The Discovery, Reservoir Attributes and Significance of the Hawkville Field and Eagle Ford Shale Trend: Implications for Future Development*

Richard K. Stoneburner[1]

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Abstract

The advent of commercial hydrocarbon production from shale reservoirs is a relatively new phenomenon as it relates to petroleum geology. This presentation will look at all phases of the life cycle of an upstream project and will address the aspects that are generally unique to shale reservoirs. Unconventional exploration involves a different way of thinking:

Conventional

- Project identification focuses “outside in”
- Seismic control works “outside in”
- Stratigraphic support eventually focuses on the facies analysis local to the prospect
- Reservoir quality issues are relegated to the area of the prospect

Unconventional Conventional

- Project identification focuses “inside out”
- Seismic control works “inside out”
- Stratigraphic support focuses on analysis of the entire basin
- Reservoir quality analysis is required over a very broad area of the basin

Prospect Identification: Conventional Analogy

- Eagle Ford Shale Prospect

- Known regional source rock across large petroliferous basin
- Reservoir quality and geochemical attributes poorly understood
- The area was >10MM acres with high side resource potential of >10 BBOE

Case Study for Unconventional Exploration involved the Hawkville Field. We targeted the Eagle Ford Shale based on its significance as a regional source rock. We 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. We acquired Eagle Ford cuttings on a key well and had them analyzed for TOC, VRO and other key parameters. In addition, we acquired ~160,000 acres and spud the initial test well. Completion occurred in October 2008 for 7.6 Mmcf/d and 251 Bc/d.

The Eagle Ford has proven to have all of the right ingredients for a world-class shale reservoir with petrophysical parameters that are among the best, if not the best, of any known shale reservoir. There is a wide range in depth (approx. 5,000'-13,000'/1,500m-4,000m) results in complete spectrum of hydrocarbon products. A majority of the trend is in moderate geopressure providing for significant hydrocarbon volumes in place. There is a favorable regulatory and mineral owner environment and these factors have lead to growth in the Eagle Ford that is truly unprecedented.

"The Discovery, Reservoir Attributes and Significance of the Hawkville Field and Eagle Ford Shale Trend: Implications for Future Development"

AAPG Eagle Ford GTW
February 24th, 2014
Richard K. Stoneburner

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Currently: Advisor to Pine Brook Partners; Director for Newfield Exploration, Yuma Exploration and Cub Energy

PINE BROOK

Exploration Process

Unconventional Exploration: A Different Way of Thinking

Conventional

- **Project identification focuses "outside in"**
- **Seismic control works "outside in"**
- **Stratigraphic support eventually focuses on the facies analysis local to the prospect**
- **Reservoir quality issues are relegated to the area of the prospect**

Unconventional

- **Project identification focuses "inside out"**
- **Seismic control works "inside out"**
- **Stratigraphic support focuses on analysis of the entire basin**
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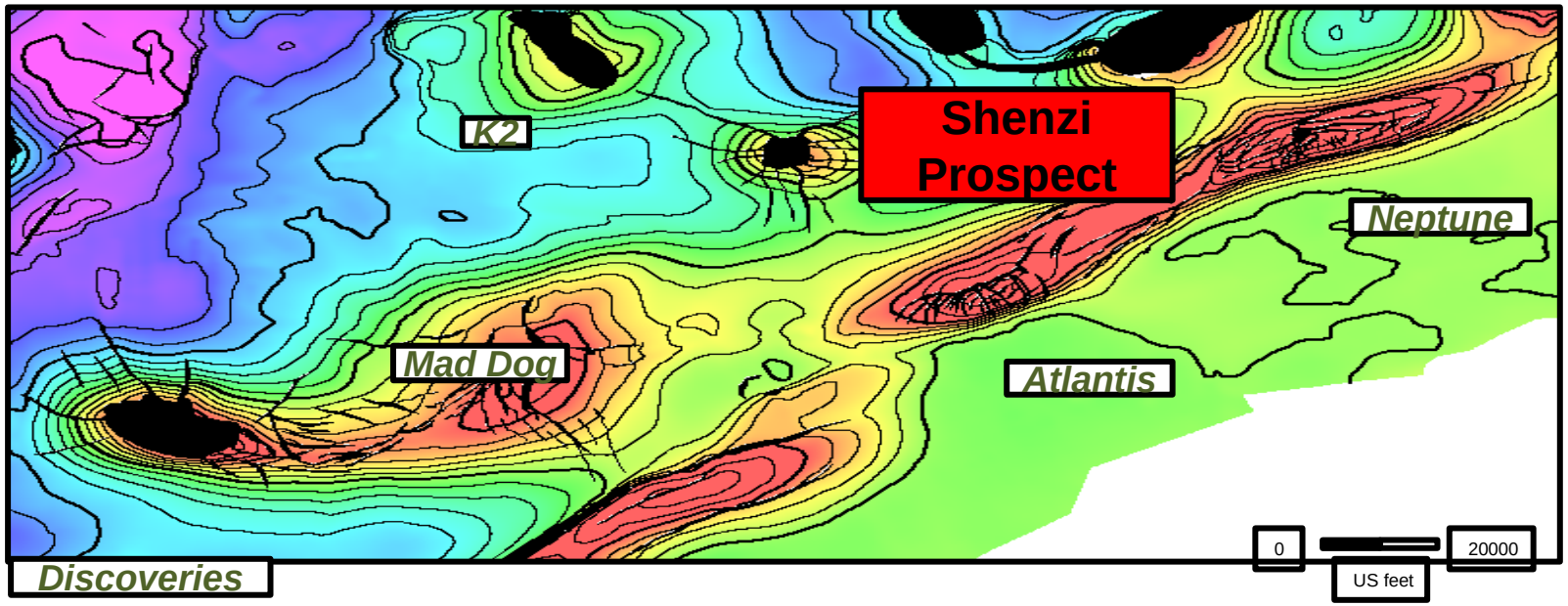
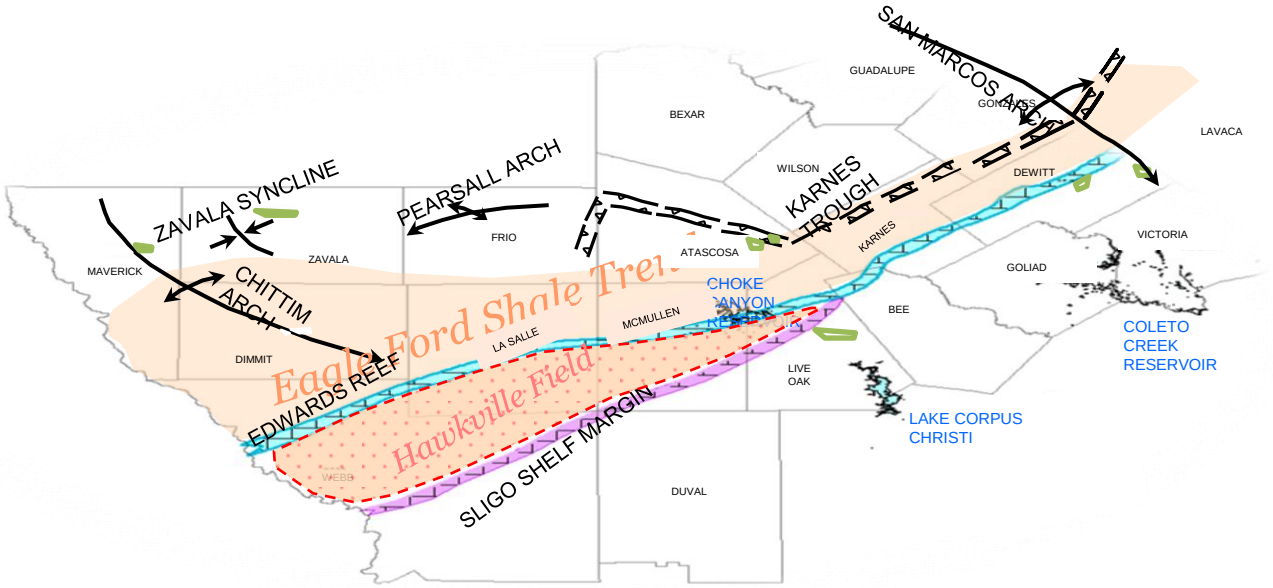
Prospect Identification: Conventional Analogy



- 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 10-200 MMBOE

Prospect Identification: Unconventional Analogy

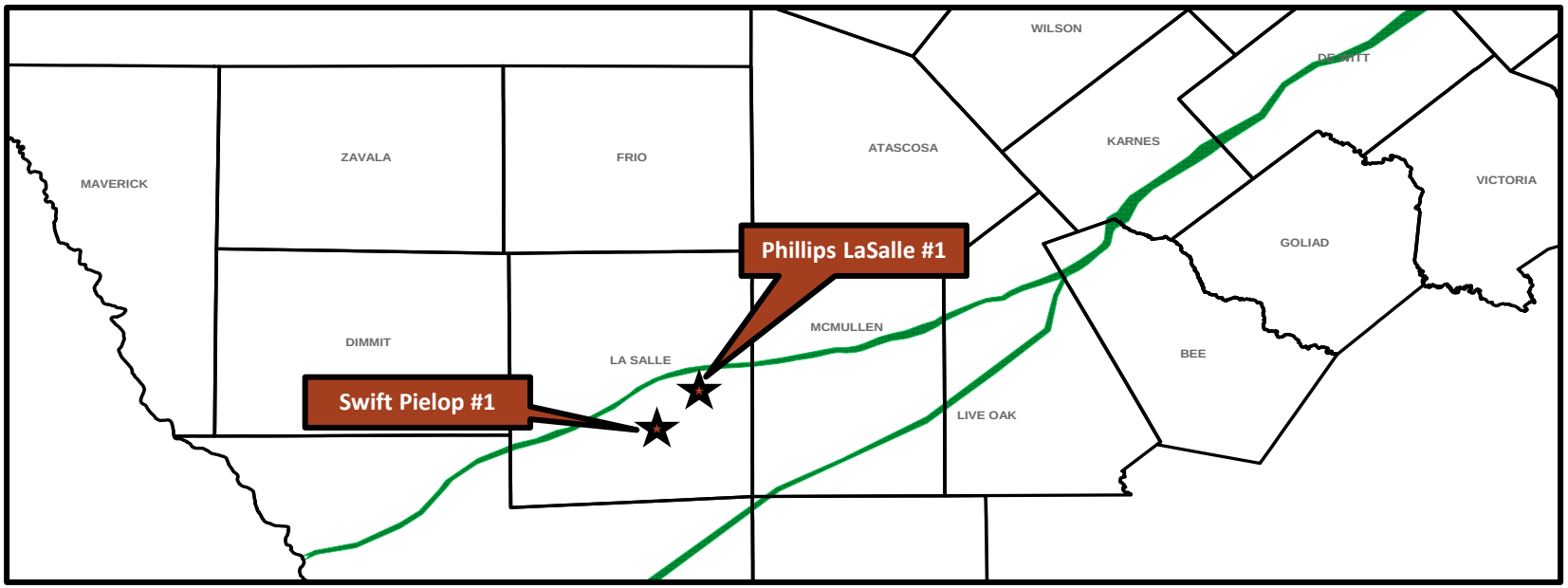


- Eagle Ford Shale Prospect
- Known regional source rock across large petroliferous basin
- Reservoir quality and geochemical attributes poorly understood
- The area was >10MM acres with high side resource potential of >10 BBOE

