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Society of Petroleum Engineers
Distinguished Lecturer Program
www.spe.org/dl
SHALE RESOURCES ASSESSMENT – A Full Life Cycle Integrated Approach

SPE 2012 -2013 Distinguished Lecturer Series

P. K. Pande
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

OIL SHALE PLAY
- Horn River Basin/ Cordova Embayment
- Montney Deep Basin
- Colorado Group
- Bakken
- Niobrara/Mowry
- Permian
- Eagle Ford
- Barnett

GAS SHALE PLAY
- Woodford
- Fayetteville
- Haynesville
- Marcellus
- Utica

Kilometers
## Key Learnings - Full Life Cycle Value Drivers

<table>
<thead>
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<th>Value Driver</th>
<th>Value &amp; Resource</th>
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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 Prediction Limitations

Shale Performance Forecasting

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

Performance Analysis Tools and Technologies
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?

To Have Value They Must Be:

- Systematic
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General Shale Play Application

- Build Database of Analogs

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

Stimulated Area
Performance Analysis Tools and Technologies

Conventional Tools

Complexity & Resource

IPM
Reservoir Simulation
Streamline Simulation
RTA / MBDTCA
Analogies
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
Mechanistic Studies In Action

- Haynesville
- Dry Gas
- Marcellus
- Dry Gas
- Natural Fractures

OIL SHALE PLAY
GAS SHALE PLAY

Eagle Ford
Rich Condensate

Marcellus - Dry Gas
Natural Fractures

Haynesville
Dry Gas

Skip Examples
Eagle Ford Rich Gas Condensate Performance (30 Years)

Pressure Distribution

Condensate Distribution

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

Well Bore

Pressure

Saturation

$$(S_0)_{\text{initial}} = 0$$

$K \sim \text{Moderate - High}$$
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

Low Side
High Side

Base Case

Base Case

Reservoir
Completion
Fluid

Skip Examples
Haynesville Dry Gas Performance (30 Years)

Pressure Distribution (psi)

1 year
2 years
5 years
30 years

Wellbore

K ~ Low
Haynesville Dry Gas Shale Sensitivity Analysis

Production Change (%)

**Short Term Rate Effects** (1 Month)
- Matrix Quality
- Natural Fractures
- SRV Size
- Frac. Density (SRV)
- Embedment
- Desorption

**Long Term Cum Effects** (10 Years)
- Low Side
- High Side

Base Case

- Reservoir
- Completion
- Fluid
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

Low Side

High Side

Low Side

High Side

Base Case

Reservoir
Completion
Fluid
Marcellus Dry Gas Fractured Shale Production Analysis

Actual Data

![Graph showing actual data with axes for Gas Rate (MSCF/D) vs. Production Time (Days)]

- "b" factor
- $\beta = D/b$
- $q$ - rate
- $D$ - decline rate

History Match & Forecast

![Graph showing history match & forecast with axes for Gas Rate (MSCF/D) vs. Production Time (Days)]

- Modified Hyperbolic

10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
Shale Technology Subsurface Integration

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

- Petrophysics
  - Cores, Logs, \((\phi, k)\)

- Geochemistry
  - Fluid Properties, \(PVT\)

- Fracture Analysis
  - Rock Mechanics, Fluid Flow

- G&G Integration
  - Seismic Integration, Horizontal Targeting

- Reservoir Modeling
  - 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

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- **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
Your Feedback is Important

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Click on: Section Evaluation
Thank You