Applied Geoscience Conference

Log Response Groups: Letting the Data Speak For Itself

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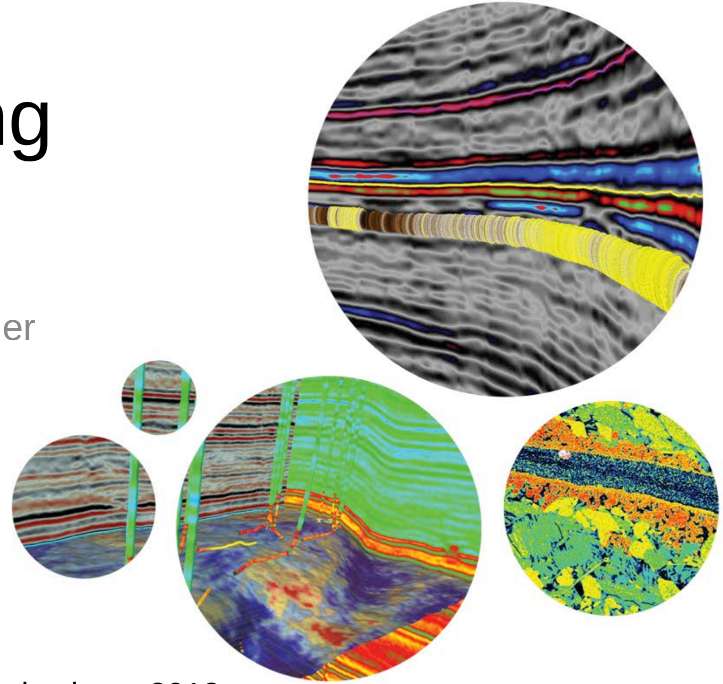


Integrated Approaches of Unconventional Reservoir Assessment and Optimization – 2018

Why are Log Response Groups Important?

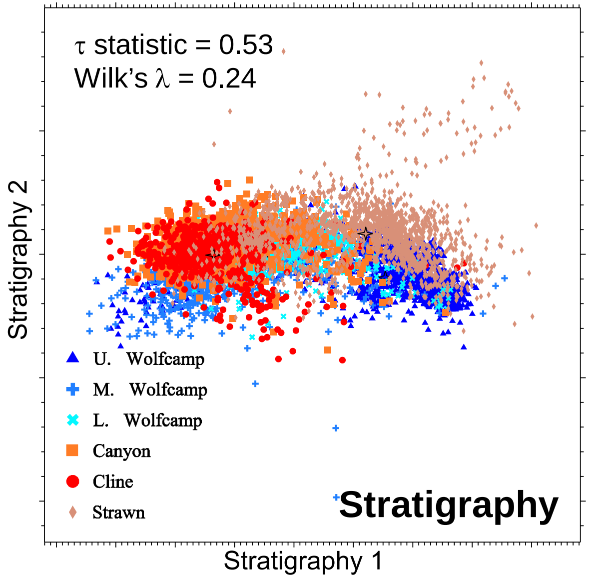
- Logs are the most detailed measurements that are related to subsurface lithology and fluids
- We are interested in examining rocks and fluids as they existed when wells were drilled and logged
- Log response groups (LRG) are objectively defined and can be directly related to rock properties if core and/or sample data are available
- Log response groups do not rely on subjective geological interpretations or petrophysical models
- Subjective geological interpretations or petrophysical models can be introduced after the fact

Log Discrimination For Two Common Rock Classifications

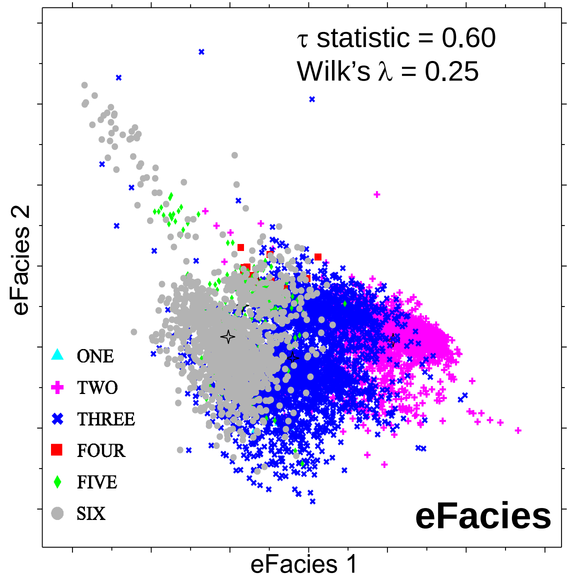
τ statistic – represents proportion of correctly classified samples

Wilk's λ - represents fidelity of variable suite as discriminators. The lower the value the better the resolution

Logs by themselves are not good discriminators for either classification



Group	Misclassification
U. Wolfcamp	25.90%
M. Wolfcamp	42.64%
L. Wolfcamp	66.40%
Canyon	48.29%
Cline	45.18%
Strawn	39.60%



Group	Misclassification
One	16.67%
Two	10.09%
Three	51.07%
Four	16.67%
Five	59.71%
Six	35.48%

Benefits of LRG's

- Independent, data driven, log analysis that is not reliant on a subjective model
- Each LRG represents a unique set of reservoir properties that are critical to understanding the reservoir
- LRG's are direct inputs to the static earth model, and provide quantitative measures for property models
- LRG's have a predictive property that is useful in asset evaluations and risk mitigation