Case Study for Unconventional Exploration: Hawkville Field

- **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: Aquired Eagle Ford cuttings on a key well and had them analyzed for TOC, VRO and other key parameters
  - Q3: Aquired ~160,000 acres and spud the initial test well
  - Q4: Completed it in October 2008 for 7.6 Mmcf/d and 251 Bc/d

Hawkville Field in Early 2008



- Very limited well control in prospective area

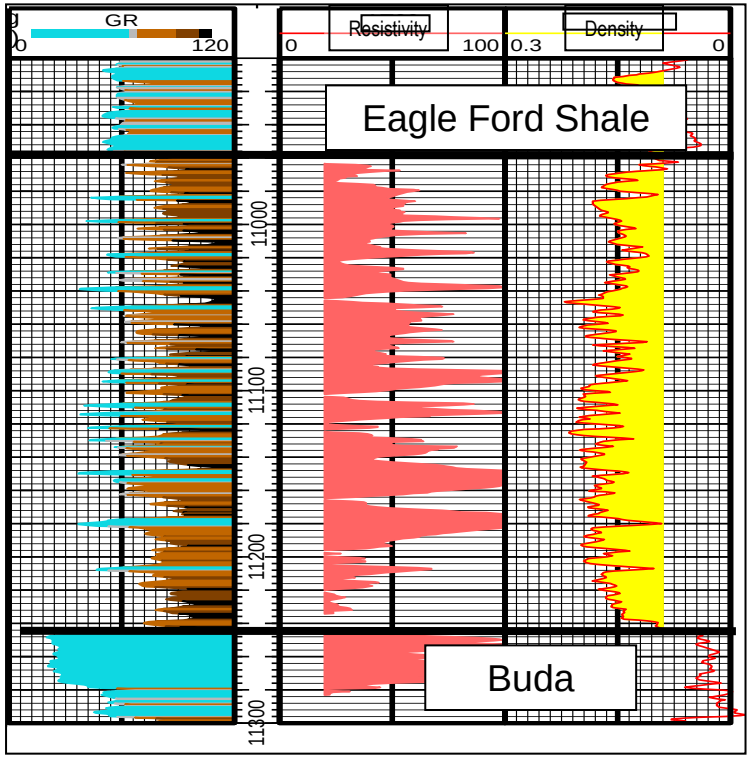
- Prospect was located in a regional setting between two divergent shelf margins which suggested the presence of a "mini-basin"

- While the geochemical properties were unknown, the depth range (10,000-11,500'/3050,-3500m) suggested a relatively mature source rock

Key Finding #1:
World Class Petrophysical Properties

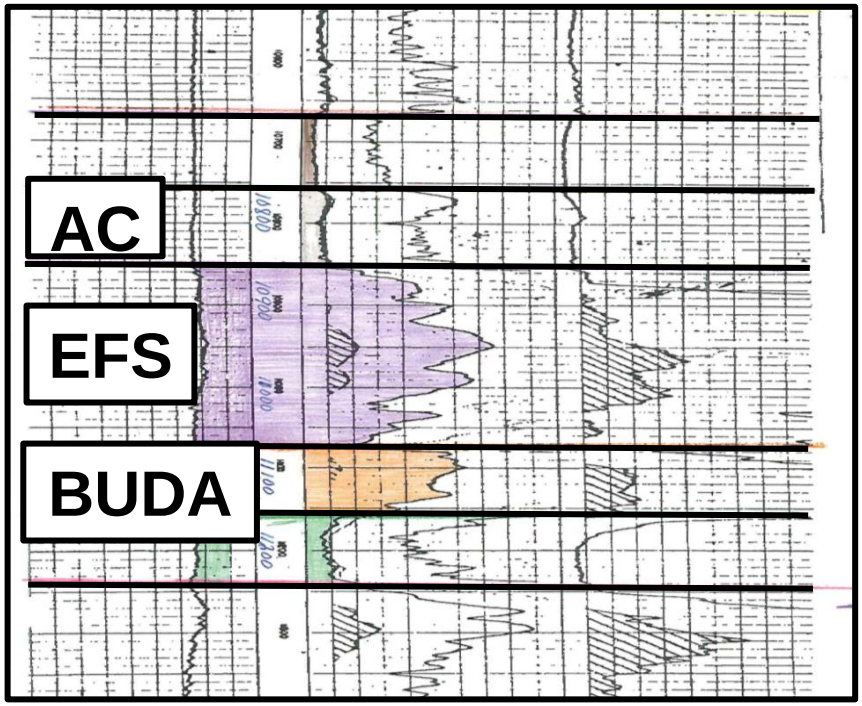
- Well was drilled in the early ‘90’s, probably targeting the Cretaceous Olmos Sands
- Eagle Ford tested small amount of gas after light acid treatment
- Over 250’ (75m) of Eagle Ford greater than 9% density, with majority greater than 15% (~100% Net/Gross)
- Excellent resistivity
- Gamma Ray character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

