Quantitative Facies Analysis: A Tool Kit in the Characterization of Eagle Ford Sequence Stratigraphy and Facies Heterogeneity*

Ariel E. Malicse[2], Erik Van Dusen[1], Bret Neff[2], Daniel Hurst[2], and Heather McGarity[2]

Search and Discovery Article #51279 (2016)**
Posted August 15, 2016

*Adapted from oral presentation given at AAPG 2016 Annual Convention and Exhibition, Calgary, Alberta, Canada, June 19-22, 2016

[1]Eagle Ford Onshore, Murphy Exploration and Production, Houston, Texas, United States (Erik_Vandusen@murphyoilcorp.com)
[2]Eagle Ford Onshore, Murphy Exploration and Production, Houston, Texas, United States

Abstract

A methodology of Quantitative Facies Analysis (QFA) was developed and conducted in several cores of the Eagle Ford in South Texas to: 1) determine vertical and regional facies heterogeneity, 2) determine the cumulative thickness of sedimentary facies, and 3) map sequence stratigraphic units regionally. A total of nine Eagle Ford facies were identified on the basis of sedimentary structures, degree of bioturbation, organic content, and textures.

By measuring the cumulative thickness of the nine key facies, QFA revealed distinct mappable transgressive and regressive units representing fluctuation in sea level. The base to top sequences in the Eagle Ford are subdivided into: First Transgressive Sequence (A), First High Stand Sequence (B), Second Transgressive Sequence (C), and Second High Stand Sequence (D). The stratigraphic distribution of these facies types suggest that the lower Eagle Ford is comprised of the A, B, and C sequences; whereas, the Upper Eagle Ford is comprised only of the D sequence. Generally, the sequence from A to B is marked by an upward decrease in the organic-rich facies, which then gradually increase from B to C.

Mapping the spatial distribution of these transgressive and high stand sequences, the Eagle Ford strata can be parsed into proximal, medial, and distal regions based on the relative fluctuation between organic-rich and organic-poor sequences. The proximal region is characterized by relatively large changes between organic-rich and organic-poor facies with thick and frequent intervals of organic poor facies and the lowest cumulative thickness of organic-rich facies at 35-50% of the total Eagle Ford. The medial region is characterized by both equal distribution of the organic-rich and organic-poor facies types with organic-rich facies comprising between 50-65% of the Eagle Ford. Lastly, the distal region is characterized by the largest organic matter comprising 75-95% of the Eagle Ford with organic-poor intervals occurring rarely in thin layers.

Reference Cited

Ferrill, D.A., A.P. Morris, and K.J. Smart, 2007, Stratigraphic Control on Extensional Fault Propagation Folding: Big Brushy Canyon Monocline, Sierra Del Carmen, Texas, *in* S. Jolley, D. Barr, J. Walsh, and R. Knipe (eds.), Structurally Complex Reservoirs: Geological Society of London Special Publication 292, p. 203–217.

Quantitative Facies Analysis: A Tool Kit in the Characterization of Eagle Ford Sequence Stratigraphy and Facies Heterogeneity

Ariel Malicse, Erik Van Dusen, Bret Neff, Daniel Hurst, and Heather McGarity

MURPHY
EXPLORATION & PRODUCTION CO.

Objectives

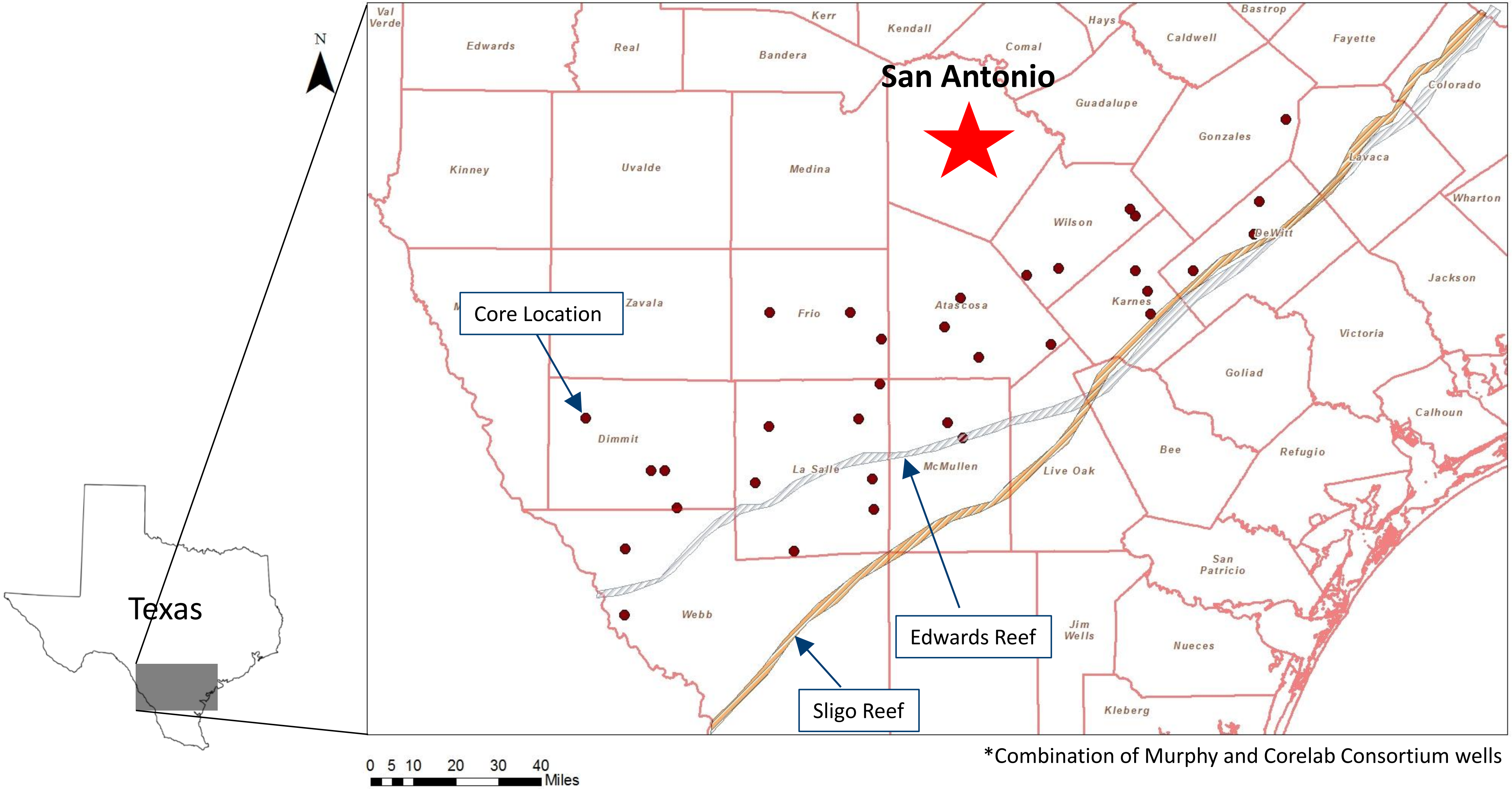
To understand regional rock variations across the Eagle Ford Shale to help Murphy's drilling and completion programs.