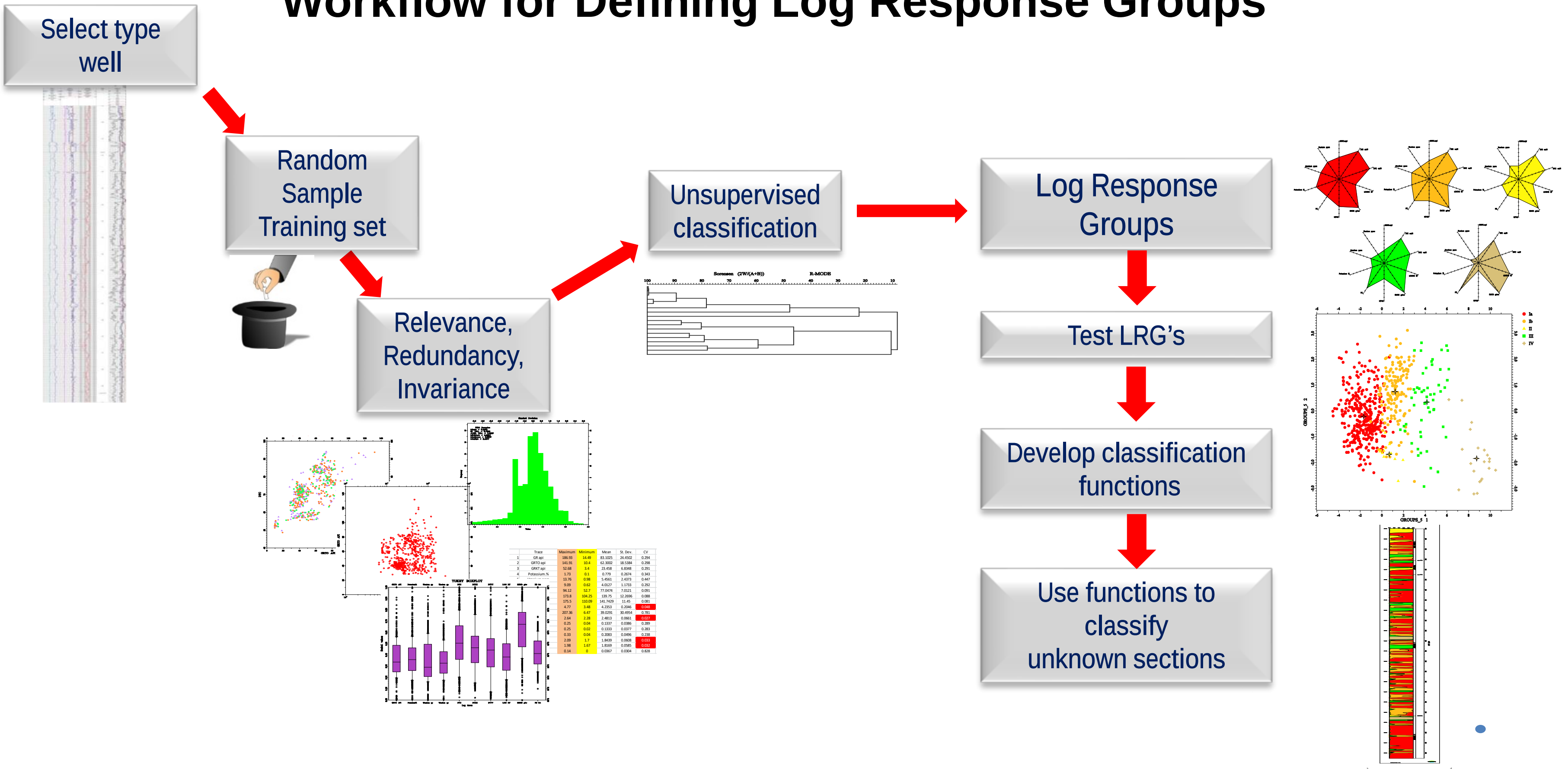
Rationale

- There is limited direct analysis (core) of the rocks in the objective unit.
- A complete reservoir characterization is required.
- Log data are the most complete data available for reservoir characterization.
- Use of the conditioned logs as a surrogate for actual rock description.
- This analysis is meant as an aid to interpretation of rock properties in lieu of a good geologically defensible facies description.

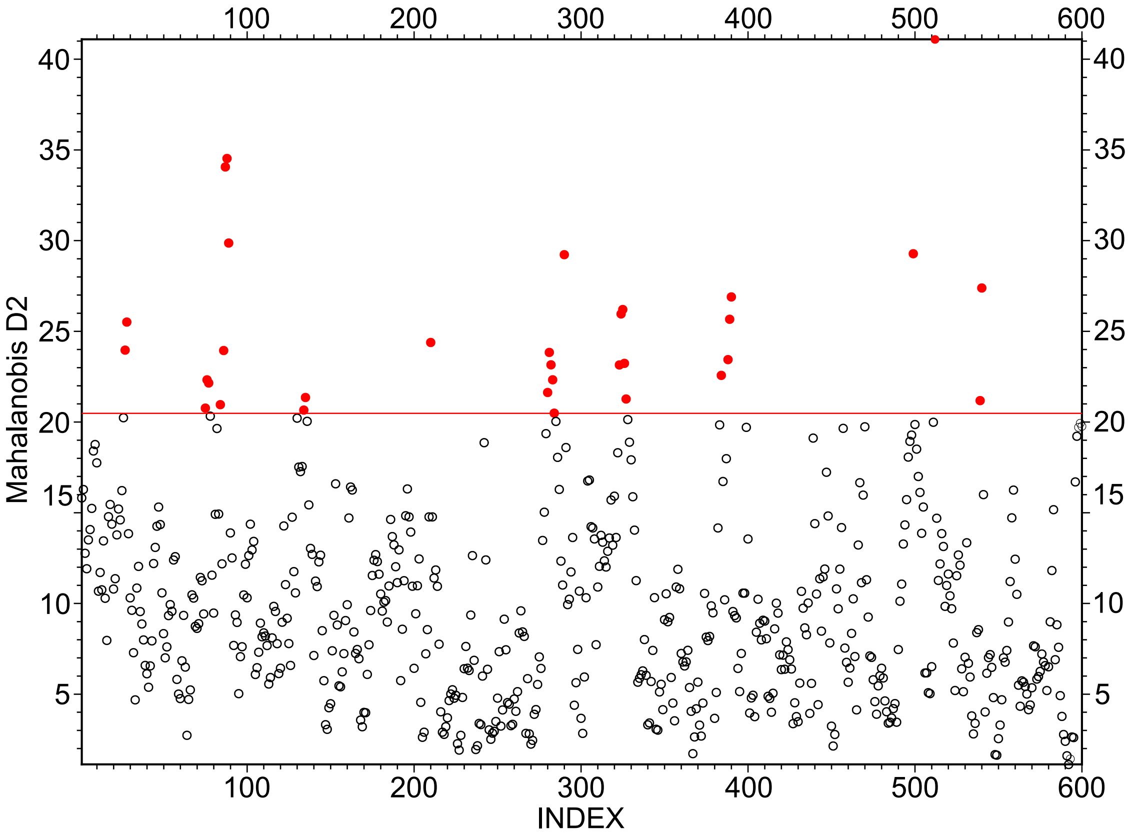
Required Data

- Wells with the most comprehensive log suites available (required)
- Core analysis reports (desirable)
- Thin section data, including point counts (desirable)
- Drilling reports detailing drilling fluids, bit size, and well path (good to have)