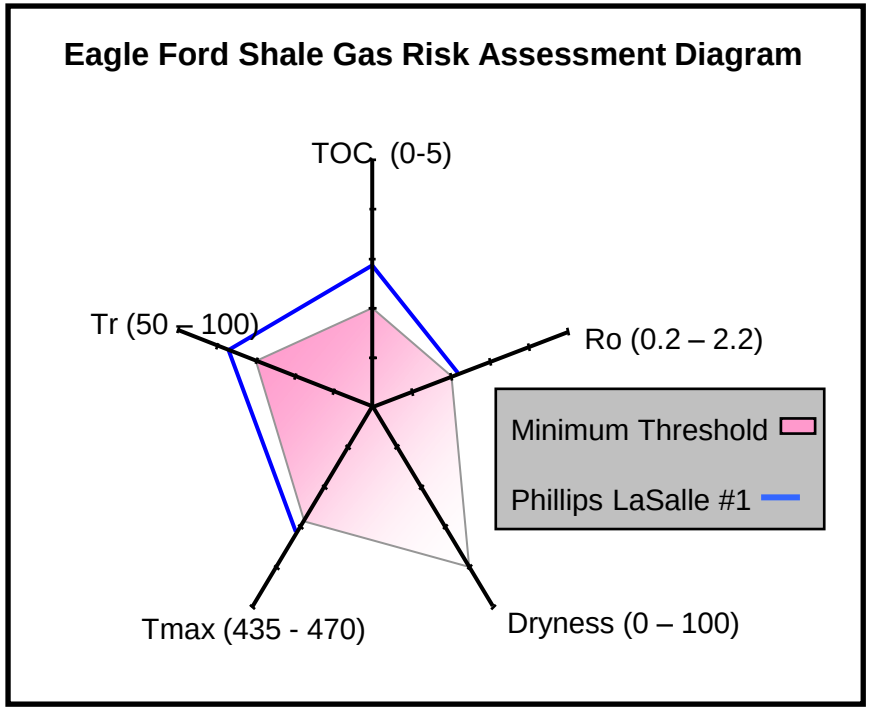
Swift Pielop 1



Key Finding #2:
Positive Geochemical Analysis

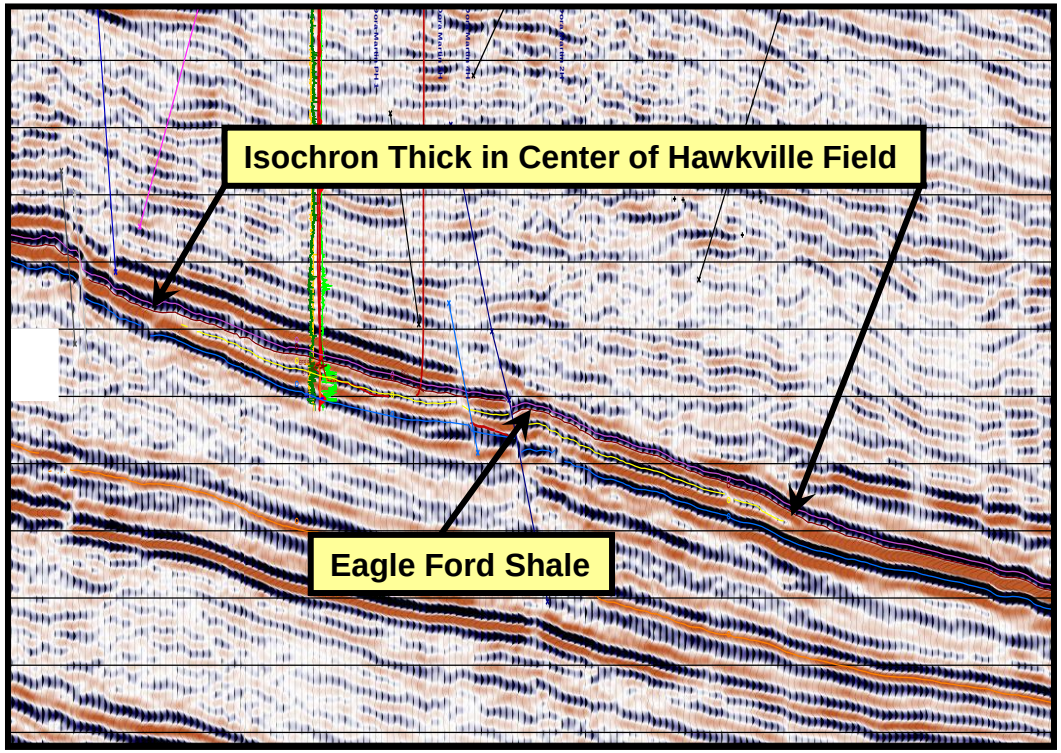
Phillips LaSalle #1
D&A in 1952





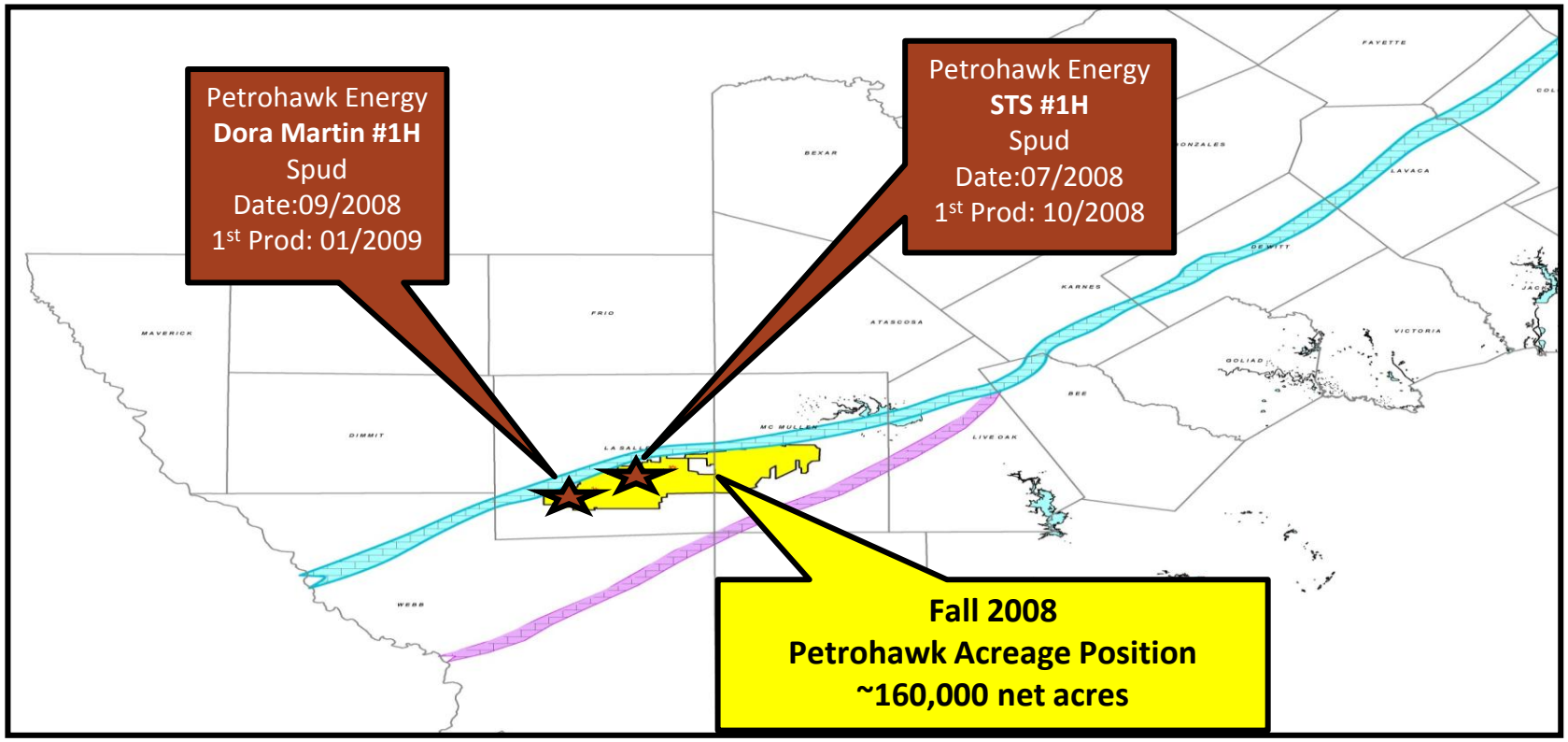
Key Finding #3:
Seismic Defines the Optimum Reservoir Thickness

- 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)

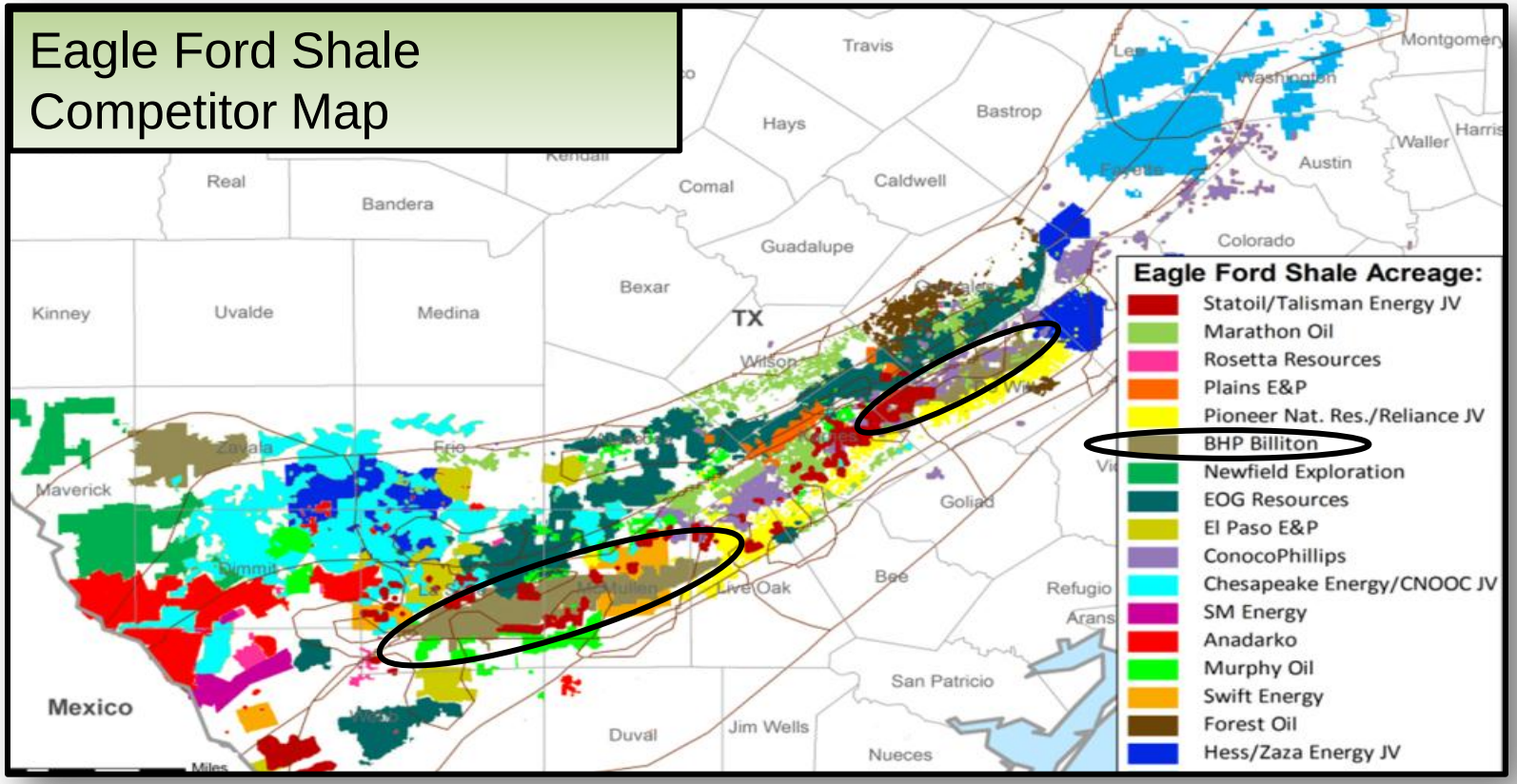


Data courtesy of Seitel, Inc.

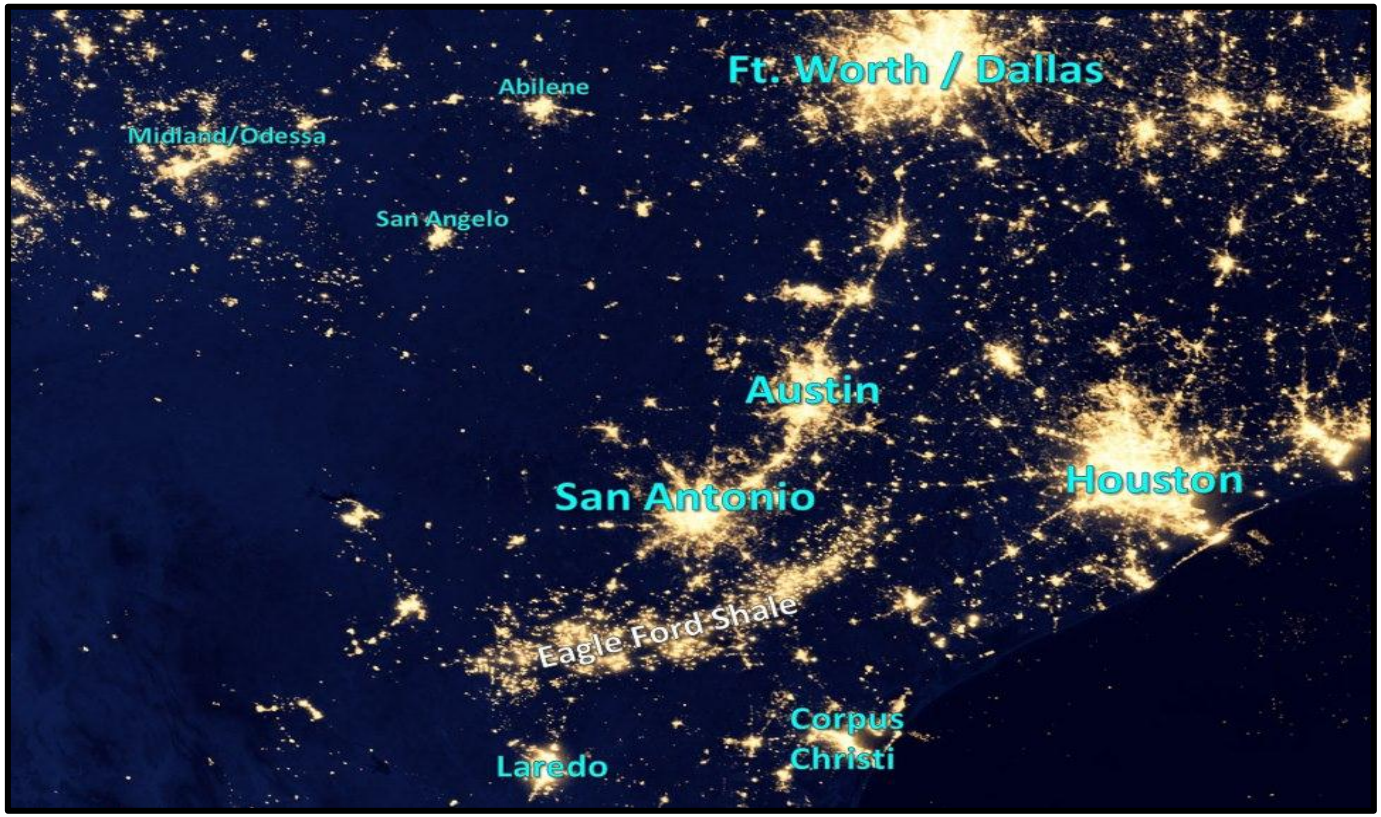
Hawkville Field in Late 2008



The Eagle Ford Shale in 2013



A New Set of Lights Visible From Space



Appraisal Process

The Appraisal Process:
Core Data and "Core to Log" Data is Critical

- **There is nothing more critical to the evaluation of a shale resource than the extensive data gathered from whole core analysis:**

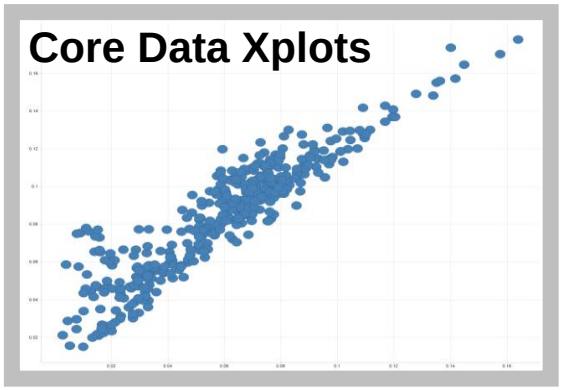
  - **Measurement of "conventional" reservoir attributes such as Porosity, Sw, Permeability, etc.**

