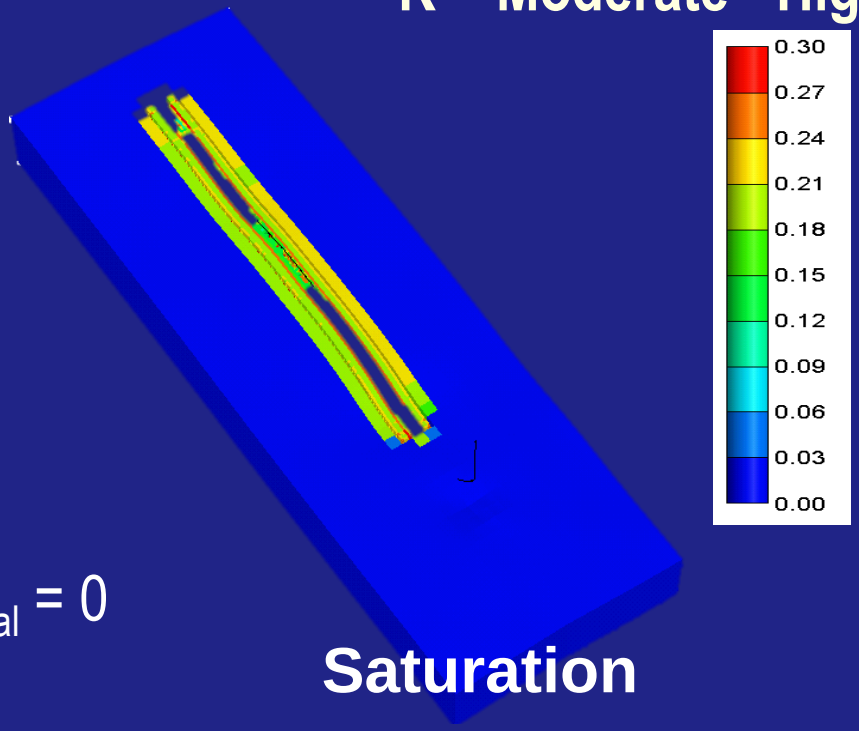
Oil RF = 19% (in SRV) / Gas RF = 30% (in SRV)

K ~ Moderate - High



Pressure

$(So)_{initial} = 0$



Saturation

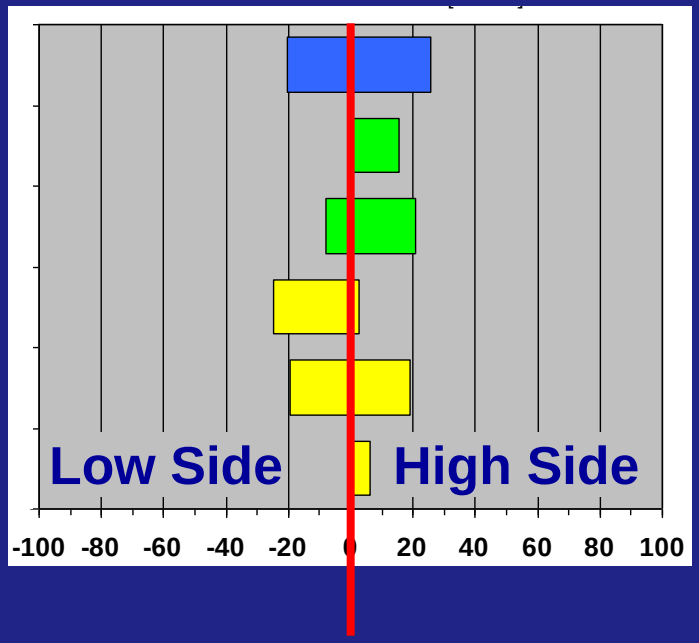
Eagle Ford Rich Gas Condensate Shale Sensitivity Analysis

Production Change (%)

