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

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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

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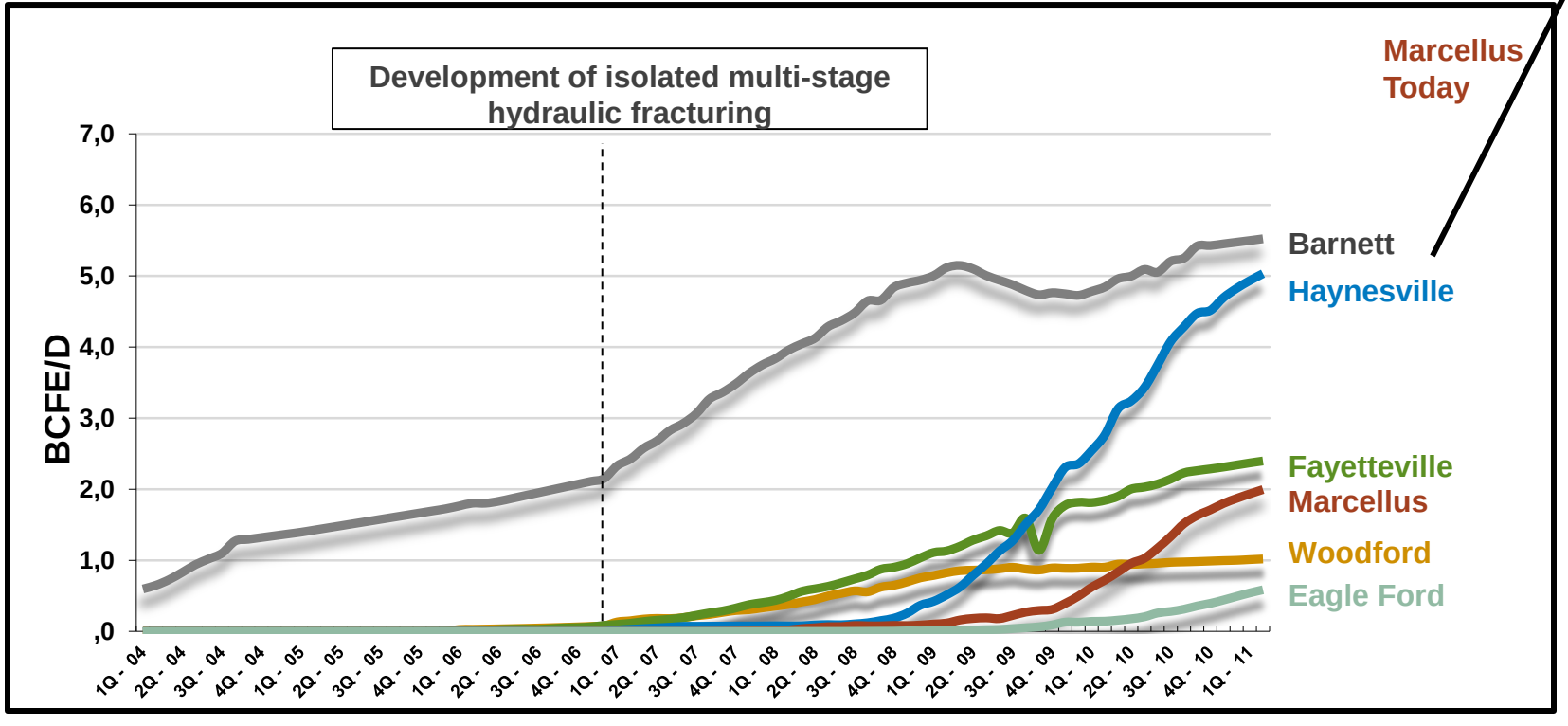
Growth of North American Shale Production

- **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

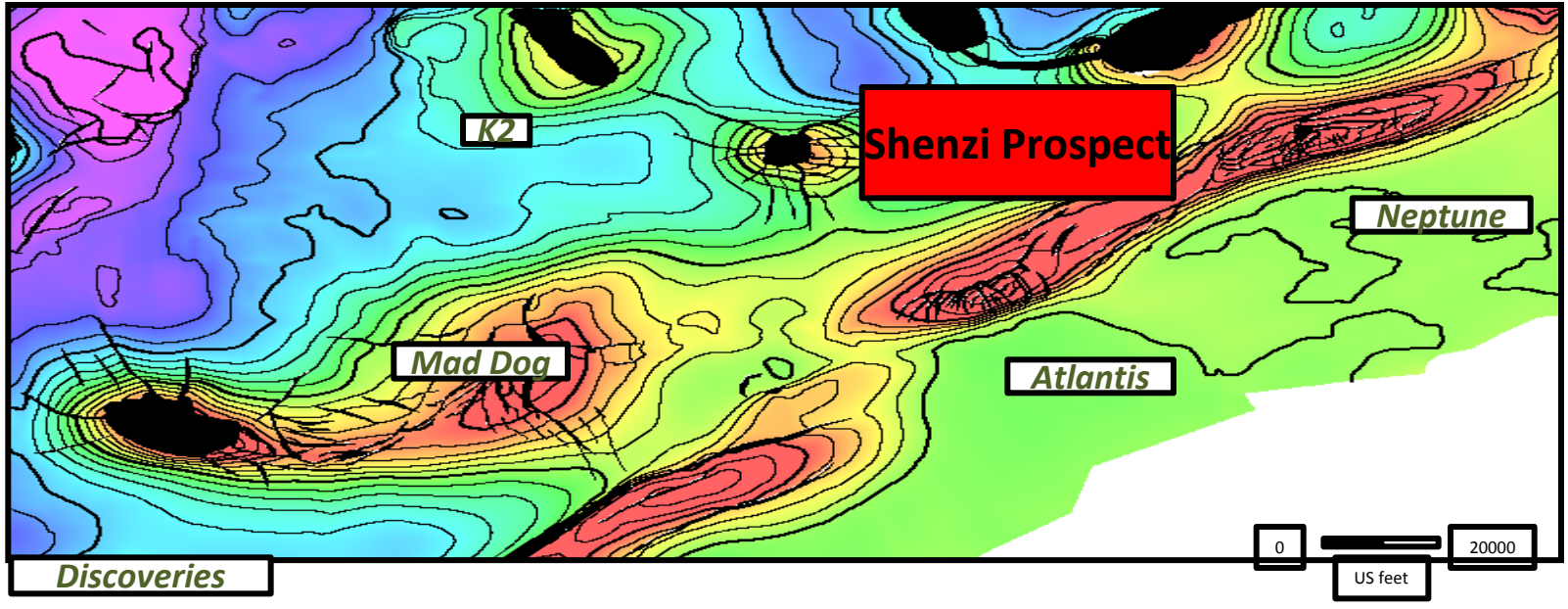
Conventional

- 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

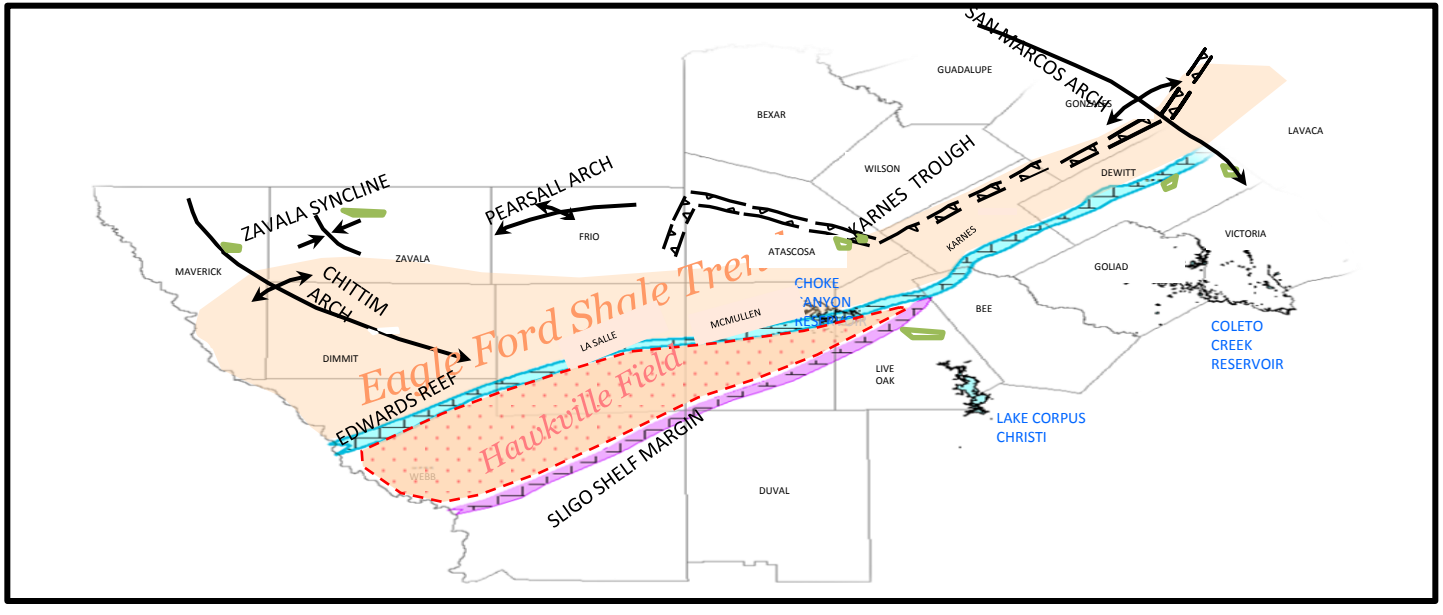
- Project identification focuses "inside out"
- Seismic control works "inside out"
- Stratigraphic support focuses on analysis of the entire basin
- Reservoir quality analysis is required over a very broad area of the basin