  - **Identify and measure the mineralogy, specifically clay minerals versus "coarse grained" constituents**

  - **Measurement of key geochemical (TOC, Thermal Maturity, etc.) and geomechanical attributes (Young's Modulus and Poisson's Ratio)**

  - **Most importantly, calibrate core measurements to conventional open hole log suites, therefore expanding knowledge regarding reservoir characterization, formation evaluation (OGIP, Recovery and EUR) and optimization of the hydraulic fracture stimulation**

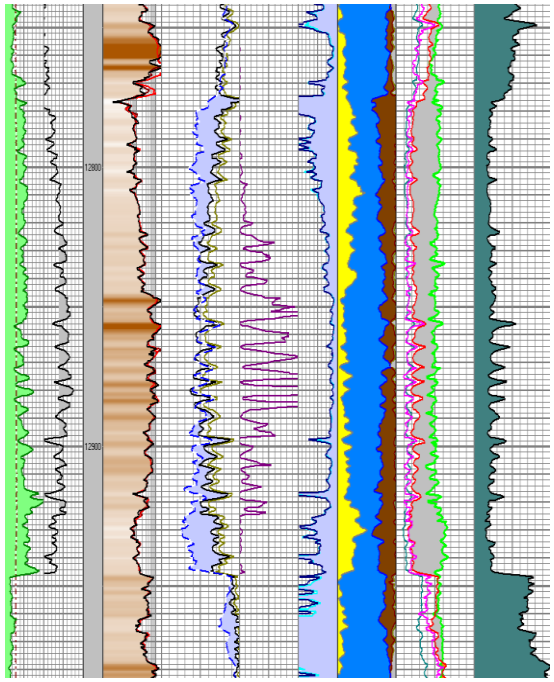
Basic Petrophysical Workflow



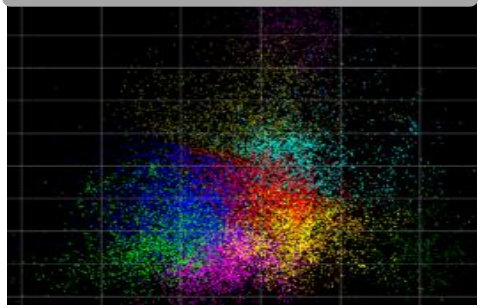
TOC
Porosity
Permeability
Saturation
Lithology
Geomechanics

ALGORITHMS

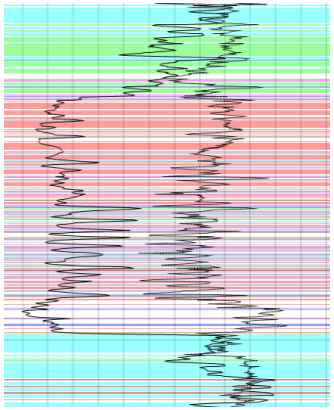
Interpreted Log Curves



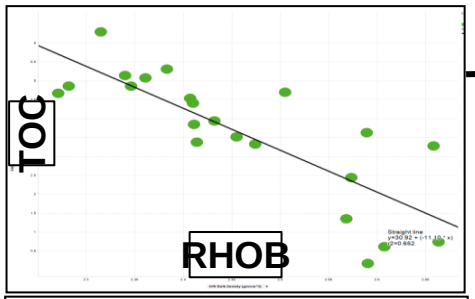
Cluster Analysis



Facies Classification

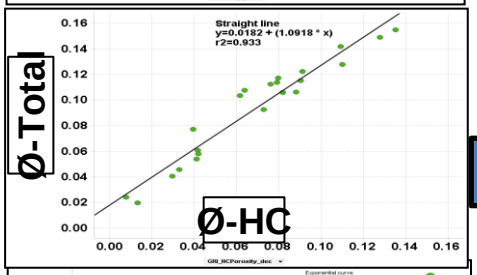


Core to Log Calibration: TOC-Porosity-Permeability



TOC/RHOB

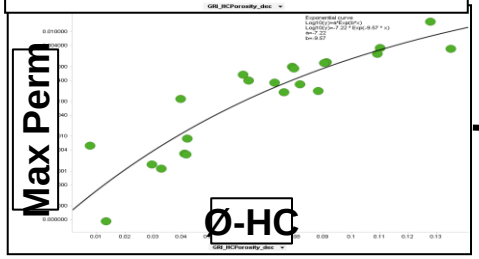
Fair correlation coefficient
$r^2 \sim 0.65$



Porosity

Highest correlation coefficient
$r^2 \sim 0.93$

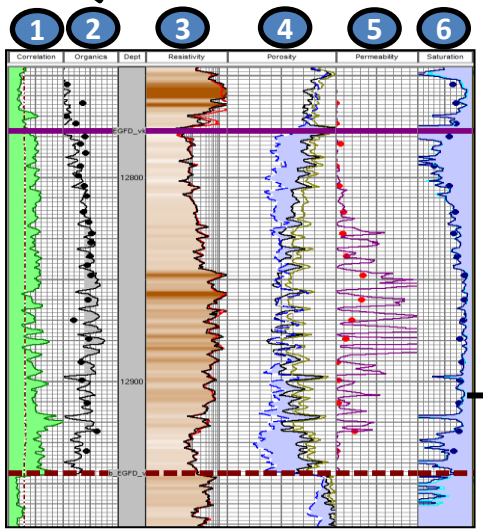
Total porosity → HC-filled porosity → 4



Permeability

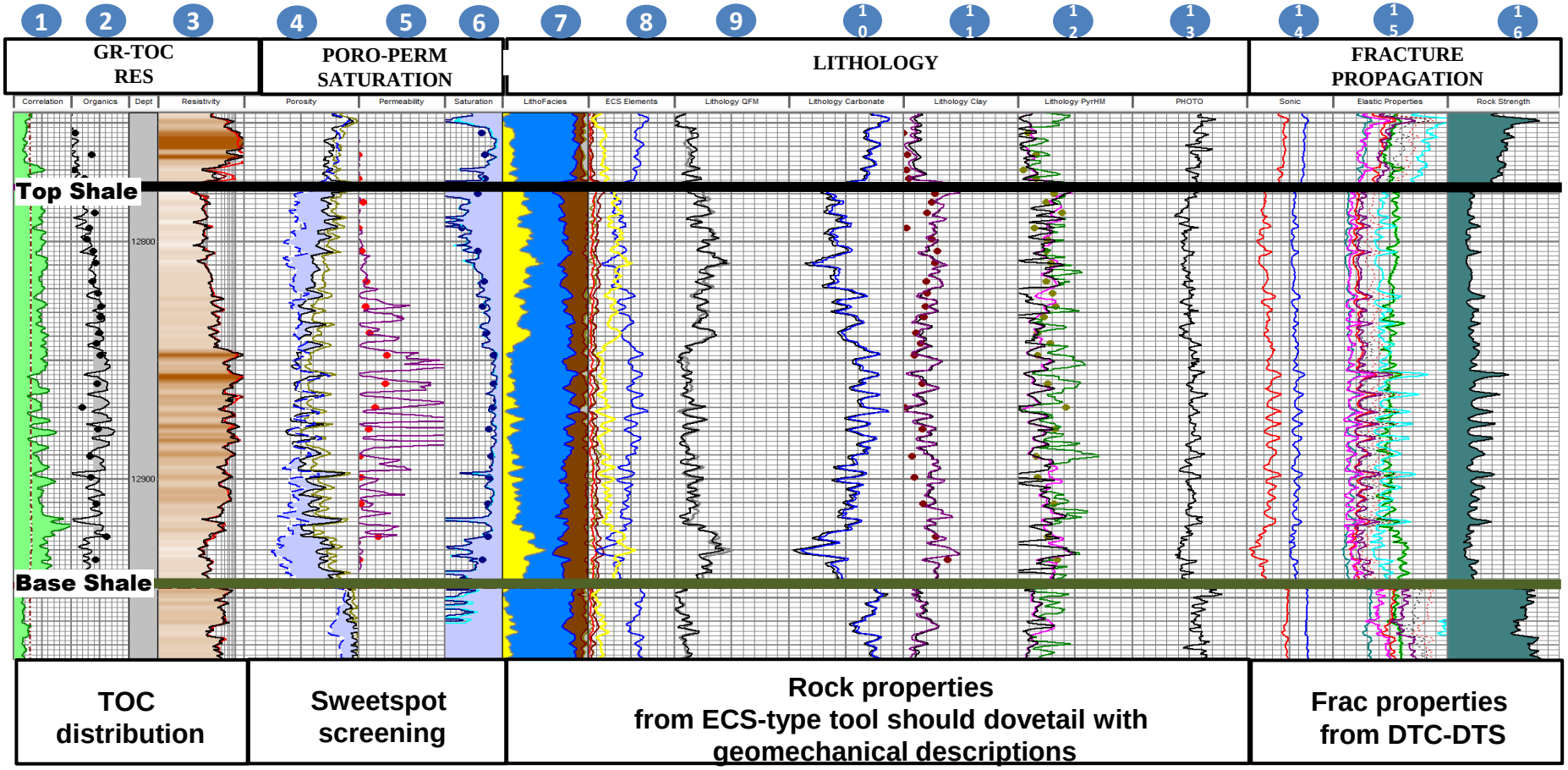
Least dependable of the algorithms (use qualitatively and in localized zones)

