The Discovery, Reservoir Attributes and Significance of the Hawkville Field and Eagle Ford Shale Trend - A Texas Giant North American Gas Discovery*

Richard K. Stoneburner¹

Search and Discovery Article #10552 (2013)
Posted December 9, 2013

*Adapted from oral presentation given at AAPG International Conference and Exhibition, Cartagena, Colombia, September 8-11, 2013. Please refer to closely related article by the author; it is entitled “The Exploration, Appraisal and Development of Unconventional Reservoirs: A New Approach to Petroleum Geology, Search and Discovery Article #41115 (2013).

**AAPG © 2013 Serial rights given by author. For all other rights contact author directly.

¹Advisor to Pine Brook Partners; Director for Newfield Exploration, Yuma Exploration and Cub Energy, (stoneburner@dontknow.com)

Abstract

The discovery of the Hawkville field in October, 2008, represented the first commercial production from the Eagle Ford Shale. Since that time the trend has seen a remarkable surge in drilling activity that has resulted in a current production level of almost 1 million barrels of oil equivalent per day. The discovery process by the Petrohawk Energy Corporation exploration team followed by the detailed petrophysical evaluation of the reservoir character verified that the Eagle Ford shale is truly a world class shale reservoir that has changed the landscape of hydrocarbon production from both the state and the country.

The exploration process was a classic example of the "inside out" approach utilized in exploring for unconventional reservoirs, as contrasted to the "outside in" approach utilized in exploring for conventional reservoirs. The subsurface study identified a local area in LaSalle and McMullen Counties that displayed excellent petrophysical parameters in the Eagle Ford. A geochemical analysis was then performed on cuttings from a well in the area of interest that produced favorable results. Lastly, a seismic signature was identified that enabled a discreet, but very large, buy outline to be defined. A total of approximately 160,000 acres was quickly assembled and a well was then drilled and completed. The entire process from concept to discovery only took approximately 10 months.

Subsequent to the discovery a thorough petrophysical, geochemical and geomechanical study was undertaken to better understand all aspects of the reservoir. The basis for this study was the data derived from the discovery well and pilot well program, with the data acquired from the whole core grid providing the basis for the study. Once the core data was acquired, a methodical effort was made to calibrate the core data to the open-hole log data. The resulting data set provided the basis for a wide array of interpretations that greatly aided the appraisal process.

The discovery of the Hawkville field and other discoveries made by industry partners in the Eagle Ford made it apparent that the trend was going to provide a significant boost to the production of oil, gas and natural gas liquids in the United States. The effects of that production
increase are beginning to make a difference in the security of the country’s hydrocarbon supply. However, the potential for significant production growth beyond what has already been achieved could greatly enhance our prosperity.
“The Discovery, Reservoir Attributes and Significance of the Hawkville Field and Eagle Ford Shale Trend: A Texas Giant North American Gas Discovery”

AAPG ICE: Discovery Thinking Forum
September 10th, 2013
Richard K. Stoneburner

Formerly: President and COO Petrohawk Energy and President NA Shale Production Division BHP Billiton Petroleum
Currently: Advisor to Pine Brook Partners; Director for Newfield Exploration, Yuma Exploration and Cub Energy
The development of isolated multi-stage hydraulic fracturing in 2006 caused a dramatic increase in shale production.
Exploration Process
### Unconventional Exploration: A Different Way of Thinking

<table>
<thead>
<tr>
<th>Conventional</th>
<th>Unconventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Project identification focuses “outside in”</td>
<td>• Project identification focuses “inside out”</td>
</tr>
<tr>
<td>• Seismic control works “outside in”</td>
<td>• Seismic control works “inside out”</td>
</tr>
<tr>
<td>• Stratigraphic support eventually focuses on the facies analysis local to the prospect</td>
<td>• Stratigraphic support focuses on analysis of the entire basin</td>
</tr>
<tr>
<td>• Reservoir quality issues are relegated to the area of the prospect</td>
<td>• Reservoir quality analysis is required over a very broad area of the basin</td>
</tr>
</tbody>
</table>
Prospect Identification: Conventional Analogy

- Deep Water Gulf of Mexico Prospect
- Structurally controlled and supported by local analogs
- At time of Prospect Identification, three significant analogs in the area of the prospect
- The area of the prospect was on the order of 10K acres with resource potential of 100-200 MMBOE
• Eagle Ford Shale Prospect
• Known regional source rock across large petroliferous basin
• Reservoir quality and geochemical attributes poorly understood
• The area was >10 MM acres with high side resource potential of >10 BBOE
In early 2008 the CEO of Petrohawk charged the Exploration team to find another “Haynesville-like” play.