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

Prospect Identification: Unconventional Analogy

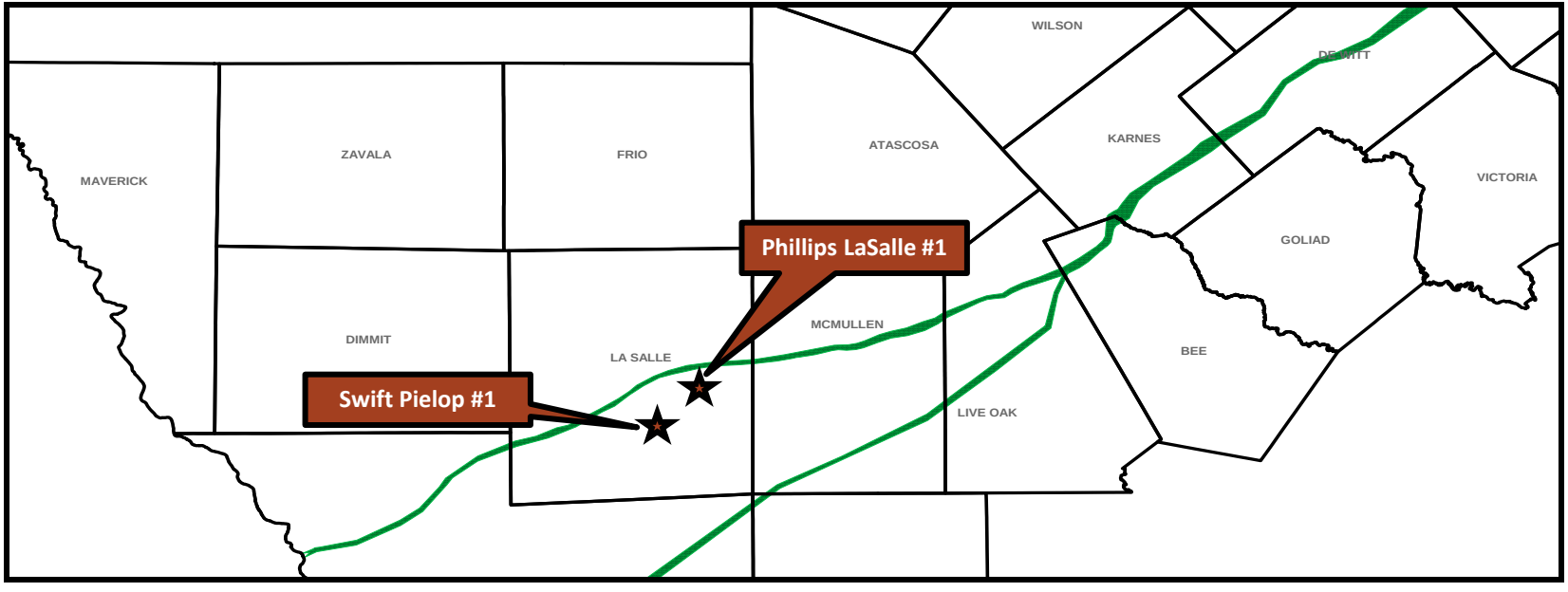


- Eagle Ford Shale Prospect
- Known regional source rock across large petroliferous basin
- Reservoir quality and geochemical attributes poorly understood
- The area was >10 MM acres with high side resource potential of >10 BBOE

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: 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

Hawkville Field in Early 2008

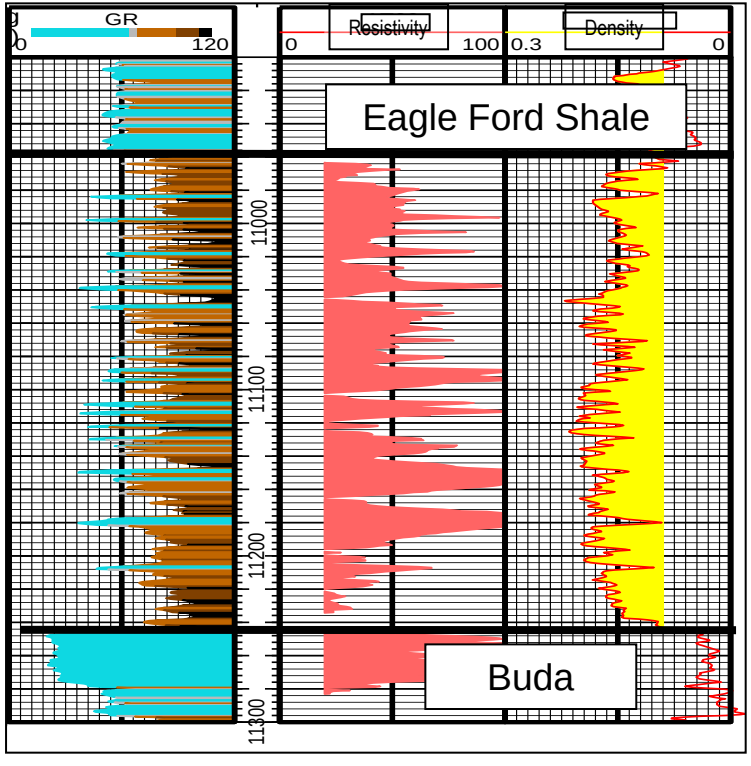


- Very limited well control in prospective area
- Prospect was located in a regional setting between two divergent shelf margins, which suggested the presence of a “mini-basin”
- While the geochemical properties were unknown, the depth range (10,000-11,500’/3050m-3500m) suggested a relatively mature source rock

Key Finding #1:
World Class Petrophysical Properties

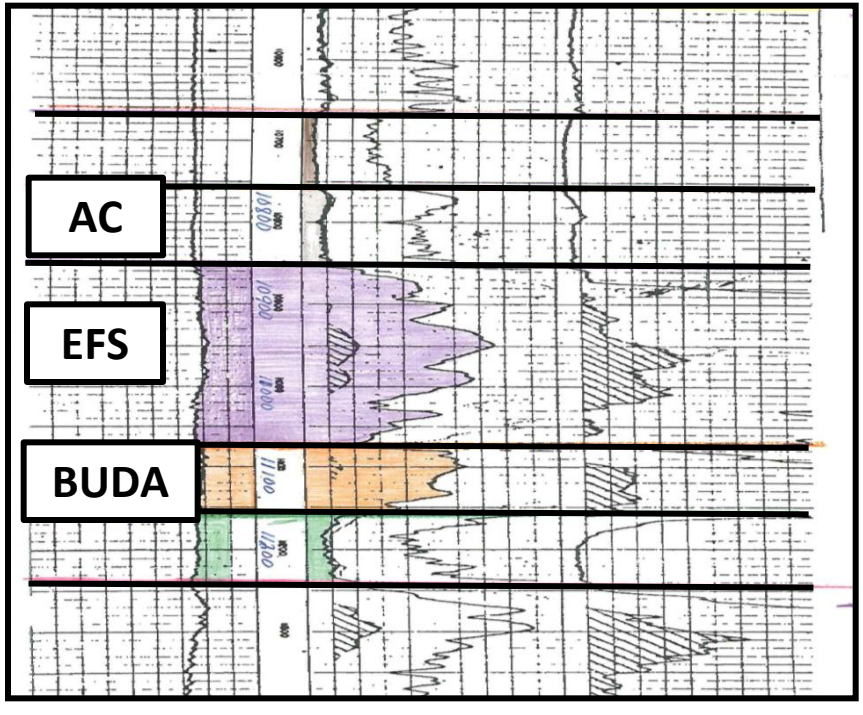
- Well was drilled in the early '90's, probably targeting the Cretaceous Olmos Sands
- Eagle Ford tested small amount of gas after light acid treatment
- Over 250' (75m) of Eagle Ford greater than 9% density, with majority greater than 15% (~100% Net/Gross)
- Excellent resistivity
- Gamma Ray character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