Triple Combo

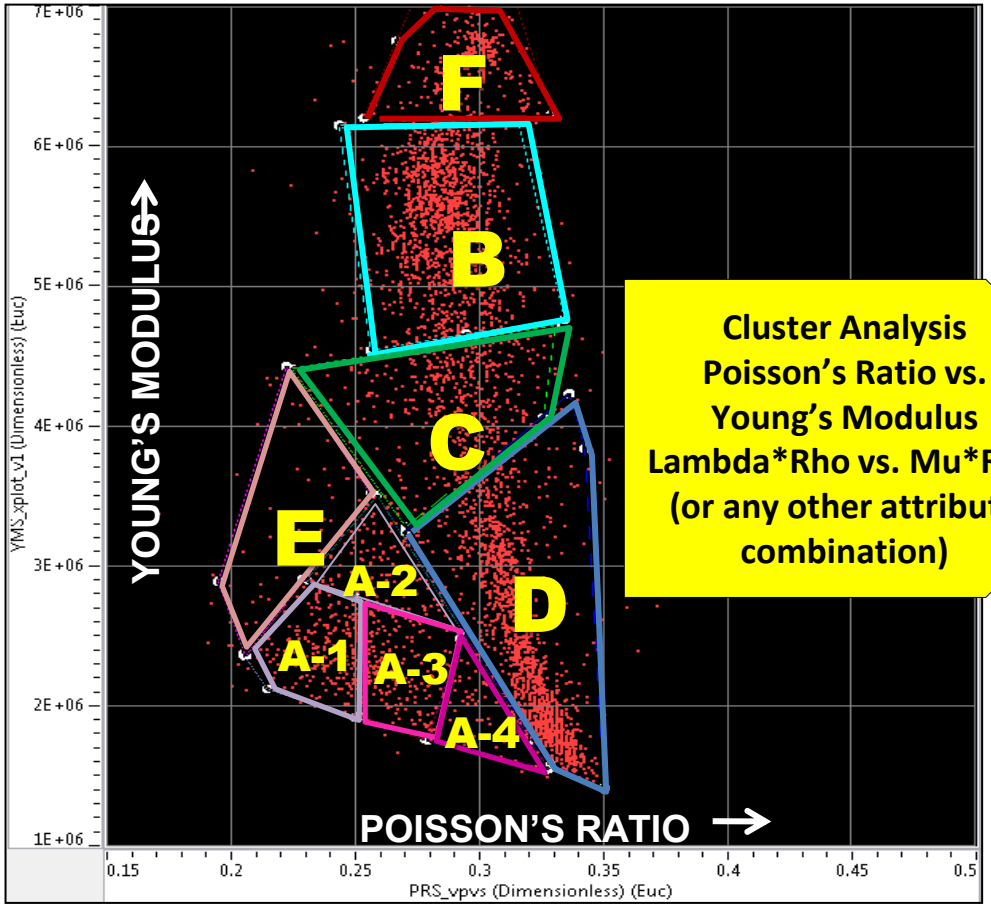


Sw based on default Rw ~ 0.025

Core to Log Process: Expanding the Data Set

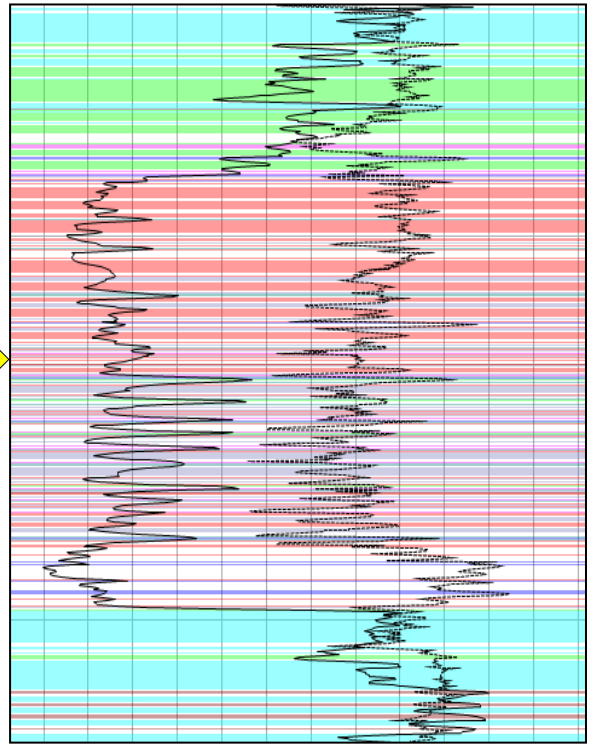


An Example of Utilizing the Expanded Data Set

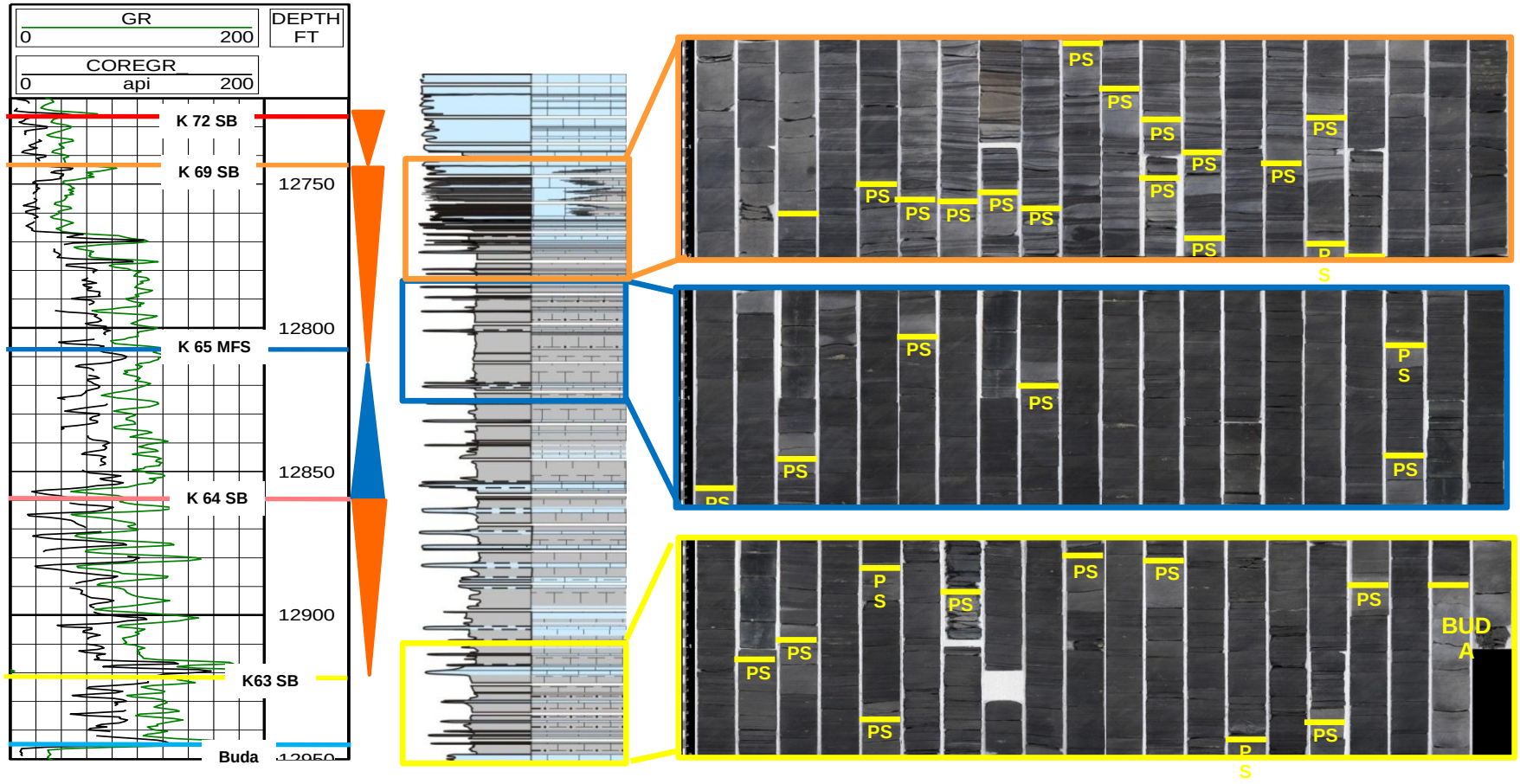


Cluster Analysis
Poisson's Ratio vs. Young's Modulus
Lambda*Rho vs. Mu*Rho
(or any other attribute combination)

Facies extracted from Crossplot

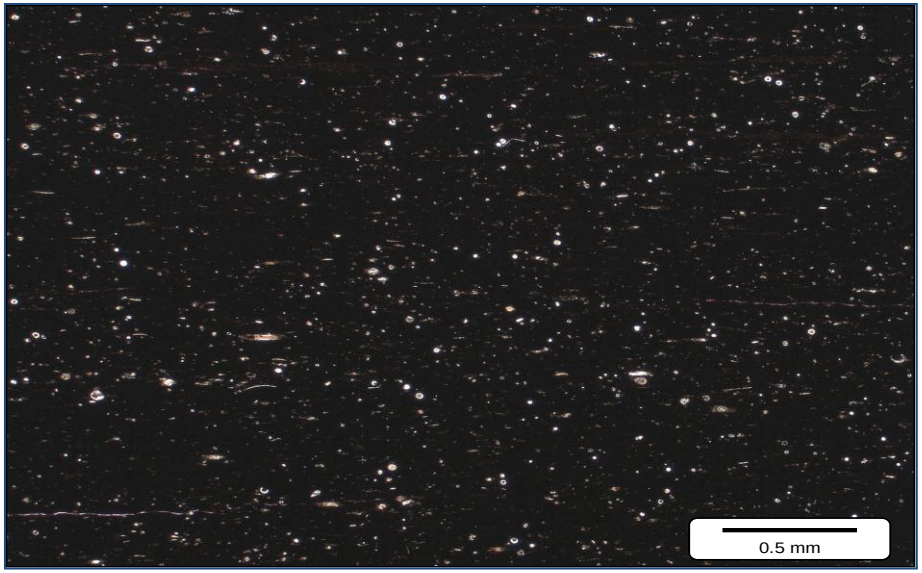


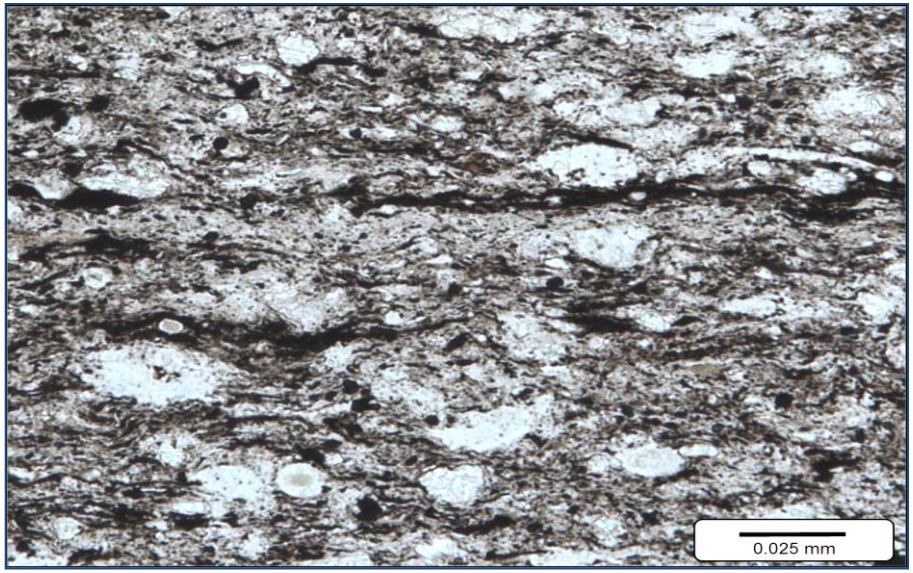
A Key Aspect of Quality Shale Reservoirs: Vertical Heterogeneity