Achieve Objectives by:

- **A regional core study using a Quantitative Facies Methodology (QFM) to determine facies distribution across the Eagle Ford Shale**

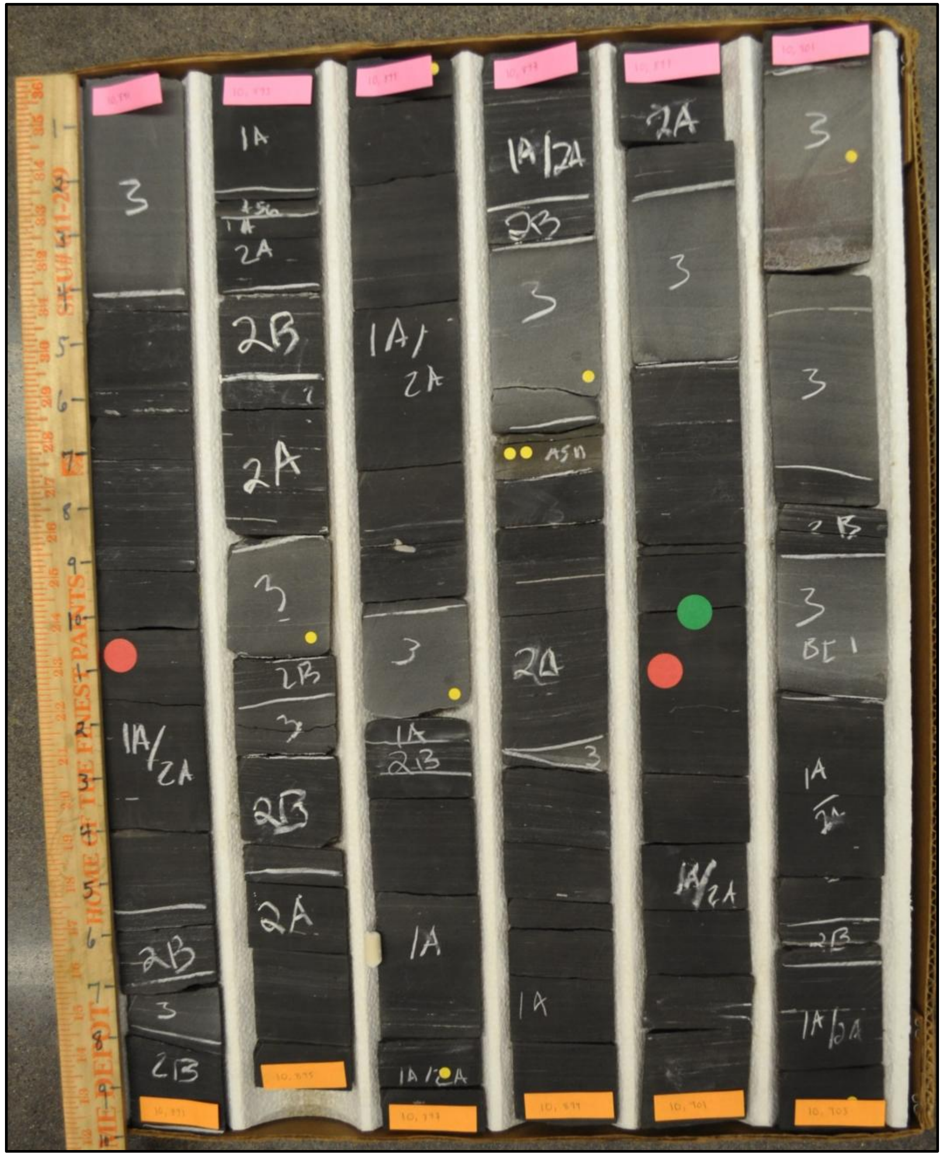
- **Combine QFM tool kit with rock mechanic data to predict ideal drilling targets across the Eagle Ford Shale**

Study Area and Location of Cores – Eagle Ford Shale



*Combination of Murphy and Corelab Consortium wells

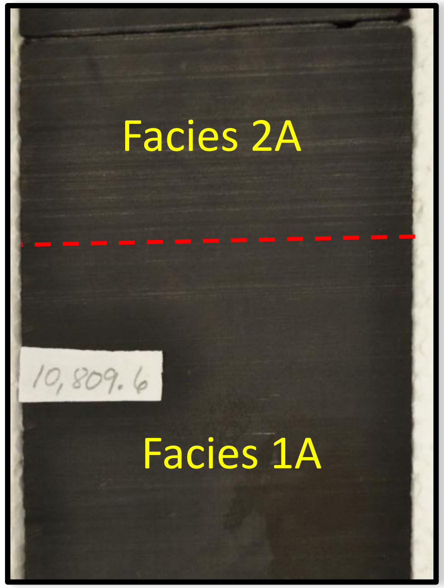
Quantitative Facies Tool Kit

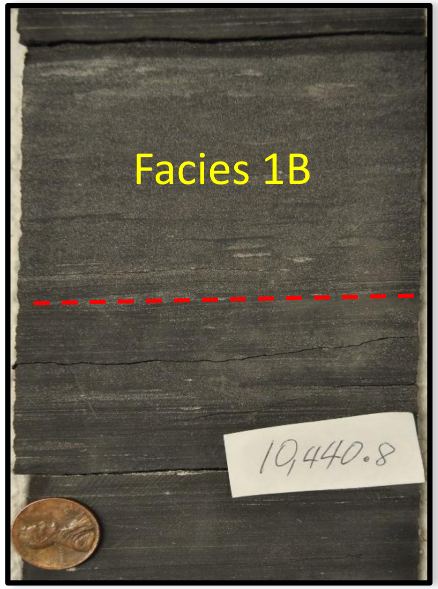


- **Subdivided cores into distinct sedimentary facies**
  - Initially divided: color, sedimentary structures, bioturbation
  - Enhance with XRD analysis: calcite content, TOC
- **Recorded:**
  - Color
  - The top and bottom depths of each facies
  - Sedimentary features
  - Nature of upper and lower contacts
  - Other features (faults, fractures, etc).
- **Incorporated other data**
  - Biostratigraphy
  - XRD
  - Rock mechanical data

Facies Types (1)

Core diameters ~3.5” (~9 cm)





1A/2A

Description:
- Black to dark gray
- Thin laminations in 2A

Composition
- TOC = 3-8% (highest)
- Calcite = 40-70%

Interpretation
- Lowest energy suspension deposits
- Facies 2A occasional low energy ripples

1B

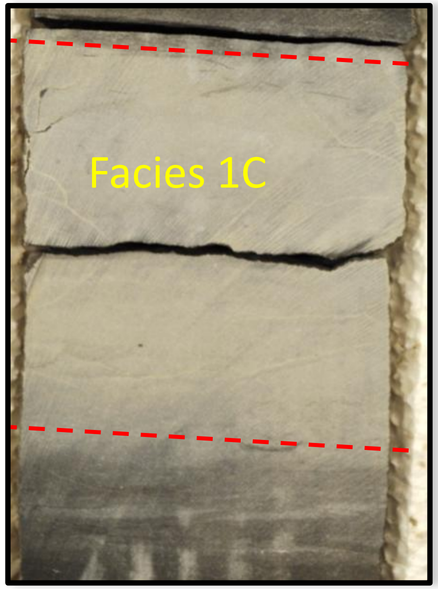
Description:
- Dark gray
- Thin laminations, bioturbated (BI 2-5)