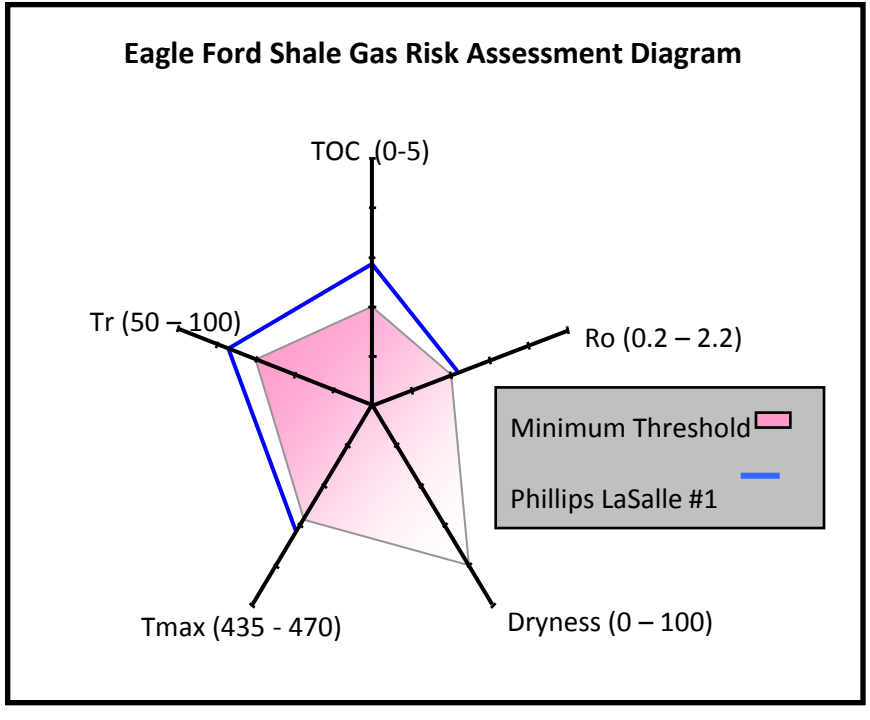
Swift Pielop 1



Key Finding #2:
Positive Geochemical Analysis

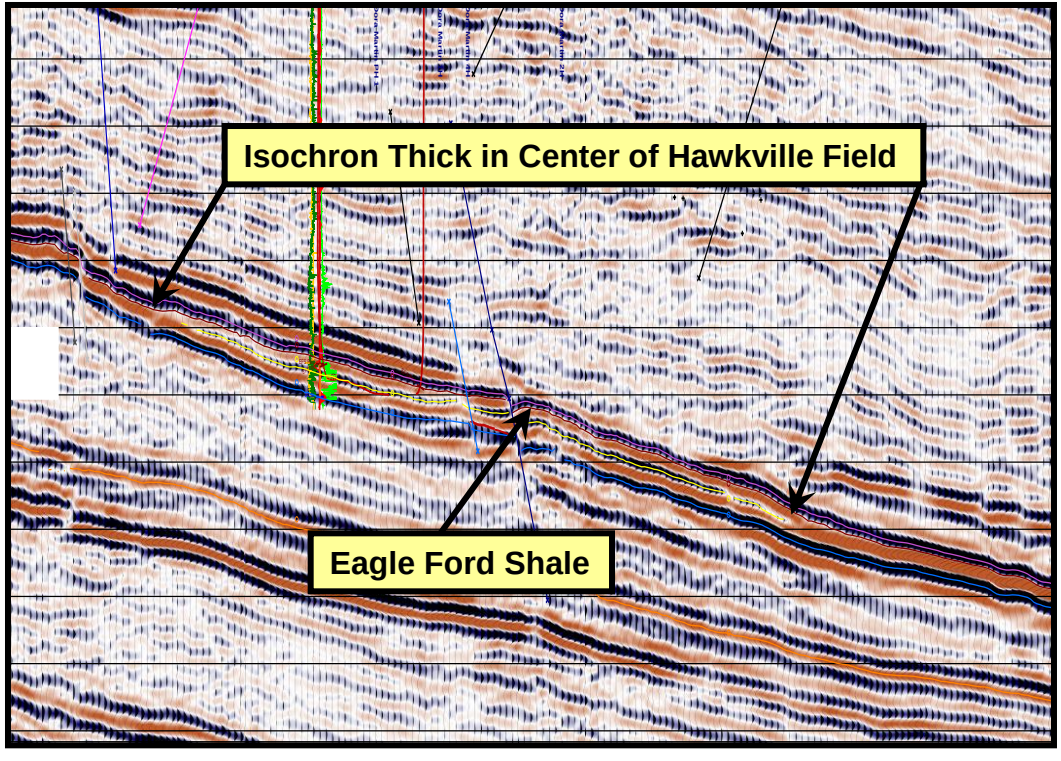
Phillips LaSalle #1
D&A in 1952





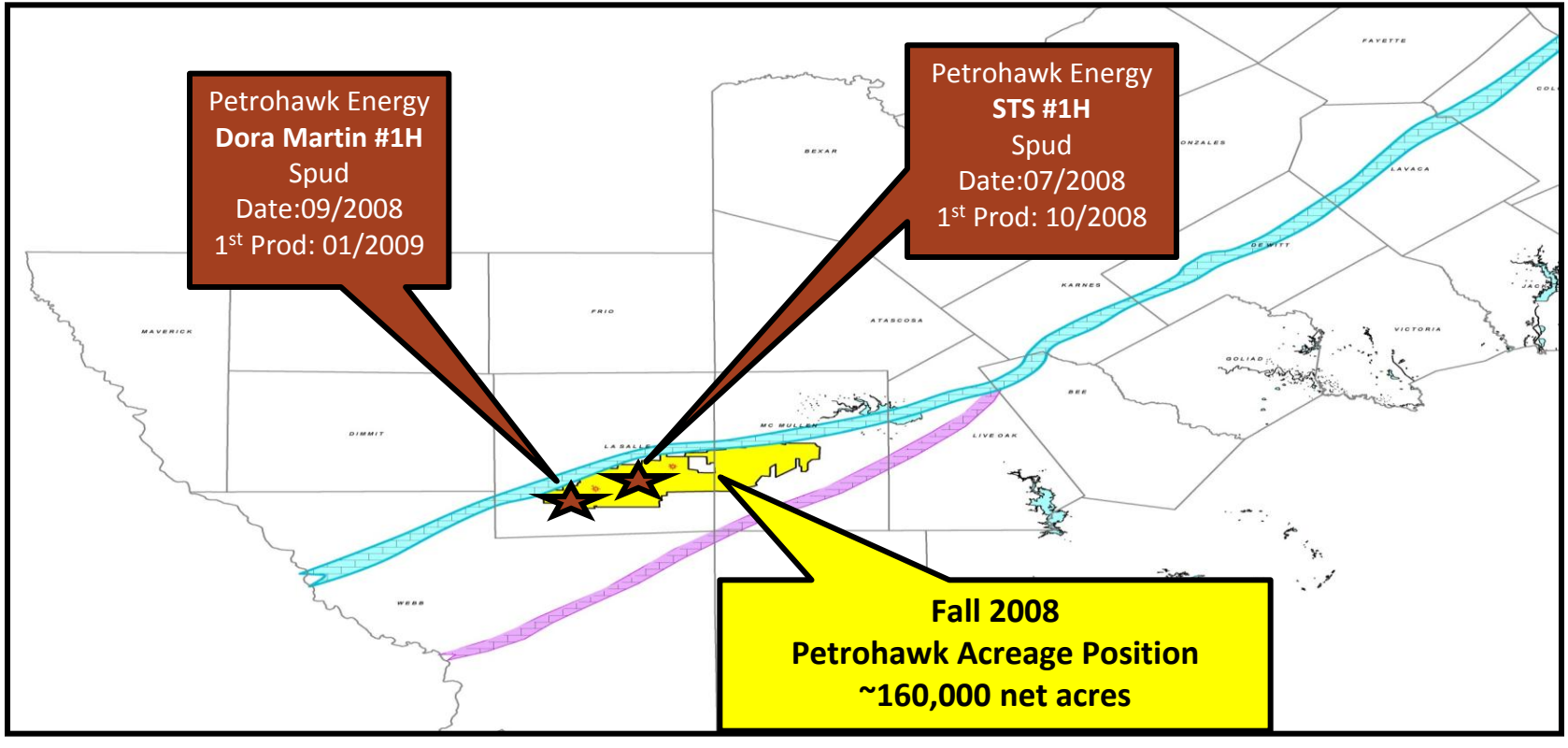
Key Finding #3:
Seismic Defines the Optimum Reservoir Thickness

- 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)

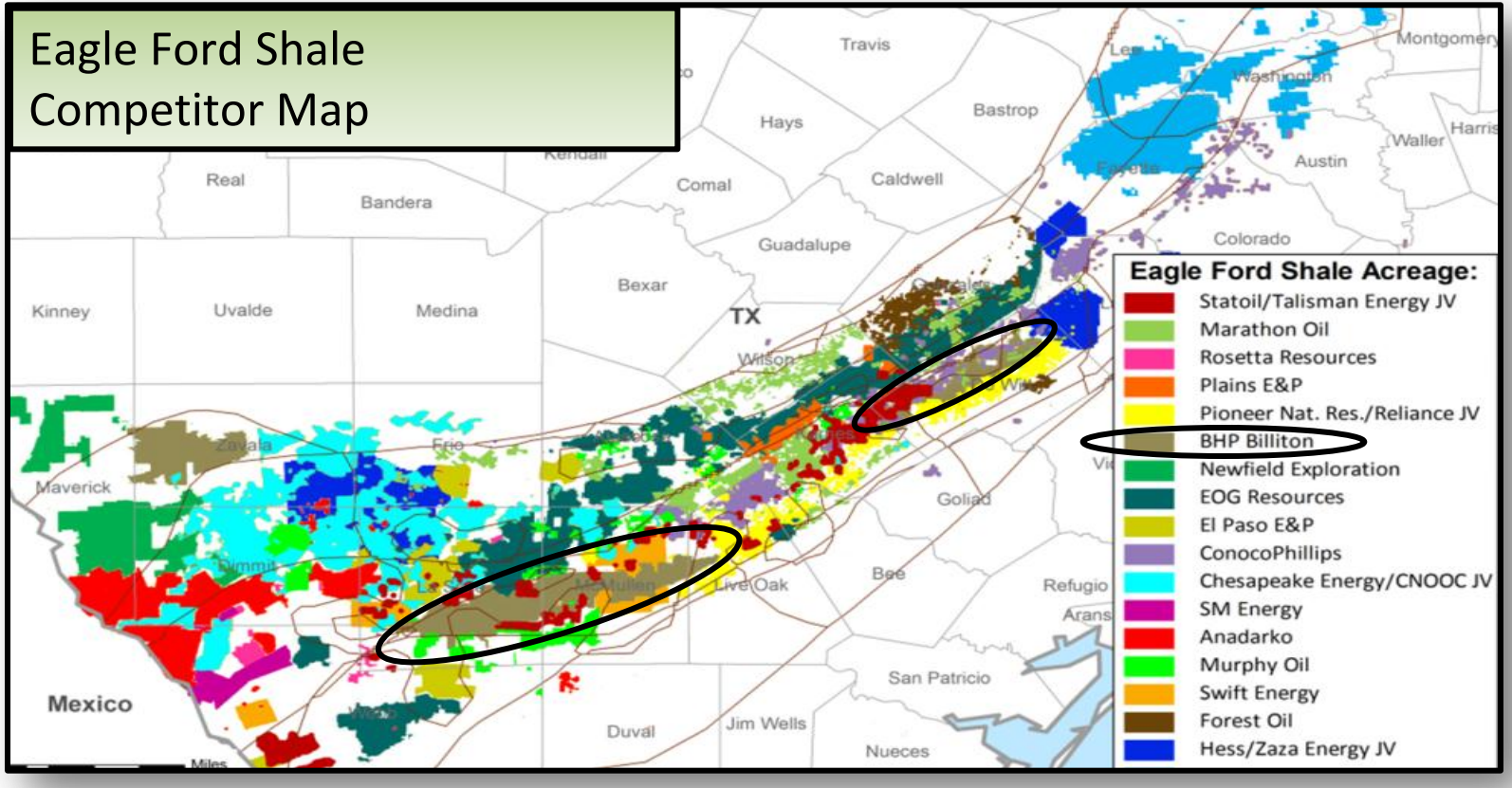


Data Courtesy of Seitel, Inc.