Workflow for Defining Log Response Groups



Multivariate Outlier Detection



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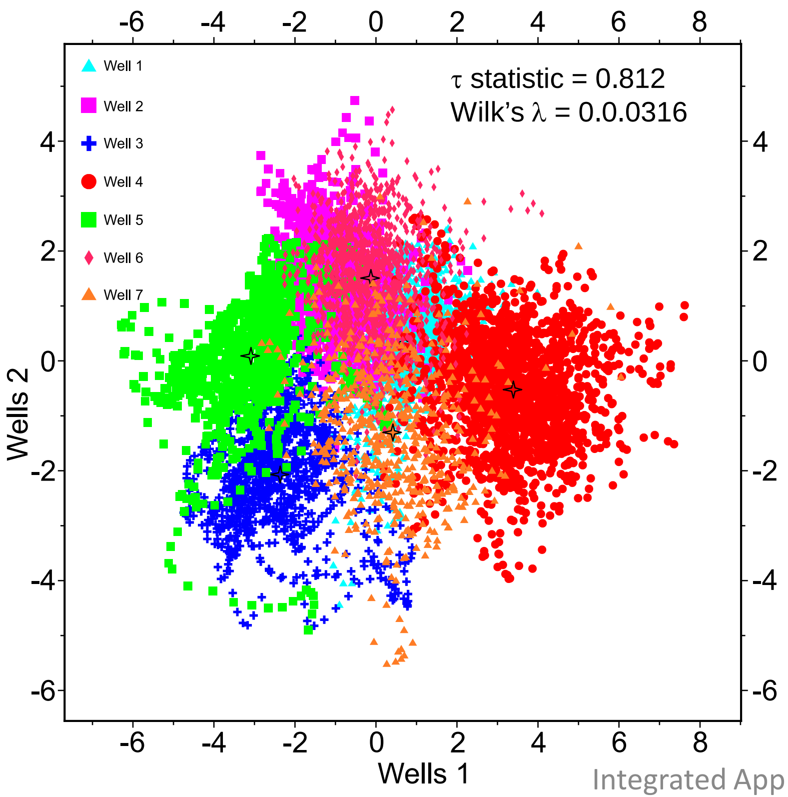
Red points are outlier candidates for evaluation. Outliers must be individually evaluated to determine why they exist

Well Differences



Curve	Wilk's λ
LOG10 RT	0.8056
NPHI dec	0.5090
GRTO API	0.3601
Uranium ppm	0.2277
Potassium %	0.1331
Thorium ppm	0.0732
DTS us/ft	0.0517
DTC us/ft	0.0397
RHOB g/cc	0.0352
PE b/e	0.0316

Curves are those planned to be used to define log response groups

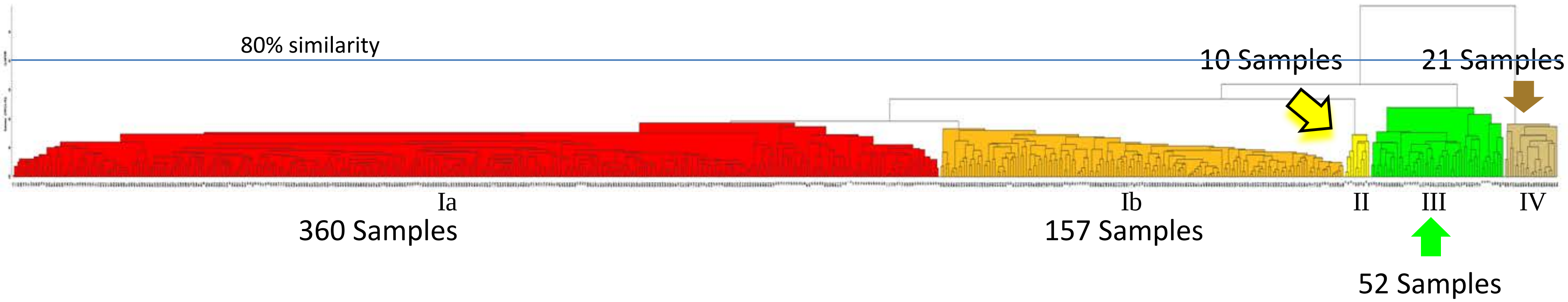
Wells can be roughly separated by logs. This represents spatial variation of the Wolfcamp