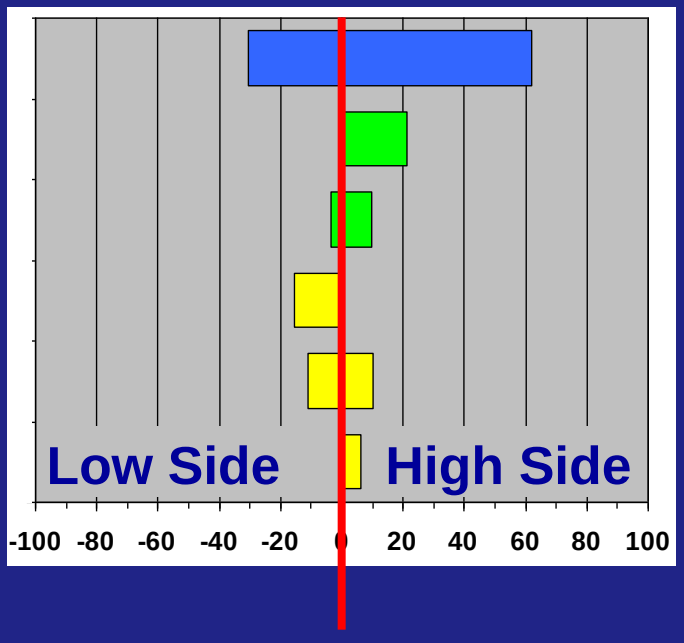
Short Term Effects
(1 Year)

Long Term Effects
(10 Years)