Hawkville Field in Late 2008



The Eagle Ford Shale in 2013



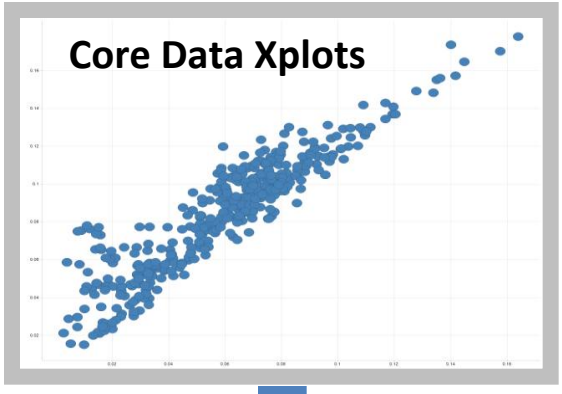
A New Set of Lights Visible From Space

Appraisal Process

The Appraisal Process:
Core Data and "Core to Log" Data are 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, thereby expanding knowledge regarding reservoir characterization, formation evaluation (OGIP, Recovery and EUR) and optimization of the hydraulic fracture stimulation**

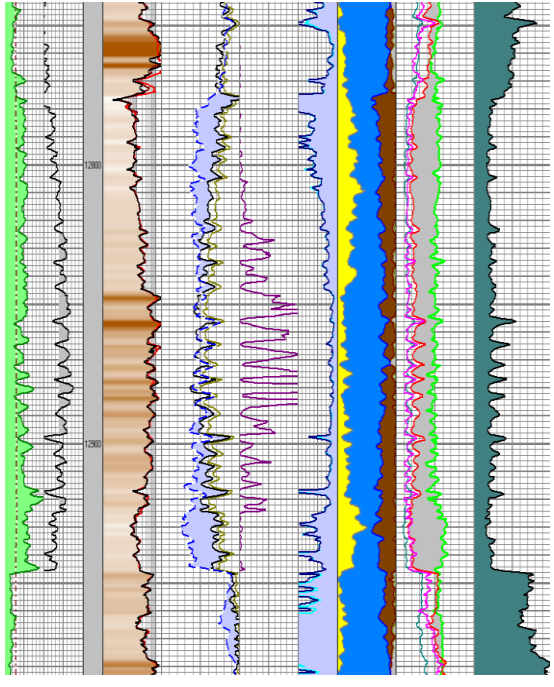
Basic Petrophysical Workflow



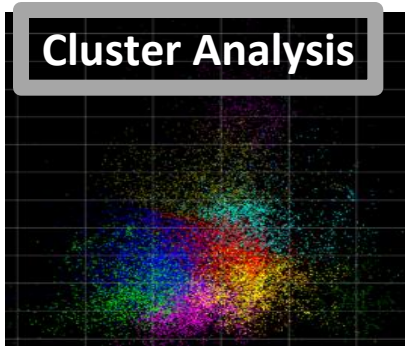
TOC
Porosity
Permeability
Saturation
Lithology
Geomechanics

ALGORITHMS

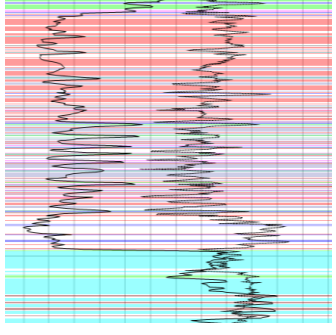
Interpreted Log Curves



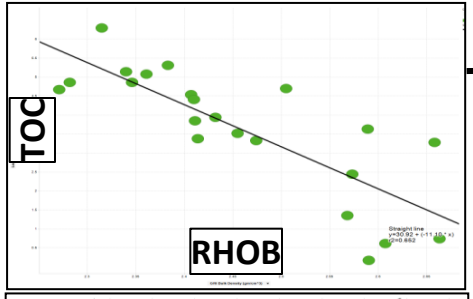
Cluster Analysis



Facies Classification

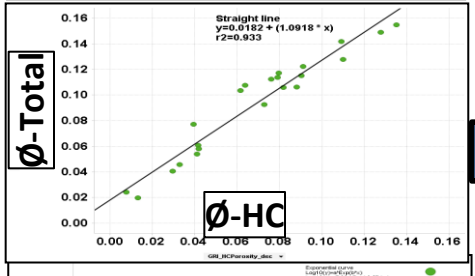


Core to Log Calibration: TOC-Porosity-Permeability



TOC/RHOB

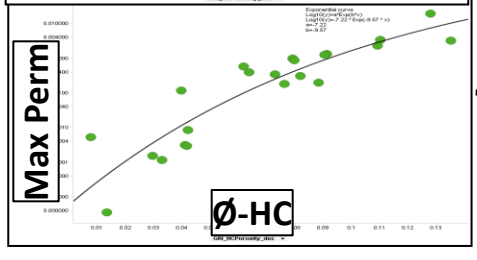
Fair correlation coefficient
$r^2 \sim 0.65$



Porosity

Highest correlation coefficient
$r^2 \sim 0.93$

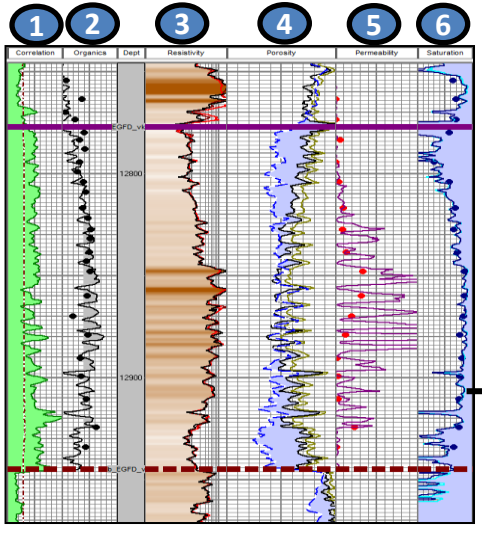
Total porosity → HC-filled porosity → 4



Permeability

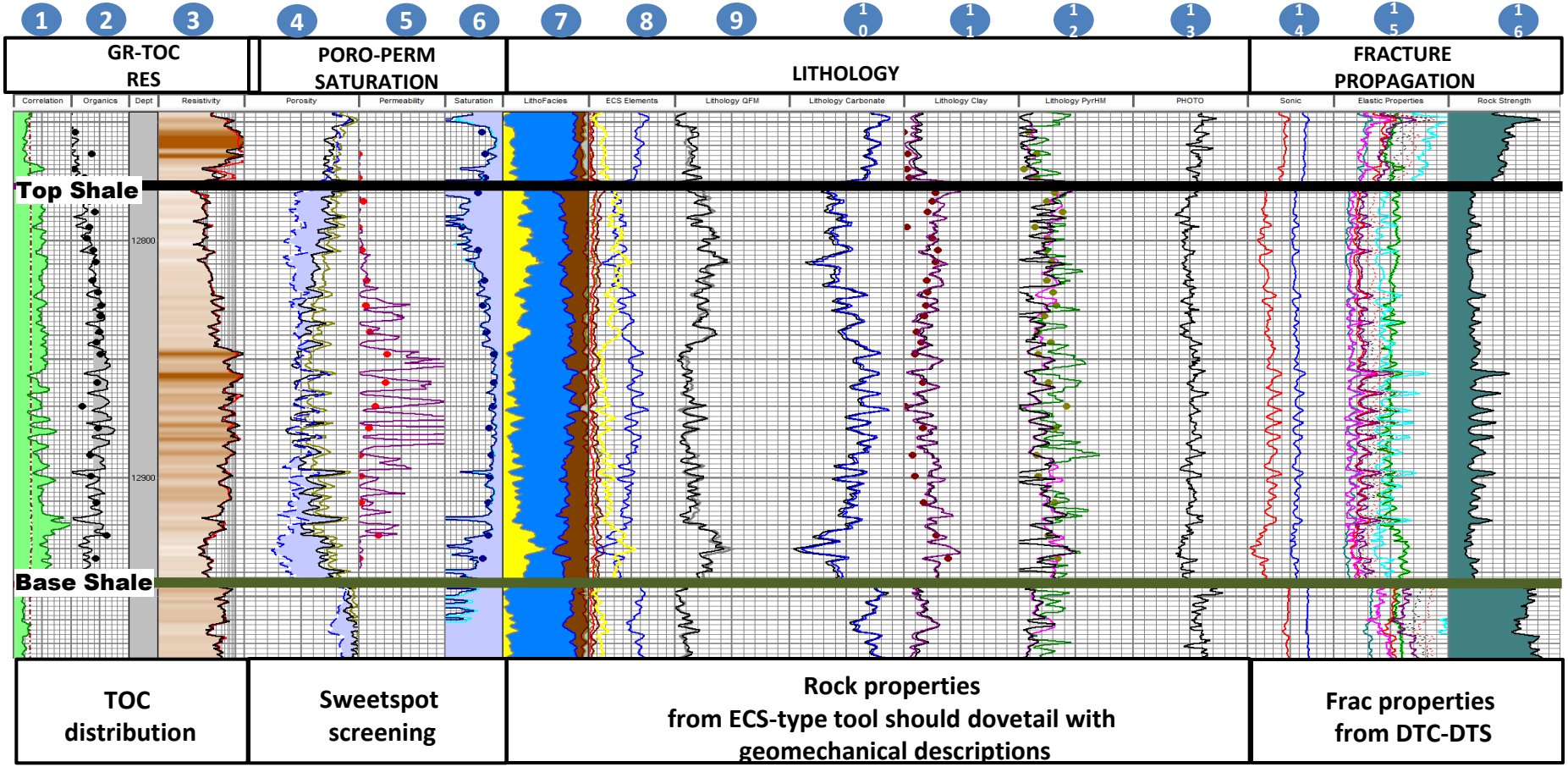
Least dependable of the algorithms
(use qualitatively and in localized zones)