Analytical Methods and Procedures

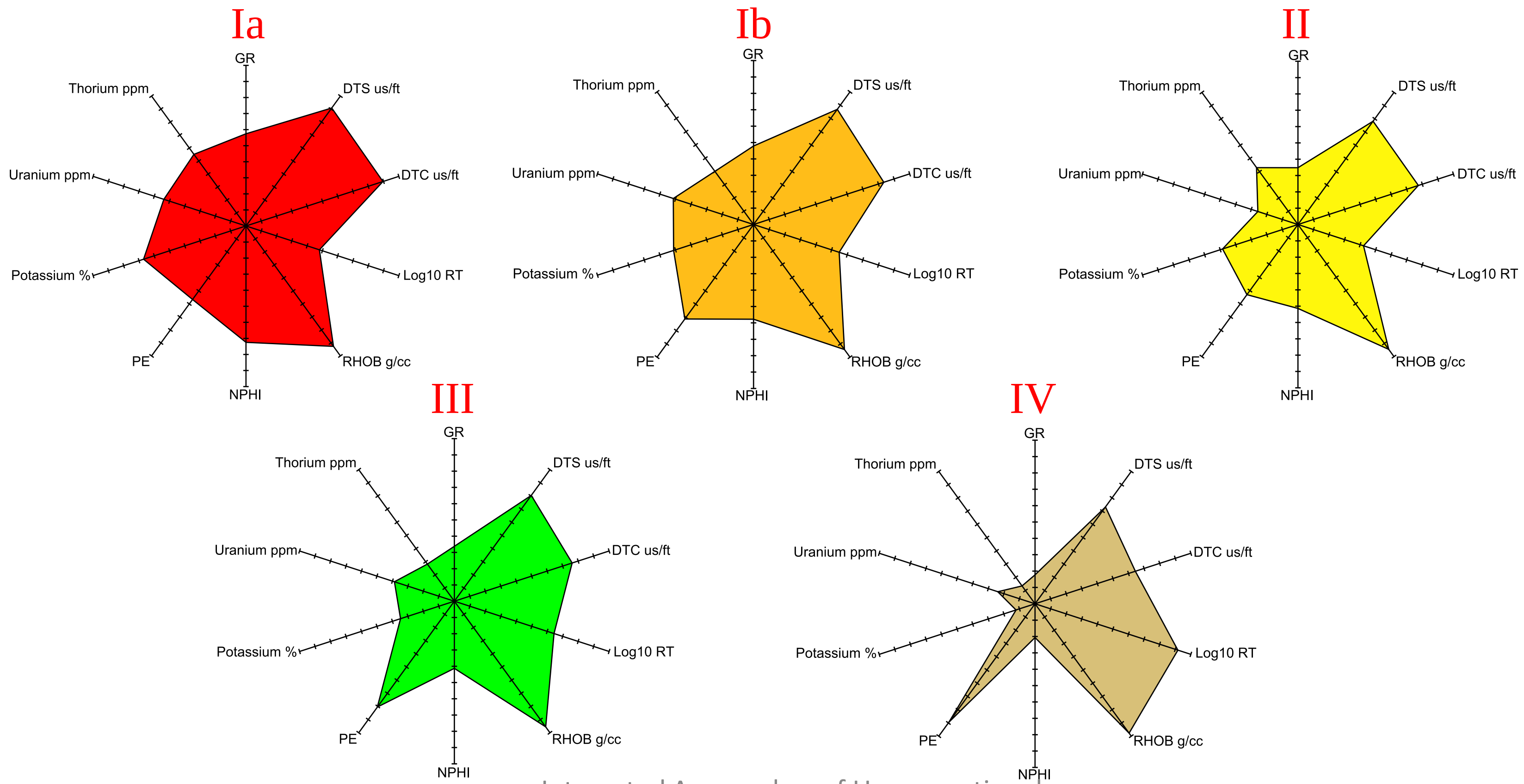
- Data conditioning and other decisions
  - Variable selection
  - Similarity coefficient selection
  - Data scaling to remove magnitude effects
- Unsupervised Classification
  - Heirarchical cluster analysis
- Classification Evaluation
  - Stepwise linear discriminant analysis (LDA)
- Supervised classification
  - Classification of unknown samples with discriminant function
- Classify unknown wells with functions obtained from LDA

Hierarchical Classification of 600 sample training set

Partitioned hierarchy



Group Compositions – Star Plots



Classification Evaluation – Discriminant Analysis

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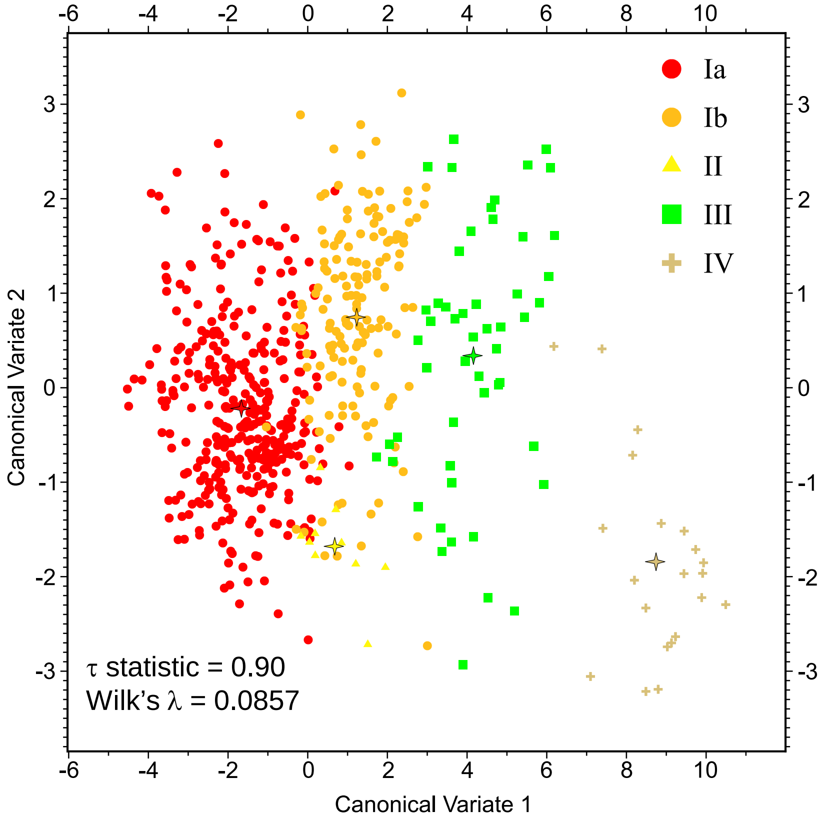
Wilk's λ - represents fidelity of variable suite as discriminators. The lower the value the better the resolution