Matrix Quality
SRV Size
Fracture Perm
Fluid Type
Initial Pressure
Desorption



Base Case



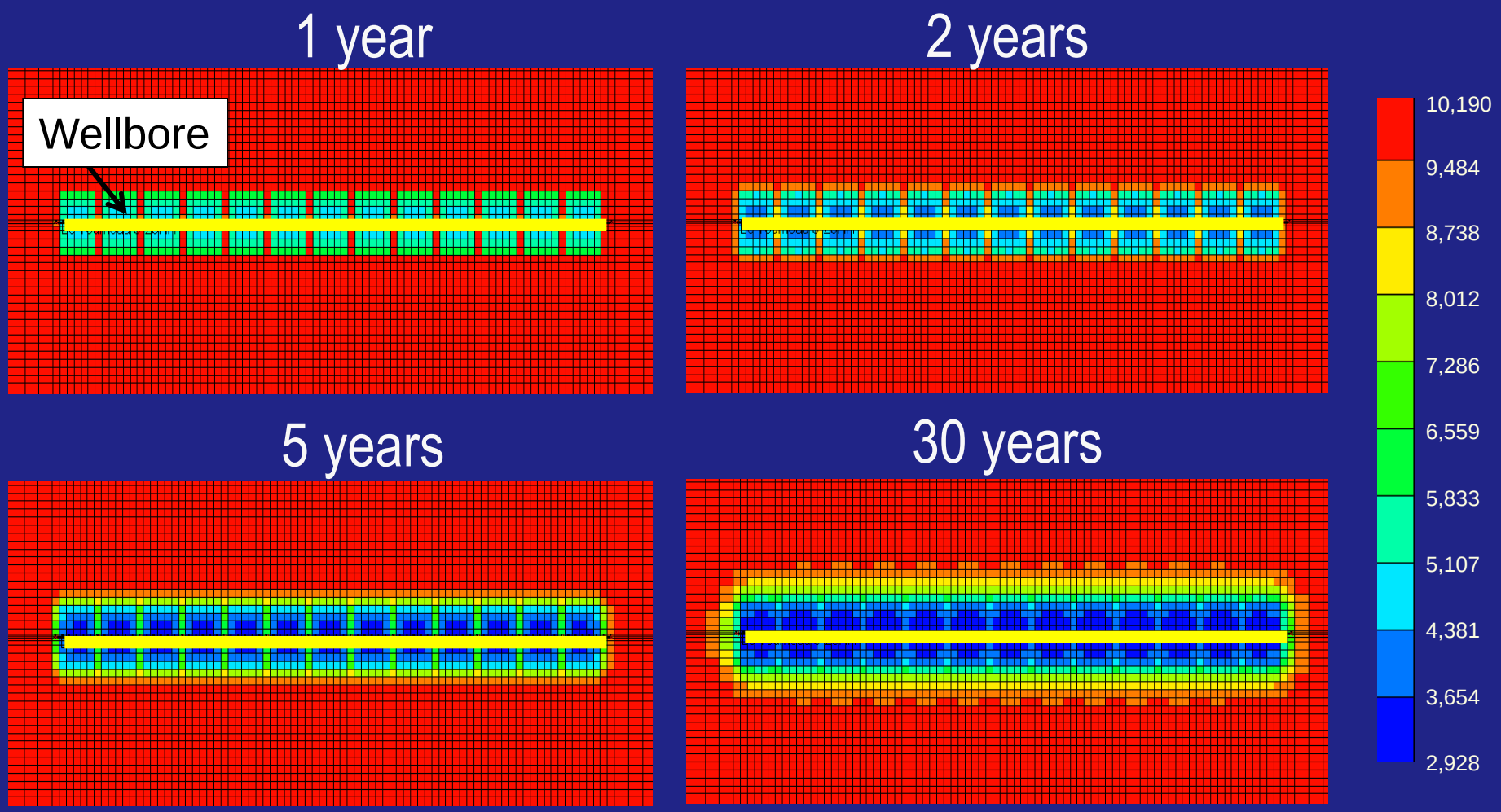
Base Case

Reservoir Completion Fluid

Skip Examples

Haynesville Dry Gas Performance (30 Years)

Pressure Distribution (psi)



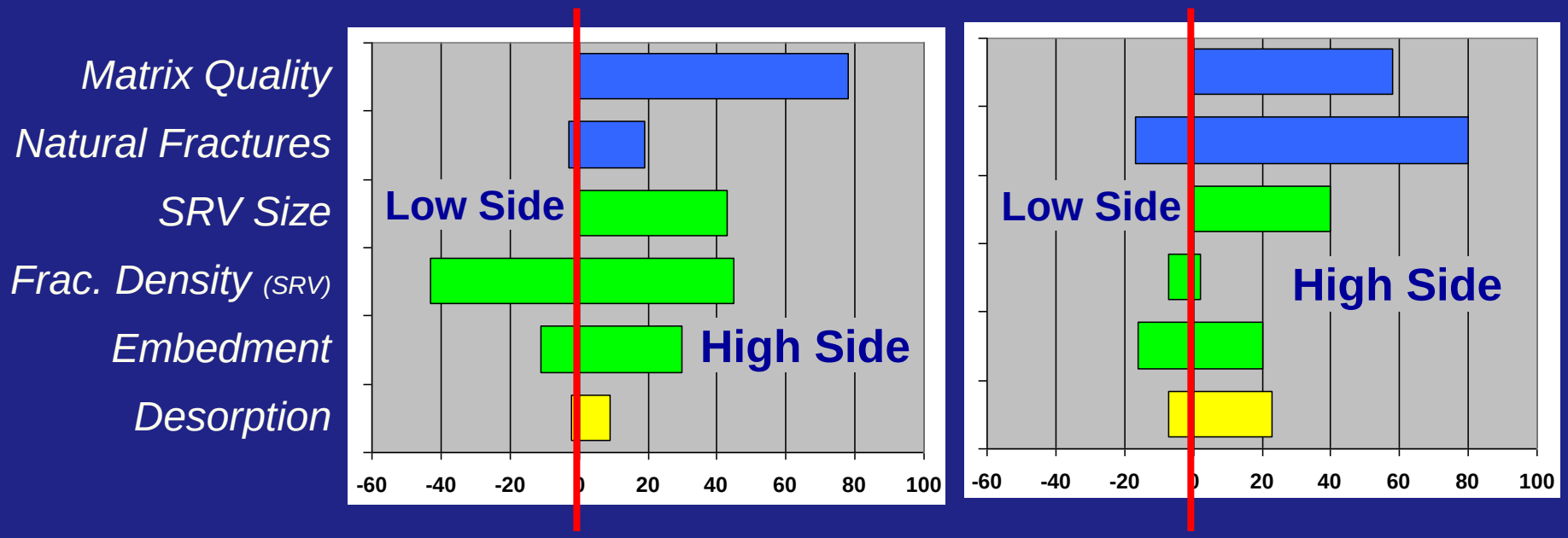
K ~ Low

Haynesville Dry Gas Shale Sensitivity Analysis

Production Change (%)

Short Term Rate Effects
(1 Month)

Long Term Cum Effects
(10 Years)