Triple Combo

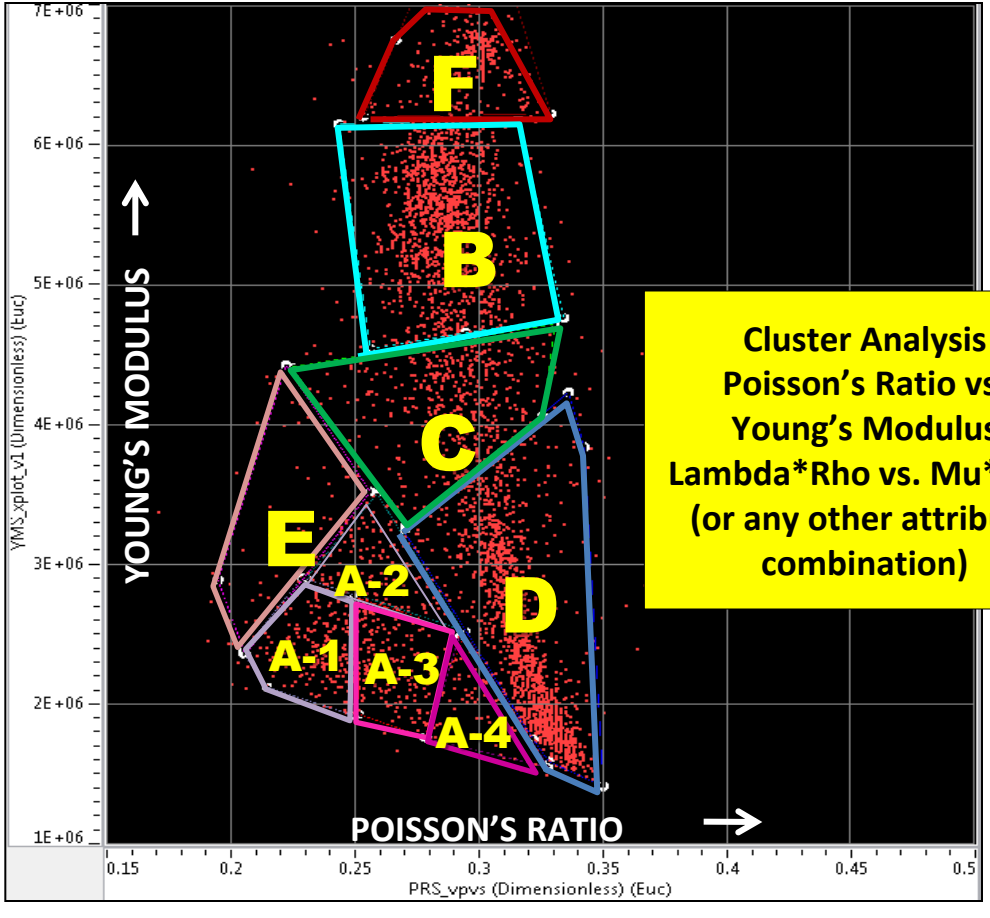


Sw based on default Rw ~ 0.025

Core to Log Process: Expanding the Data Set

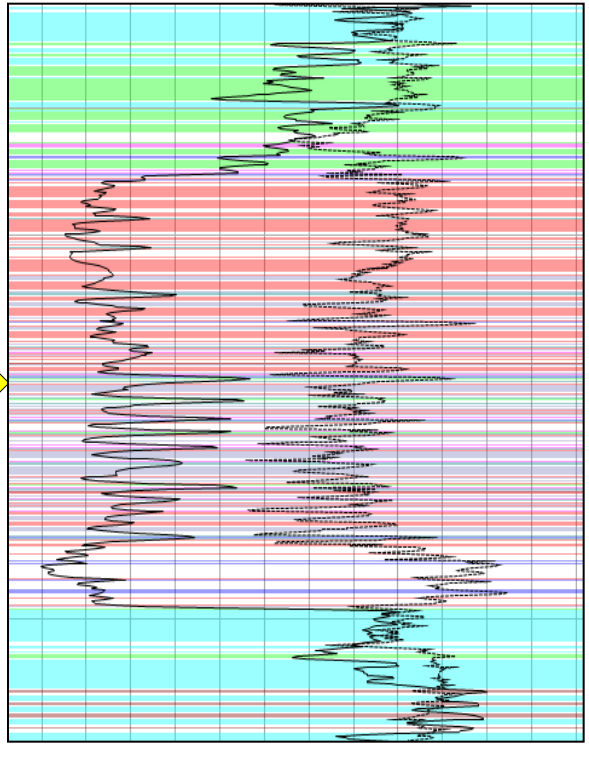


An Example of Utilizing the Expanded Data Set

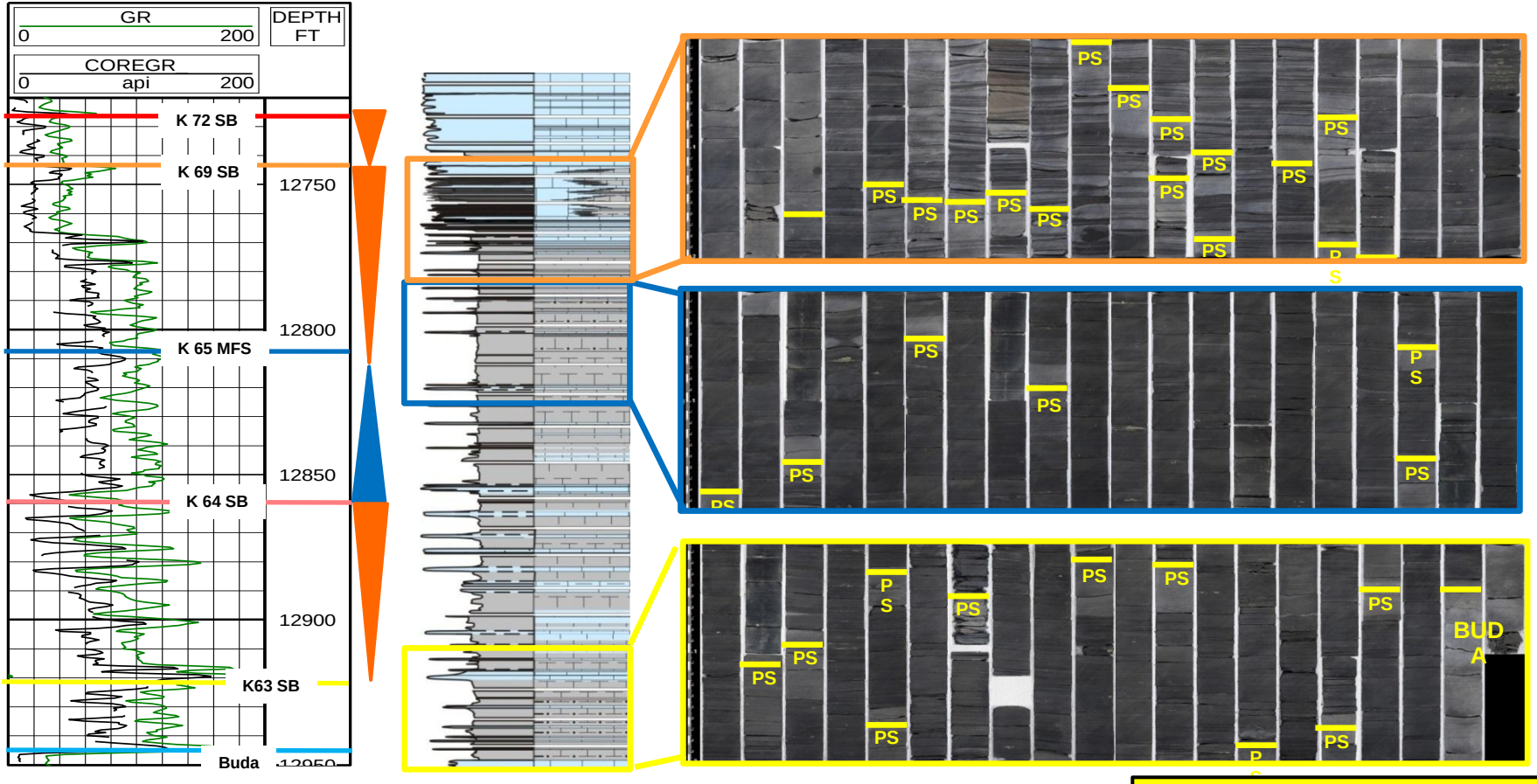


Cluster Analysis
Poisson's Ratio vs. Young's Modulus
Lambda*Rho vs. Mu*Rho
(or any other attribute combination)

