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Geology of the Louisiana Haynesville Shale Play

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Shale-Abundant, Clastic Sedimentary Rock Comprised Primarily Of Clay (Less Than 0.00015 Inches) And Silt (Between 0.00015 And 0.0025 Inches)\(^{(1)}\) Sized Particles That Have Been Consolidated Into Rock Layers. Shale Typically Exhibits Extremely Low Permeability And Is Often Considered A Natural Barrier Or “Seal” To The Migration Of Hydrocarbons.


The First Commercial Shale Gas Well Was Drilled In 1821. It Was Drilled 27’ Deep Into The Devonian Dunkirk Shale And Supplied The Residents Of Nearby Fredonia New York With Gas To Illuminate Their Homes.\(^{(1)}\)

\(^{(1)}\) Franz, Joseph H., Jochen, Valerie, Shale Gas White Paper, Schlumberger, 2005
Considering Source Rock Potential

- Geologic Conditions.
- Organics.
- Petrophysics.
- Reservoir Conditions.
Considering Source Rock Potential

• Geologic Conditions.
  - Early.
    • Suitable Source Rocks
    • Depositional Environment
  - Late
    • Geological Complexity
    • Well Control

Geological Conditions Required For Sediments (Shale) to Generate Hydrocarbons

• Source Of Clastic Material With Sufficient Amounts Of Organic Content.
• Rapid Burial In An Anoxic Environment.
• Additional Sedimentation To Increase Pressure And Temperature.
• Sufficient Heat And Time (Millions Of Years) To Facilitate The Maturation Of Kerogen.
Considering Source Rock Potential

- Organics.
  - Total Organic Content ("TOC").
    - Type Specific
    - Minimum % Values
  - Thermal Maturity.
    - Measured By Vitrinite Reflectance (Ro)
    - Gas Window

Kerogen Types

- Type I-Lacustrine (Lake) Or Marine In Origin, Algal Or Planktonic Matter, Tends Towards Oil Production.
- Type II-Deep Marine, Planktonic, Oil Or Gas Production Depending Upon Maturity.
- Type III-Shallow to Deep Marine, Terrestrial Plant Debris, Dry Gas Production.
Vitrinite Reflectance As Indicator of The Thermal Maturity Of Kerogen

- Reflectance Measurements Are The % Light Reflected In Oil (Ro).
- Reflectance Increases With Temperature.
- Ro Values Vary From One Organic (Kerogen) Type To Another.
- High Ro Values (>1.5%) Indicate Presence Of Dry Gas.
- Lower Ro Values (0.6 to 0.8%) Indicate The Presence Of Oil.
Thermal Transformation of Kerogen-The Precursor Of Oil & Natural Gas

Haynesville Organics

- TOC 0.5 to 4% By Weight. (1)
- Vitritine Reflectance (Ro) 2.2 to 3%. (2)
- Kerogen Type III 5.2% By Volume. (3)

(1) Tristone Capital
(2) Chesapeake
(3) Tristone Capital
Considering Source Rock Potential

• Petrophysics.
  – Rock Matrix Porosity (>4%).
    • Well Logging
    • Core Analysis
  – Rock Matrix Permeability (>100 Nanodarcies).
    • Core Analysis
  – Fluid Saturation (Wtr. < 45% & Oil < 5%).
    • Core Analysis

Typical Source Rock Well Evaluation Tools

• Mud Log With Gas Detector.
• Wireline Logging Tools Or Logging While Drilling (“LWD”) Formation Evaluation Tools.
• Conventional Core Recovery And Analysis.
High Organic Shale Well Log Indicators

- High (Radioactive) Gamma Counts Commonly Above 135 API Units.
- $R_{wa}^{(1)}$ Response Higher Than Background.
- Density Porosity Values Up To 15%.

$R_{wa} = \frac{R_t}{F}$ Where $R_t$ is Formation Resistivity From Well Log; $F$ is Resistivity Of Rock Matrix/Formation Water Resistivity.

Comparison of 5" Detail Log to 1" Correlation Log
Camterra-Bozeman 35-1
Casplana Field
Section 35, T-16N, R-14-W

Completed: 3-5-08
Perforations: 11716-11835 Overall
IP: 320 MCFD, 0.2 BCD, GVTY 50
GOR: 1,600,000:1 ccf/bbl
FTP: 410 psig
CK: 12/64"

Porosity and Permeability Comparison of Haynesville and Bossier with Other Shale Plays

Multiple formations – Porosity and Permeability

Shale rock properties as measured with GRI methodology at CoreLabs:
Barnett, Bossier, Caney,
Conasauga, Fayetteville,
Haynesville, Manning Canyon,
Marcellus, Woodford
Haynesville Shale Petrophysics

- Porosity (Log) 9-15%.
- Porosity (Core) 8-9%.
- Permeability (Measured in Nanodarcies).
- Water Saturation 15-20%.

(1) Density Log Porosity
(2) Tristone Capital
(3) Chesapeake

Critical Cutoff Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porosity</td>
<td>&gt;4%</td>
</tr>
<tr>
<td>Water saturation</td>
<td>&lt;45%</td>
</tr>
<tr>
<td>Oil saturation</td>
<td>&lt;5%</td>
</tr>
<tr>
<td>Permeability</td>
<td>&gt;100 nanodarcies</td>
</tr>
</tbody>
</table>

^ Critical reservoir parameters. Experience in multiple US shale-gas basins has shown that shale-gas reservoirs must meet or exceed these parameters to be commercially viable.

Considering Source Rock Potential

- Reservoir Conditions.
  - Depth
  - Formation Thickness
  - Formation Pressure
  - Rock Mechanics
    - Natural Fracture Induced Permeability
    - Acceptance Of Hydraulic Fracturing

Reservoir Characteristics

- Depth 10,000’ to 13,700’+.
- Pressure Up To +11,000 psi. (1)
- Temperature 240° to 322° F. (2)
- Excellent Frac Barriers (Bossier & Smk.)
- GIP/Section 150 to 225 BCF.
- EUR/Horizontal 4.0 to 8.5 BCF.

(1) Geo-pressured Gradient Up to 0.9 psi/ft
(2) Chesapeake
Developing The Haynesville Shale

- Units Typically 640 Acre Governmental Sections. Definition Includes Haynesville And Bossier Shale (Haynesville Zone).
- Can Be Developed With Horizontal Or Conventional (Vertical) Wells.
- Legal Well Location 330' From Unit Lines And 660' Between Wells.
- May Be Downhole Combined With Production From Other Intervals.
E.G. Plantation No. 63-Alt
IP 17,076 MCFD; EUR 8,841 BCFG
(Horizontal Well)

SRLT No. 29-2-H Alt. (Type Curve)
IP 2,647 MCFD; EUR 2,021 BCFG
(Horizontal Well)

Courtesy of Coutret & Associates, Shreveport
Additional Potential

- Some Porosity Logs And Limited Early Completions Indicate Additional Potential Exists In The Bossier Shale Which Is Commonly Over >1,000' Thick.
- Stacked Pays-Shallow Opportunities In The Pettet, Hosston (Travis Peak) And Cotton Valley Formations.

Haynesville Benefits

- Geological Knowledge.
- Regional Depositional Area.
- Good Rock Properties.
- Good Frac Barriers (Bossier & Smackover).
- Existing Industry Infrastructure.
- Adequate Water Supply.
- Largely Rural Area.
- Reasonable Lease Costs?
- Established Regulatory Procedures.