Base Case

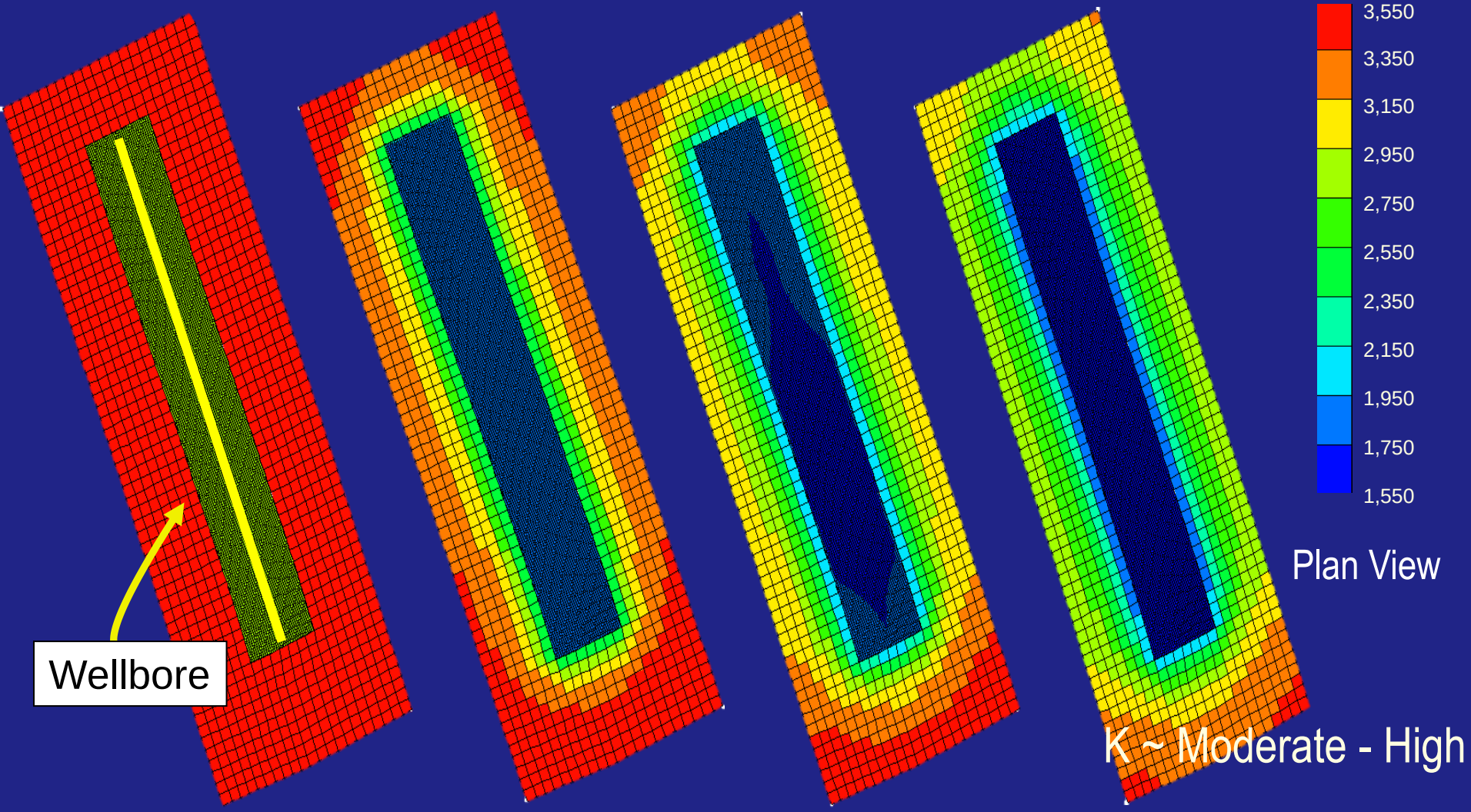
Base Case

Reservoir Completion Fluid

Skip Examples

Marcellus Dry Gas Fractured Performance

Pressure Distribution (psi)



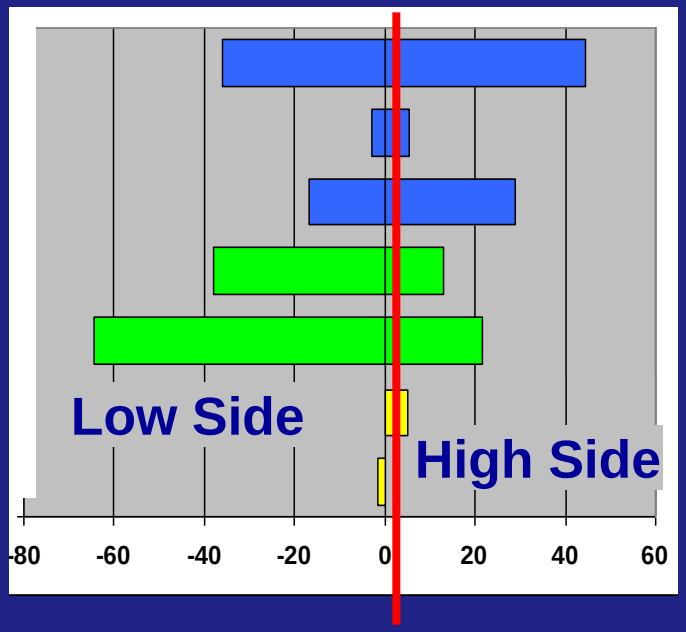
Marcellus Dry Gas Fractured Shale Sensitivity Analysis

