Evaluating Petrophysical Variations of Turbidite Depositional Systems with Implications for Enhanced Reservoir Modeling in Ewing Bank 873 (Lobster Field), Gulf of Mexico

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ABSTRACT

Advanced shale distribution analysis was conducted on ten triple combo-logs throughout seven separate deep-water marine reservoirs of varying environments of deposition in Lobster Field of Ewing Bank 873. Conventional and sidewall core photos and data, laser particle sieve analysis, thin section photographs, X–ray diffraction analysis, and scanning electron microscopy were integrated to determine shale type within these reservoirs. By identifying spatial distribution of varying shale type, an enhanced reservoir model may be constructed to aid in reservoir development.

Shale may be distributed in reservoirs in multiple types (laminar, dispersed, and/or structural), which will variably affect reservoir performance. By utilizing high-resolution conventional slabbed core and thin section photographs, intervals which exhibit multiple shale types may be flagged and analyzed. By doing this, a more accurate reservoir model will be constructed that will aid in the evaluation and allow for a better understanding of these mature reservoirs.

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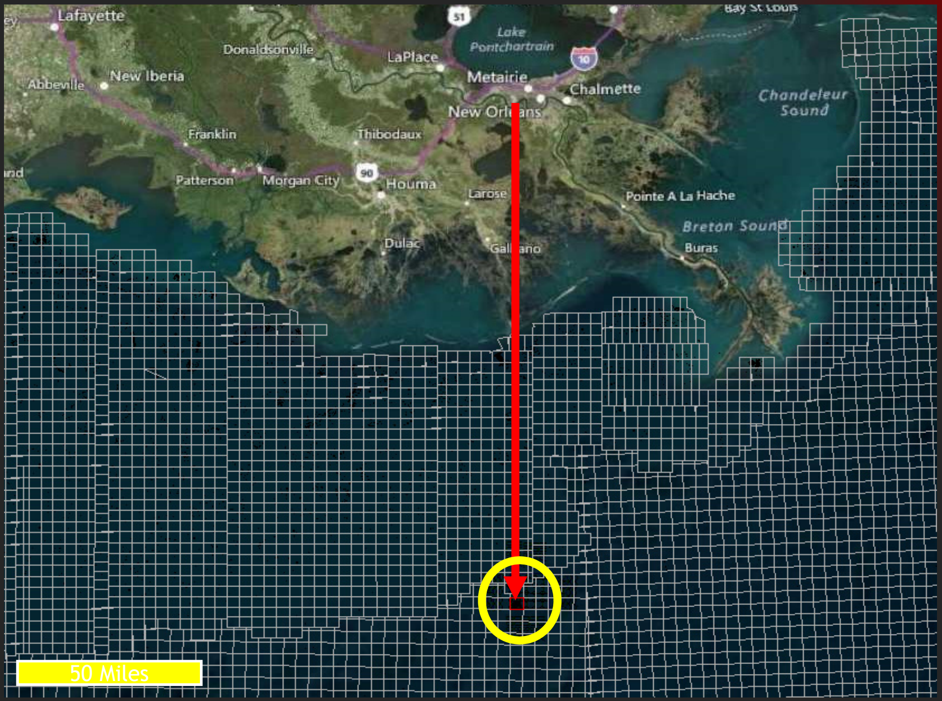
Outline

- Introduction and Project Overview
- Case Study
  - Field Background and Geologic Evolution
  - Field Maps, Reservoir Distribution, and Spatial Data Distribution of Data
  - Methodology
  - Application of Vsh_T Log Curve Analysis and Facies Analysis
  - Three-Type Shale Models in Cored Intervals
- Conclusions

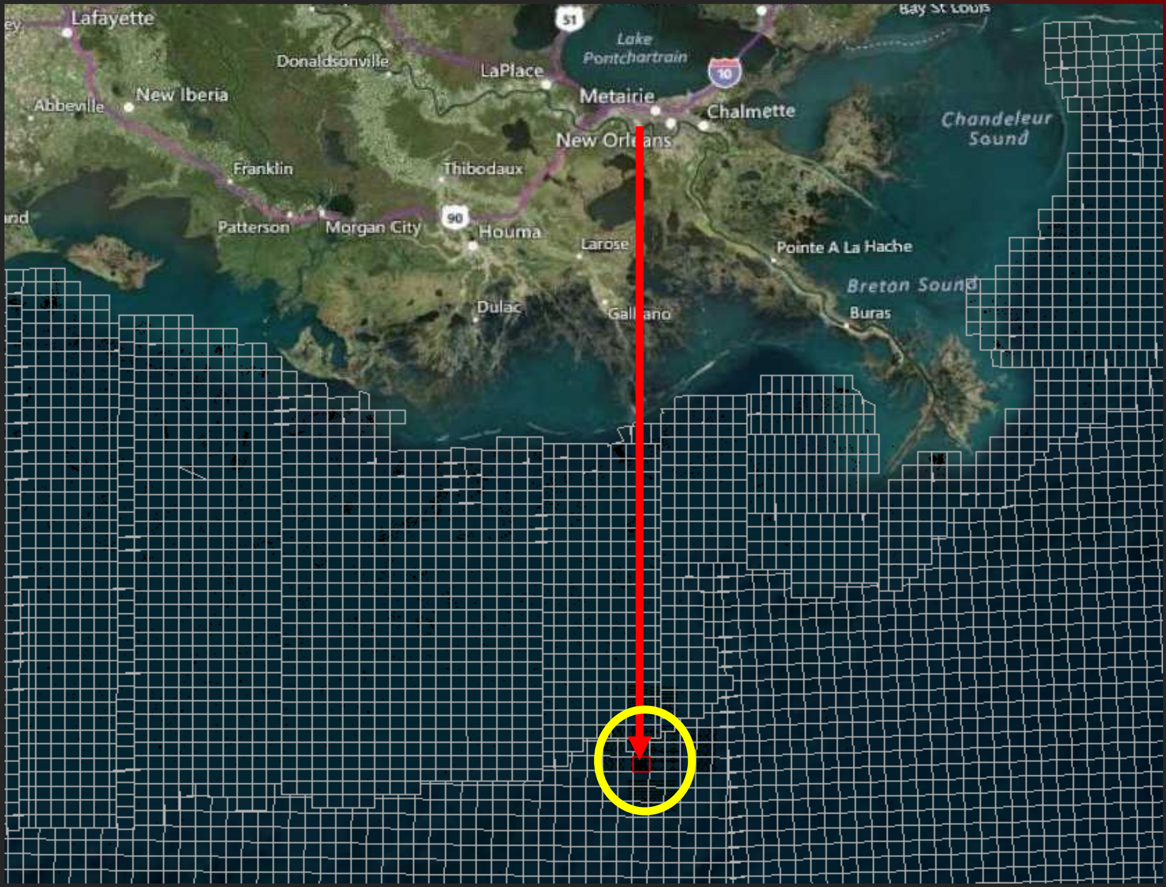
Introduction

- <u>Project Overview:</u>
  - To characterize reservoir systems within EW 873 (Lobster) Field.
  - Turbidite depositional system with unconfined distributary lobes and confined channel-levee systems.
  - Common shale distribution analysis yields optimistic results
  - Refined analysis yields better understanding of reservoir properties



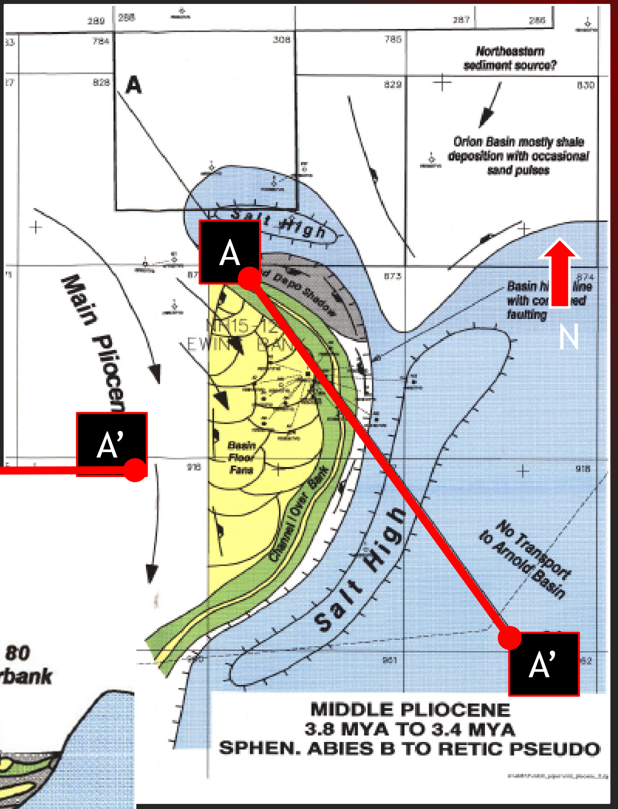
Field Background and Geologic Evolution

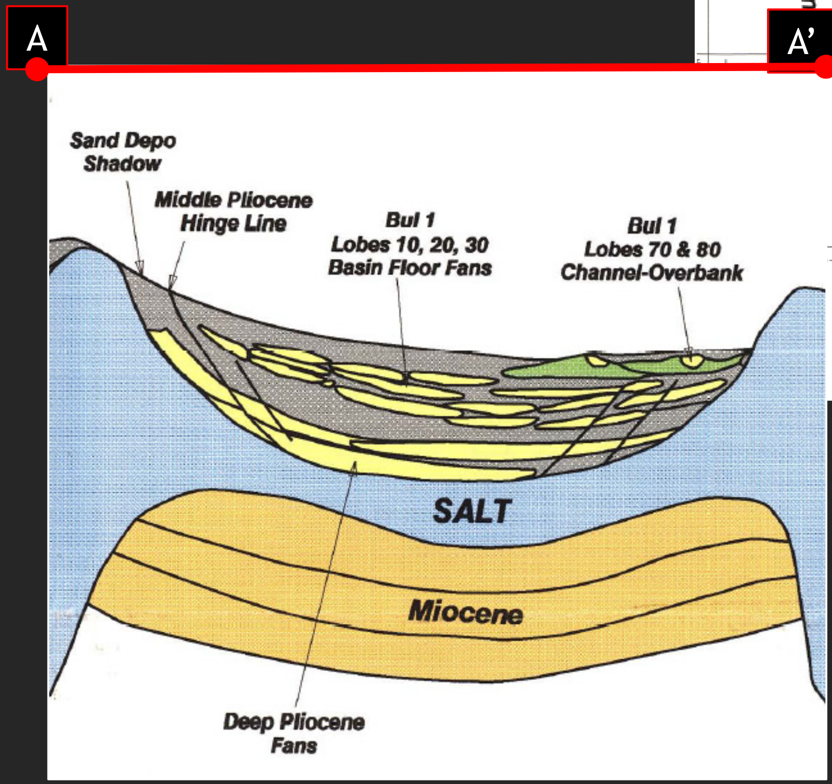
- EW 873 (Lobster Field) is located in 780' of water approximately 130 miles south of New Orleans, LA