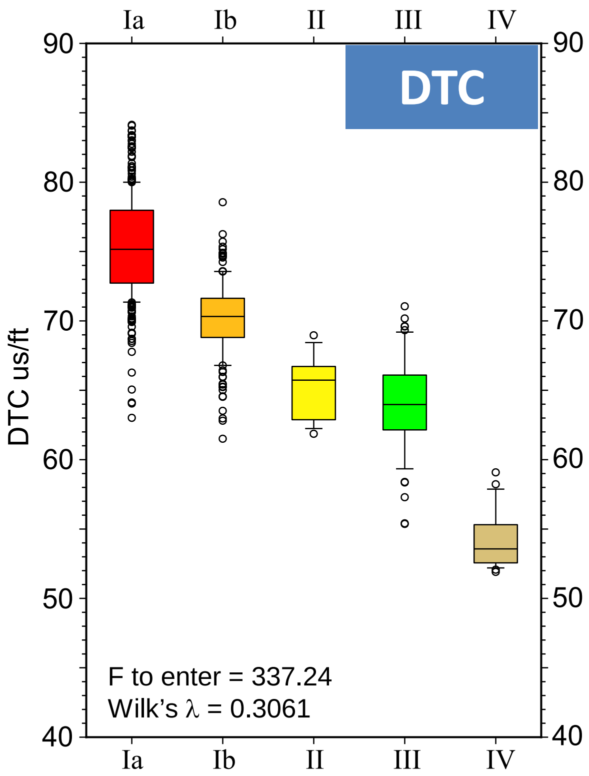
Variable order

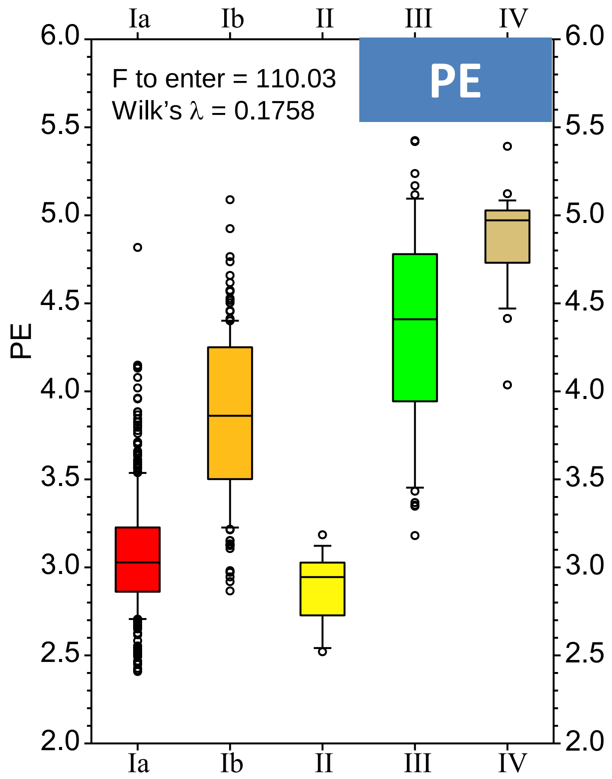
DTC us/ft
PE
Log10 RT
Thorium ppm
DTS us/ft
Uranium ppm
NPHI
Potassium %

Misclassifications

Ia - 8.89%
Ib - 7.01%
II – 0.00%
III - 9.62%
IV – 4.76%

Group Composition - Boxplots





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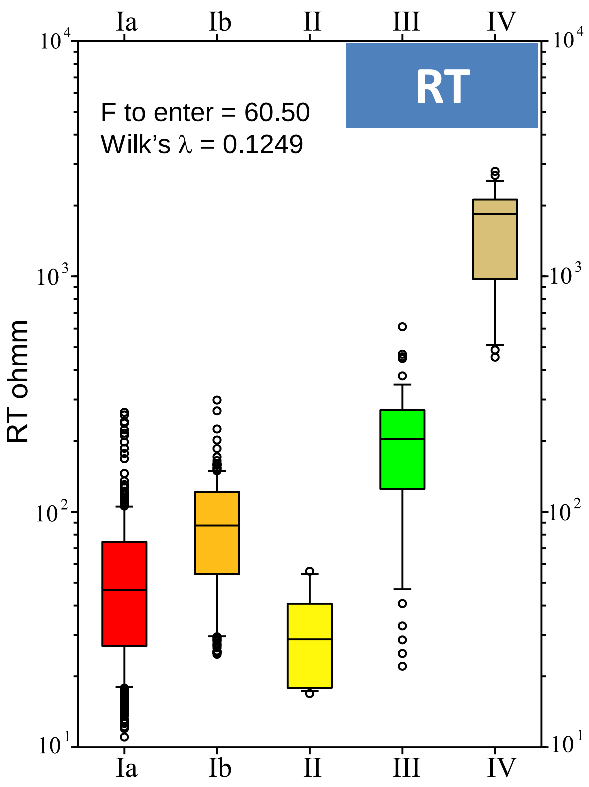
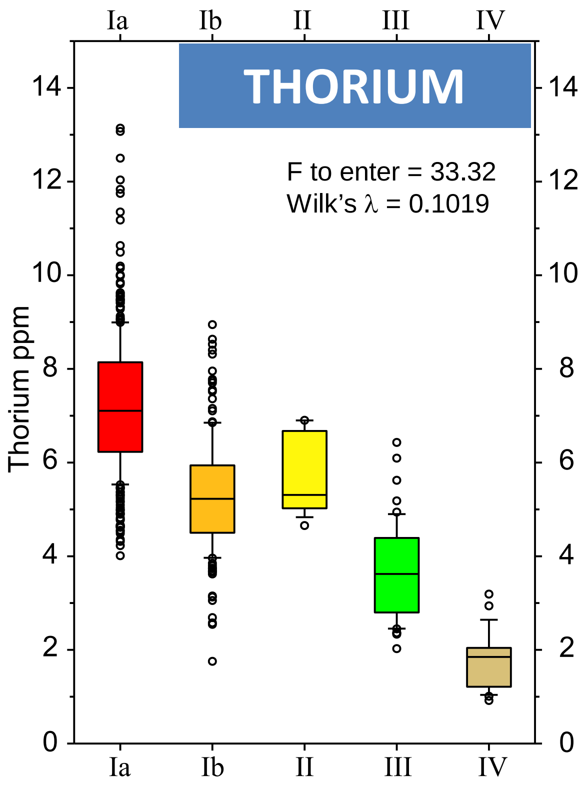
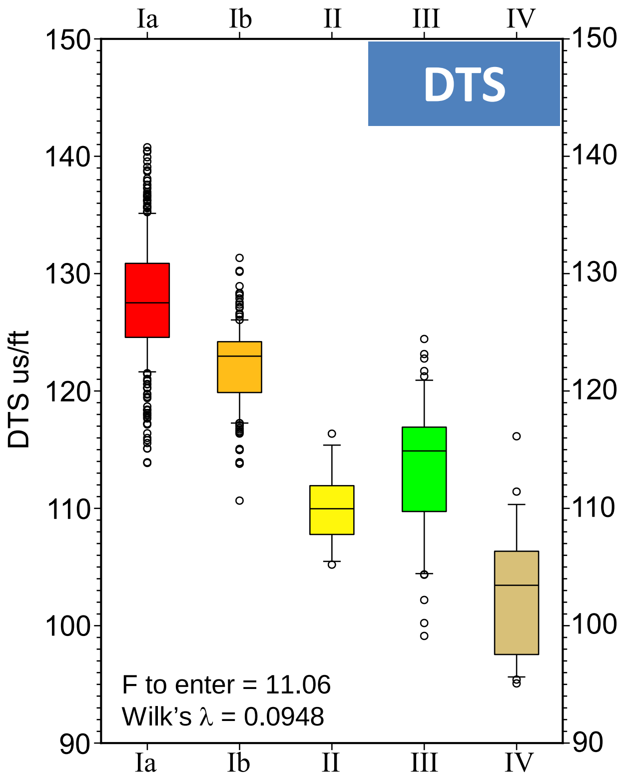
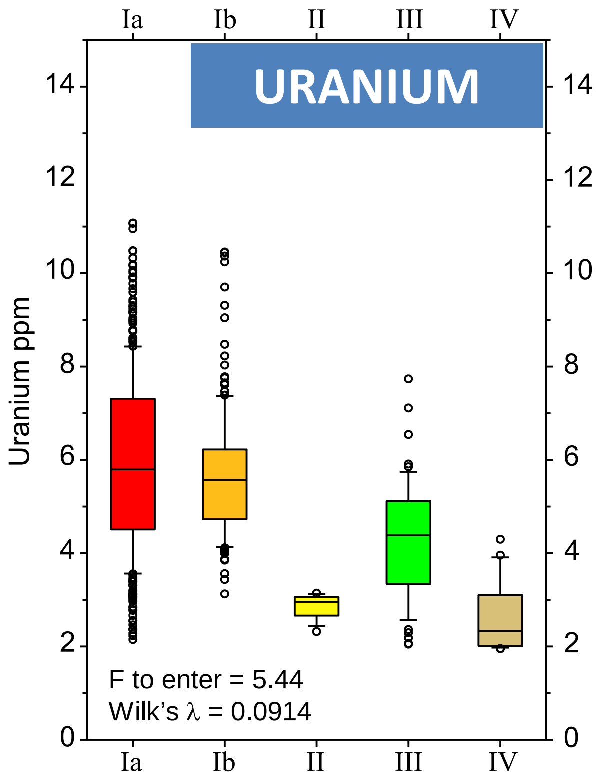