Facies extracted from Crossplot

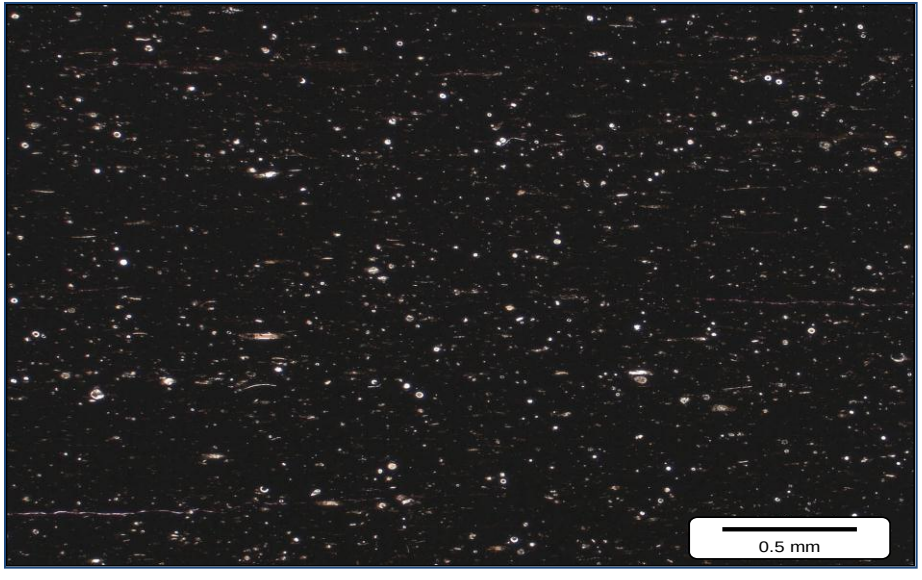


A Key Aspect of Quality Shale Reservoirs: Vertical Heterogeneity

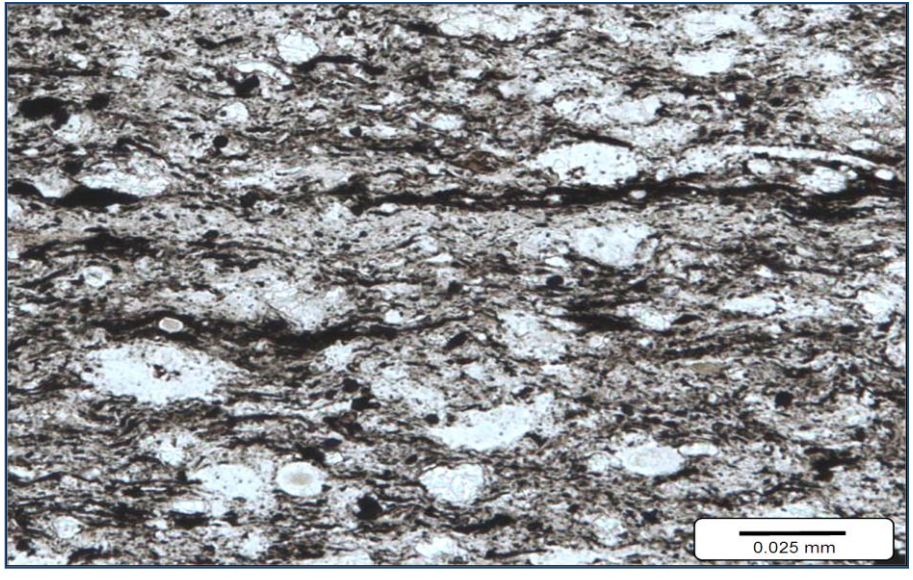


Courtesy of Core Laboratories

Micro-Textural Relationships: The Importance of Scale



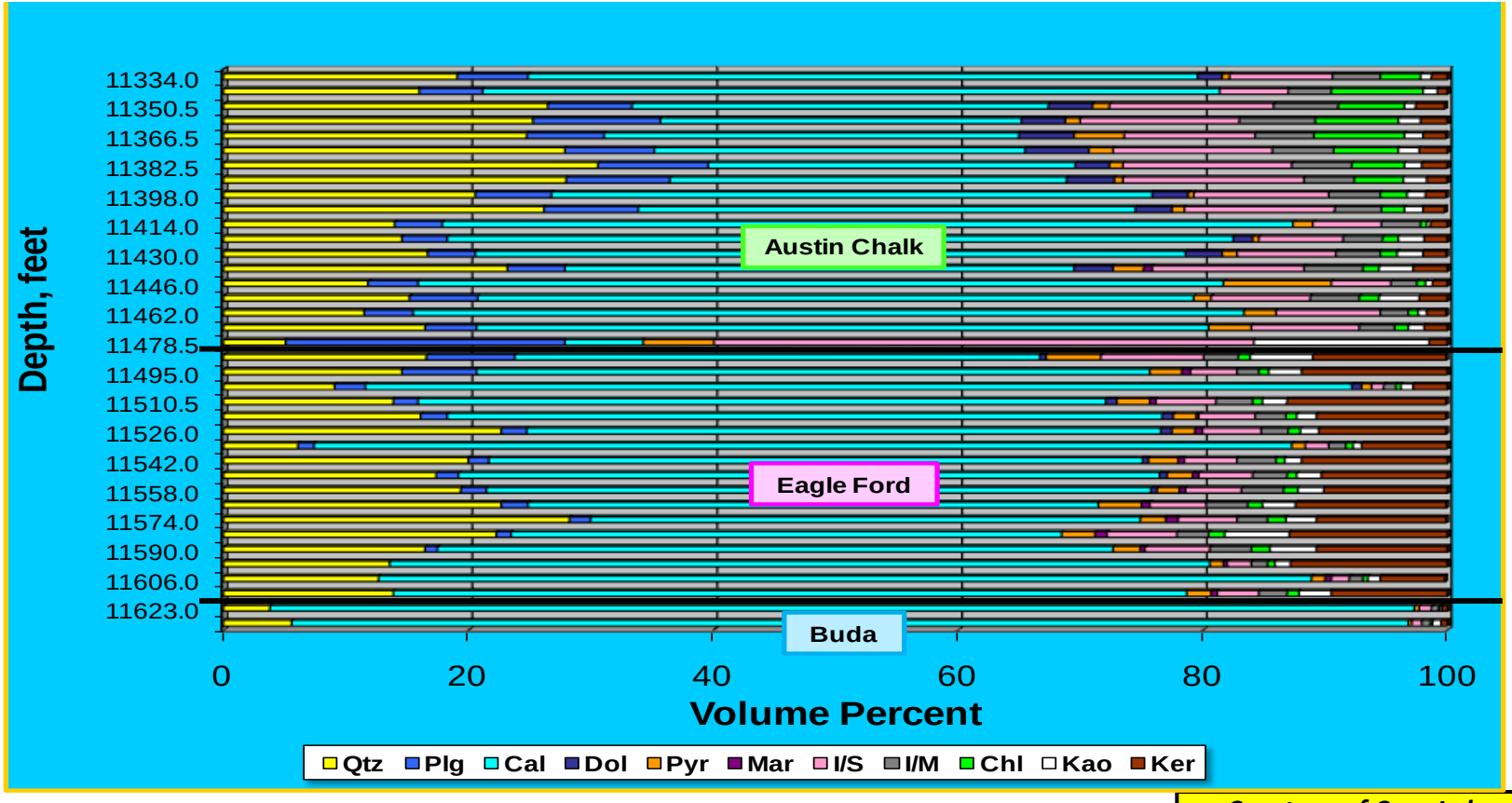
Standard 30 micron thick slide:
No apparent grain support which would suggest poor reservoir quality



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

Courtesy of Core Laboratories

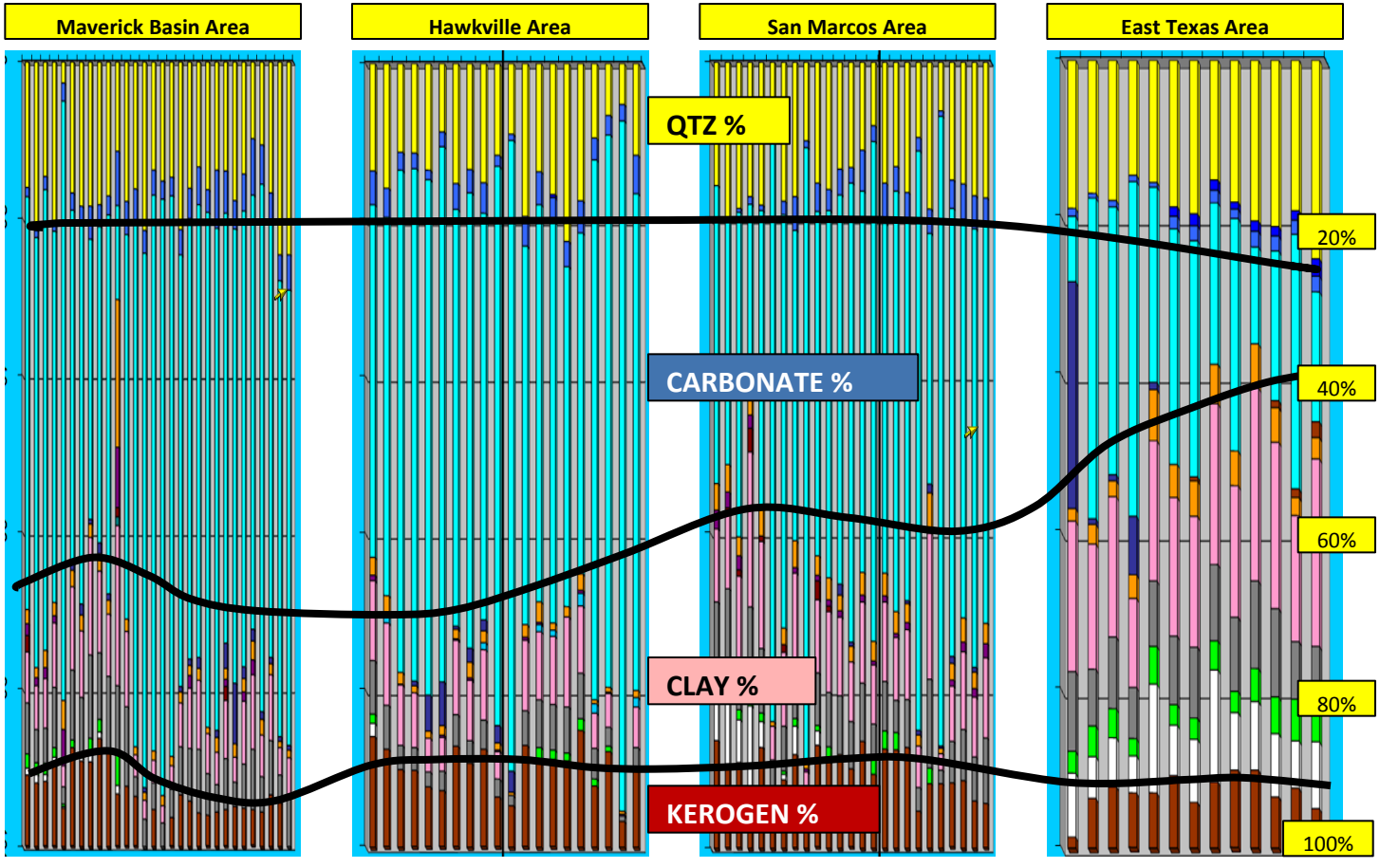
The Importance of "Coarse"-Grained Constituents: Eagle Ford Shale



Courtesy of Core Laboratories

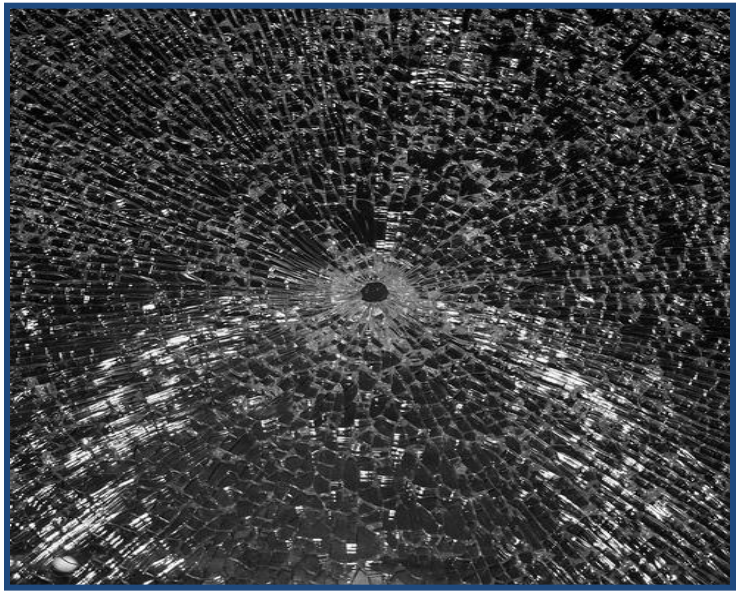
Eagle Ford: Mineralogical Variation Across the Trend