Field Background and Geologic Evolution

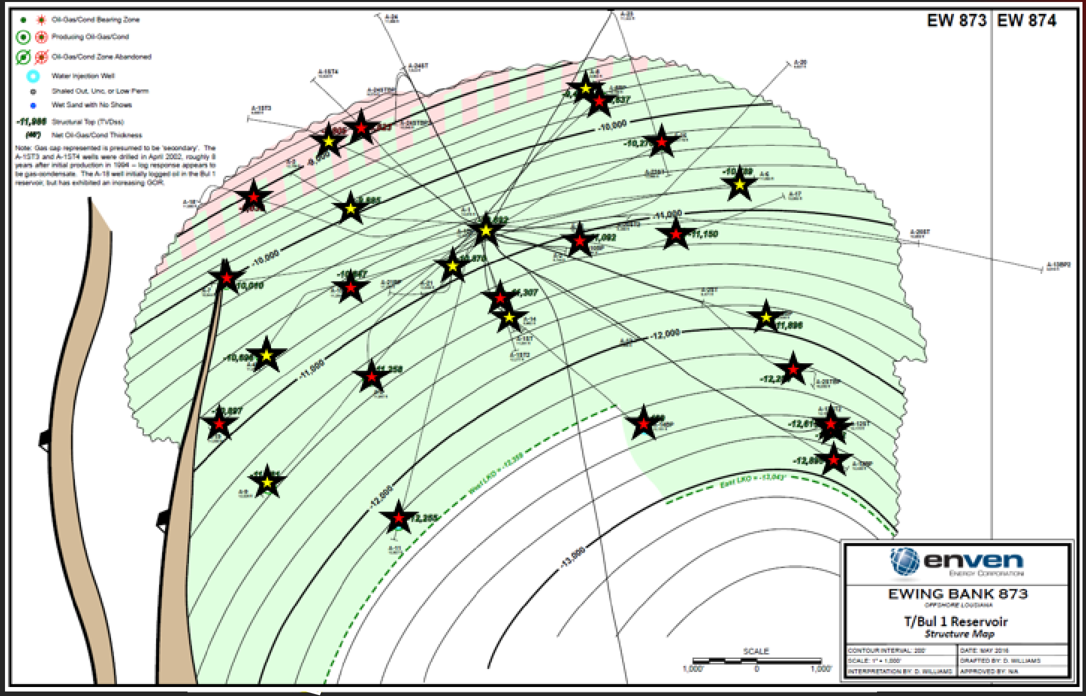
- Reservoirs were deposited during the middle Pliocene (3.8 Ma to 3.4 Ma)
- Reservoirs include:
  - Unconfined Distributary Lobes
  - Channel-Levee Depositional Systems





Spatial Distribution of Data

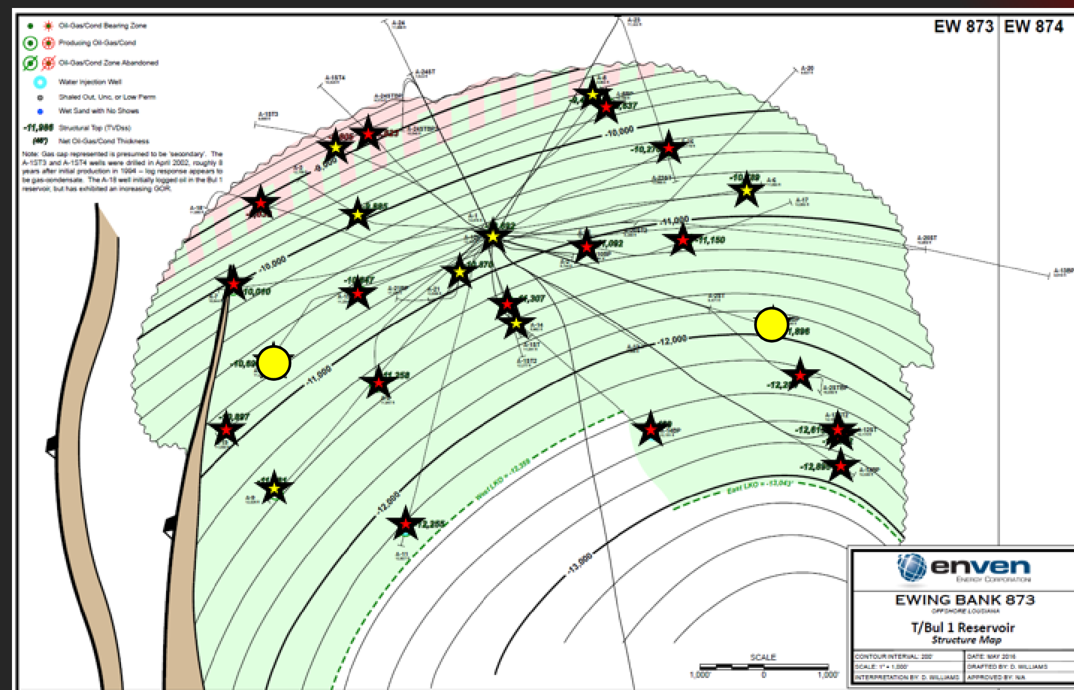
- Data includes logs from 27 boreholes
  - 10 Triple Combo Logs (Yellow)
  - 17 GR-Resistivity Logs (Red)



Courtesy of Enven (Interna

Spatial Distribution of Data

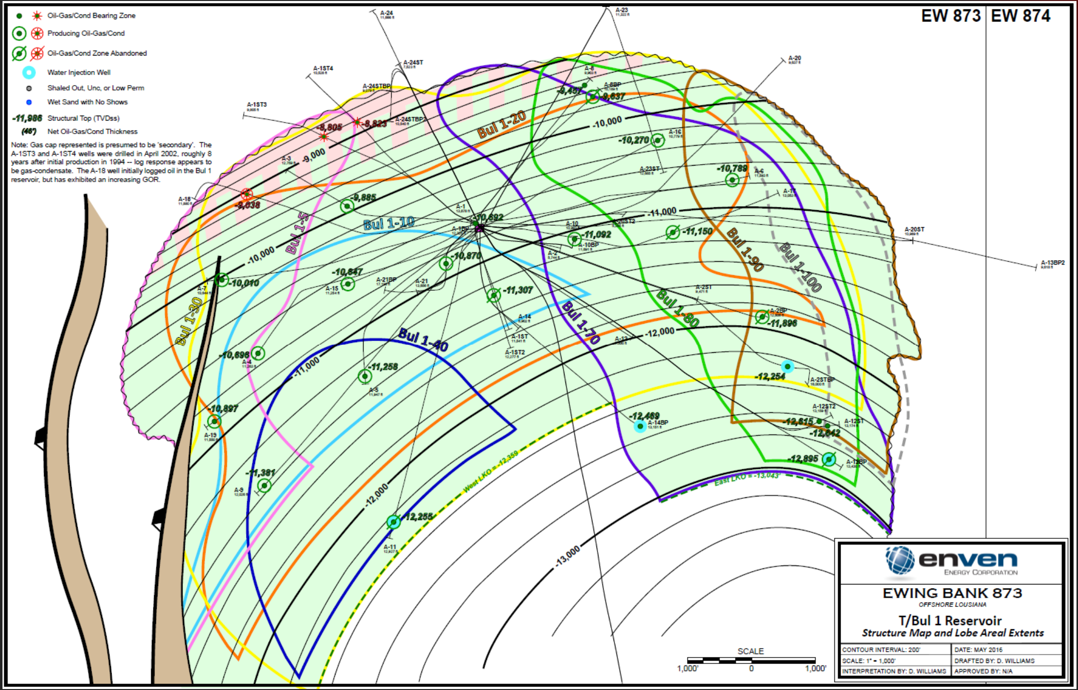
- Data includes logs from 27 boreholes
  - 10 Triple Combo Logs (Yellow)
  - 17 GR-Resistivity Logs (Red)
- Conventional Core in A002 & A004
  - High resolution core images and thin sections



Courtesy of Enven (Interna

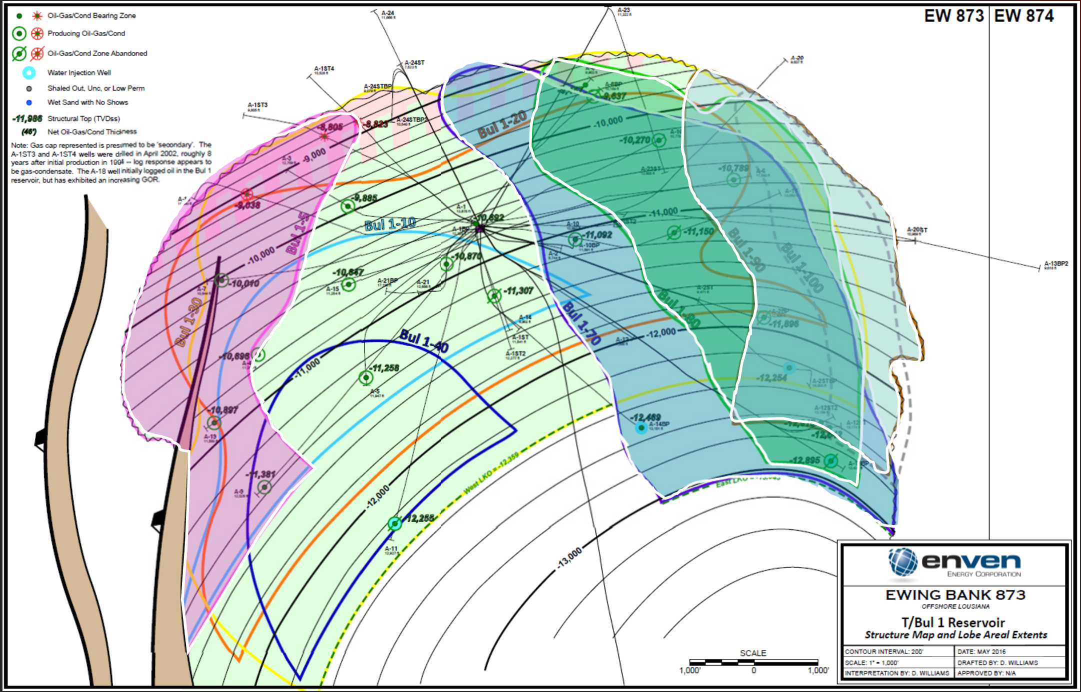
Field Maps and Reservoir Distribution

- Reservoirs were deposited during the middle Pliocene (3.8 Ma to 3.4 Ma)
- EW 873 exhibits stacked 8 reservoirs



Field Maps and Reservoir Distribution

- Reservoirs were deposited during the middle Pliocene (3.8 Ma to 3.4 Ma)
- EW 873 exhibits stacked 8 reservoirs
  - 4 Channel-Levee Systems
  - 4 Unconfined Distributary Lobes