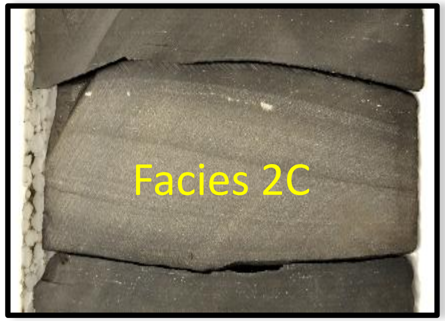
Composition
- TOC = 1-3%
- Calcite = 70-80%

Interpretation
- Suspension to ripple regime deposits
- Oxic to suboxic conditions

Facies Types (2)

Core diameters ~3.5” (~9 cm)





1C

Description:
- Light gray to cream
- Bioturbated (BI 4-5)

Composition
- TOC = < 2%
- Calcite = 80-95%

Interpretation
- Suspension to ripple regime deposits
- Oxic conditions

2B/2C

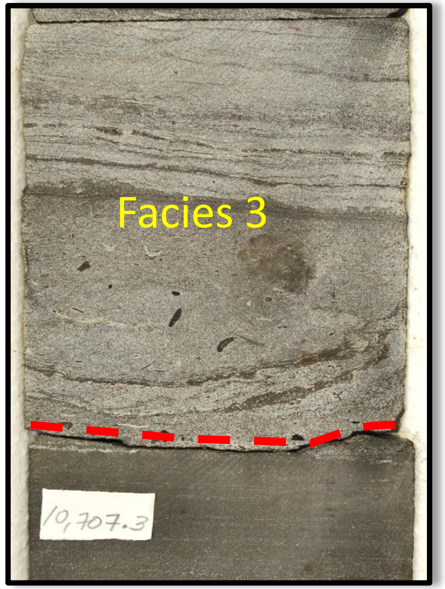
Description:
- Alternating light and dark gray layers
- Cross bedding in 2C

Composition
- TOC: 2B = 1-3%; 2C = < 2%
- Calcite = 70-80%

Interpretation
- Variable ripple regime conditions
- Alternating suspension-traction deposition

Facies Types (3)

Core diameters ~3.5” (~9 cm)



3

Description:
- Light gray
- Horizontal and inclined laminations
- Local hummock-swale features

Composition
- TOC = < 1%
- Calcite = 80-95% (highest)

Interpretation
- High energy traction deposits – storm/turbiditory

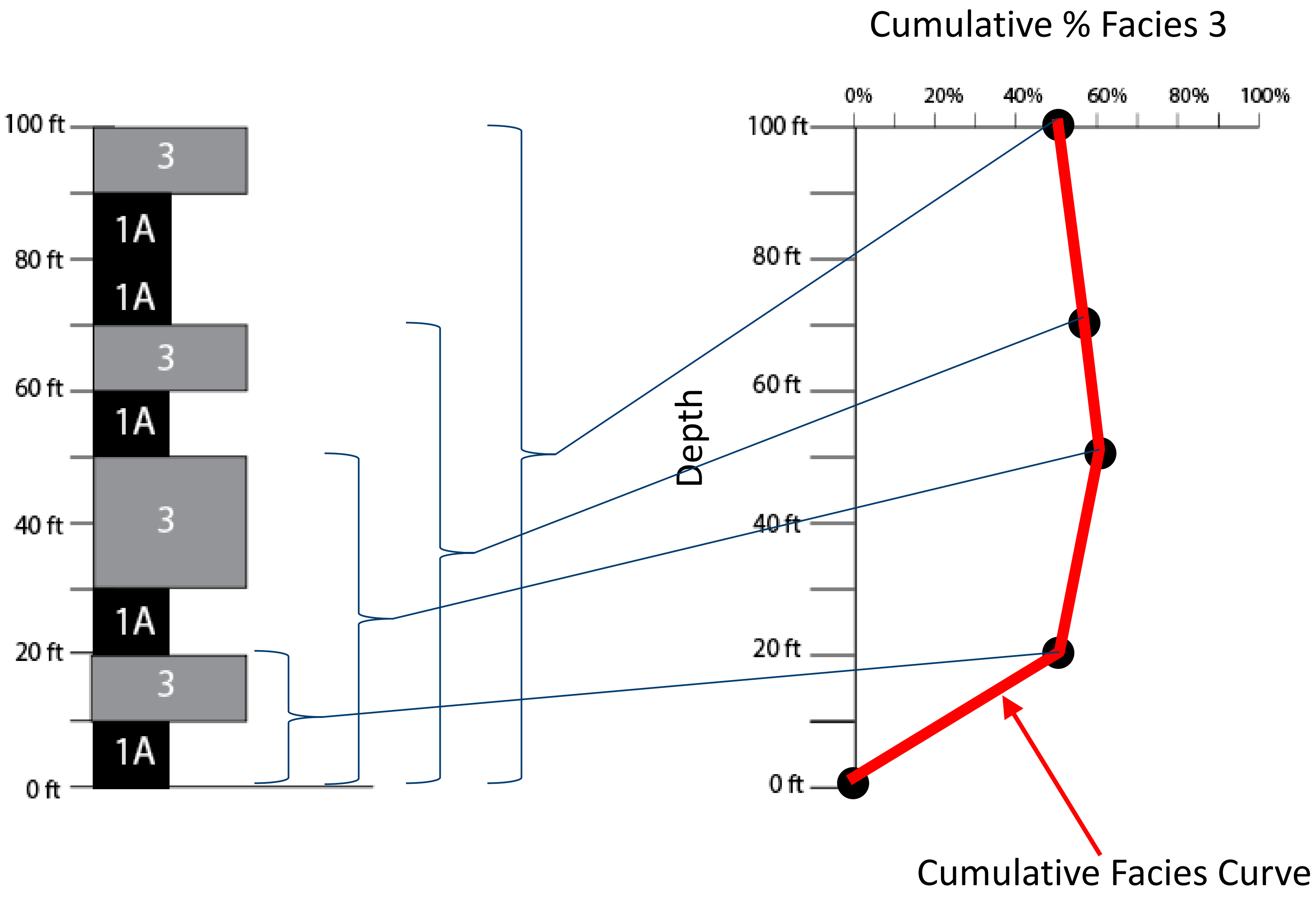
Facies 5/6

Description:
- Dark to light gray
- Convoluted laminae (facies 5)
- Matrix supported clasts (facies 6)

