A Case Study into the Successful Evaluation and Completion Non-conventional Wells in Mexico

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VP Reservoir Intelligence, NUTECH
Presentation Outline

- NUTECH experience in the Eagle Ford and Burgos Basins
- How NUTECH’s unconventional analysis process is used in new shale plays
- Highlight similarities and differences between the Eagle Ford, Haynesville and La Pimienta formations
- Tangram and Céfiro examples – Petrophysical analysis, geomechanical modeling and completion design considerations
- Well performance and lessons learned
- Moving forward in La Pimienta and Eagle Ford
NUTECH Timeline

2002
NULOOK
Determine pore size and texture

1998
NULOOK PETROPHYSICS
Determine bound water fraction and permeability

2003
NUSTIM COMPLETION ENGINEERING
Multi-scenario stimulation optimization

2003
NULOOK
Method of determining TOC, porosity and permeability of organic shales

2005
NUVIEW
Texture based reservoir mapping

2006
NUSTIM
Diagnostic Fracture Injection Test Analysis

2006
NULOOK
Inflection points are utilized to increase vertical resolution in low contrast/highly laminated intervals thru binary logic

2006
NULOOK
Utilize multiple triple combo data fracture indicators to identify frequency of natural fractures

2008
NUSTIM
Geomechanical properties log
NUTECH Experience in the Eagle Ford and Burgos Basins

- Field Studies developed with publically available data since 2009
- Over 2000 wells evaluated and over 500 completions designed for operators
- Over 1000 wells evaluated in the Burgos basin with conventional and tight gas targets since 2004
- Eagle Ford analog analysis
- Analysis and completion design of 8 new wells in the Eagle Ford and 2 new wells in La Pimienta
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Unconventional Analysis in New Plays

- Use of depositional analogs
- Use of local knowledge and available research
- Core Analysis
- NULOOK petrophysical analysis
- Geo-Mechanical modeling using sonic data and calibrated acoustic modeling
- NUSTIM multi-scenario completion design for vertical section
- NUSTIM optimization of spacing for horizontal completion

Source: BHPBilliton (Formerly Petrohawk)

© NUTECH Geo-mechanical log Eagle Ford example
Petrophysical Process

- Determine Clay Volume using multiple clay indicators
- Determine Kerogen fraction using modeling from GR, Resistivity, Density, and Neutron
  - Gamma Ray Method (Uranium Model) Russell 1945 & Fertl 1978
  - Density Method (Modified Schmocker) Schmocker 1983
- Correct for Kerogen effect on log data
- Use Kerogen corrected data to solve for Silica, Lime, Heavy Minerals, and Porosity

Eagle Ford example La Salle Co., TX
Petrophysical Process

- Determine Bound Water using Multi-Modeling Logic
- Determine Permeability using algorithm developed from completed well production and stimulation matching and/or good core data
- Determine Adsorbed and Free Gas volumes from core determined data (Langmuir Isotherms)

La Pimienta Example, Nuevo León, Mexico
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Eagle Ford

La Salle County “Sweet Spot”

<table>
<thead>
<tr>
<th>Zone</th>
<th>Summaries</th>
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<tbody>
<tr>
<td>DEPTH M</td>
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<td>PERMSHM uD-M</td>
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<td>TOC %</td>
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Area A

Area B

Area C

5-Well Average Statistics

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Area A

Area B

Area C

Well Statistics

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</table>

Area A

Area B

Area C

NUTECH
La Pimienta

- Upper Jurassic deposition
- EIA/ARI: “Correlates with the productive Haynesville shale of the East Texas Basin”
- Expected TOC: ~3%
- Expected Thermal Maturity: >1.4% Ro (Gas)
- BUT Anhélido-1 well had IP of 432 BOPD + 1.9 MMCFPD (Source: Pemex)

Eagle Ford, La Casita and La Pimienta formations map.
Source: EIA/ARI World Shale Gas and Shale Oil Resource Assessment 2013