Courtesy of Core Laboratories

Micro-Textural Relationships: The Importance of Scale



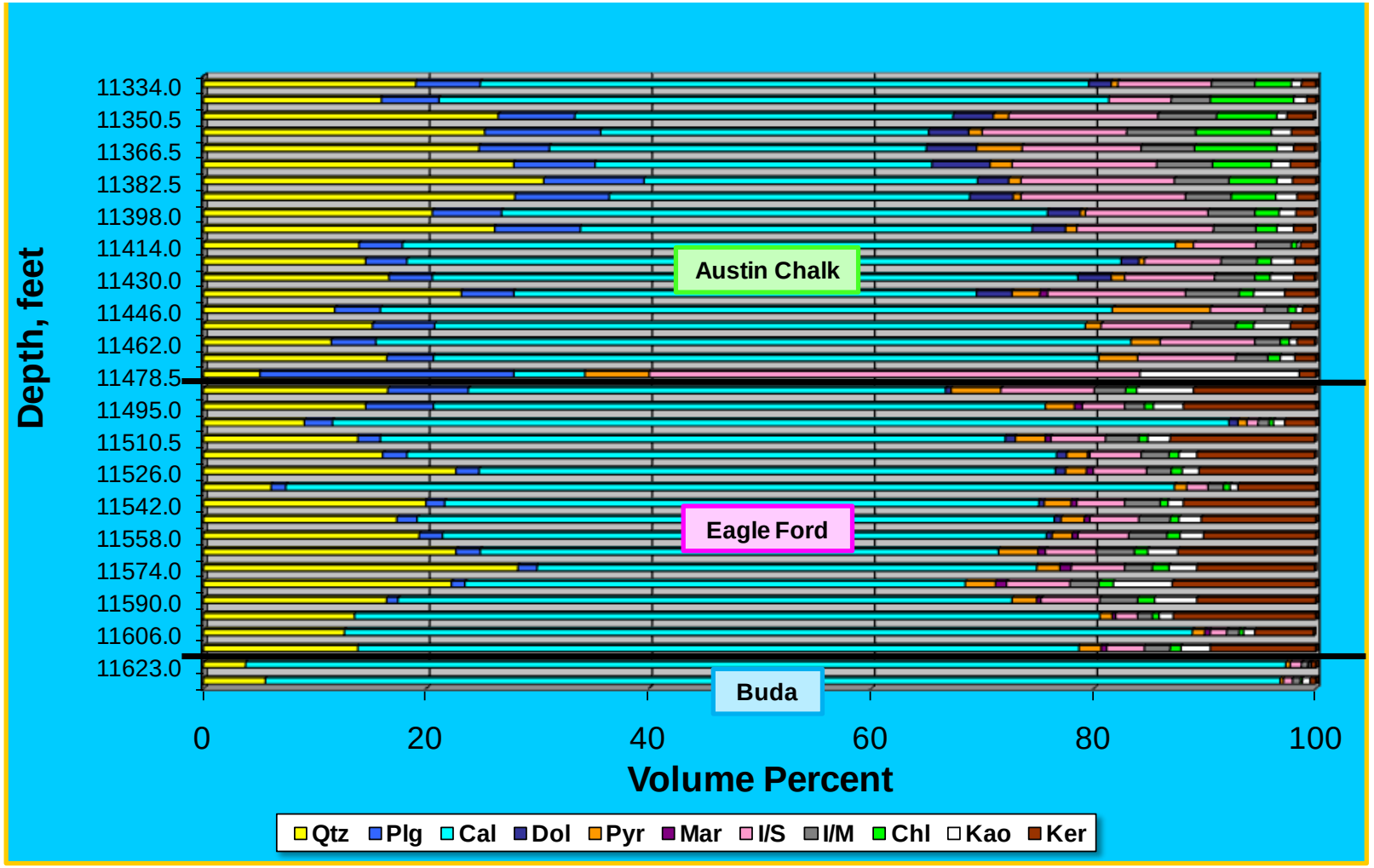


Standard 30 micron thick slide:
No apparent grain support which would suggest poor reservoir quality

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

Courtesy of Core Laboratories

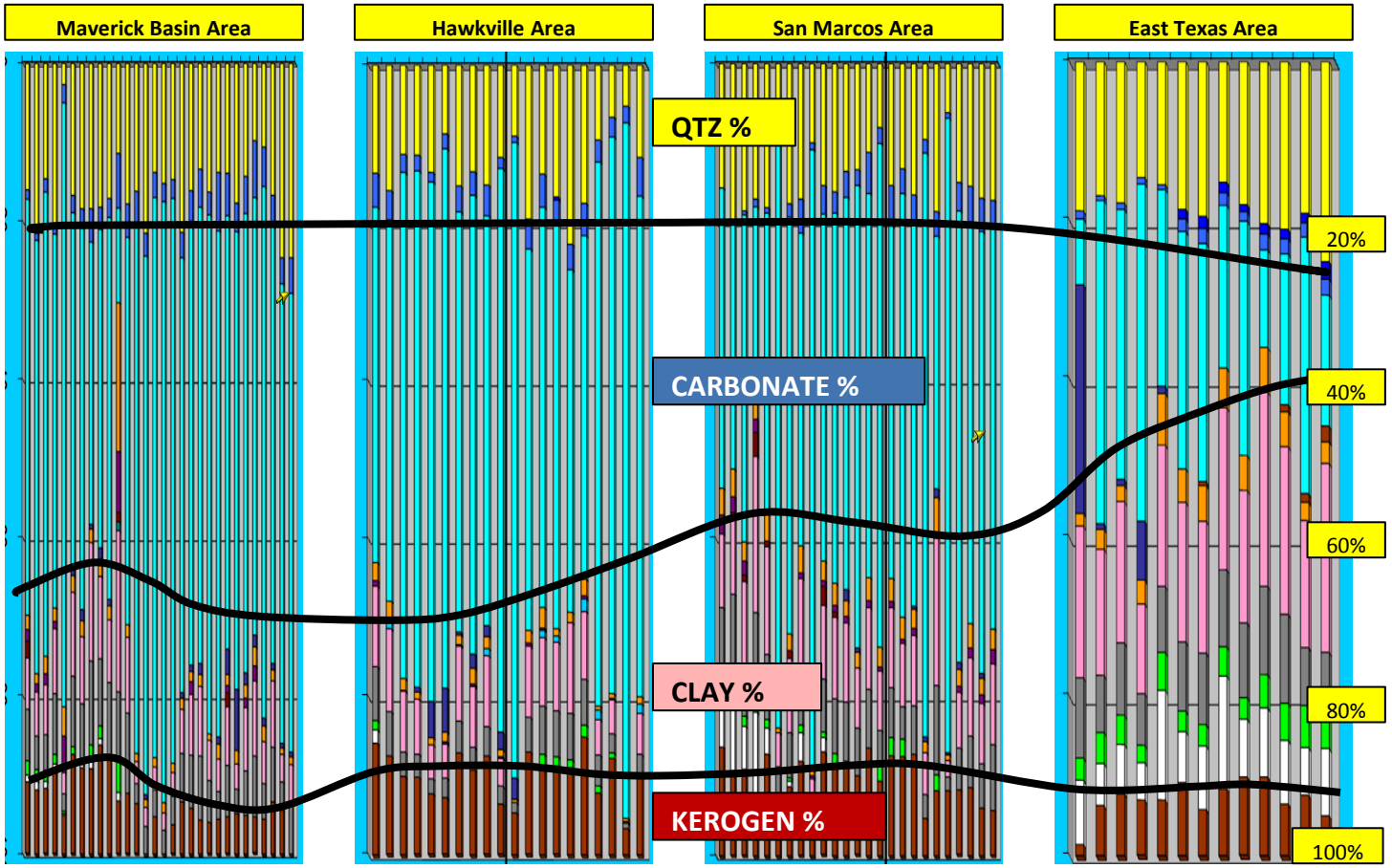
The Importance of "Coarse" Grained Constituents: Eagle Ford Shale



Courtesy of Core Laboratories

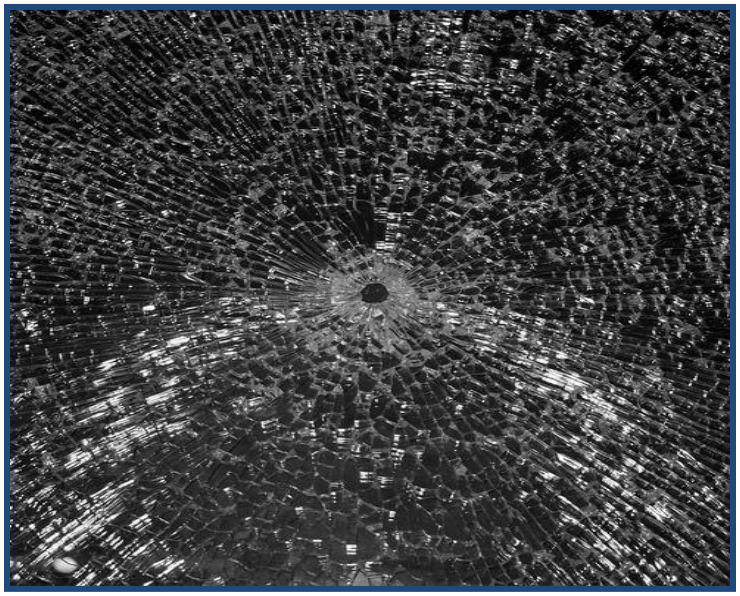
Eagle Ford: Mineralogical Variation Across the Trend