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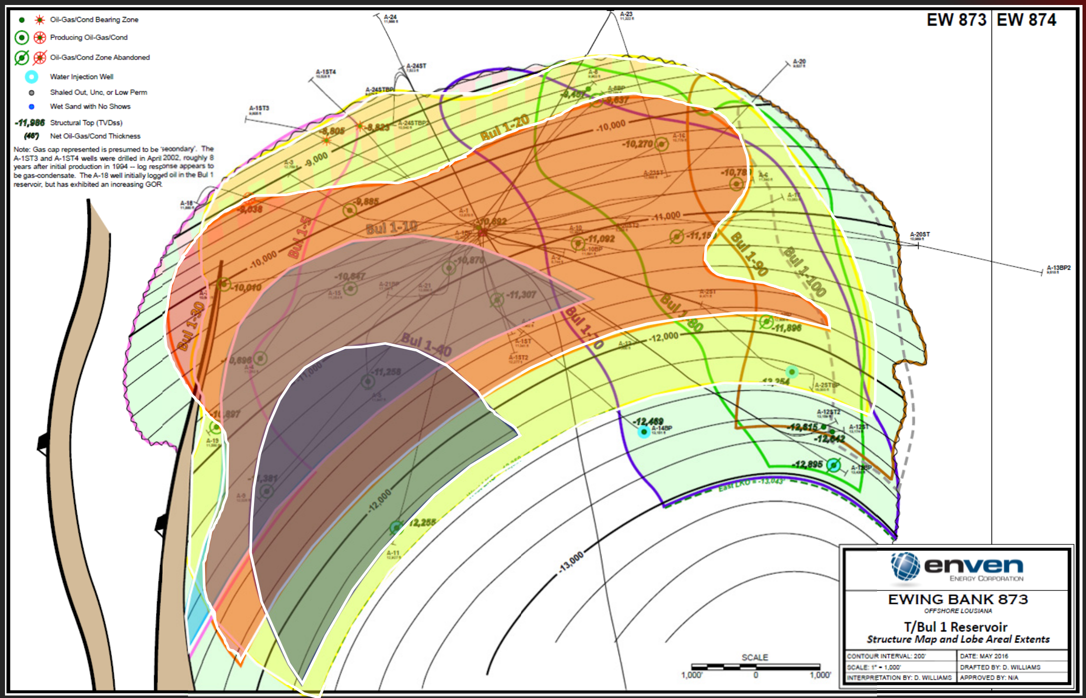

Courtesy of Enven (Interna

Methodology

- **Digitized well data from 27 wells**
- **Calculated Vsh using GR log and ND logs**

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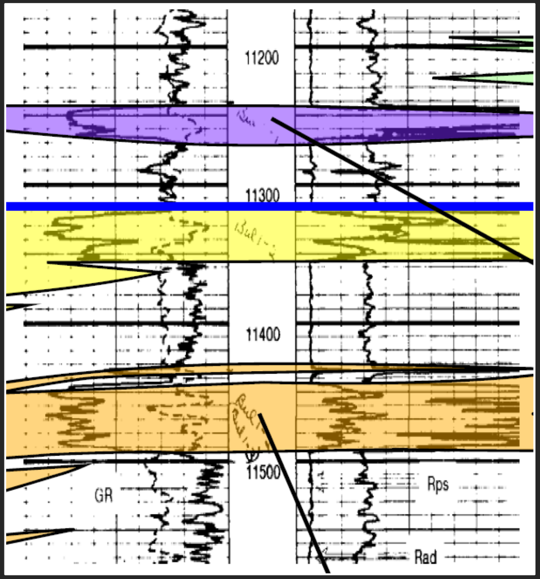

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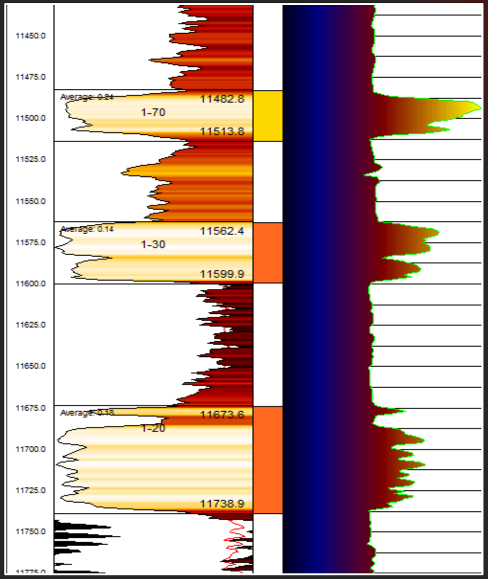
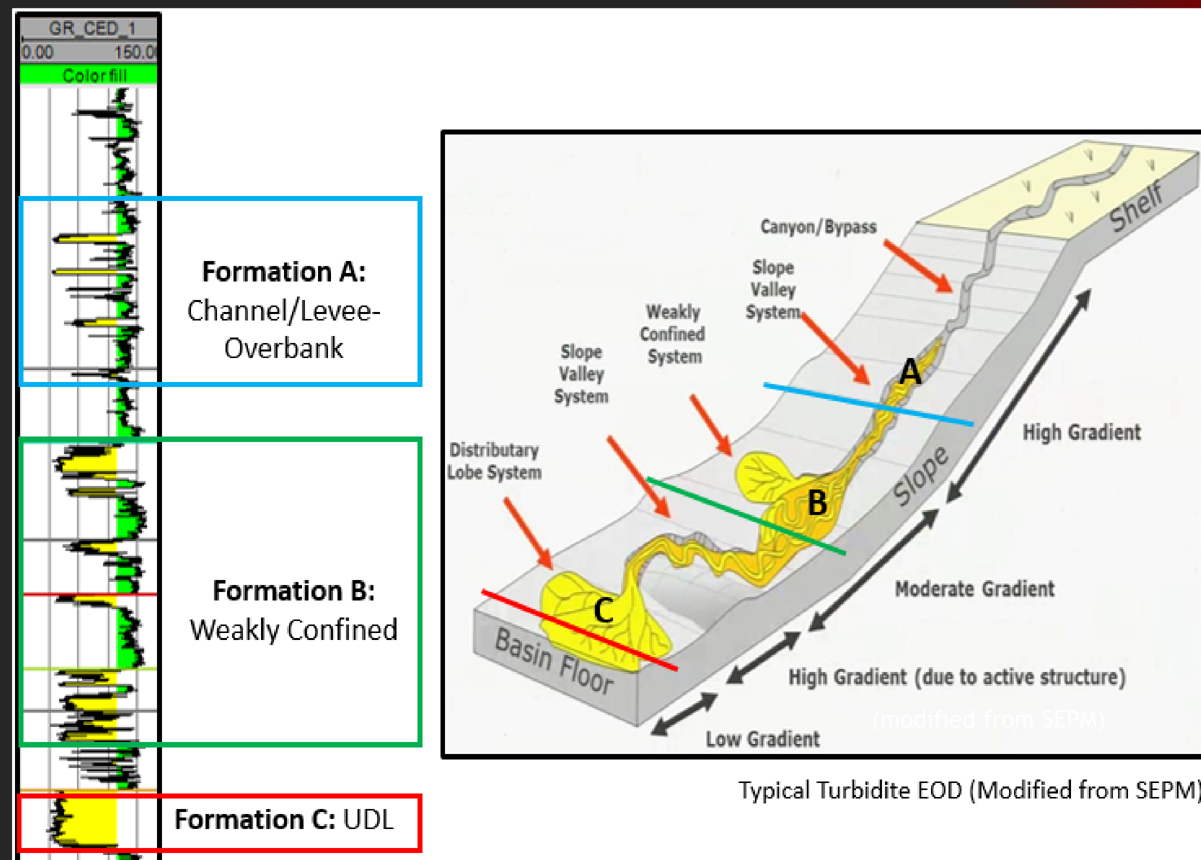


Methodology

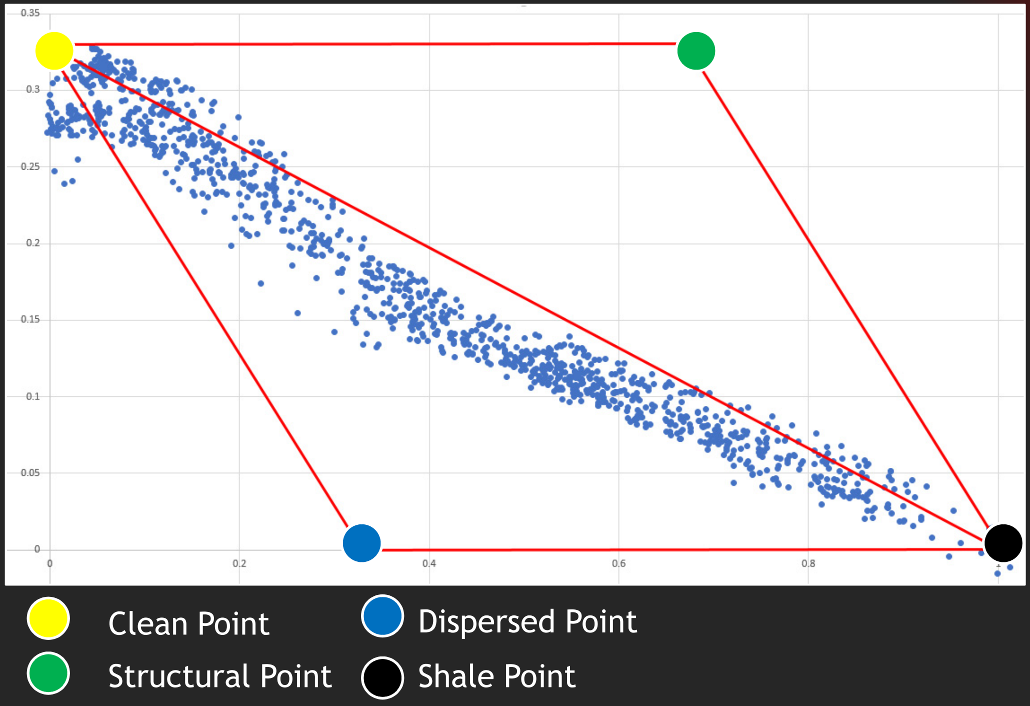
- Digitized well data from 27 wells
- Calculated IGR and Vsh(STB)
- **Evaluated EOD using VshT and facies analysis**



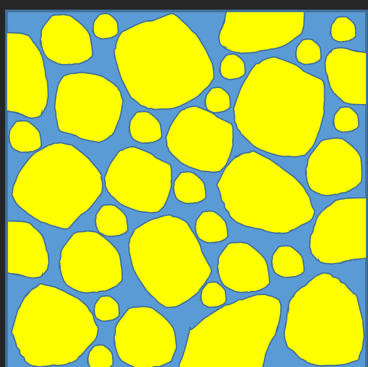
Typical Turbidite EOD (Modified from SEPM)

Methodology

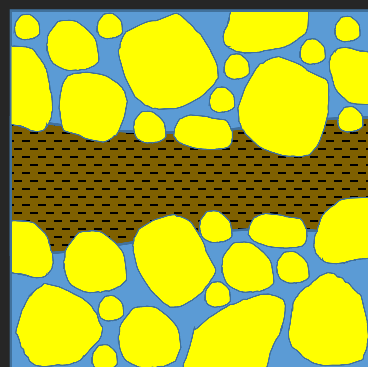
- Digitized well data from 27 wells
- Calculated IGR and Vsh(STB)
- Evaluated EOD using VshT and facies analysis
- **Performed shale distribution analysis**