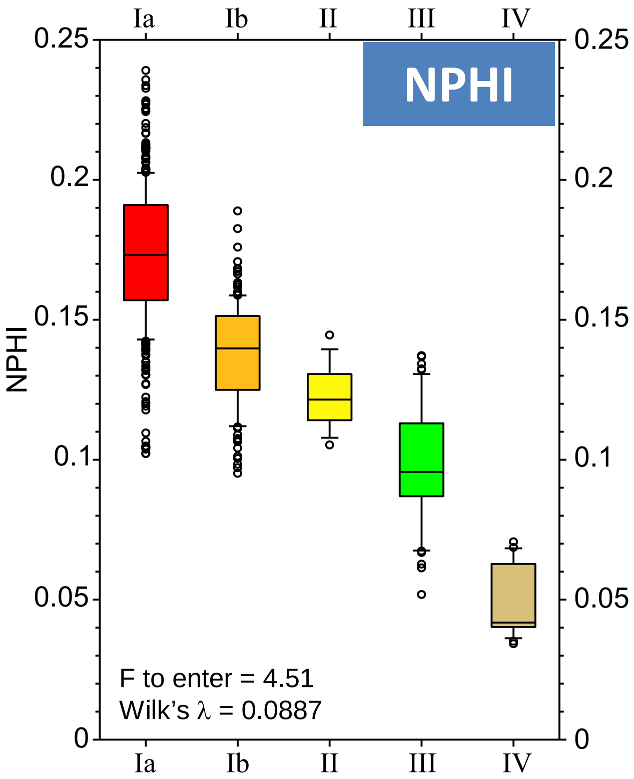


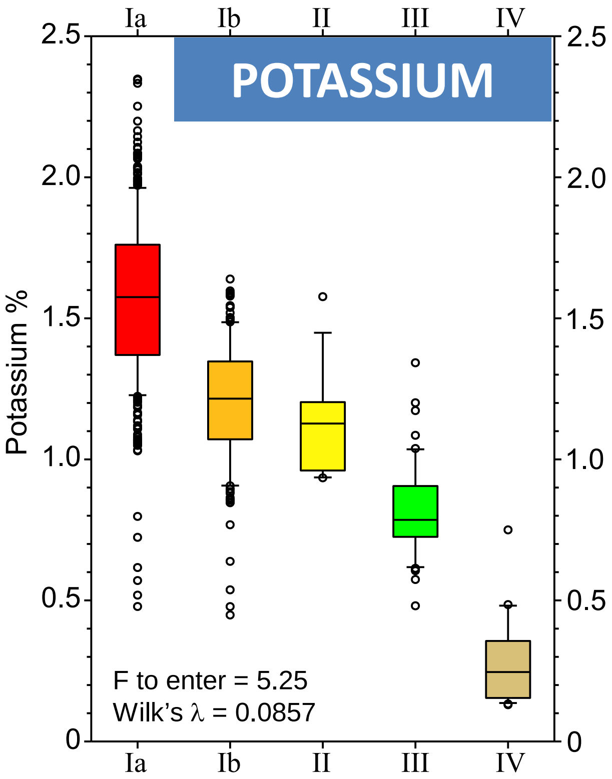
Group Composition - Boxplots



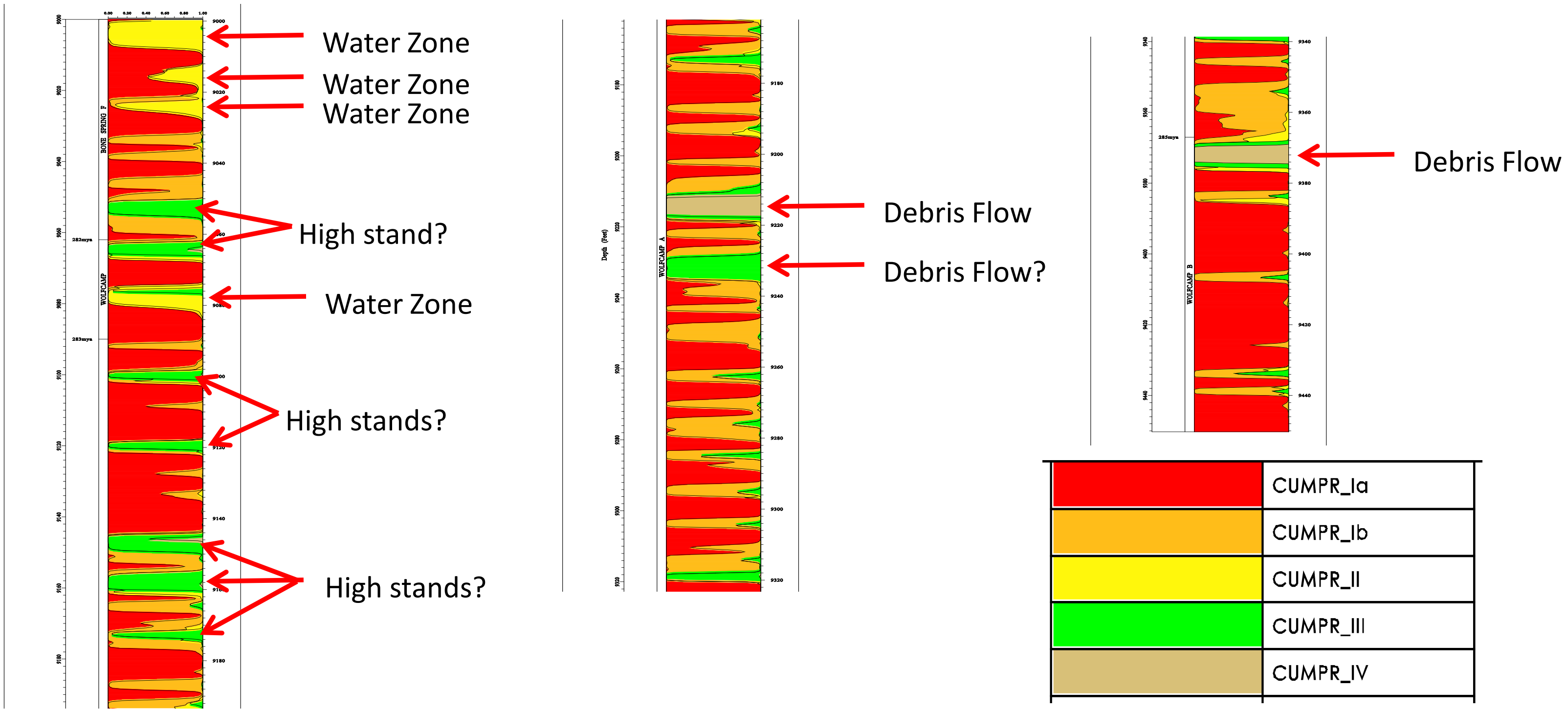


Group Composition - Boxplots





Geological Interpretation



Case Study – Wolfcamp of the Delaware Basin

Challenge

- Many reservoir rocks consist of several alternating lithologies in varying proportions