Source: Pemex Preliminary Results 2012
La Pimienta- Haynesville Comparison

### Shale Play

<table>
<thead>
<tr>
<th>Haynesville/ Bossier</th>
<th>LA Pimienta NUTECH</th>
<th>LA Pimienta ARI</th>
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<tbody>
<tr>
<td>Region</td>
<td>East TX/ LA</td>
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</tr>
<tr>
<td>Age</td>
<td>Late Jurassic</td>
<td></td>
</tr>
<tr>
<td>Basin</td>
<td>East TX/North LA Salt</td>
<td></td>
</tr>
<tr>
<td>Area (Sq Miles)</td>
<td>9,000</td>
<td>9,000</td>
</tr>
<tr>
<td>Depth (Ft)</td>
<td>10,500-13,500</td>
<td>8,200-9,100</td>
</tr>
<tr>
<td>Thickness (Ft)</td>
<td>200-300</td>
<td>300-375</td>
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<tr>
<td>Quartz (Wt %)</td>
<td>30-35%</td>
<td>20-40%</td>
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<tr>
<td>Carbonate (Wt %)</td>
<td>13-44%</td>
<td>25-60%</td>
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<tr>
<td>Clay (Wt %)</td>
<td>35-45%</td>
<td>10-20%</td>
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### Reservoir Rock

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<tr>
<th></th>
<th>Temperature (°F)</th>
<th>Reservoir Pressure (Psi)</th>
<th>Pressure Gradient (Psi/Ft)</th>
<th>Permeability (µD)</th>
<th>Porosity (%)</th>
<th>YM (x10^6 Psi)</th>
<th>Poisson's Ratio</th>
<th>Brinell Hardness Number</th>
<th>Fracture Gradient (Psi/Ft)</th>
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<tr>
<td></td>
<td>300-370</td>
<td>9,000-11,000</td>
<td>0.8-0.9</td>
<td>0.1-1</td>
<td>8-10%</td>
<td>2-5</td>
<td>0.2-0.35</td>
<td>18</td>
<td>1</td>
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<tr>
<td></td>
<td>260-280</td>
<td>Normal</td>
<td></td>
<td>0.4</td>
<td>8.40%</td>
<td>2-8</td>
<td>0.25-0.35</td>
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### Play Maturity

<table>
<thead>
<tr>
<th></th>
<th>TOC (%)</th>
<th>Kerogen Type</th>
<th>Thermal Maturity (% Ro)</th>
<th>Tmax (°F)</th>
<th>HH (mg HC/g TOC)</th>
<th>S1/TOC (mg HC/g TOC)</th>
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<tr>
<td></td>
<td>0.5-4%</td>
<td>Type II</td>
<td>1.8-2.5%</td>
<td>905-940</td>
<td>100-205</td>
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<tr>
<td></td>
<td>0.1 - 4.5</td>
<td>Type II</td>
<td>0.85 - 2.2%</td>
<td>822-850</td>
<td>78-249</td>
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<tr>
<td></td>
<td>3%</td>
<td></td>
<td>0.85-1.4%</td>
<td></td>
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</tr>
</tbody>
</table>

© NUTECH La Pimienta NULOOK

Sources: © NUTECH Unconventional Catalog/ EIA/ARI World Shale Gas and Shale Oil Resource Assessment 2013

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Tangram-1 and Céfiro-1 Evaluations
Tangram-1 Completion

- Recommended completion based on 1-year NPV as requested by Client
- Completion optimized in the vertical section for different variables of proppant type and concentration, injection rate, treatment size
- Horizontal spacing optimized based to maximize customer-specific financial terms
Céfiro-1 vs. Tangram-1 Completions

- For the Céfiro-1 well, the client requested the evaluation of treatments in three different landing depths.

- The selected scenario was not the most optimal for production because horizontal trajectory had been drilled.

- The mainstream approach to completion design in unconventional reservoirs is to use “Best Practices” for a specific field. However, the stratigraphic variation and geo-mechanical heterogeneity typical of shale reservoirs makes this approach inefficient. Even though Tangram-1 and Cefiro-1 are in the same field, their completion design was significantly different.
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Production

Both Tangram and Céfiro-1: IP: 10.9 MMCFPD (in-line with NUTECH’s prediction)

Céfiro-1 production reached over 12 MMCFPD and Pemex estimates it could get to 20 MMCFPD but do not have the surface facilities.

Tangram-1 and Céfiro-1 are the best two shale gas wells in Mexico.

- Simulated 180 day rates range from 9,090 to 12,101 MCFE/D after fracturing a 1,500 m lateral.
- 10 year CUM’s range from 16,345 to 21,451 MMCFE after fracturing a 1,500 m lateral.
Lessons Learned

- La Pimienta shows geologic similarities to the Haynesville formation in East Texas but with better expected production rates and a likely oil window to the south.
- Carbonate content increases S-N as the formation dips deeper.
- Landing points should be selected based on stratigraphic changes in the formation.
- Geomechanical variation is key to proppant selection.
- Eagle Ford completions can be improved with proper proppant selection and treatment size optimization.
- Less economical wells should be used for field characterization.
- “Best Practices” approach not ideal for La Pimienta and Eagle Ford formations.
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