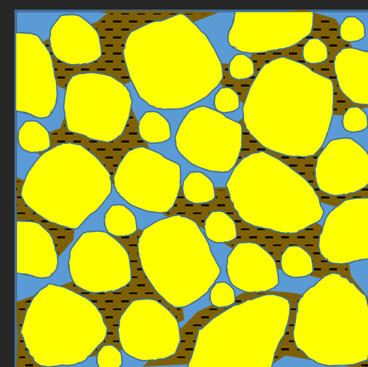
Shale Distribution Types



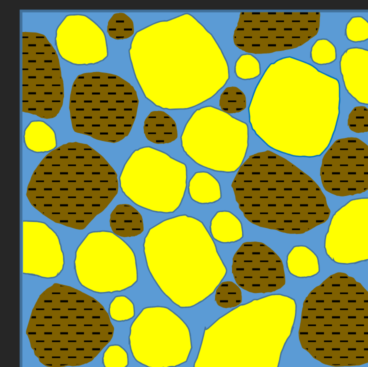
Clean Sandstone



Laminar Shale



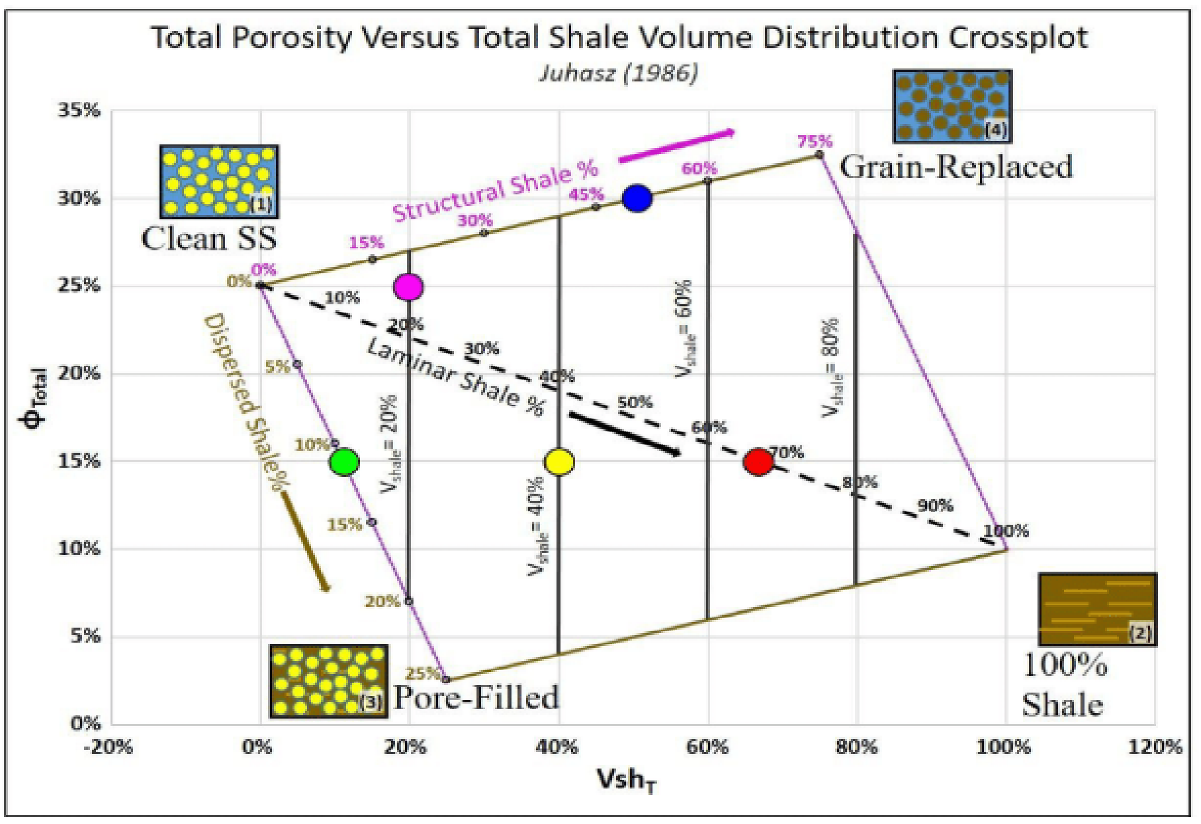
Dispersed Shale



Structural Shale

Shale Distribution Theory and Analysis

- Evaluation of the Vsh curve is a critical step to ensuring further petrophysical work is accurate
- In 1975, Thomas and Stieber identified and classified three types of shale
- In 1986, Juhasz developed a cross-plot tool to distinguish shale types in reservoirs (Φt and Φe vs VshGR)
- Research group at UL-Lafayette has expanded analytical techniques



Thomas-Stieber (1975), Juhasz (1986), McIntosh (2017)

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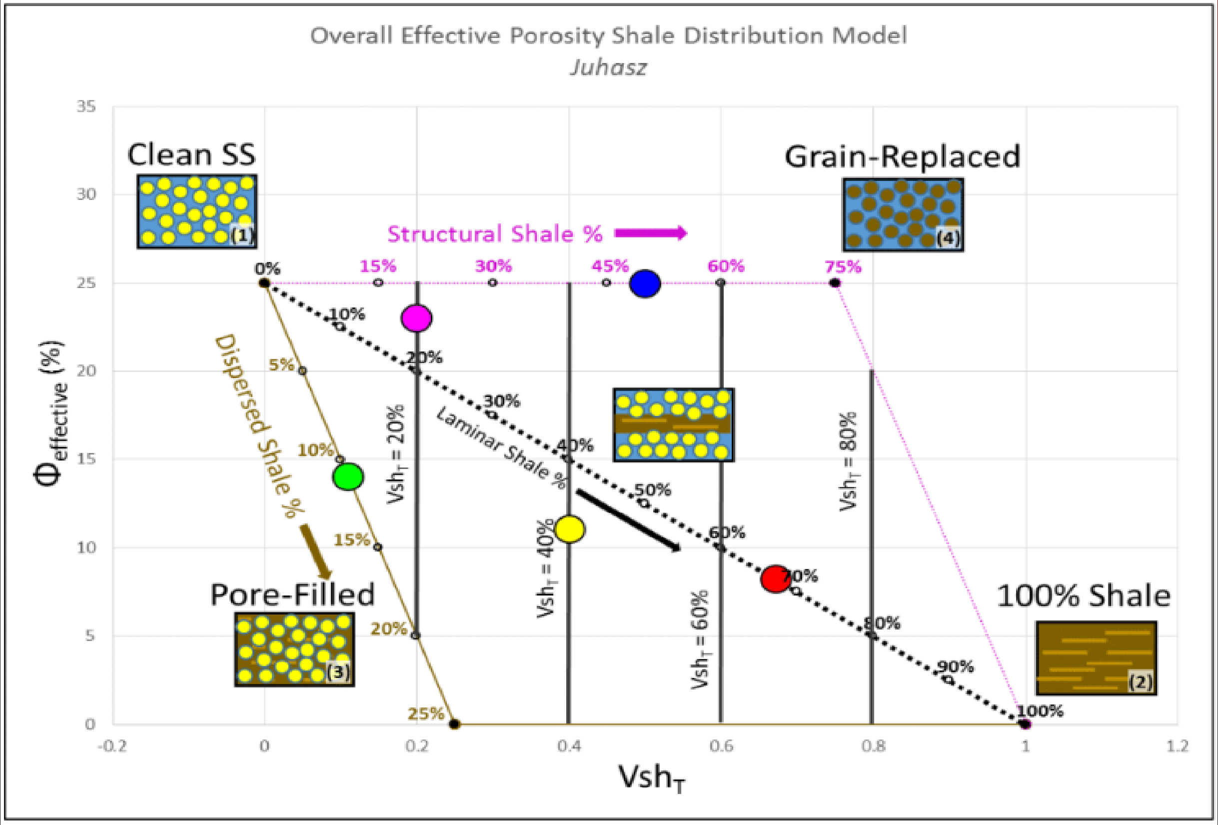
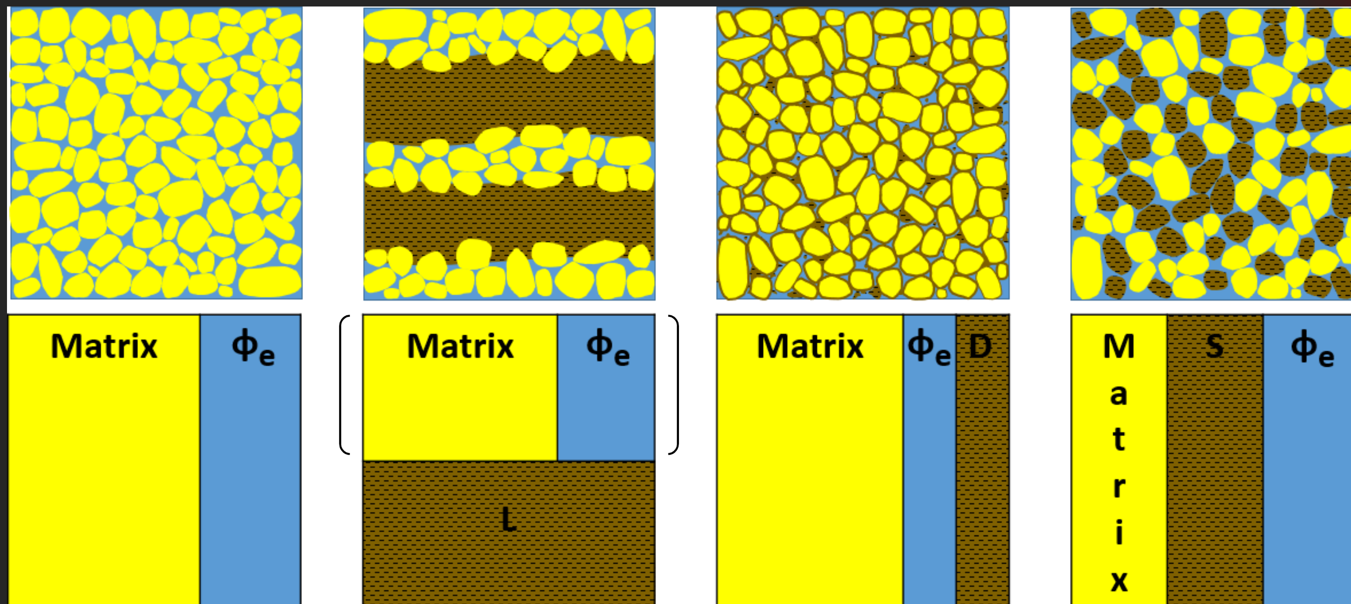
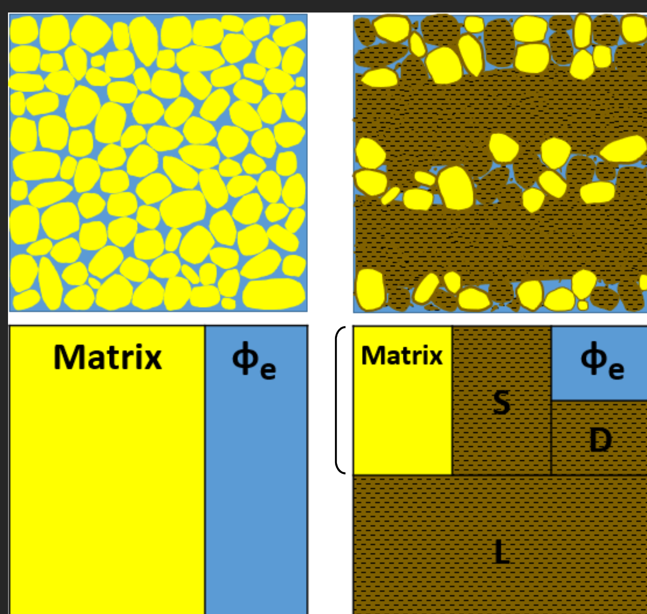


Juhasz (1986), McIntosh (2017), Ferguson (2018)