- Difficult to accurately develop a sufficiently detailed lithological correlation to apply to a reservoir model

Solution

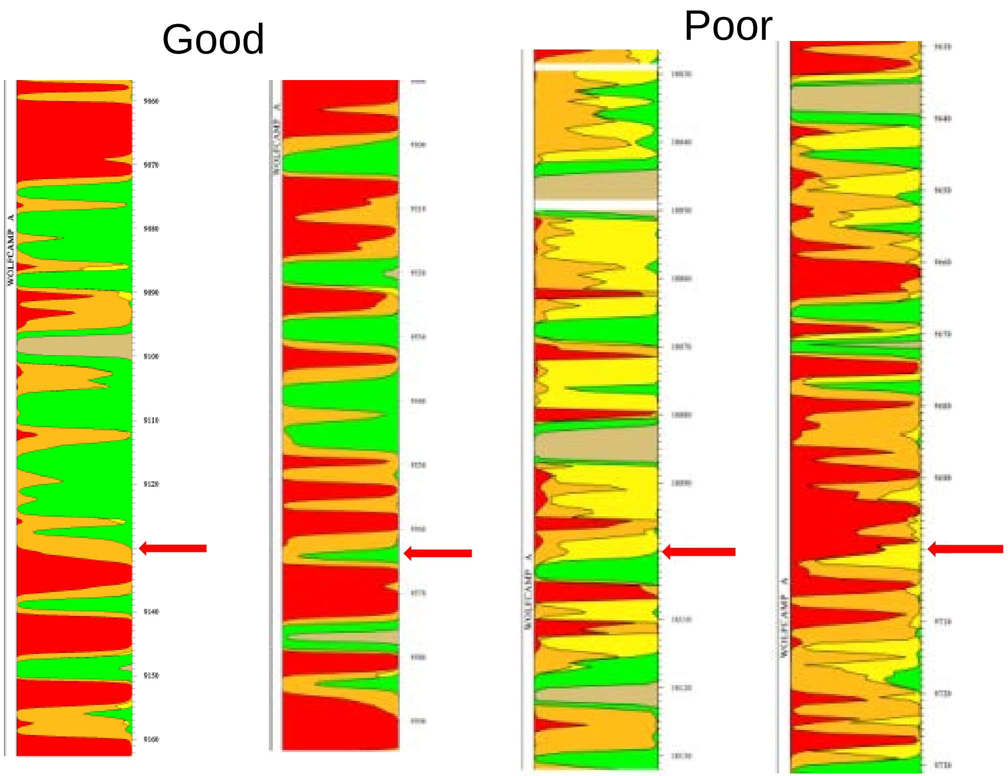
- Log suites used to represent rock types
- Use pattern recognition methods to derive multivariate log response groups
- Use log response groups to populate earth model with important properties