- Our Fayetteville and Haynesville experience provided a level of experience in evaluating shale reservoirs that potentially allowed for a quick evaluation.

We targeted the Eagle Ford Shale based on its significance as a regional source rock.

- Q1: Mapped the Eagle Ford across the entire Gulf Coast Basin and identified an anomalously thick, porous and highly resistive Eagle Ford section in La Salle and McMullen Counties.
- Q2: Acquired Eagle Ford cuttings on a key well and had them analyzed for TOC, VRo and other key parameters.
- Q3: Acquired ~160,000 acres and spudded the initial test well.
- Q4: Completed it in October 2008 for 7.6 Mmcf/d and 251 Bc/d.
• Very limited well control in prospective area
• Prospect was located in a regional setting between two divergent shelf margins, which suggested the presence of a “mini-basin”
• While the geochemical properties were unknown, the depth range (10,000-11,500’/3050m-3500m) suggested a relatively mature source rock
Key Finding #1:
World Class Petrophysical Properties

• Well was drilled in the early ‘90’s, probably targeting the Cretaceous Olmos Sands
• Eagle Ford tested small amount of gas after light acid treatment
• Over 250’ (75m) of Eagle Ford greater than 9% density, with majority greater than 15% (~100% Net/Gross)
• Excellent resistivity
• Gamma Ray character indicative of “coarse”-grained mudstone
Key Finding #2: Positive Geochemical Analysis

Phillips LaSalle #1
D&A in 1952

Eagle Ford Shale Gas Risk Assessment Diagram

- TOC (0-5)
- Ro (0.2 – 2.2)
- Tr (50 – 100)
- Tmax (435 - 470)
- Dryness (0 – 100)

Minimum Threshold
Phillips LaSalle #1
Key Finding #3: 
Seismic Defines the Optimum Reservoir Thickness

- The anomalously thick Eagle Ford at Hawkville could be identified with 2D seismic data.
- A grid of existing 2D data was acquired that allowed the mapping of the Eagle Ford >150’ (45m).
Hawkville Field in Late 2008

Petrohawk Energy
Dora Martin #1H
Spud
Date: 09/2008
1st Prod: 01/2009

Petrohawk Energy
STS #1H
Spud
Date: 07/2008
1st Prod: 10/2008

Fall 2008
Petrohawk Acreage Position
~160,000 net acres
The Eagle Ford Shale in 2013

Eagle Ford Shale Competitor Map
A New Set of Lights Visible From Space
Appraisal Process
The Appraisal Process: 
Core Data and “Core to Log” Data are Critical

• There is nothing more critical to the evaluation of a shale resource than the extensive data gathered from whole core analysis:
  
  o Measurement of “conventional” reservoir attributes such as Porosity, Sw, Permeability, etc.
  o Identify and measure the mineralogy, specifically clay minerals versus “coarse”-grained constituents
  o Measurement of key geochemical (TOC, Thermal Maturity, etc.) and geomechanical attributes (Young’s Modulus and Poisson’s Ratio)
  o Most importantly, calibrate core measurements to conventional open-hole log suites, thereby expanding knowledge regarding reservoir characterization, formation evaluation (OGIP, Recovery and EUR) and optimization of the hydraulic fracture stimulation
Basic Petrophysical Workflow

Core Data Xplots
- TOC
- Porosity
- Permeability
- Saturation
- Lithology
- Geomechanics

Interpreted Log Curves

Cluster Analysis

Facies Classification

ALGORITHMS
Core to Log Calibration: TOC-Porosity-Permeability

TOC/RHOB

- Fair correlation coefficient
  \( r^2 \sim 0.65 \)

Porosity

- Highest correlation coefficient
  \( r^2 \sim 0.93 \)

Permeability

- Least dependable of the algorithms
  (use qualitatively and in localized zones)

Sw based on default
\( R_w \sim 0.025 \)

Triple Combo
Core to Log Process: Expanding the Data Set

<table>
<thead>
<tr>
<th>GR-TOC</th>
<th>PORO-Perm</th>
<th>LITHOLOGY</th>
<th>FRACTURE PROPAGATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Shale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base Shale</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- TOC distribution
- Sweetspot screening
- Rock properties from ECS-type tool should dovetail with geomechanical descriptions
- Frac properties from DTC-DTS
An Example of Utilizing the Expanded Data Set