Shale Distribution Theory and Analysis

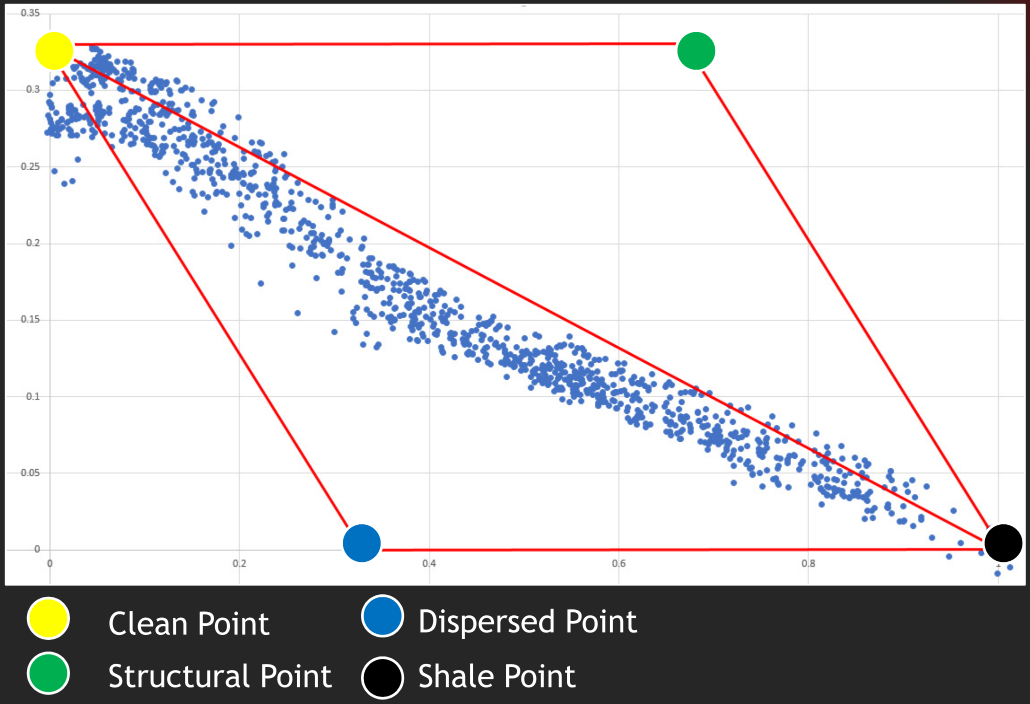




(Ferguson et al., 2018)

Methodology

- Digitized well data from 27 wells
- Calculated IGR and Vsh(STB)
- Evaluated EOD using VshT and 1D sequence stratigraphy analysis
- **Performed shale distribution analysis**
  - **Construct Φe rhombus for each well**
  - **Shale Distribution Mathematical Analysis**



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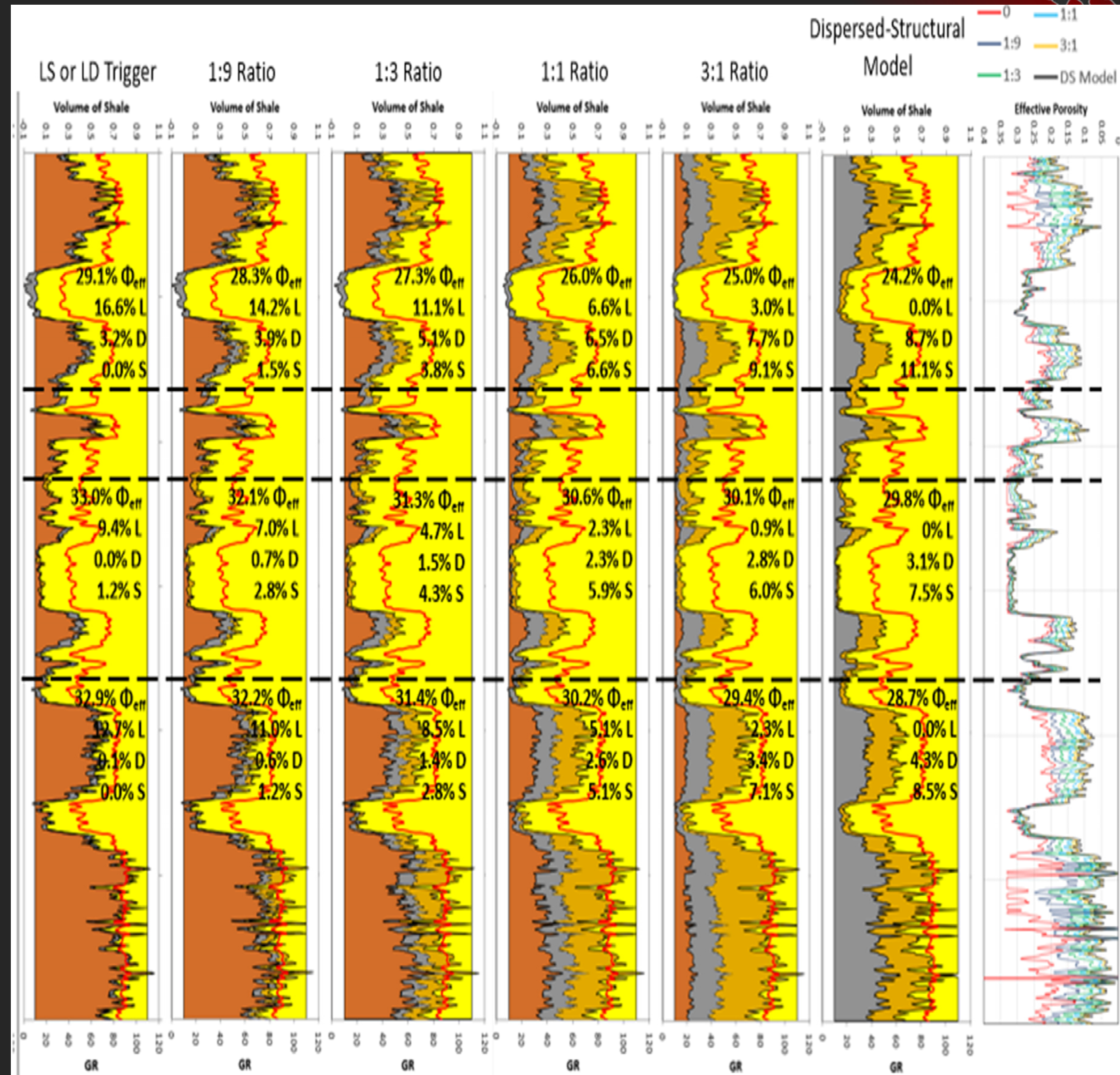
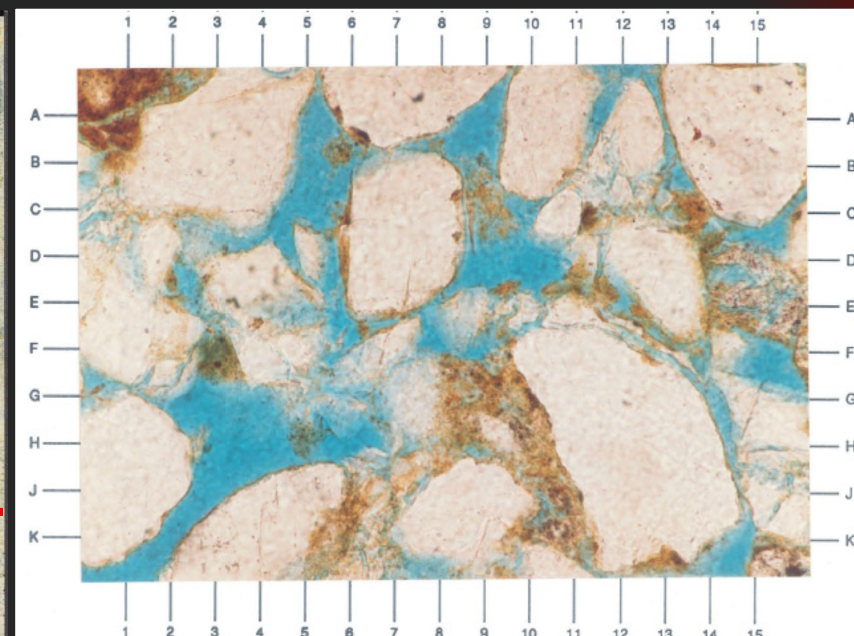
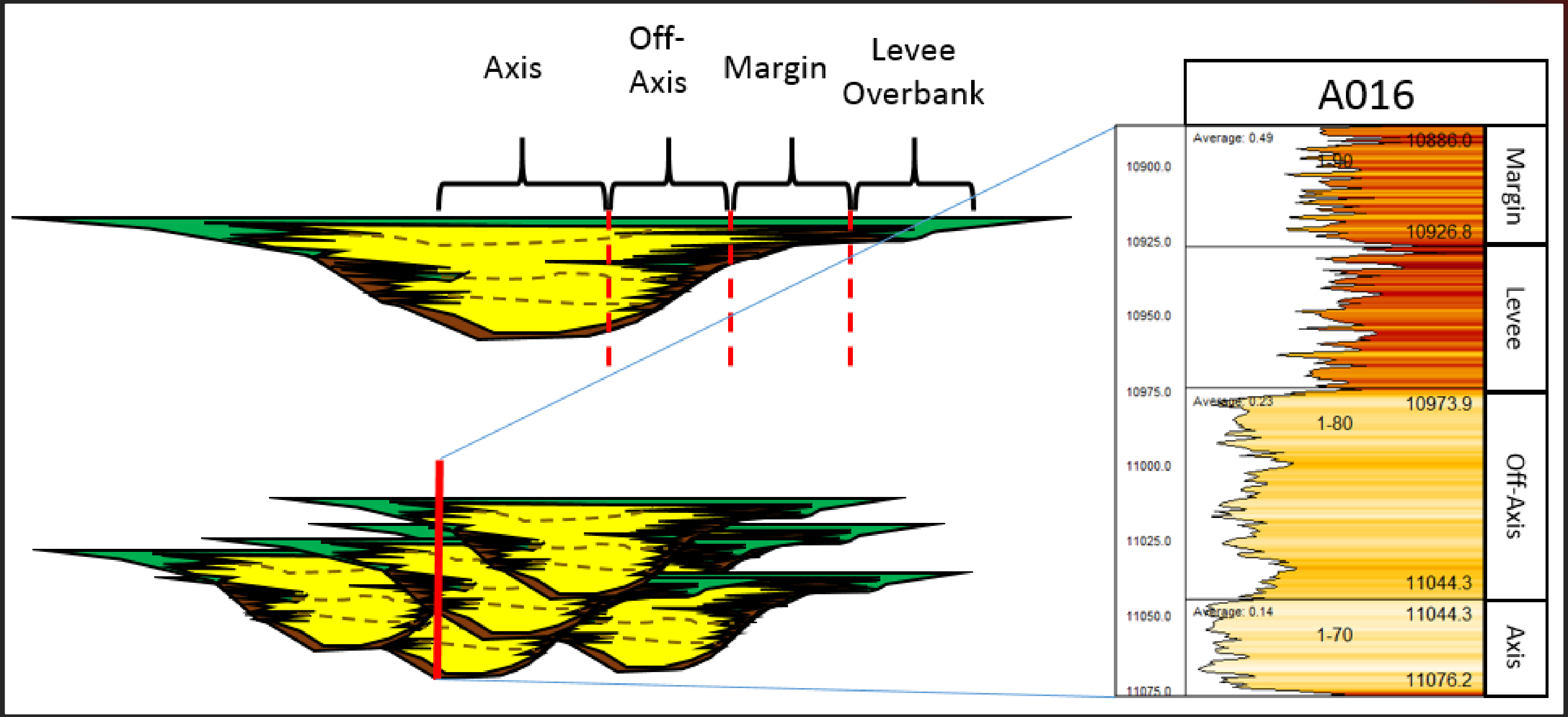