Composition
- Variable composition

Interpretation
- Slumps and debris flow structures

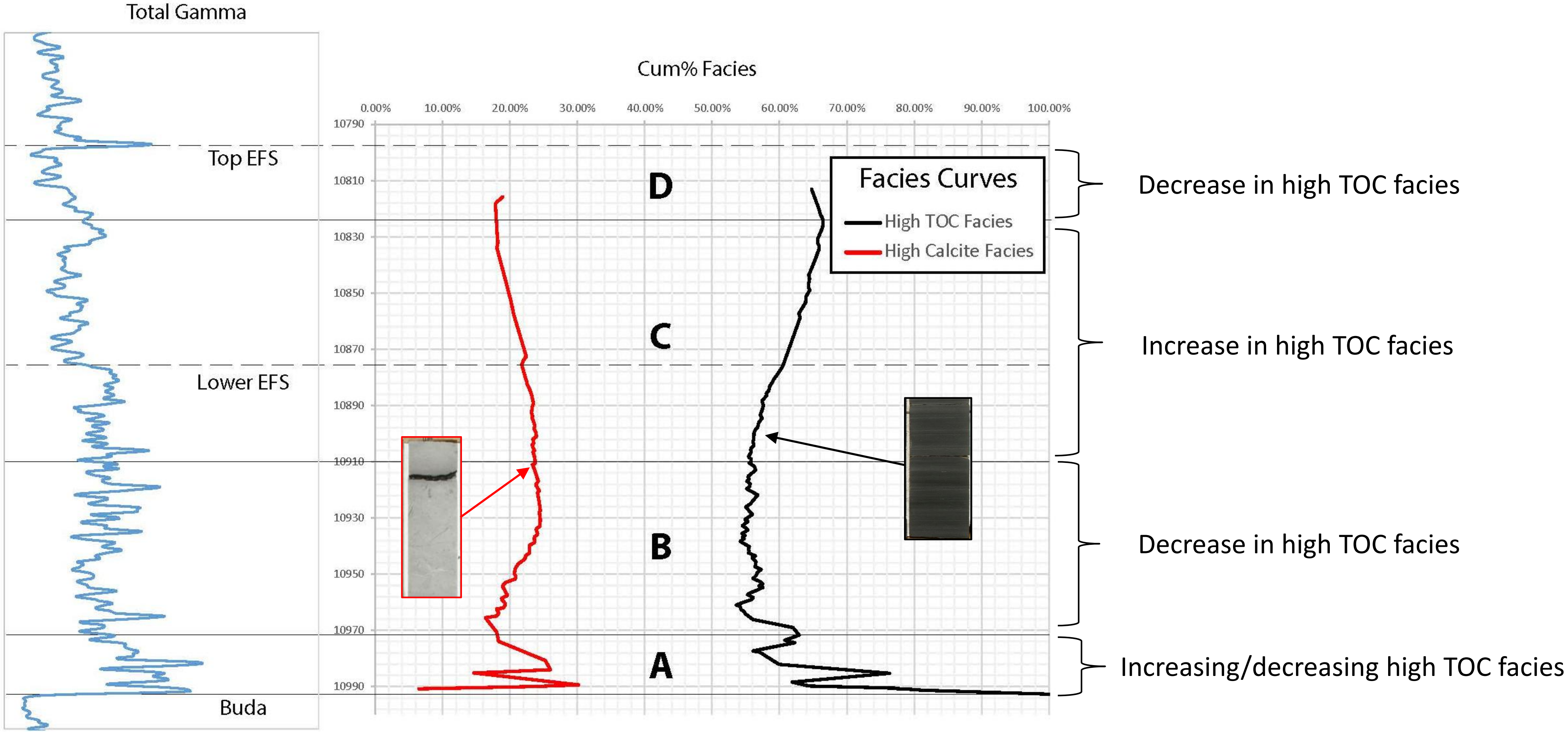
Quantitative Facies Methodology (QFM)



- **QFM is a running net-to-gross calculation**
  - Isolate facies type/group
  - Measure facies thickness over given interval
    - Calculate cumulative %
  - Incrementally expand interval
- **Generate a cumulative percentage curve**
  - Observed changes in facies abundance
    - Increasing cumulative % = higher abundancy
  - Different curves for different facies types.