Cluster Analysis
Poisson’s Ratio vs. Young’s Modulus
Lambda*Rho vs. Mu*Rho
(or any other attribute combination)
A Key Aspect of Quality Shale Reservoirs: Vertical Heterogeneity

Courtesy of Core Laboratories
Micro-Textural Relationships: The Importance of Scale

Standard 30 micron thick slide:
No apparent grain support which would suggest poor reservoir quality

Ultra Thin (20 micron) slide:
Significant grain support which leads to better reservoir quality

Courtesy of Core Laboratories
The Importance of “Coarse”-Grained Constituents: Eagle Ford Shale

MINERALOGY by XRD
(PC-Q #1H)
 Qtz Plg Cal Dol Pyr Mar I/S I/M Chl Kao Ker
 Austin Chalk
 Eagle Ford
 Buda

Volume Percent

Depth, feet

Courtesy of Core Laboratories
Eagle Ford: Mineralogical Variation Across the Trend

- Clay content increases from west to east
- Kerogen content remains relatively constant
- Increase in clay resultant from clastic influence of the East Texas Basin

[Graph showing mineralogical variation across different areas with labels: Maverick Basin Area, Hawkville Area, San Marcos Area, East Texas Area.]

Courtesy of Core Laboratories
The Importance of Stress

Isotropic ‘Tempered’ Glass: One extreme

Anisotropic ‘Natural’ Glass: The other extreme

Preferred: Something in between

Courtesy of Core Laboratories
Development Process
3D Seismic Data: Unconventional Approach is After Discovery, Not Before

- The cost of 3D seismic data is minimal in the total field development cost, is not critical to the exploration process

- 3D seismic data is critical in identifying faults and dip changes that could compromise the stratigraphic targeting of a horizontal wellbore

- Merged ~650 square miles (~1100 square kilometers) of acquired proprietary data and licensed data in Hawkville Field
Geo-Steering: An Important New Geoscience Skill Set

- Horizontal drilling creates significant *geological* challenges
  - Unforeseen dip changes and/or faults can cause a well to be out of zone for a large portion of a lateral

- The combination of 3D seismic data and MD to TVD Gamma Ray correlation allows the geologist to direct the *drilling* operation in order for the well to stay within the target window

- The post-drill geologic interpretation of the wellbore can cause the *completion* engineer to design the fracture geometry to conform to the geology of the wellbore

- The use of the geologic interpretation can be utilized with *production* logs to determine which portions of the wellbore are contributing and why
Stage by Stage Fracture Stimulation Montage: Geometric Completions vs Geologic Completions?
The Eagle Ford After Five Years

- Approximately 10,000 wells have been permitted to date with more than 200 rigs operating and approximately 290 wells being drilled each month
- Average EUR across the play is ~450 MBOE
- Risked remaining resource is estimated at 28 BBOE from over 70,000 undrilled locations
  - Current B/E prices are $62/BBL rising to $100 by 2019
- At B/E price below $90/BBL, EOG and BHP have remaining resource 2.2 BBOE and 1.7 BBOE, respectively, with B/E price of $62/BBL
- Spacing assumptions range from 110 acres in the dry gas areas to 40 acres in the oil window

Eagle Ford Natural Gas Production Growth 2008-2013

Source: Texas Railroad Commission Production Data Query System

2013 thru Q1
Eagle Ford Oil and Condensate Production Growth 2008-2013

OIL AND CONDENSATE

YEAR

OIL & CONDENSATE/MBD

Source: Texas Railroad Commission Production Data Query System

2013 thru Q1
Eagle Ford Oil Drilling Permits 2008-2013

DRILLING PERMITS

YEAR

2008 2009 2010 2011 2012 2013

TOTAL DRILLING PERMITS

Source: Texas Railroad Commission Production Data Query System

2013 Annualized from Q1
Conclusions

- The Eagle Ford has proven to have all of the right ingredients for a world class shale reservoir
  - Petrophysical parameters that are among the best, if not the best, of any known shale reservoir
  - A wide range in depth (approx. 5000’-13,000’/1500m-4000m) results in complete spectrum of hydrocarbon products
  - A majority of the trend is in moderate geopressure, providing for significant hydrocarbon volumes in place
  - Favorable regulatory and mineral owner environment

- These factors have lead to growth in the Eagle Ford that is truly unprecedented