Methodology

- Digitized well data from 27 wells
- Calculated IGR and Vsh(STB)
- Evaluate EOD using VshT and 1D sequence stratigraphy analysis
- Performed shale distribution analysis
- **Compared data point locations to thin sections and core photographs**
  - **Able to constrain model range for ratio and Φe analysis**



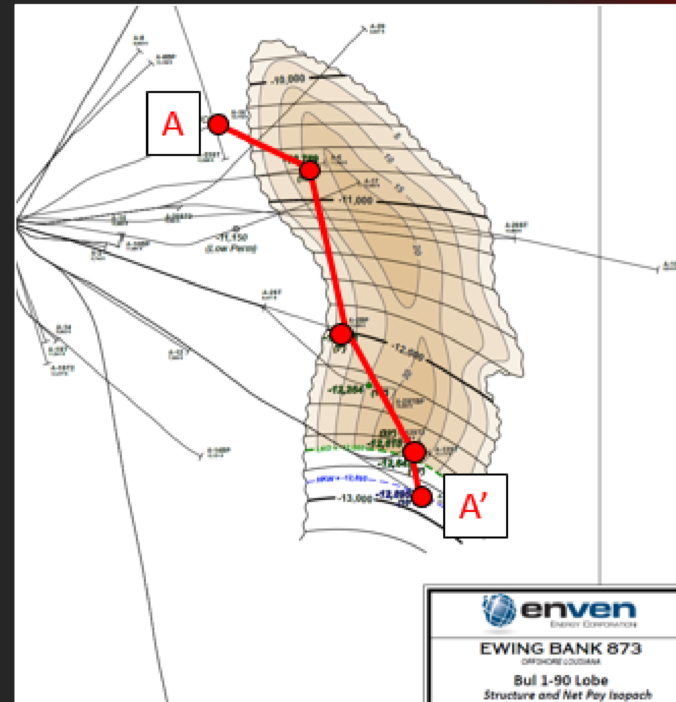
Facies Analysis

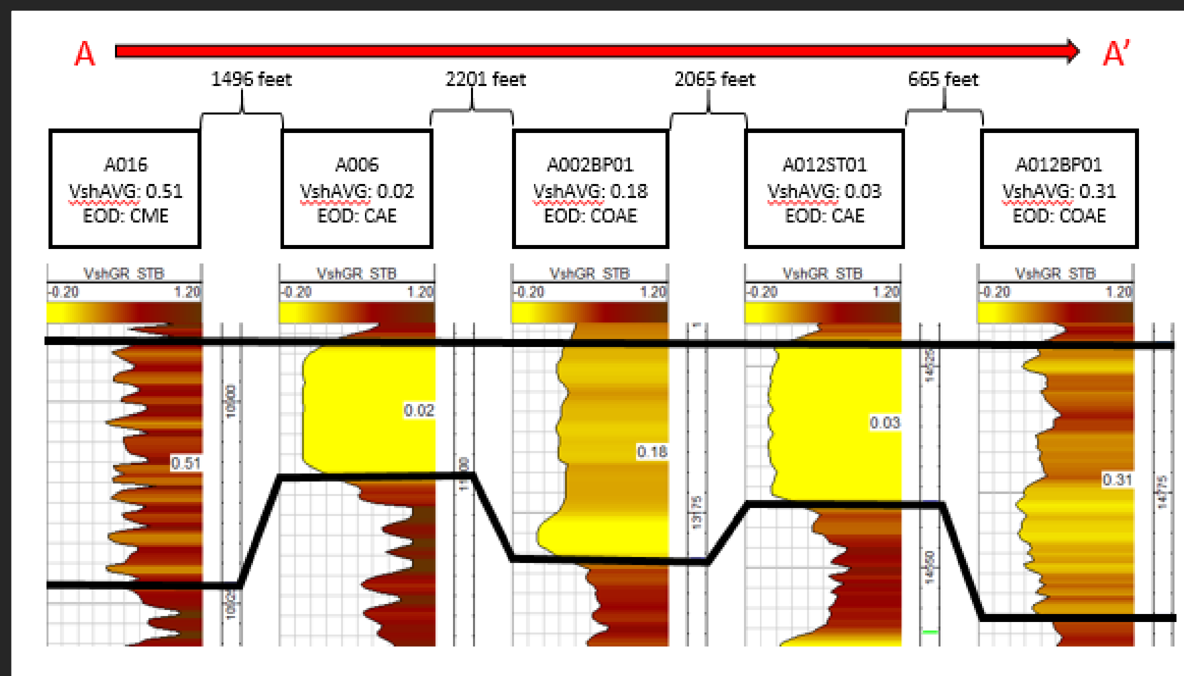


- Utilized VshT curve shape to evaluate well location within a deepwater system
    - Red Stick represents well with associated VshT signature

Facies Analysis

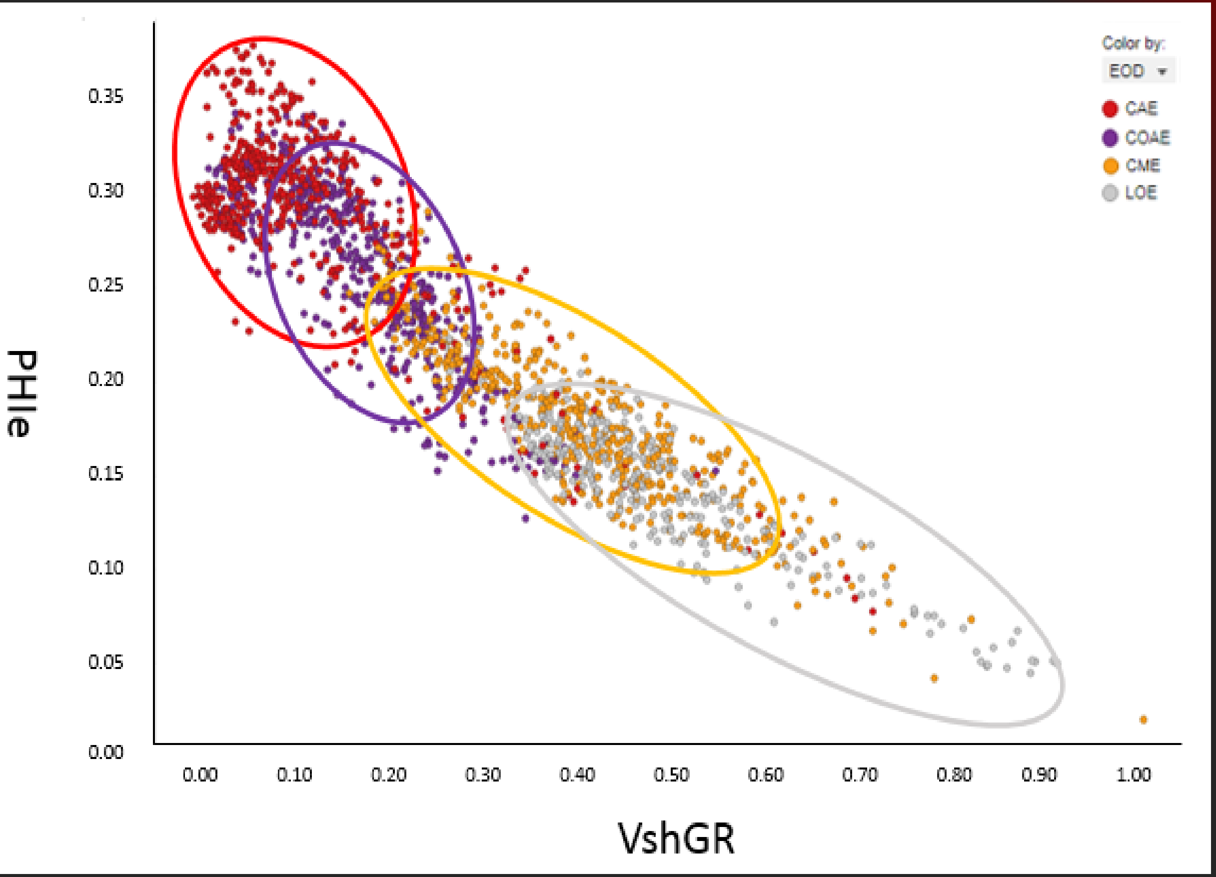
- Utilized VshT curve shape to evaluate well location within a deepwater system
- Utilized this system to evaluate well positions relative to channel-axis





Facies Analysis

- Utilized VshT curve shape to evaluate well location within a deepwater system
- Utilized this system to evaluate well positions relative to channel-axis
- When these interpretations were plotted on the Φe vs VshT Rhombus, a clear distinction of EOD type can be distinguished
  - Red: Axis
  - Purple: Off-Axis
  - Gold: Margin
  - Grey: Levee



