“Sweet Spot” Identification and Optimization in Unconventional Reservoirs

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Jeffrey B. Aldrich and Dr. John S. Seidle
FUNDAMENTAL QUESTIONS

• What is an Unconventional Reservoir?
• How are They Different from Conventional Reservoirs?
• What are the Characteristics that We can Measure?
• Which of Those Characteristics are Really Important?
• What Do We Mean by “Sweet Spot”? 
The Difference Between Conventional and Unconventional Reservoirs

Producing Conventional Reservoirs

**EARTH**
(What can vary)

- Porosity
- Thickness
- Area
- Saturation
- FVF
- Permeability
- Pressure
- Temperature

**TOOLS**
(What we can vary)

- OHcIP Reserves
- Rate
- Phase
- Wellbore Diameter
- Well Spacing
- Tubing Pressures
- Artificial Lift
- Enhanced Recovery Mechanisms
THE DIFFERENCE BETWEEN CONVENTIONAL AND UNCONVENTIONAL RESERVOIRS

Producing Unconventional Reservoirs

**EARTH**
(What can vary)

- TOC
- Maturity
- Kerogen Type
- Adsorption Capacity
- Porosity
- Thickness
- Minerology
- Area
- Saturation
- FVF
- Permeability
- Pressure
- Temperature
- Hmax/Hmin
- PR
- YM
- Fractures
- Fracture Initiation Pressure
- Fracture Closure Pressure

**TOOLS**
(What we can vary)

- Horizontal Lateral Length
- Perf size
- # of perfs\ cluster
- # of clusters \ stage
- Stage length
- Stage spacing
- Frac Pressure [> FIP]
- Frac Time
- Fluid Viscosity
- Fluid Slickness
- Proppant Size
- Amount of Proppant
- Uniformity of Proppant
- Strength of Proppant
- Amount of Frac Fluid

STIMULATED ROCK VOLUME
What are the characteristics that we can measure?

- Many different authors have tried to categorize the “productive” shale capabilities.

- 2 Primary Approaches
  - Pre-Drill:
  - Post-Drill:
    - Methods vary from using as few as 2 parameters to as many as 14 parameters to define a “Sweet Spot”

- We reviewed papers from most active North American shale plays as well as advanced international shale plays.

- The major papers are summarized in the handout.
THE 3 “QUALITIES”

ORGANIC QUALITY

TOC    Maturity    Kerogen Type
Storage Capacity

ROCK QUALITY

Thickness    Porosity    Permeability
Saturation    Mineralogy

MECHANICAL QUALITY

Poisson’s Ratio    Young’s Modulus
Mineralogical Brittleness    Stress    Pressure
Fractures
FACTORS THAT ARE NEEDED FOR SWEET SPOT QUANTIFICATION

When there are the optimum factors from all three Qualities then the reservoirs will be in the Sweet Spot.
With No “RQ” there is HC and the rock can be frac’d but it is just a source rock
With No “MQ” there is HC and storage but the rock can’t be frac’d so no sustainable production
FACTORS THAT ARE NEEDED FOR SWEET SPOT QUANTIFICATION

With No “OQ” there is no HC and the rock can be frac’ed but it is non-productive
## What Can Make a Sweet Spot “Sweet”?

### Not Hard Rules – But Guidelines

<table>
<thead>
<tr>
<th>Variable</th>
<th>Range for Commercial Shales</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OQ</strong></td>
<td></td>
</tr>
<tr>
<td>Organic Content</td>
<td>&gt;3% and &lt;12% of correct macerals</td>
</tr>
<tr>
<td>Maturity (Vr, Tmax, CAI)</td>
<td>Wet gas or dry gas windows</td>
</tr>
<tr>
<td>Storage Capacity (Langmuir Isotherm, BCF/ac-ft, etc.)</td>
<td>Variable by shale and thickness</td>
</tr>
<tr>
<td><strong>RQ</strong></td>
<td></td>
</tr>
<tr>
<td>Thickness</td>
<td>&gt;100’ and bounded for Frac</td>
</tr>
<tr>
<td>Porosity</td>
<td>&gt;8% - can be much higher</td>
</tr>
<tr>
<td>Permeability</td>
<td>&gt;.001mD – not firm rule</td>
</tr>
<tr>
<td><strong>MQ</strong></td>
<td></td>
</tr>
<tr>
<td>Clay Content</td>
<td>&lt;40%</td>
</tr>
<tr>
<td>Poisson’s Ratio</td>
<td>&lt;.2</td>
</tr>
<tr>
<td>Young’s Modulus</td>
<td>&gt;5x10e6</td>
</tr>
<tr>
<td>Pressure</td>
<td>Generally – overpressure is positive</td>
</tr>
</tbody>
</table>
FACTORS THAT ARE NEEDED FOR SWEET SPOT QUANTIFICATION

Organic Quality
- Organic Content
- Maturity
- Storage Capacity
- Maceral Type

Mechanical Quality
- Poisson’s Ratio
- Young’s Modulus
- Clay Content
- Stress Fields
- Pressure Regime

Rock Quality
- Thickness
- Porosity
- Permeability
- Mineralogy
- Saturation

FIT FOR PURPOSE OPERATIONS
SUFFICIENT FISCAL ENVIRONMENT
PROPER REGULATIONS AND ENVIRONMENTAL MANAGEMENT
HOW DO WE QUANTIFY THESE SURFACE FACTORS?