Percent Change in Production

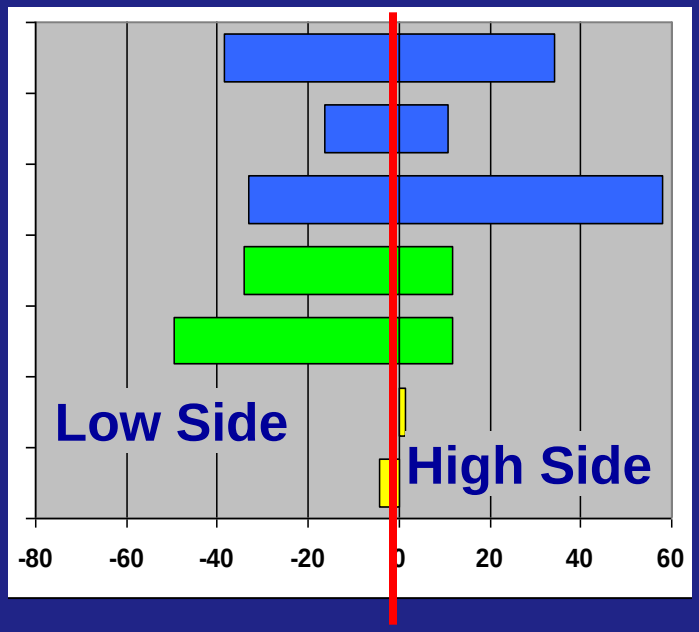
Short Term Effects
(1 Year)

Long Term Effects
(10 Years)

Matrix Quality
Nat. Frac. Spacing
Nat. Frac. Perm
SRV Size
Frac. Perm (SRV)
Initial Pressure
Desorption