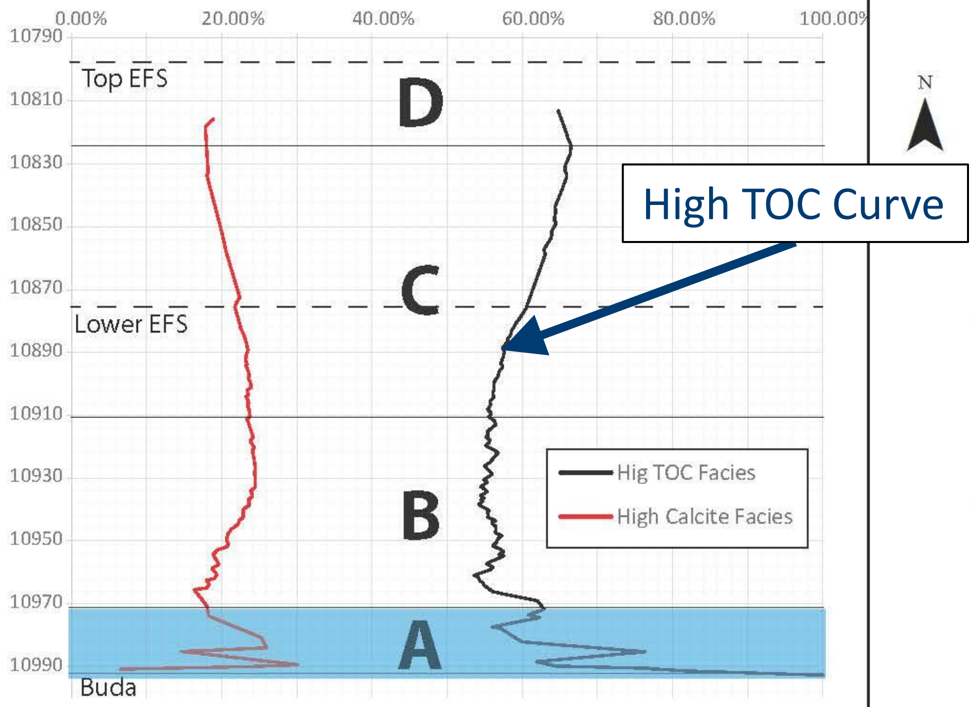
Cumulative Facies Curves: Eagle Ford

- **High TOC Facies:**
  - 1A, 2A
- **High Calcite Facies:**
  - 2C, 3

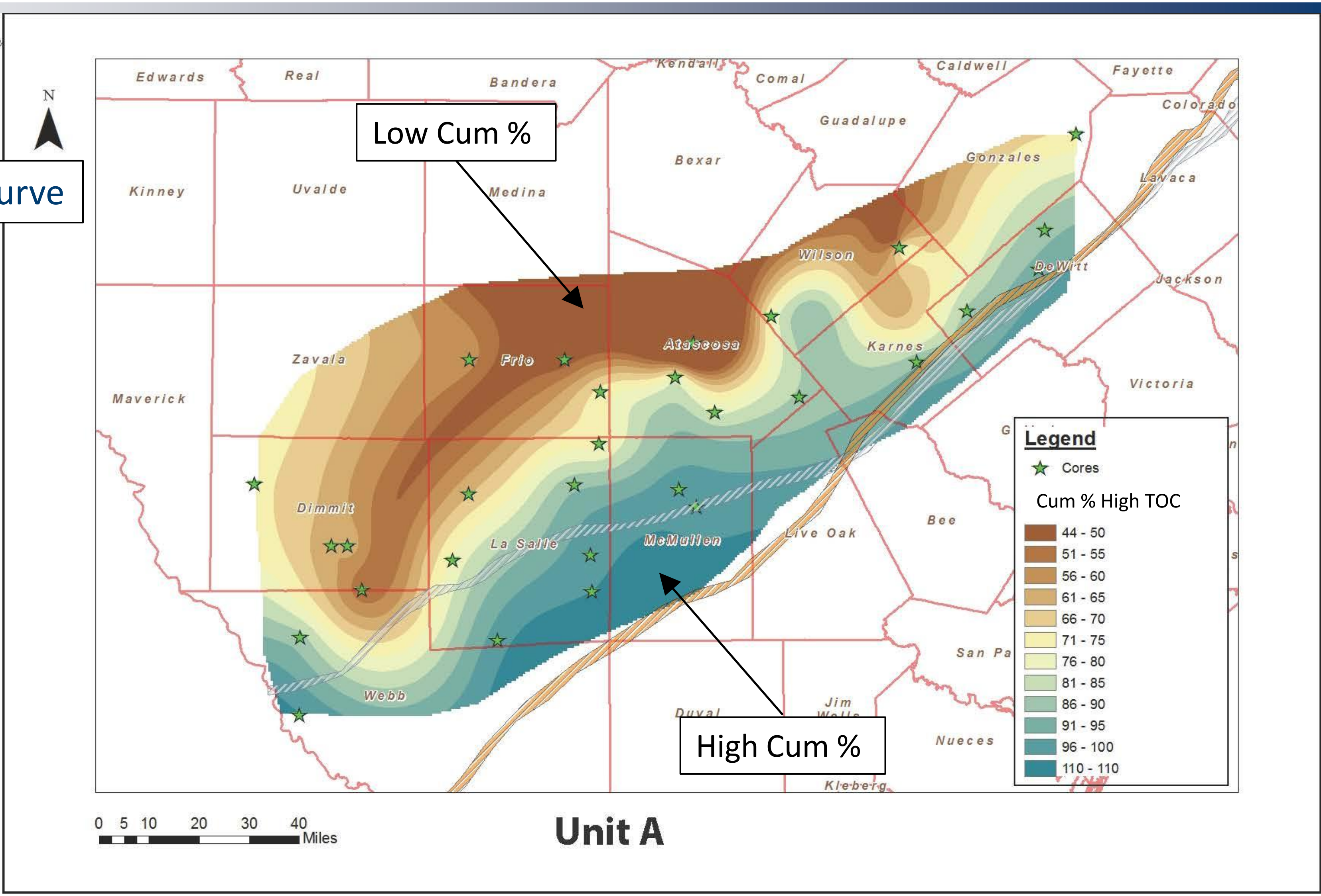


- **Curves represent high calcite facies (red) and high TOC facies (black) – not all facies represented with displayed curves**
- **Curves subdivided by increases and decreases in cumulative %**
- **Pattern of cum% curves are controlled by sea level changes**
- **Cum% curve patterns change across the Eagle Ford Shale**

Eagle Ford Facies Distribution

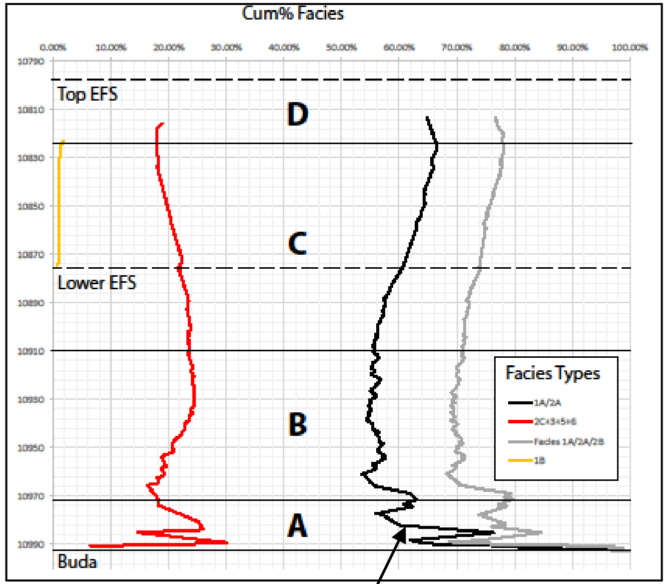


- **Cum % map: high TOC facies**
  - Top of Unit A
  - Brown = Low Cum%
  - Blue = High Cum%
- **Illustrates changes in facies abundancies across EFS**