- If Proper Operations, Fiscal Environment, Regulations are also critical how do we measure or quantify them?
- Is there a Single System?
  - Organic Quality  Rock Quality  Mechanical Quality
  - Operations  Fiscal  Regulations

- Can we get to Commerciality? Economics?
The PRMS has both a Commerciality and an Uncertainty measure built into the system. These measures can be used to quantify sweet spots in unconventional reservoirs.
RESERVE DEFINITION FOR SHALES

• Normally by decline curve analysis plus economic analysis to meet threshold values.
  ➢ Commercial Rate
  ➢ Commercial Gas Composition
  ➢ Developable Gas Volume
  ➢ Feasible Development Plan
  ➢ Reasonable Time Frame
  ➢ Viable Market
  ➢ Existing or Imminent Approvals

(Facilities and Volumes and Rate align)

Notice that for Conventional – normally a well test will suffice!
Example where the PRMS can define the “Sweet Spot” on both Commerciality (Reserves) and Uncertainty (Probable vs Possible) within a field at an early stage of development.

200m Lateral Pilot Wells
Examples of External Impacts on Sweet Spot Area from the Niobrara in the DJ Basin, Colorado
Advent of horizontal wells and MHF opened more rock volume to be commercial reservoir
Effect of Technology

NGI’s Map of Shale/Resource Plays & North America Pipelines
Extent of Niobrara Production in Wattenberg Field in 1970 vs 2018, vertical vs MHF in horizontal wells
Effect of Price

Effect of Price

Map of EOG’s original field development
Effect of Price

EUR’s of the original wells

Sweet Spot based on EUR
INCREASE IN $$ INCREASES SWEET SPOT

- NPV of the wells at $100/Bbl WTI Price

Sweet Spot based on $100/Bbl
DECREASE IN $$ DECREASES SWEET SPOT

- NPV of the same wells at $69.36 WTI Price

Sweet Spot based on $69.36/Bbl
KEY TAKEAWAYS

• Key Take Away #1

Sub-Surface Productivity Factors (PF) can vary by basin, shale or field but can be subdivided into:

• Organic Quality Factors (OQ)
• Rock Quality Factors (RQ) and
• Mechanical Quality Factors (MQ).
Key Take Aways

- Key Take Away #2

  ➢ Sweet Spot quantification needs to include commercial terms:
    - Operations
    - Fiscal
    - Regulations

  and the AAPG-SPE PRMS has the built-in tools for quantification of both commerciality and uncertainty.
• Key Take Away #3

➤ Due to above ground factors of:
  • commodity price
  • Drilling and Completion efficiency
  • Regulations and
  • Societal challenges

  “Sweet Spots” are not static but change over time.
Appreciation goes to MHA Petroleum Consultants for the time and material used in this presentation.

The authors would like to offer special thanks to Mrs. Shawna Harrison, Jessica Davey, and Traci Paine for their hard work in helping us prepare this presentation.
MAY I MAKE A RECOMMENDATION?

• DENVER INTERNATIONAL PETROLEUM SOCIETY (DIPS)

➤ Meets the 2nd Friday of every month at the Wyncoo Brewery
  • September – May

➤ You will not always work your current basin for the rest of your career!

➤ The lowest cost geoscience lunch, the most fascinating geology!

➤ Walk-ins welcome

➤ Contact Kurt.Reisser@gmail.com to get on mailing list
# Literature Review

<table>
<thead>
<tr>
<th>Organic Quality</th>
<th>Rock Quality</th>
<th>Mechanical Quality</th>
<th>Mechanical Brittleness</th>
<th>Mineralogical Brittleness</th>
<th>Britteness</th>
<th>Stress Fields</th>
<th>Pressure</th>
<th>Fractures</th>
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<tbody>
<tr>
<td>TOC</td>
<td>Maturity</td>
<td>Kerogen Type</td>
<td>Storage Capacity</td>
<td>Height</td>
<td>Porosity</td>
<td>Permeability</td>
<td>Saturation</td>
<td>Mineralogy</td>
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<tr>
<td>Algarhy, Soliman, Boteman, Asquith</td>
<td>Shale Gas Plays Screening Criteria, ”A Sweet Spot Evaluation Methodology”</td>
<td>Fracturing Impacts &amp; Technologies Conference, Texas Tech Univ, 2014</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Brian Toelle</td>
<td>Shale Sweet Spot Detection with Surface Seismic</td>
<td>SPE Distinguished Lecturer Program (2014?)</td>
<td>X</td>
<td>X</td>
<td></td>
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<tr>
<td>Ktamar and Murtazash</td>
<td>Identification of Brittle/Ductile Areas in Unconventional Reservoirs using Seismic and Microseismic Data: Application to the Barnett Shale</td>
<td>SEG Interpretation, Nov, 2015 T233</td>
<td></td>
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<tr>
<td>Renfang, Qin, Je, Jineng</td>
<td>Elements and Gas Enrichment Laws of Sweet Spots in Shale Gas Reservoir: Case Study of the Longmaxi Fm in Changning Block, Sichuan Basin</td>
<td>Natural Gas Industry, B3, 2016, pp 196-201</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Dotsey</td>
<td>Logs Reveal Marcellus Sweet Spots</td>
<td>AOGR, 3-3M, T1, A2</td>
<td>X</td>
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<tr>
<td>Naizheng Liu, Guoyang Wang</td>
<td>Shale Gas Sweet Spot Identification and Precise Geo-steering drilling In Weiyuan Block of Sichuan Basin, SW China</td>
<td>Petroleum Exploration and Development V48, Is 5, Dec 2016</td>
<td>X</td>
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<tr>
<td>Chopram Sharma, Nemat and Keay</td>
<td>Organically Rich Sweet Spot Determination in Utica Shale</td>
<td>Search and Discovery, Article #42137, 2017</td>
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