- 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

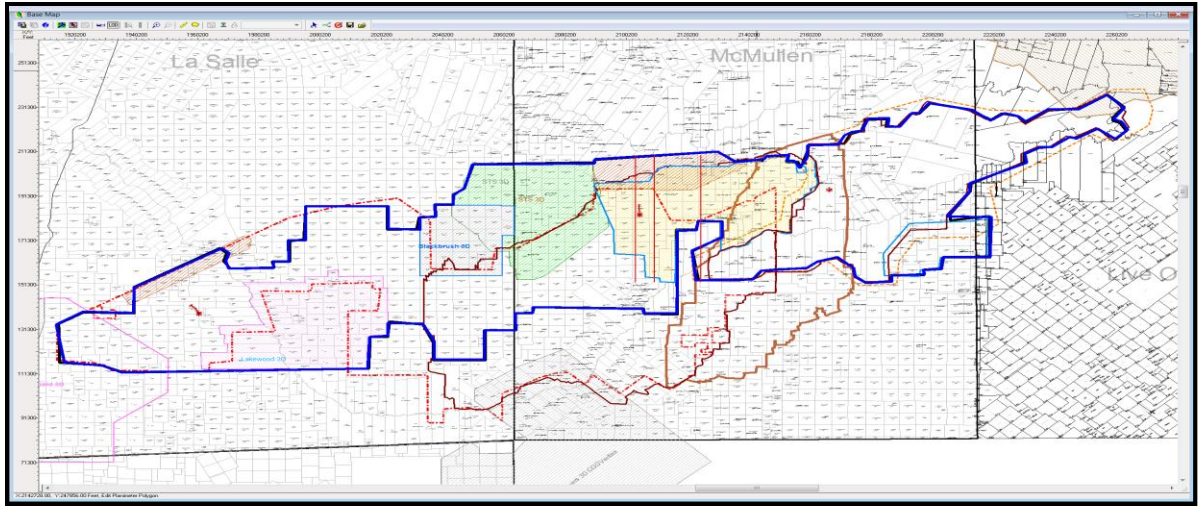
Anisotropic ‘Natural’ Glass:
The other extreme

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, 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

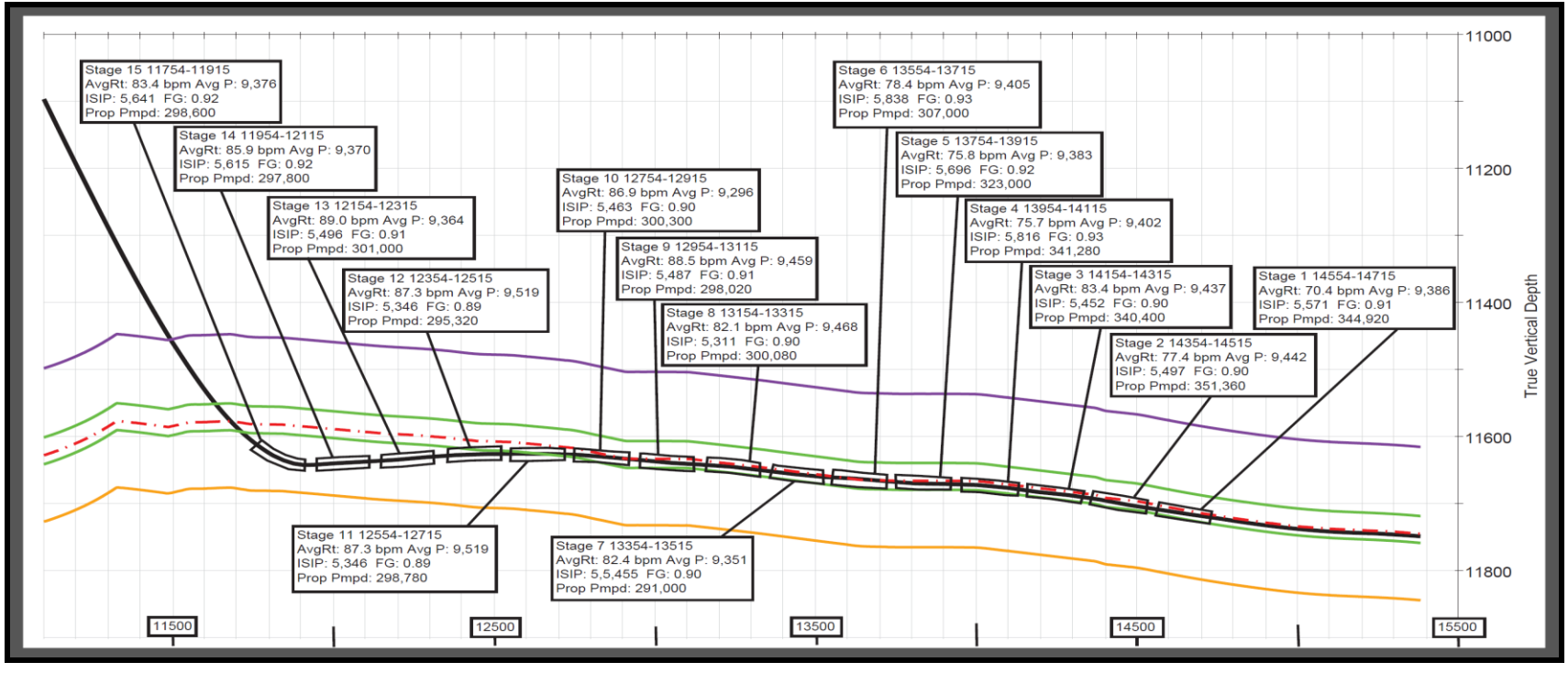
- **Horizontal drilling creates significant *geological* challenges**
  - **Unforeseen dip changes and/or faults can cause a well to be out of zone for a large portion of a lateral**

- **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?