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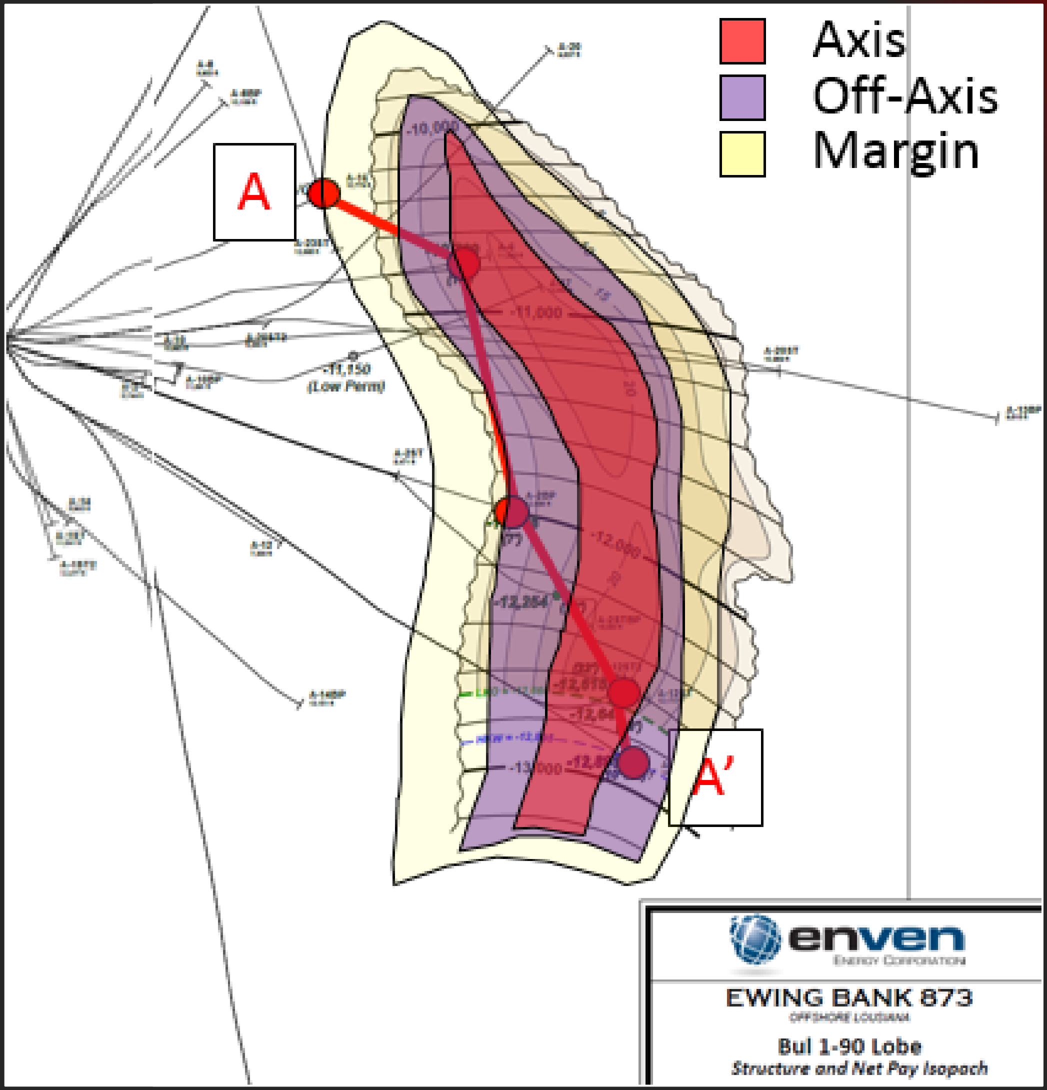
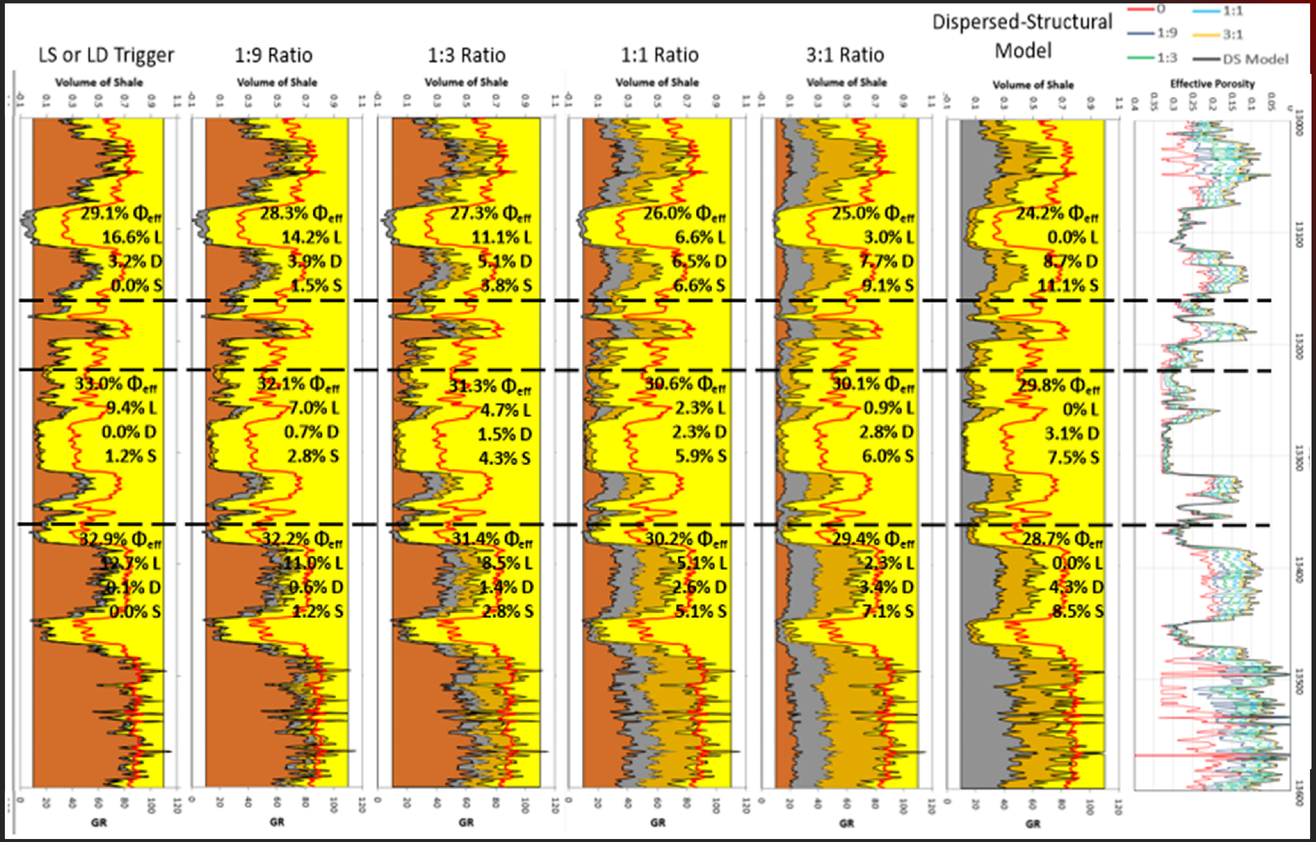


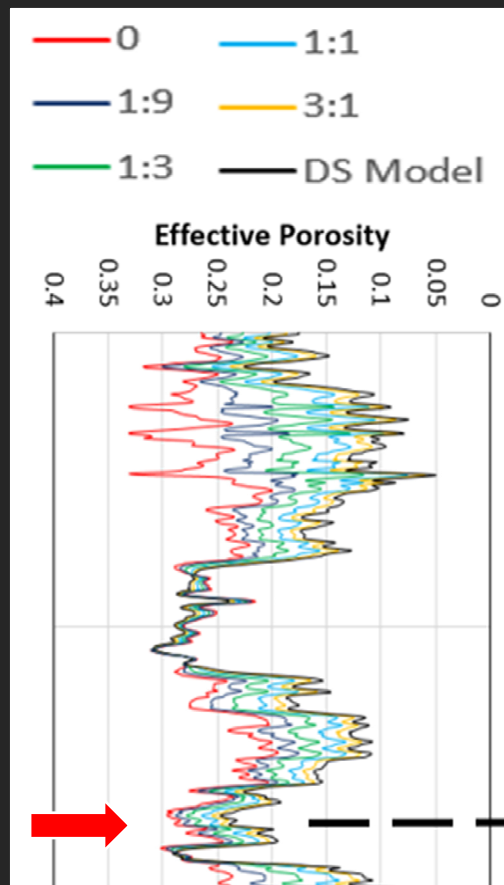
Three-Type Shale Distribution Models

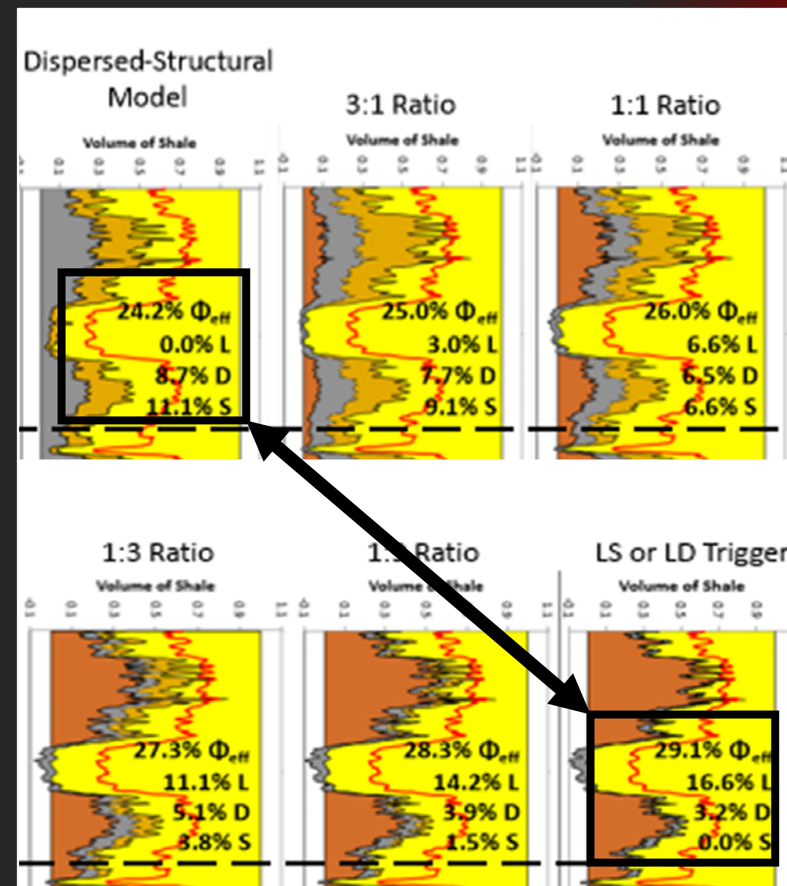
- A shale distribution panel utilizing McIntosh's ratio method to evaluate the range of possibilities for shale type
  - And subsequent effects on porosity



Three-Type Shale Distribution Models

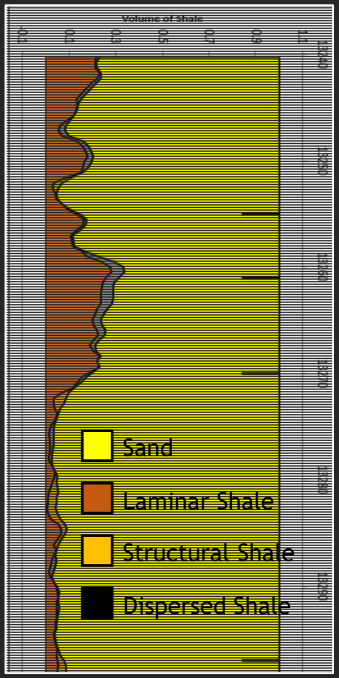
- Using Ferguson's Φe equations for the various shale types, porosity curves were constructed for each of the ratios
- Detailed zone shown by red arrow
- Effective porosity ranges from 29.1% in the Juhasz model to 24.2% in McIntosh's DS Model