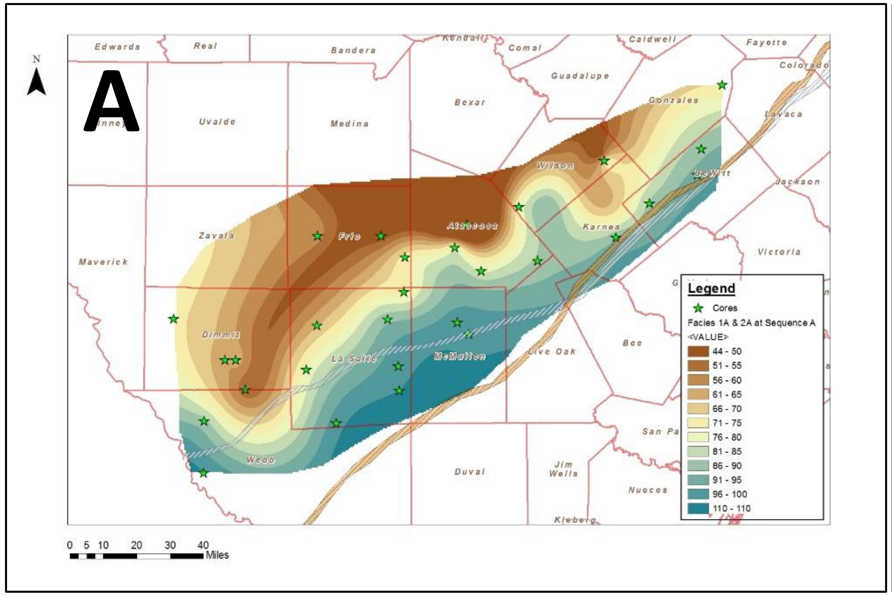


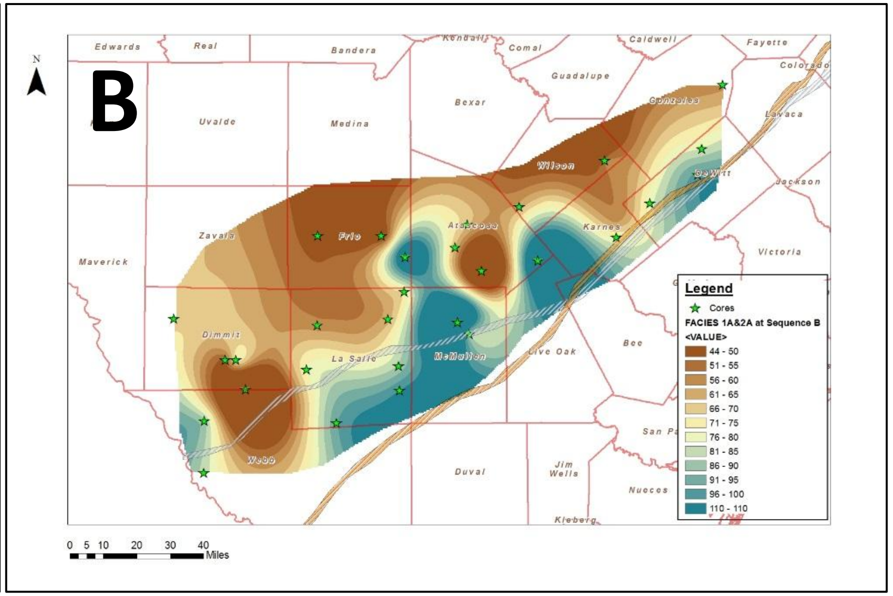
Cumulative Percent: High TOC Facies

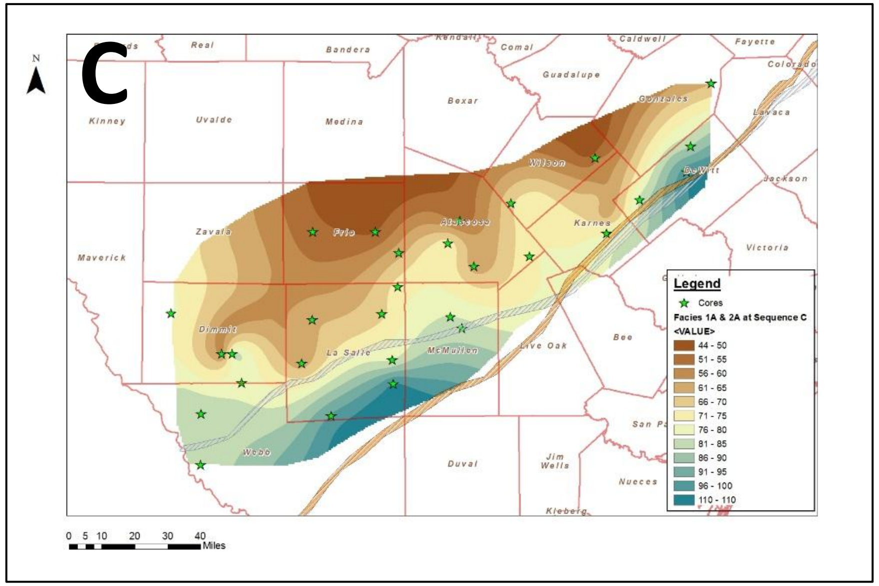
Eagle Ford Facies Distribution (High TOC)