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

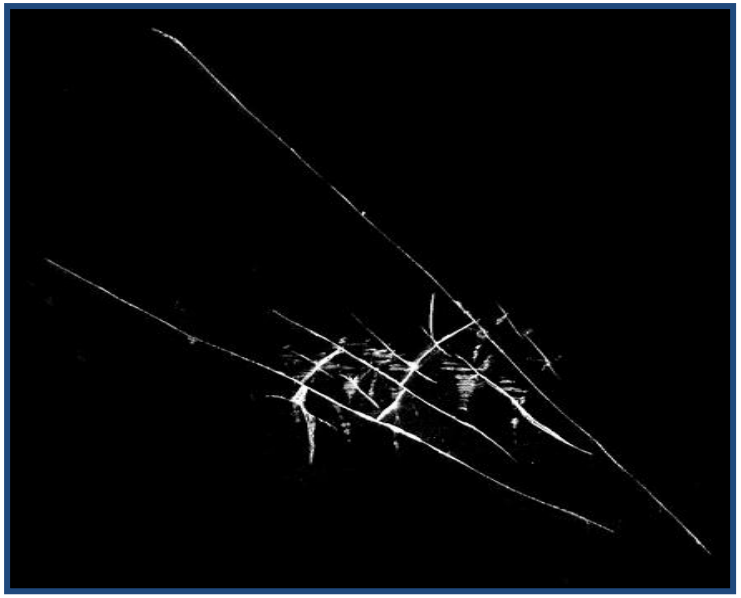


Courtesy of Core Laboratories

The Importance of Stress



Isotropic 'Tempered' Glass:
One extreme



Anisotropic 'Natural' Glass:
The other extreme

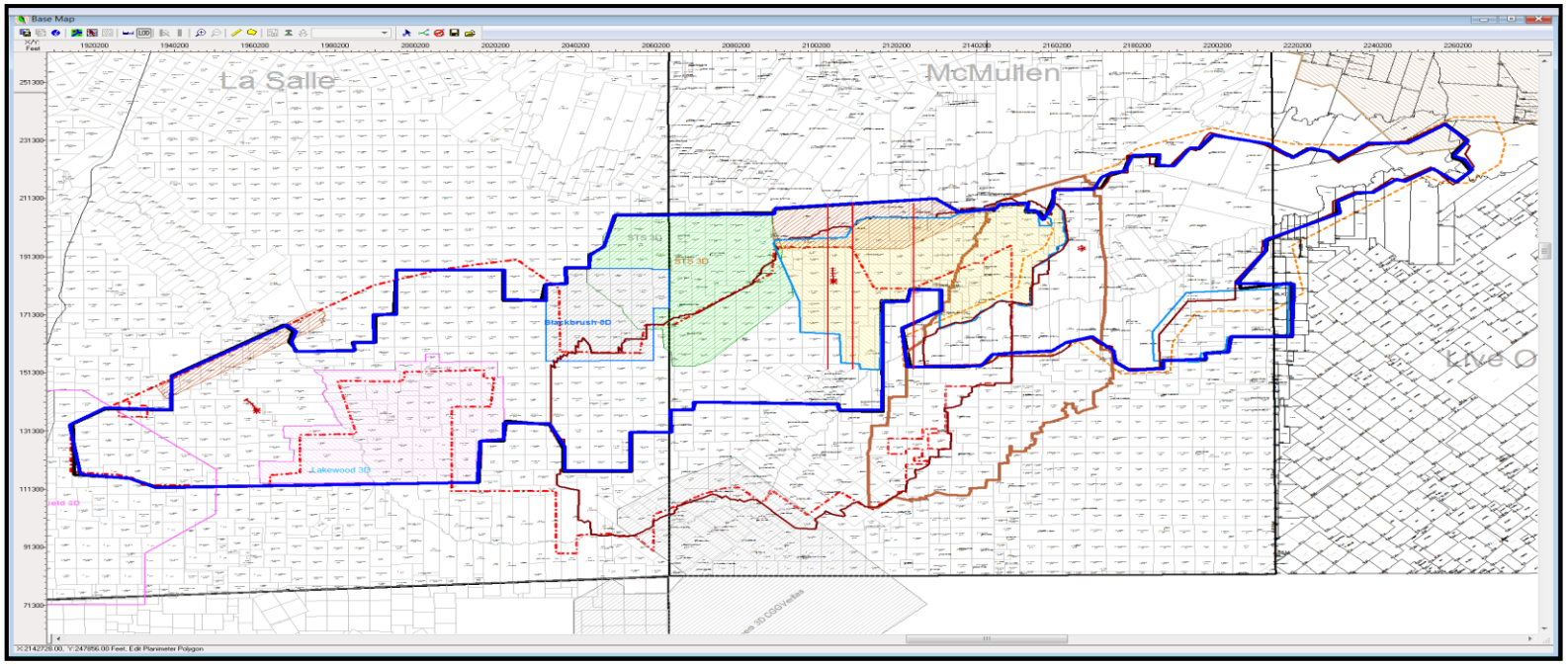
Preferred: Something in between

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, but 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

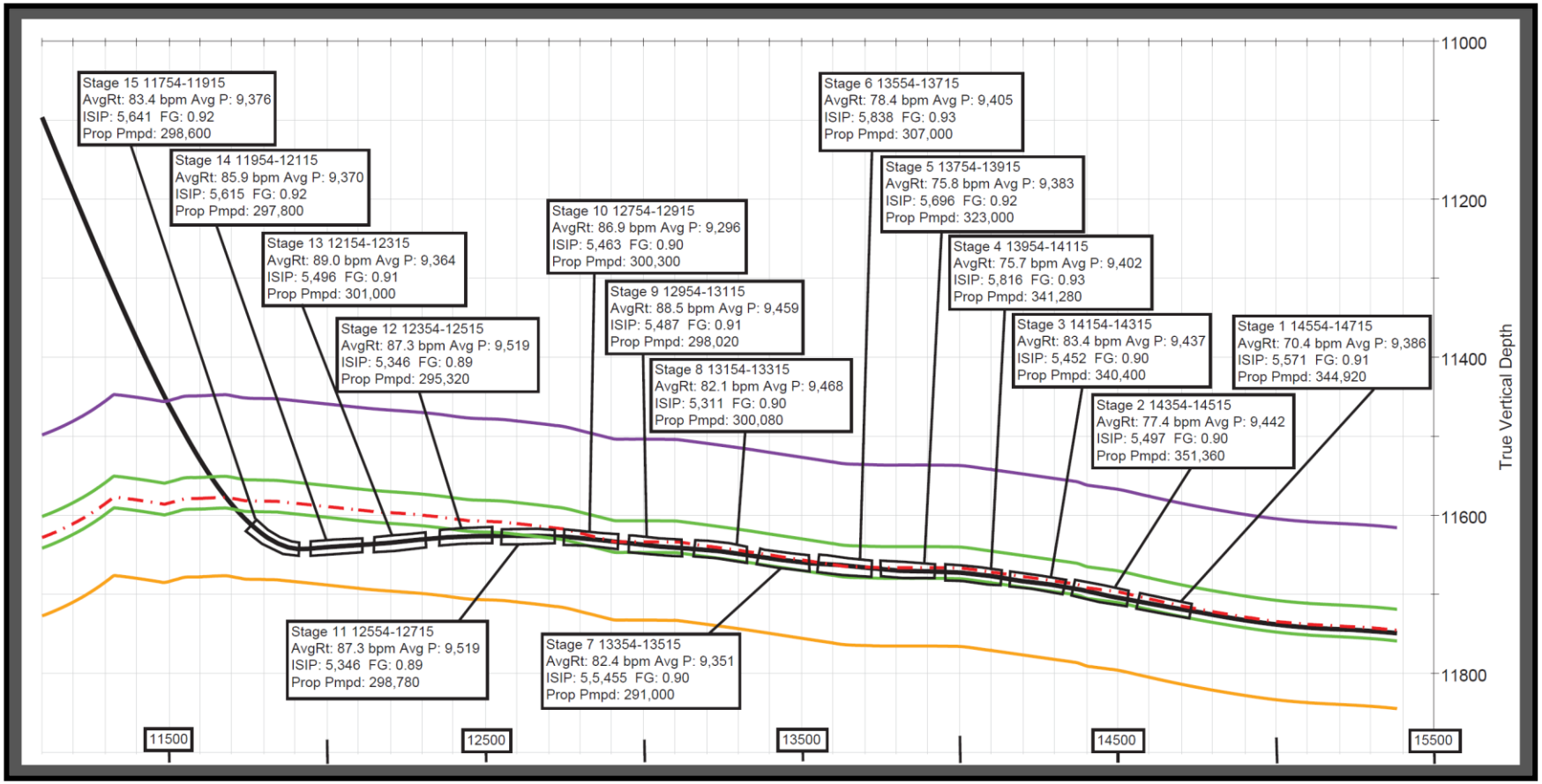
- **Horizontal drilling creates significant ***geological*** challenges**
  - **Unforeseen dip changes and/or faults can cause a well to be out of zone for a large portion of a lateral**

- **The combination of 3D seismic data and MD to TVD Gamma Ray correlation allows the geologist to direct the ***drilling*** operation to allow 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?