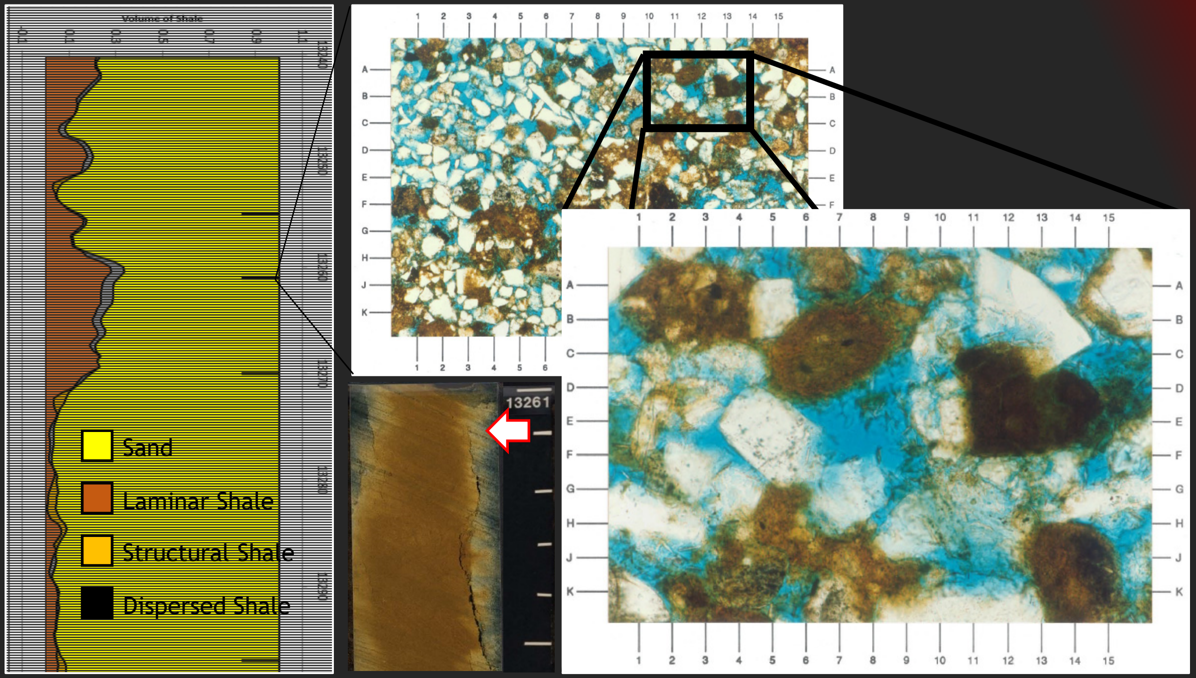
Three-Type Models in Cored Intervals

- Thin sections were used and compared to the Trigger Model (black ticks on the right represent thin section depths)



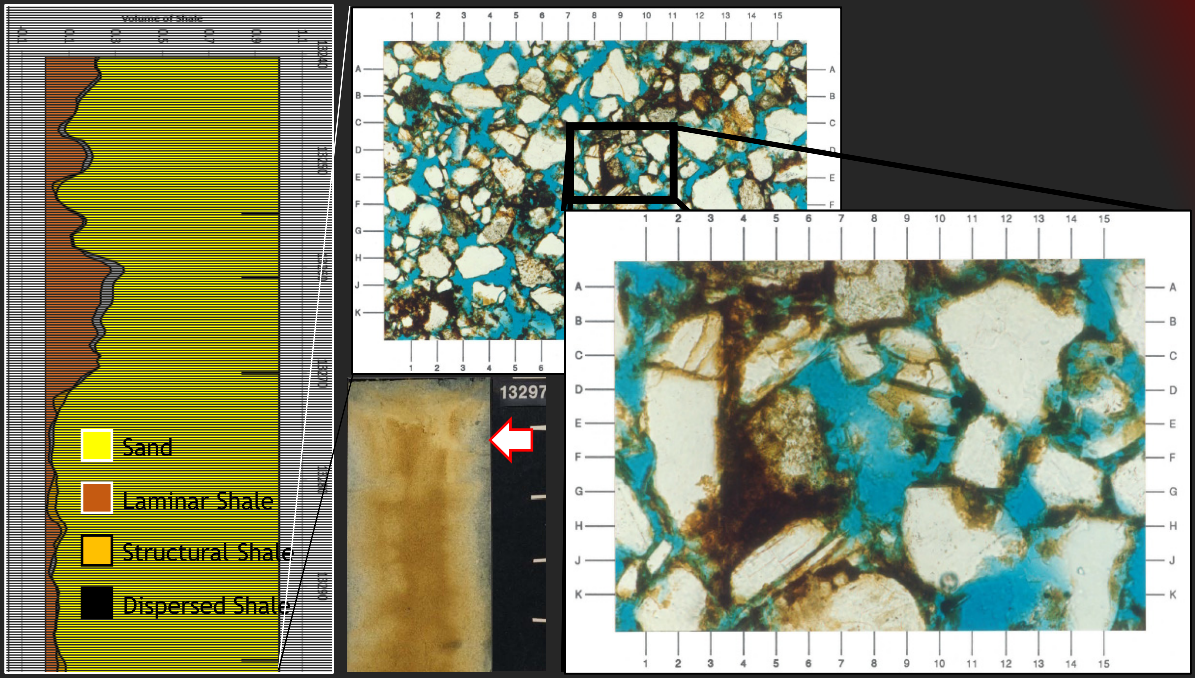
Three-Type Models in Cored Intervals

- Thin sections were used and compared to the Trigger Model (black ticks on the right represent thin section depths)
- The Trigger Model predicts that shale in this interval is Laminar-Dispersed with no Structural shale present
- Yet thin section clearly shows some Structural shale



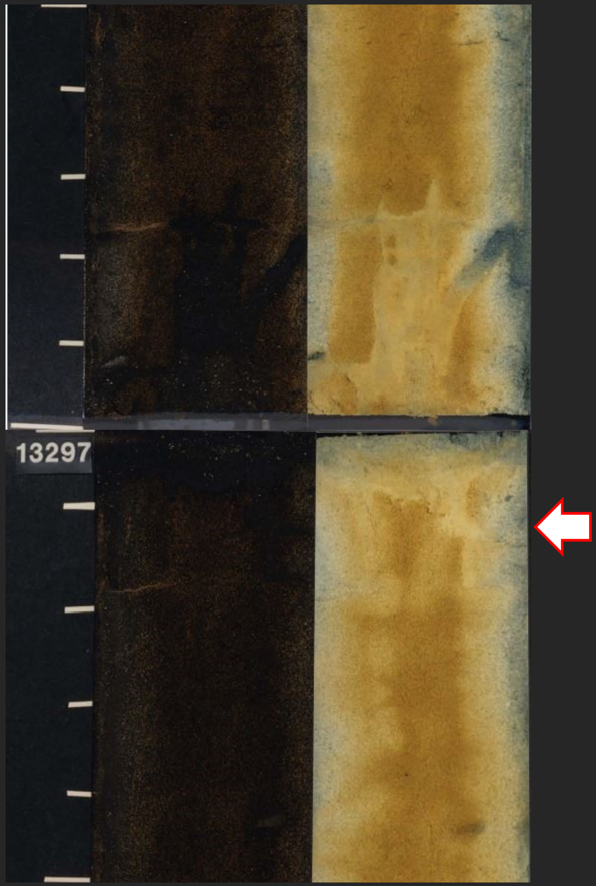
Three-Type Models in Cored Intervals

- Thin sections were used and compared to the Trigger Model (black ticks on the right represent thin section depths)
- The Trigger Model predicts that shale in this interval is Laminar-Structural with no Dispersed shale present
- Yet, thin section shows some Dispersed shale



Three-Type Models in Cored Intervals

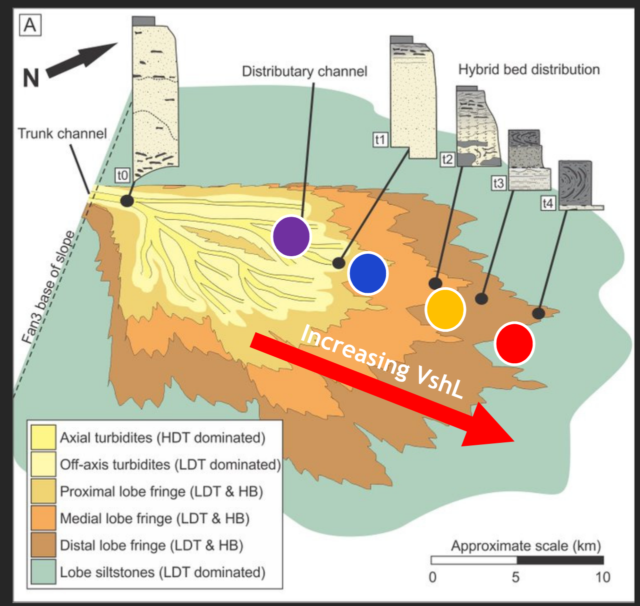
- Trigger model predicted Laminar shale in Massive Sands.
- Yet, Core showed no laminations.
- Dispersed-Structural model applies.



Model	Φe-ss
Trigger	33.0%
1:9	32.5%
1:3	32.0%
1:1	31.6%
3:1	31.3%
DS	31.1%

Integration with Facies Analysis

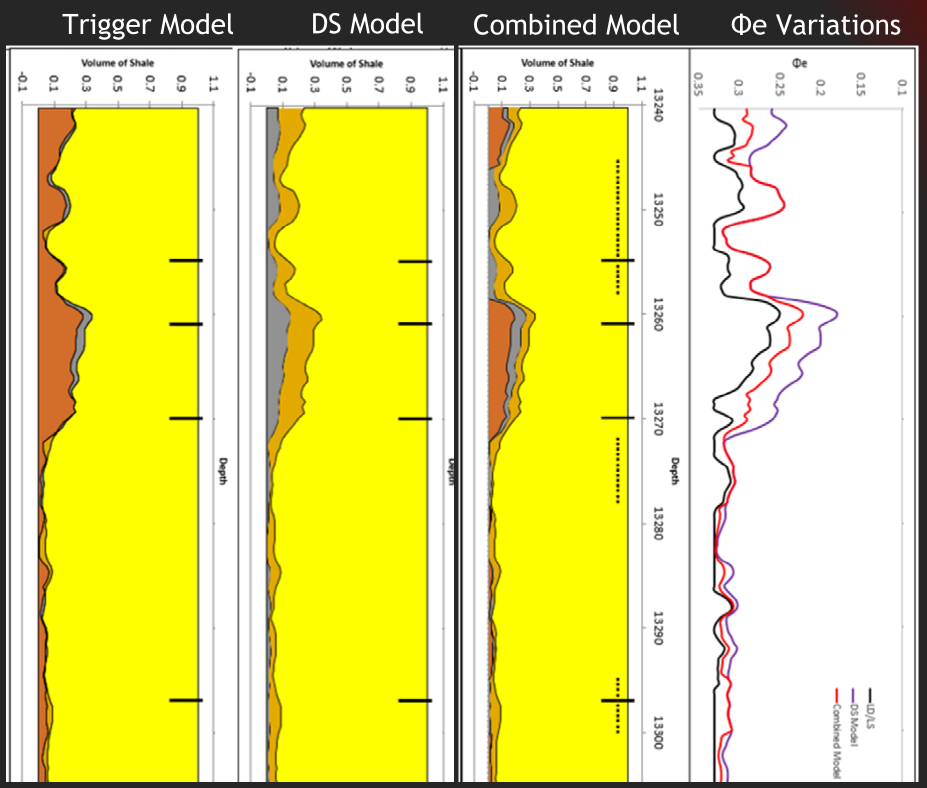
- Therefore, if massive sands more closely resemble the Dispersed-Structural model then this must be taken into account when modeling EODs which are prone to this type of lithology
- It is difficult to assign a certain ratio/model to a certain EOD, however, it is entirely possible that the various VshD:VshL or VshS:VshL ratios will change depending on EOD



(modified from Kane et al., 2016)

Extrapolating the Three-Type Model and Associated Limitations

- For the entire cored interval a generic ratio of 1:3 was applied
  - In massive sands the Dispersed-Structural Model was utilized
- The new 'Combined Model' (Red line in the Φe log) switches from between the ratio model and the Dispersed-Structural model
- The Combined Model represents a more accurate and refined version which reflects lithology from cored intervals



Conclusions

- In deepwater systems, depositional environment analysis is critical to properly modeling reservoirs
- Earlier methodology → too optimistic
- Better to consider range of possibilities
- When advanced downhole tools such as 3D resistivity are not available, incorporating facies and EOD analysis can help constrain reservoir models