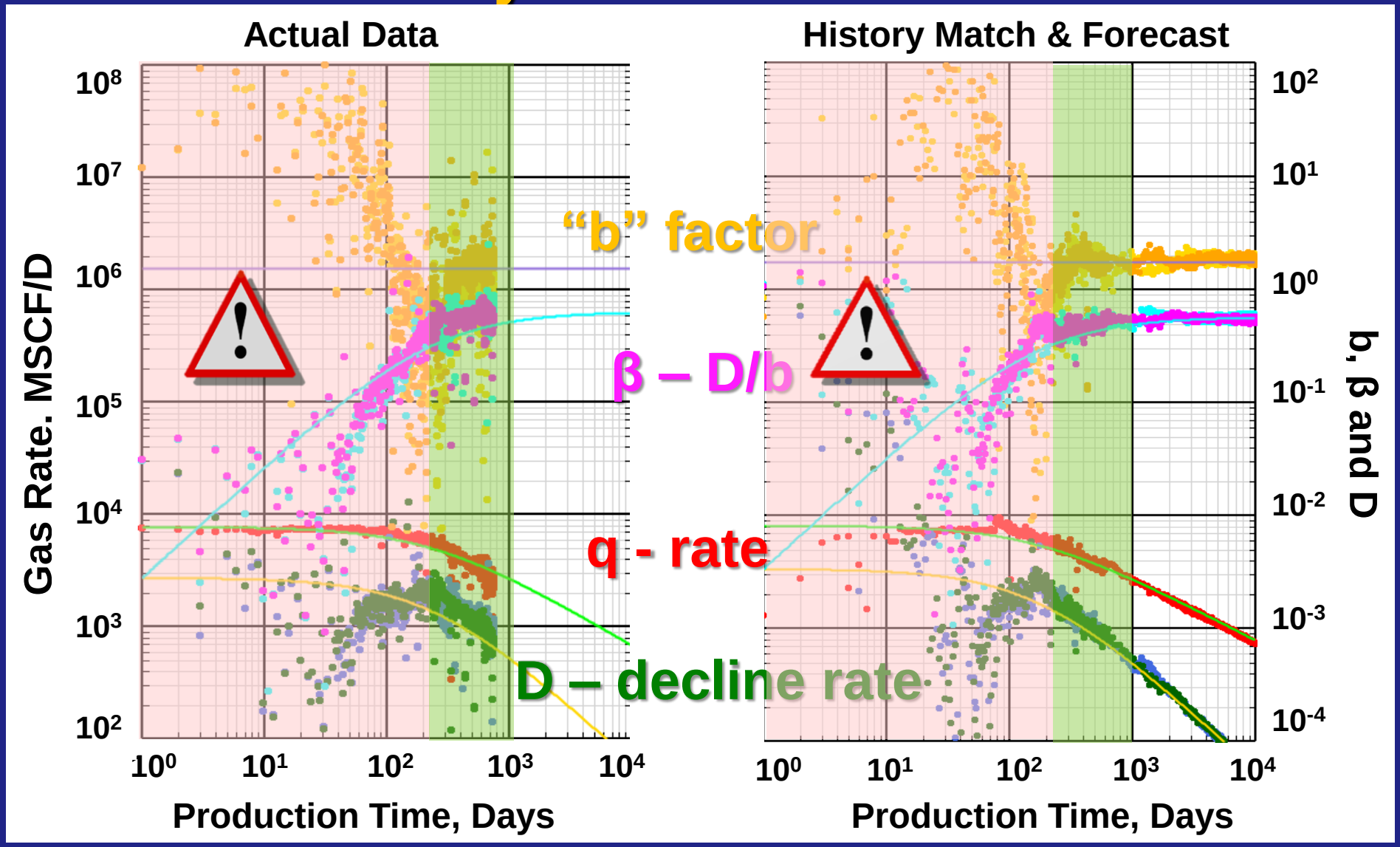
Base Case



Base Case

Reservoir Completion Fluid

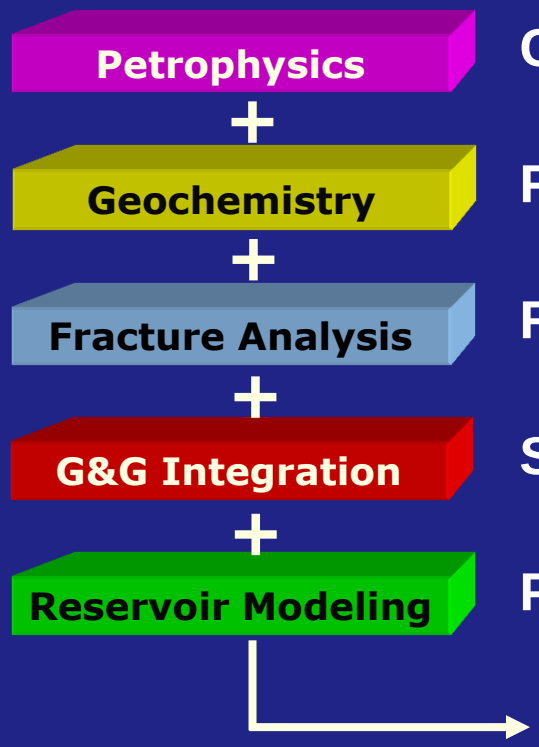
Marcellus Dry Gas Fractured Shale Production Analysis



Modified Hyperbolic

Shale Technology Subsurface Integration

- **Field Demonstrations and Mechanistic Studies**
  - Capture Static / Dynamic Data
  - Validate Results



Cores, Logs, (ϕ, *k*)