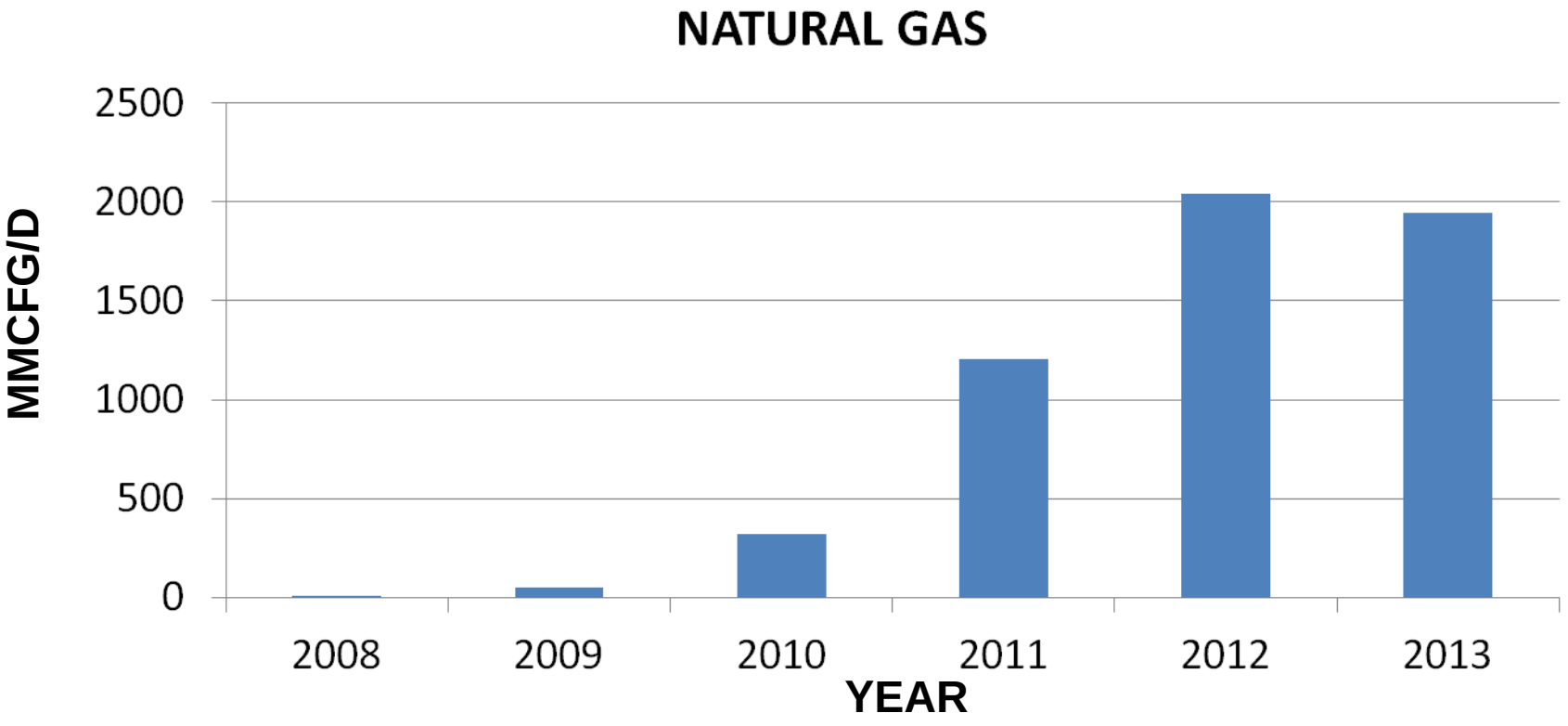


The Eagle Ford After Five Years

- 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

Source: ITG Energy Play Report July 24, 2013

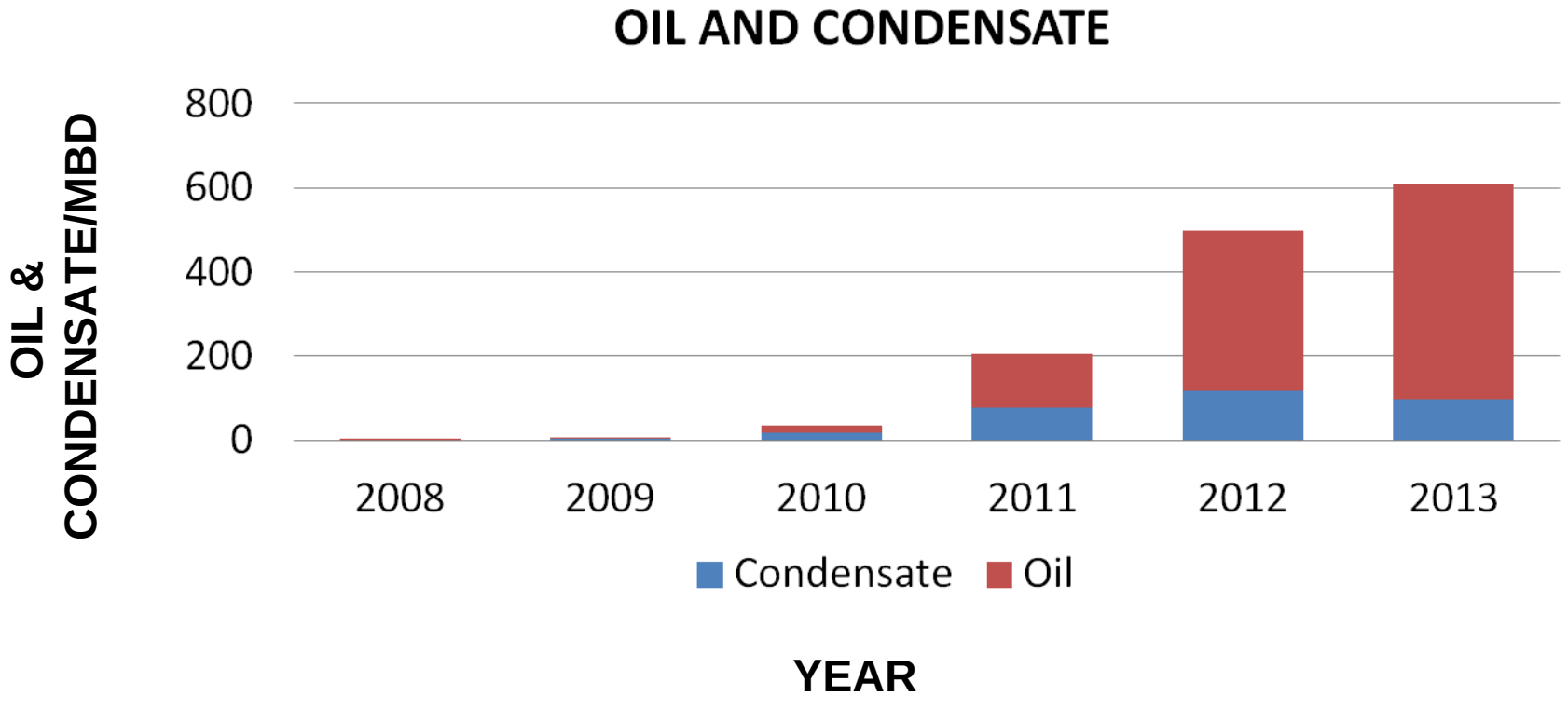
Eagle Ford Natural Gas Production Growth 2008-2013



Source: Texas Railroad Commission Production Data Query System

2013 thru Q1

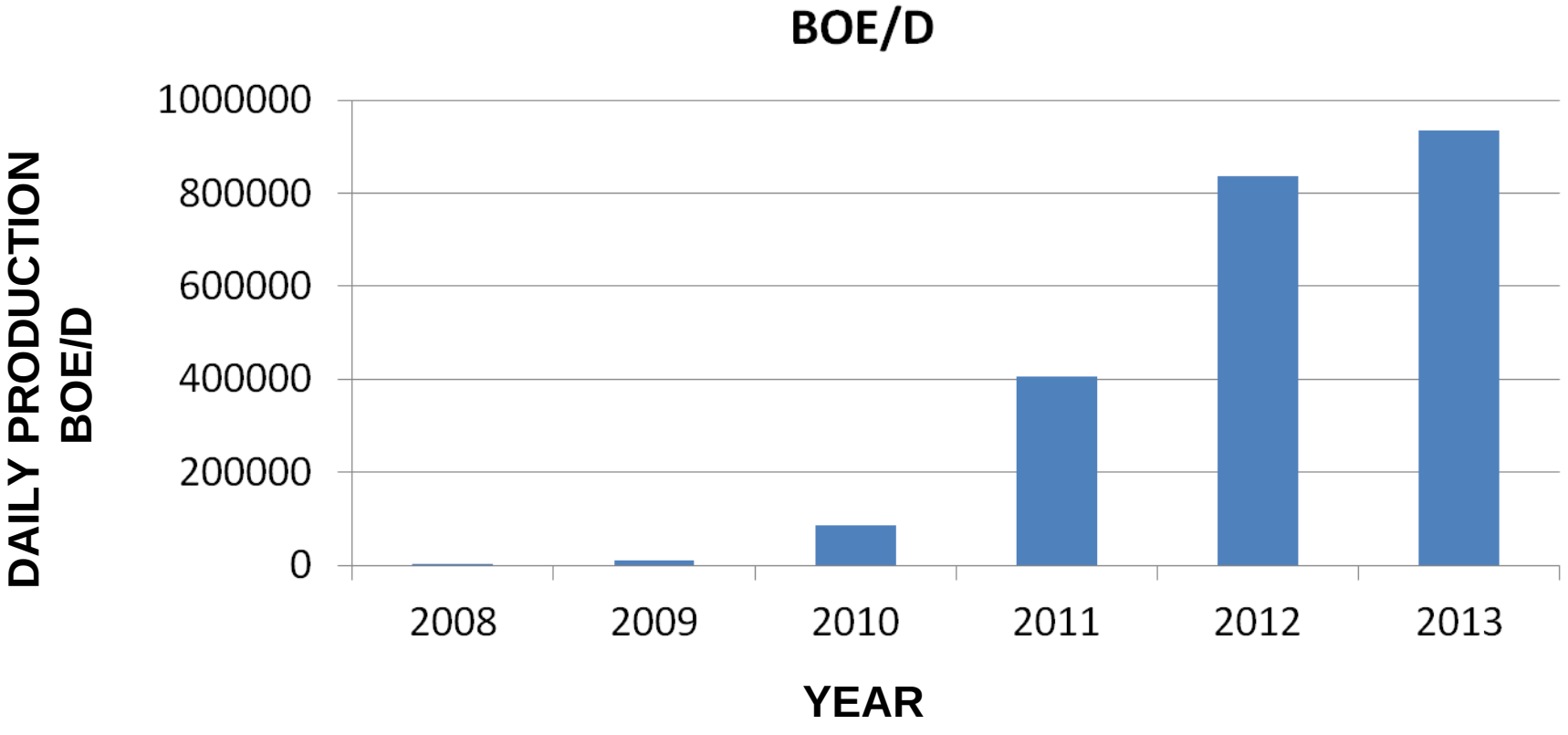
Eagle Ford Oil and Condensate Production Growth 2008-2013



Source: Texas Railroad Commission Production Data Query System

2013 thru Q1

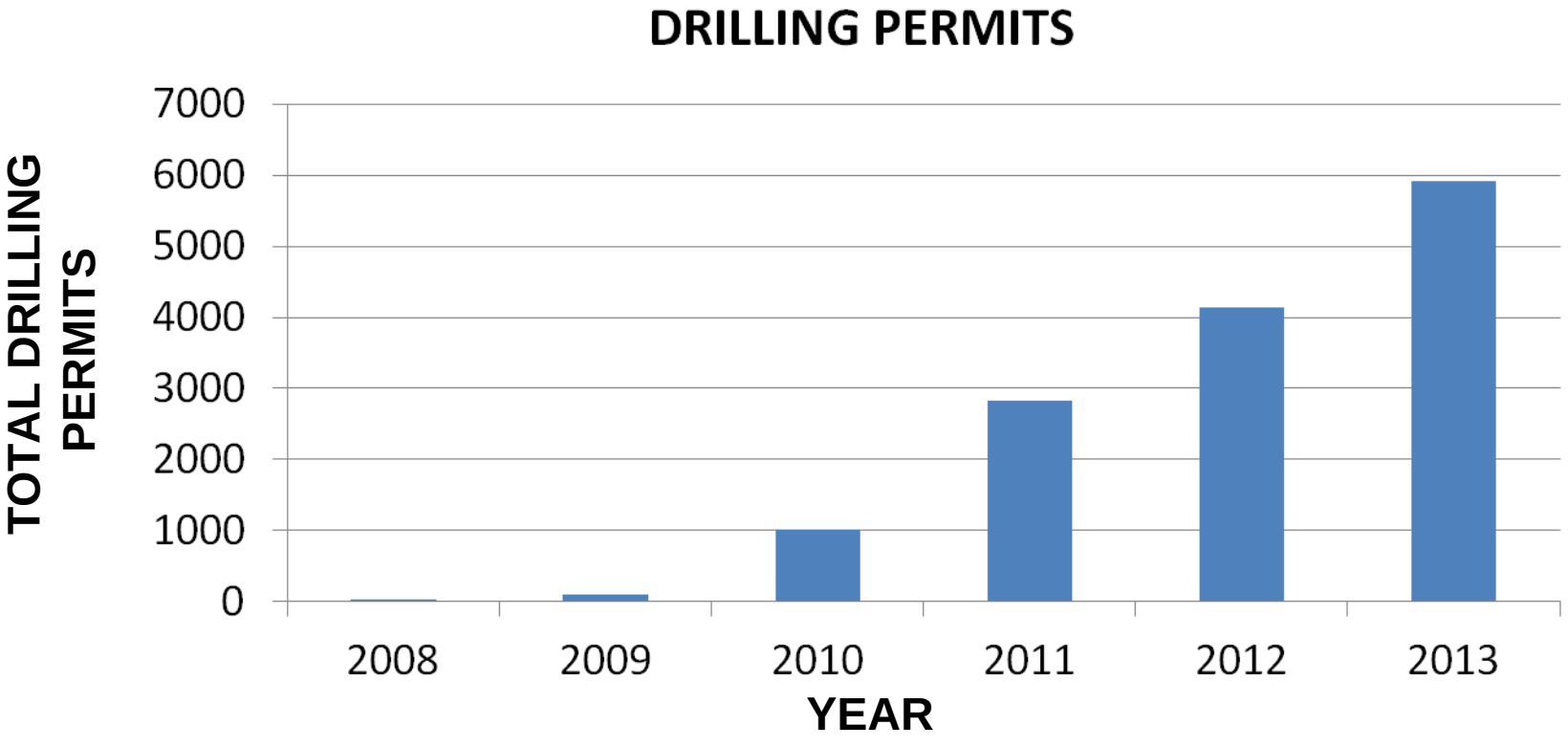
Eagle Ford Oil Drilling Permits 2008-2013



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