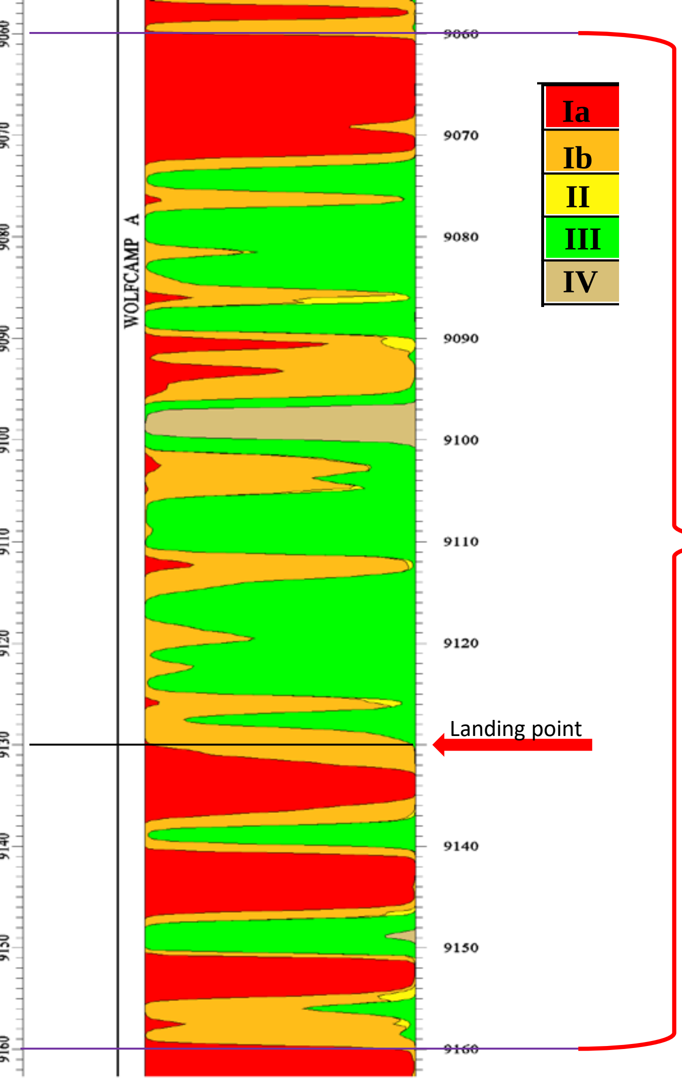
Results

- Earth model with spatial predictability
- Better definition of well locations and lateral locations

Good and Poor Producing Wells

Lateral Landing





Example Well

Net thickness

Ia – 13.25

Ib – 19.25

II – 0.0

III – 34.5

IV – 3.0

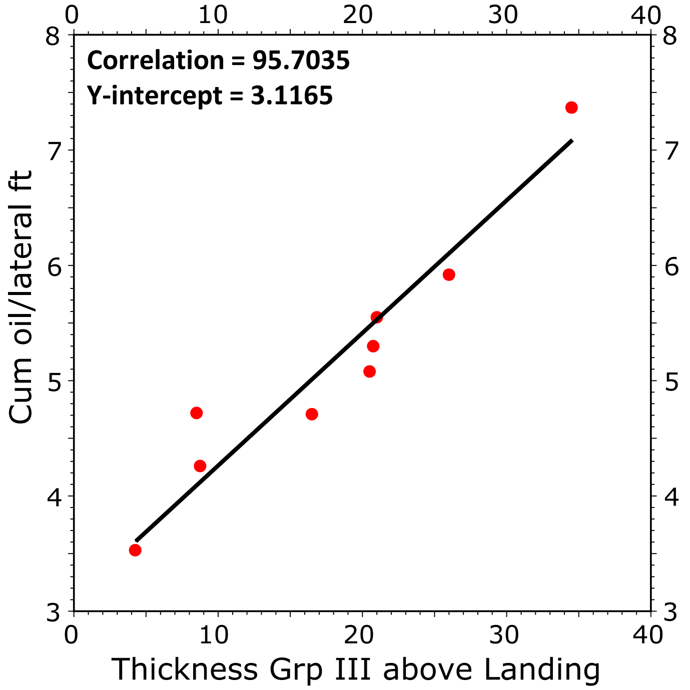
Presumed productive interval

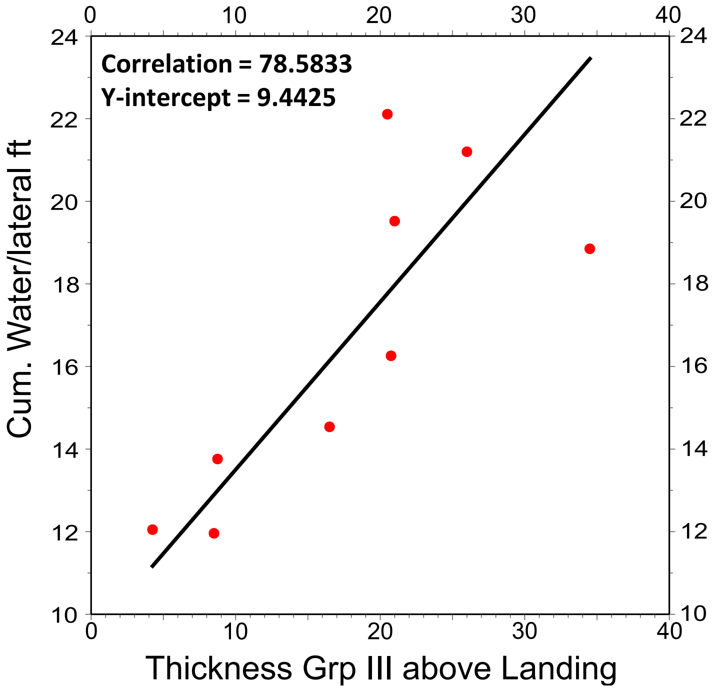
30 day 32/64" average = 1354BOE, 2350 water

30 day average IP/lat. Ft. = 0.36BOE, 0.63 water

30 day Cum/lat. ft. = 10.86BOE, 18.65 Water

Relationship Between LRG and Production





Correlation between LRG and gas production is low, suggesting that gas is everywhere and not related to LRG.

Conclusions

- A variety of statistical and non-statistical methods are used to recognize similar log response patterns that can be applied to unconventional production
- Use of these methods has enabled selection of the best rock types for fracturing, production, etc.
- High correlation of Group III rocks with production suggests that most oil and water production originate in Group III rocks.
- Gas can originate in either rock type
- Intercepts of the reduced major axis regressions suggest that some oil and water have migrated into the carbonate marls from elsewhere.

Acknowledgements / Thank You / Questions

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