Fluid Properties, *PVT*

Rock Mechanics, Fluid Flow

Seismic Integration, Horizontal Targeting

Performance Analysis

EUR Determination

Production Forecasting

Commercial / Technical Success

Conclusions & Key Learnings

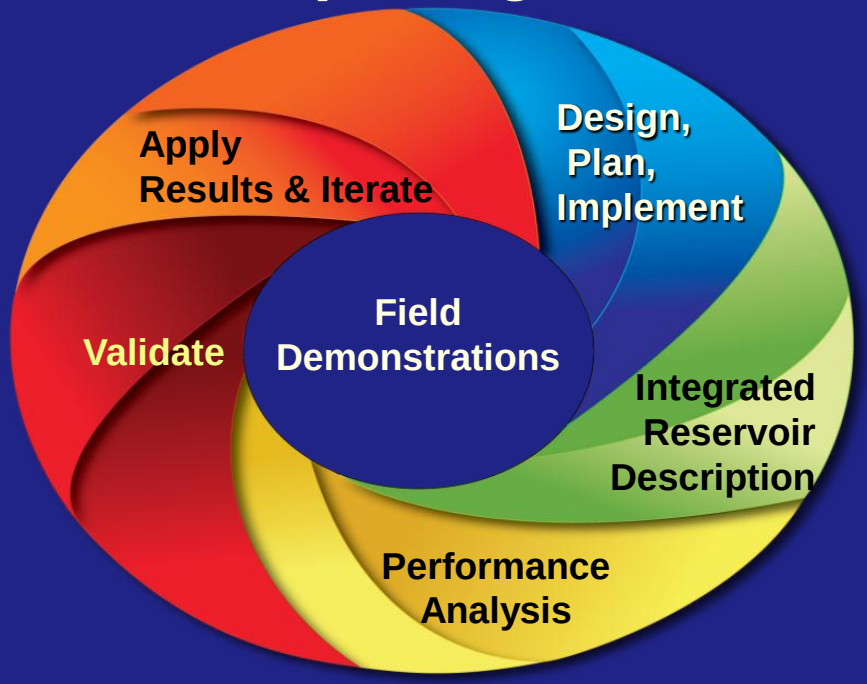
- Inter and Intra Play Development Drivers Change
  - Fluid Type, Permeability & Heterogeneity are Key Reservoir Drivers
- Reservoir Characterization and Performance Analysis, Processes are Critical
  - Well Thought-out & Executed Field Demos
  - Targeted Data Acquisition

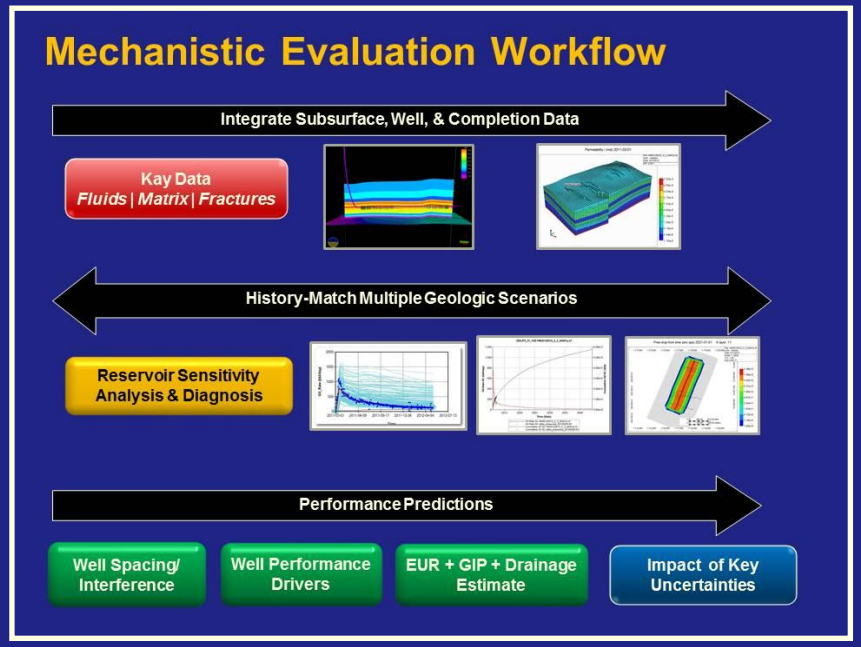
Key Learnings - Full Life Cycle Value Drivers

Value Driver	--- Value & Resource +++	
Development Approach	Uniform Spacing, Offset Practices	Geologically Targeted Semi-Custom Spacing
Performance Analysis	Type Curves, Arps, Statistical	Advanced Analytical, Numerical, SRV Diagnosis
Data Acquisition	Ad Hoc	Appropriate Combinations & Timing
Subsurface Analysis	Single Domain	Static & Dynamic Data Geology, Geophysics, Petrophysics, Reservoir Eng.

Conclusions & Key Learnings

- **Field Demonstration and Mechanistic Models Key to Development and Optimization**
  - **Target interval**
  - **Thermal Maturity Window**
  - **Well Spacing**





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