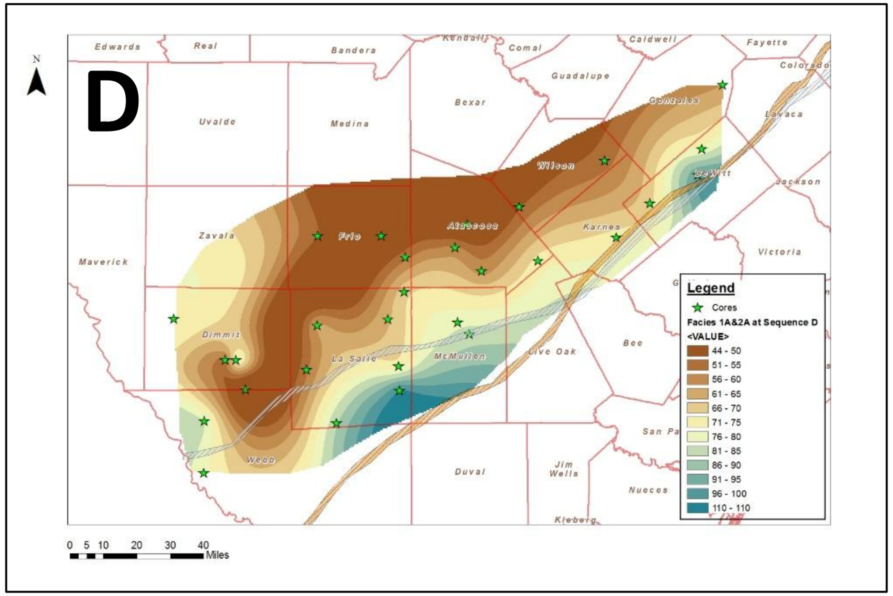


1A/2A Cumulative Facies Percent

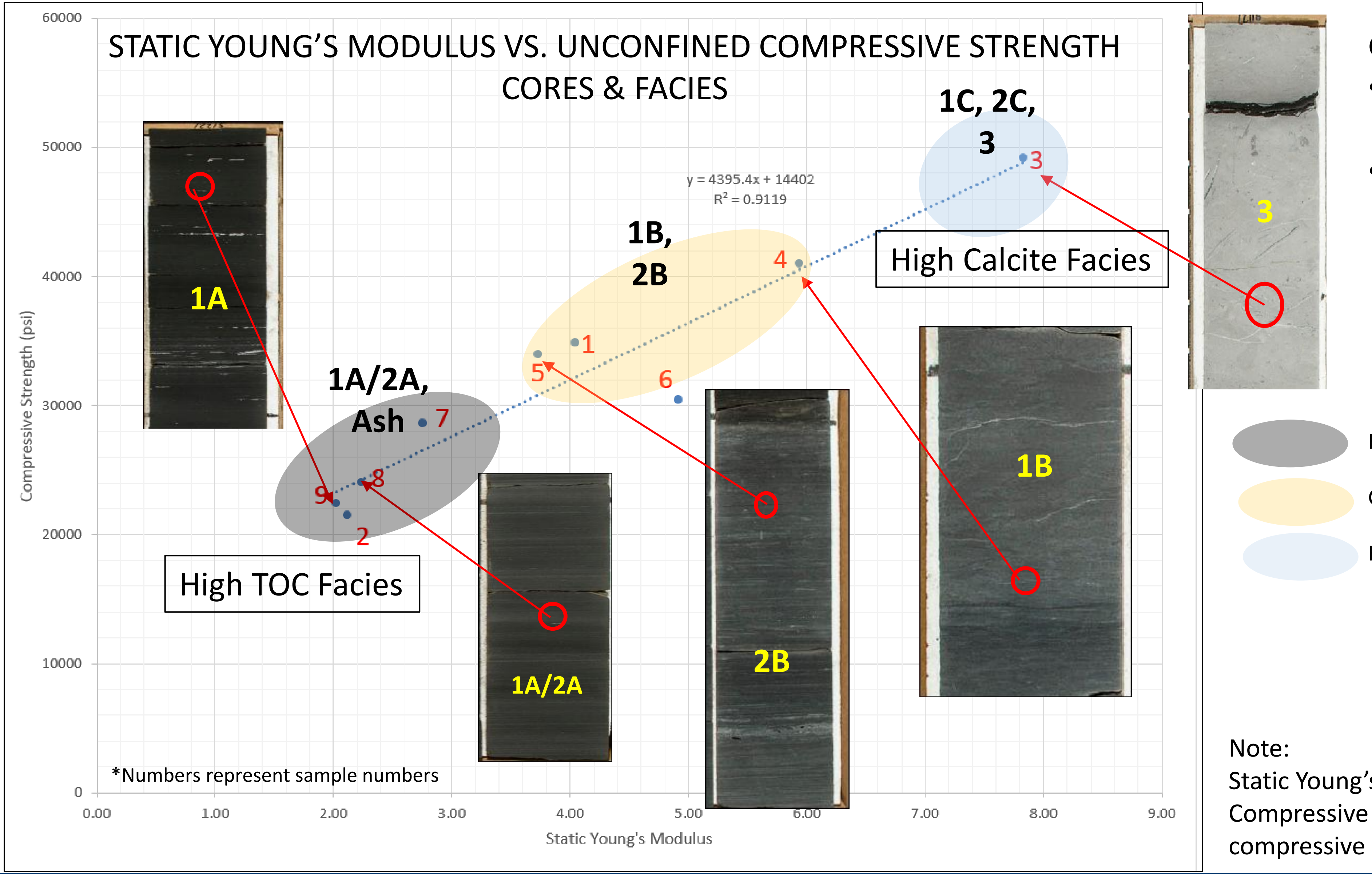








Facies Competency



Grouped Facies:

- **Incompetent**
  - 1A, 2A, 1B, 2B
- **Competent**
  - 1C, 2C, 3
  - 5,6*

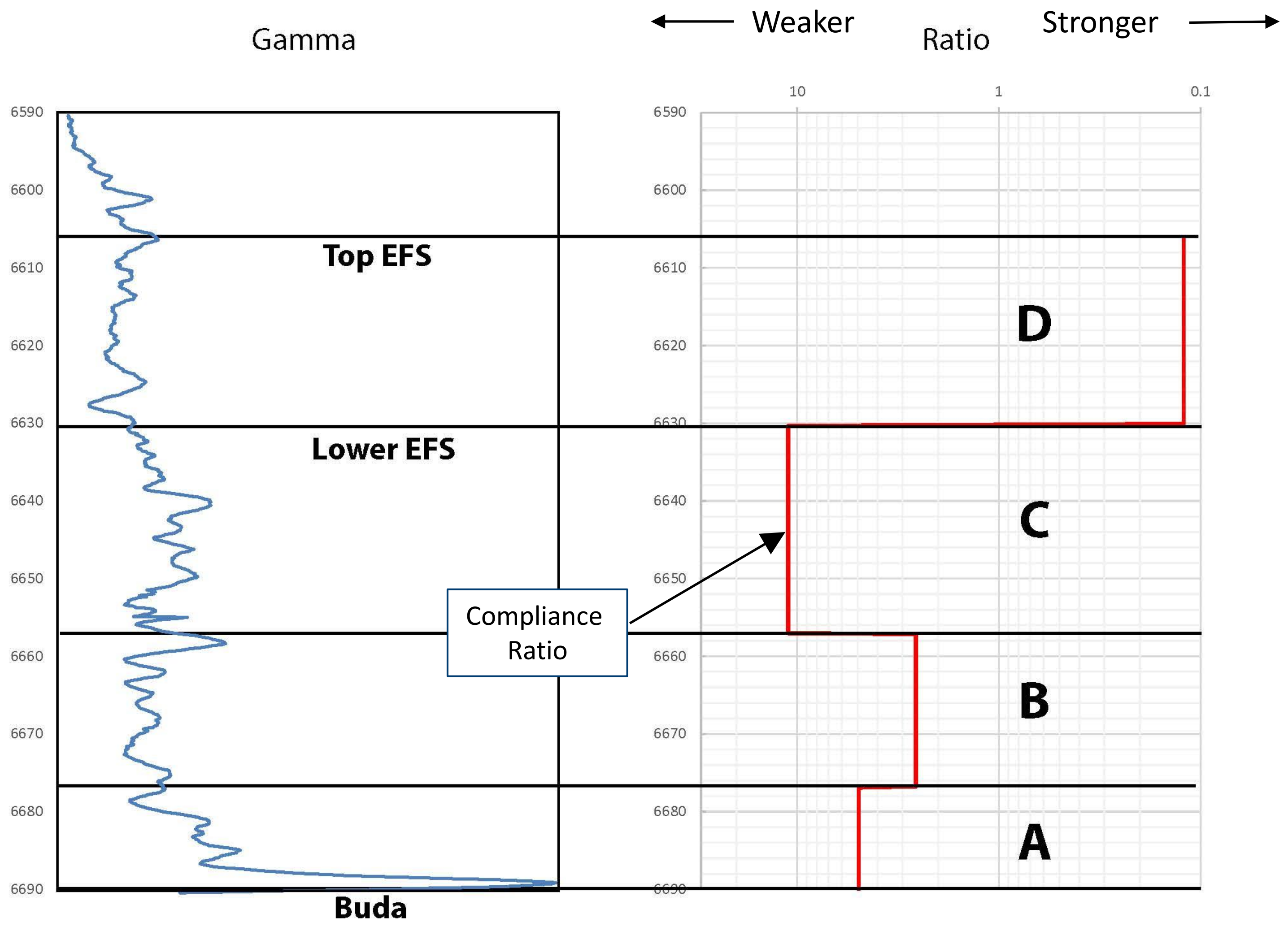
Note:
Static Young's Modulus is x 10^6 psi; whereas, Compressive strength is unconfined compressive strength in psi.