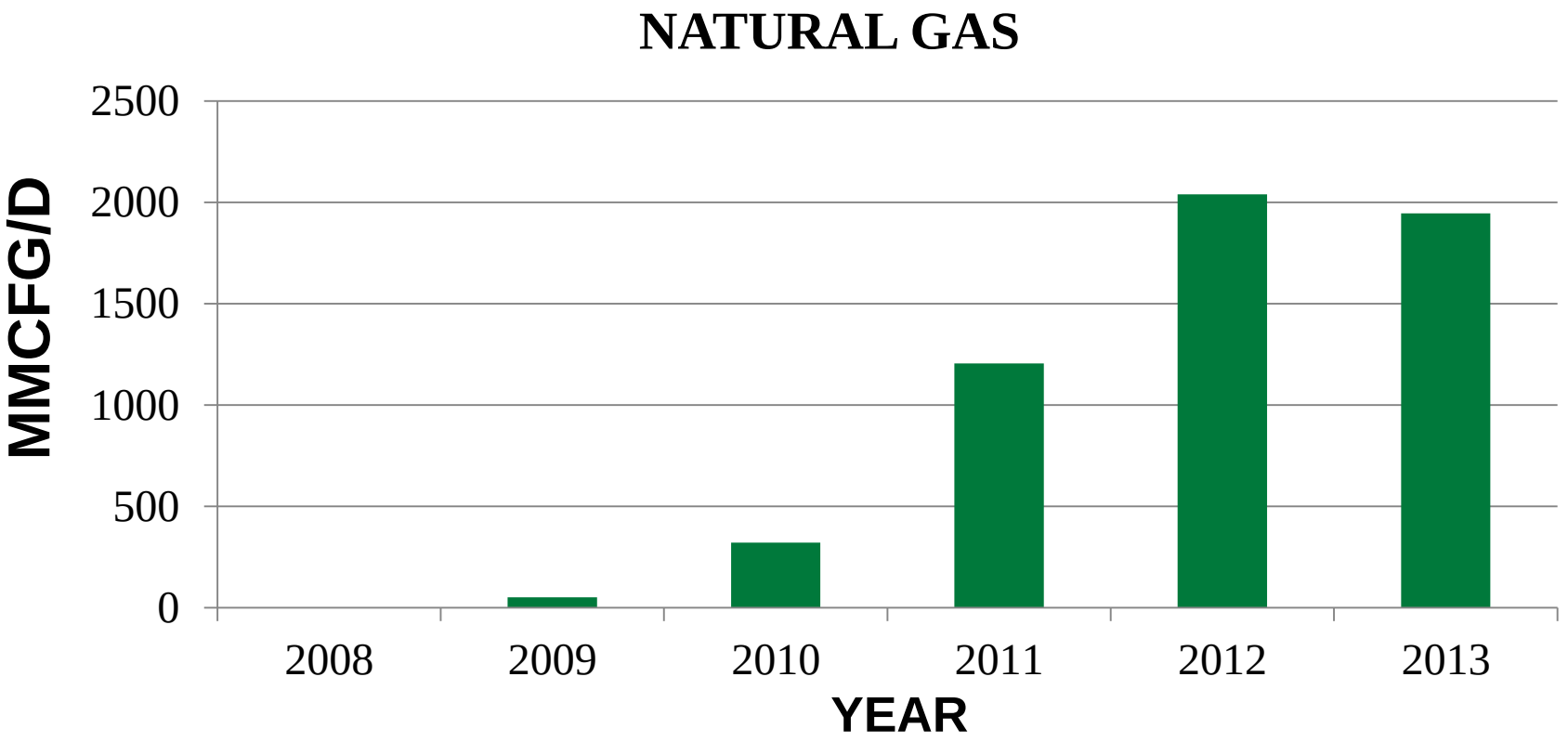


The Eagle Ford After Five Years

- 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

Source: ITG Energy Play Report July 24, 2013

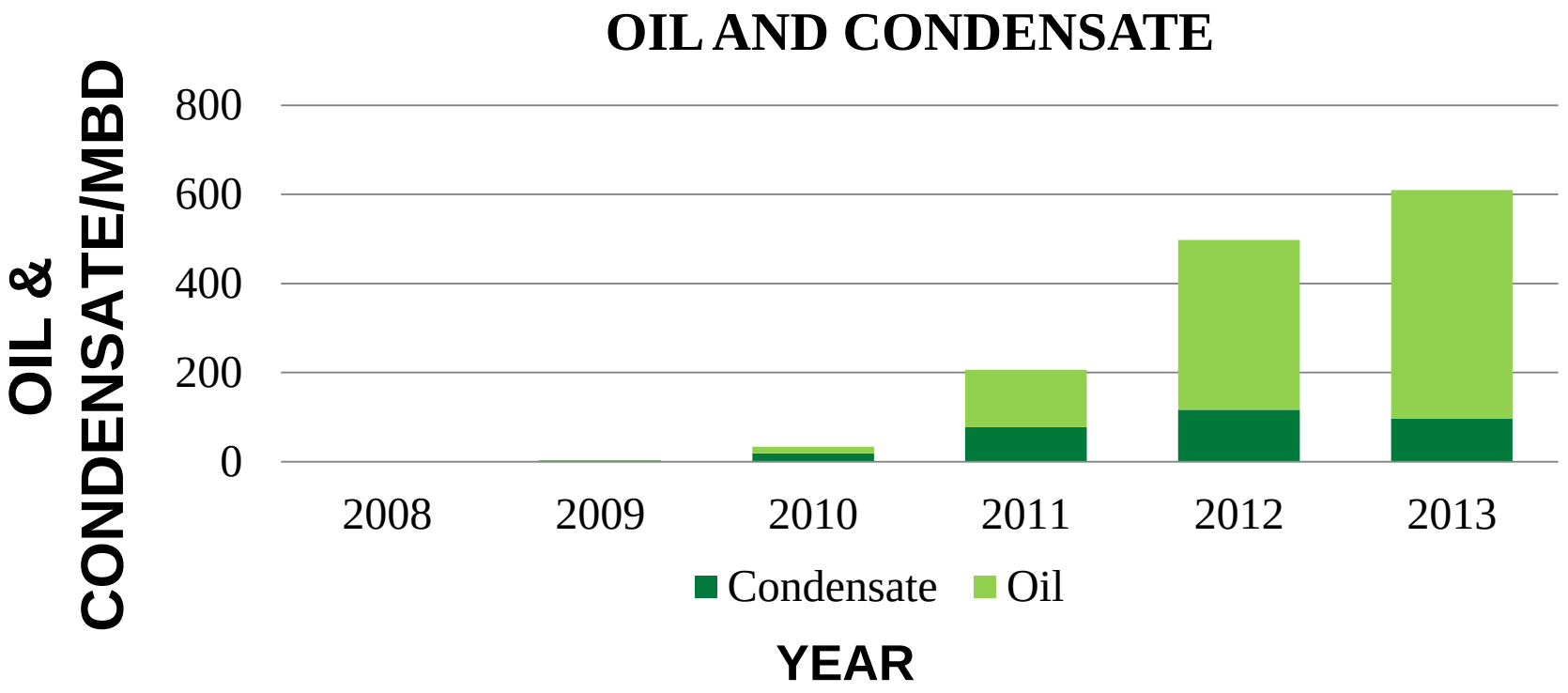
Eagle Ford Natural Gas Production Growth 2008-2013



Source: Texas Railroad Commission Production Data Query System

2013 thru Q1

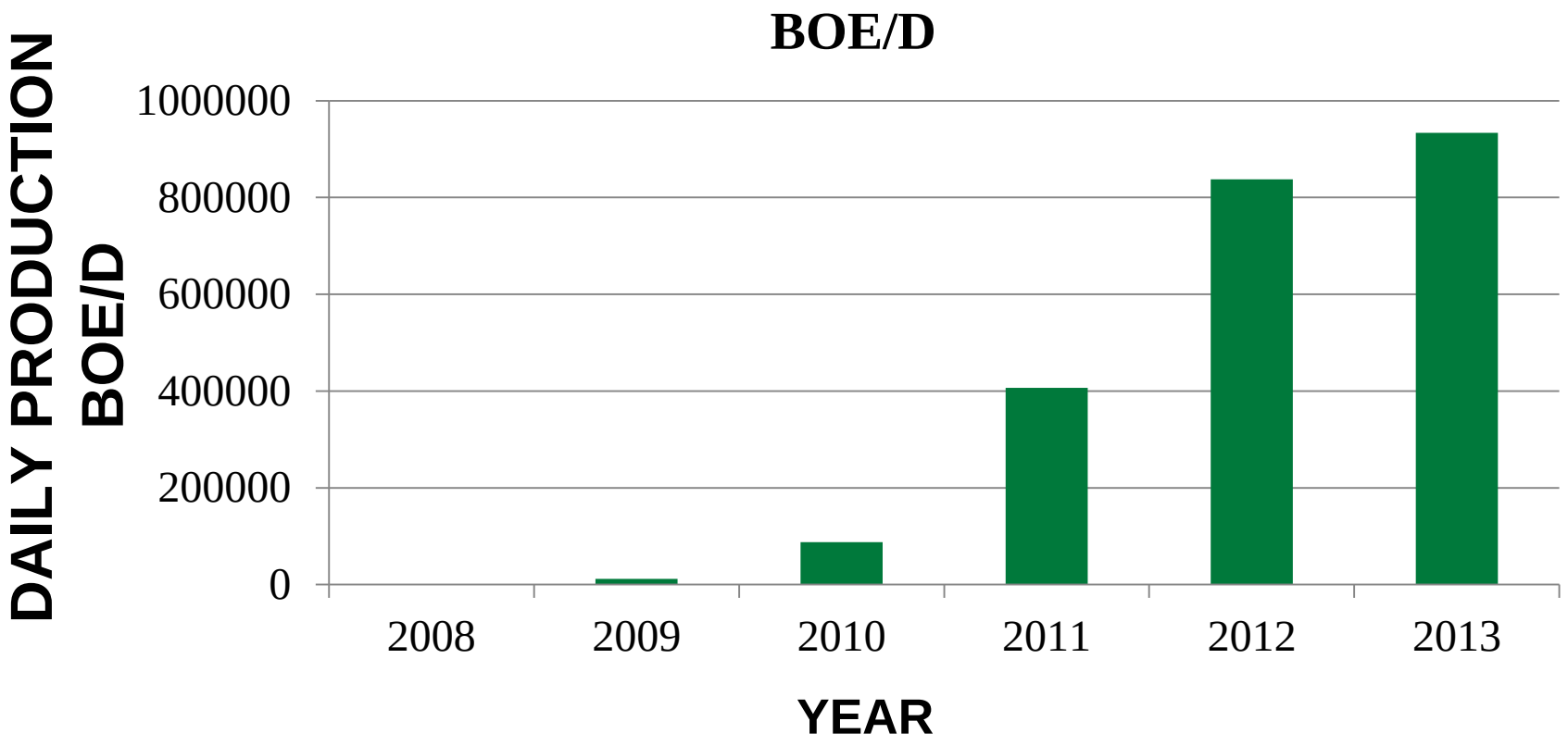
Eagle Ford Oil and Condensate Production Growth 2008-2013



Source: Texas Railroad Commission Production Data Query System

2013 thru Q1

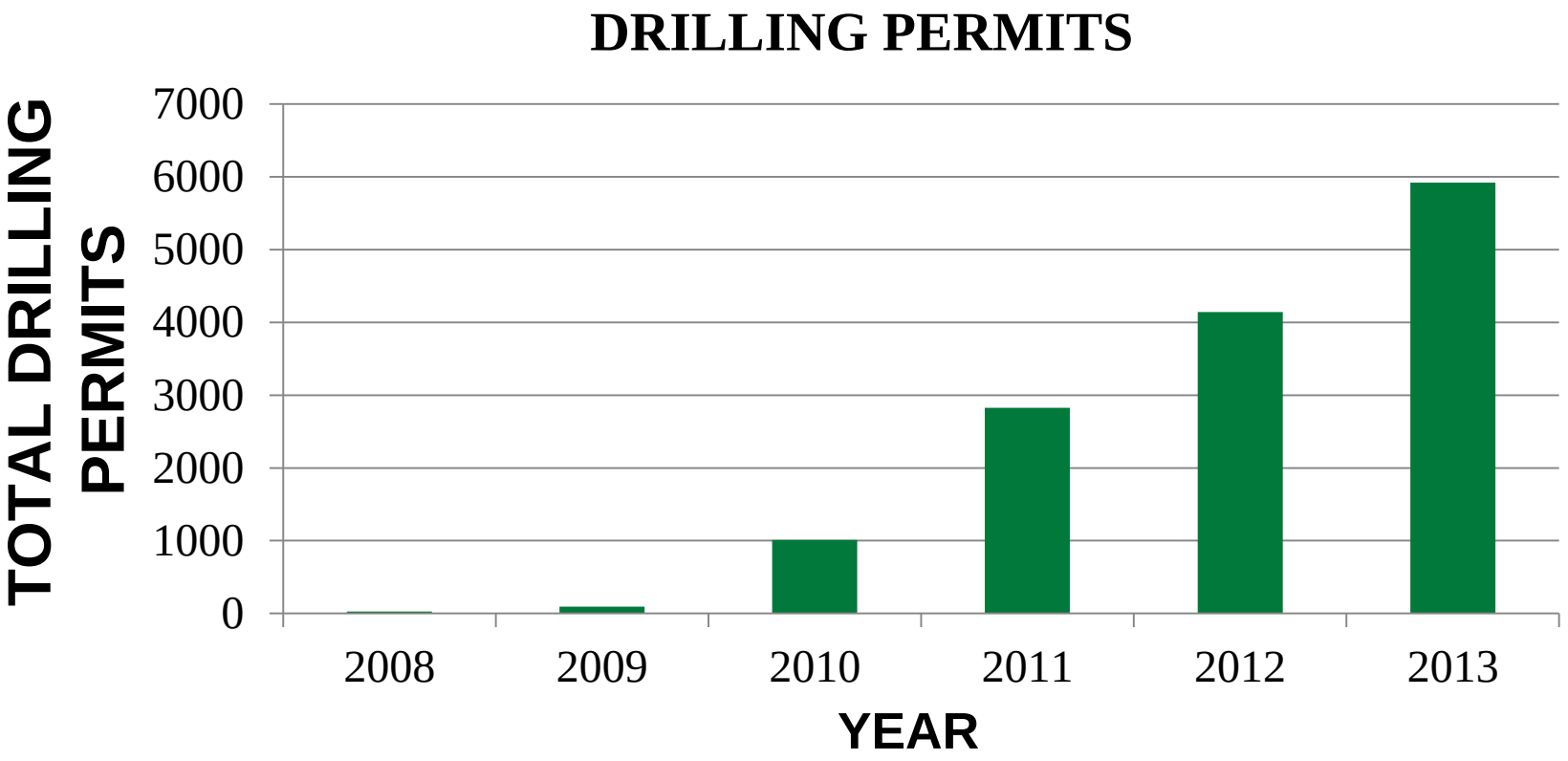
Eagle Ford Oil Drilling Permits 2008-2013



Source: Texas Railroad Commission Production Data Query System

2013 thru Q1

Eagle Ford Oil Drilling Permits 2008-2013



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**