Compliance Ratio

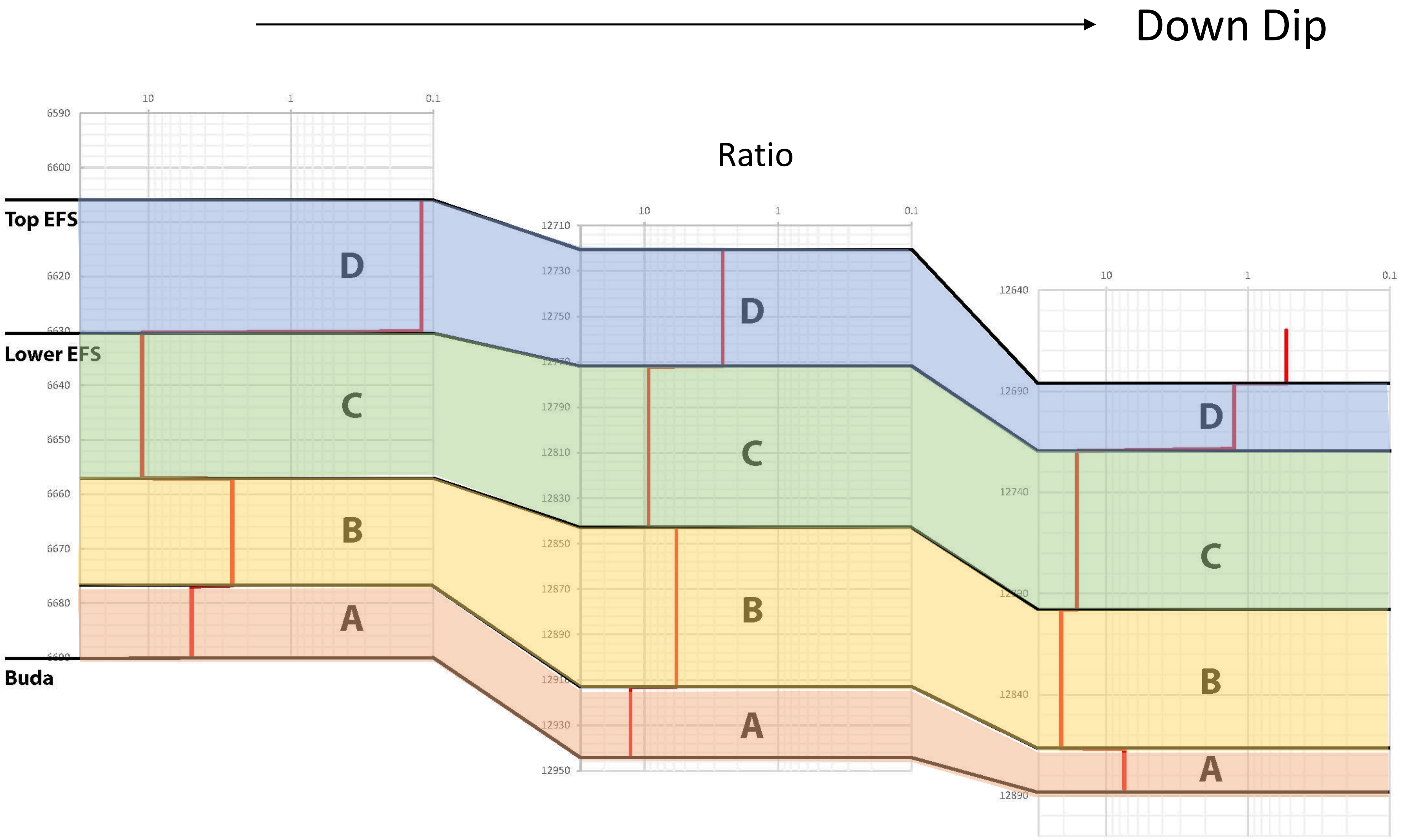
$$\frac{\text{\# Incompetent Beds}}{\text{\# Competent Beds}} = \text{Compliance Ratio}$$

Modified after Ferrell et al. 2007

- **Compliance ratio to understand mechanical nature of sequences**
  - Brittle vs ductile
- **Infer frac behavior**
  - Effectiveness of frac
  - Orientation away from well bore
- **Helps operationally**
  - Properly place Horizontals
  - Guides proper frac design



Incompetent/Competent Ratio Cross-Section



Summary

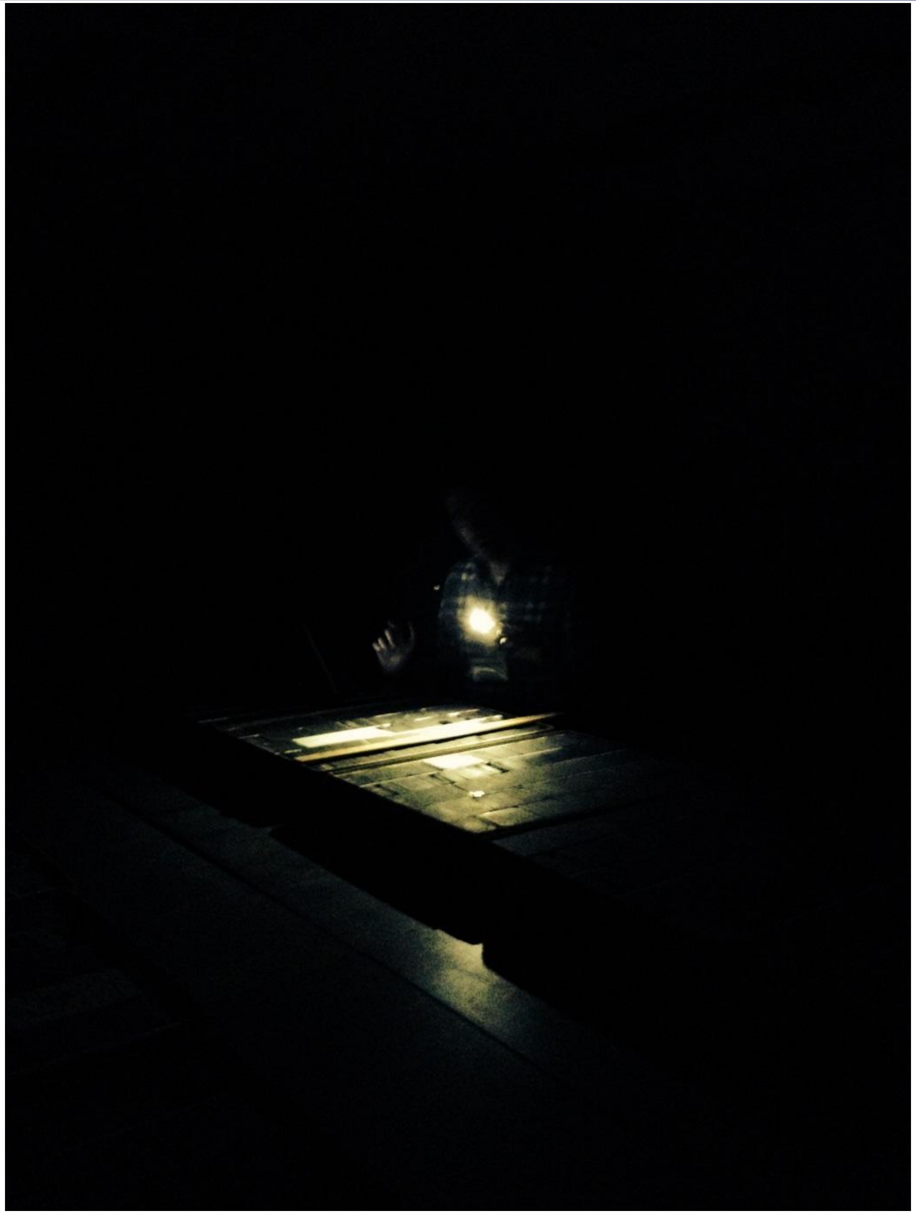
- **Divided Eagle Ford Shale into various litho-facies on the basis of mineralogy and sedimentary features**

- **Utilizing a quantitative facies measurement tool kit we:**
  - 1) Measured net to gross distribution of unique facies per core
  - 2) Grouped facies into as many as four stratigraphic units
  - 3) Mapped facies distribution across the Eagle Ford Shale

- **Measured relative strength of stratigraphic units based on ratio of incompetent and competent facies**

Acknowledgments

- Core Labs – Houston, TX
- Murphy Exploration and Production Company
- Co-Authors



Core Lab™

MURPHY
EXPLORATION & PRODUCTION CO.