Geologic Evaluation of the Wolfcamp Formation in Reeves County, Delaware Basin, West Texas

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M.S. Geology

MUDTOC Consortia Meeting Fall 2020

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Project Summary

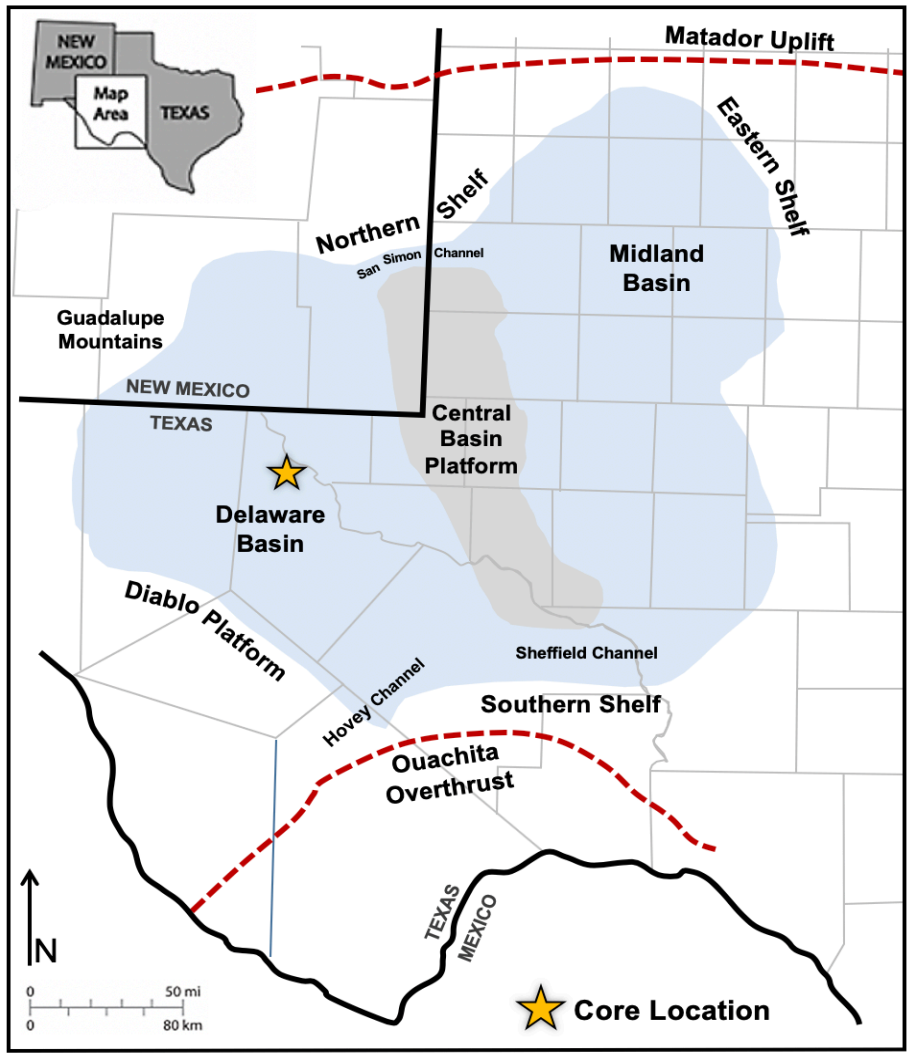
Objective:

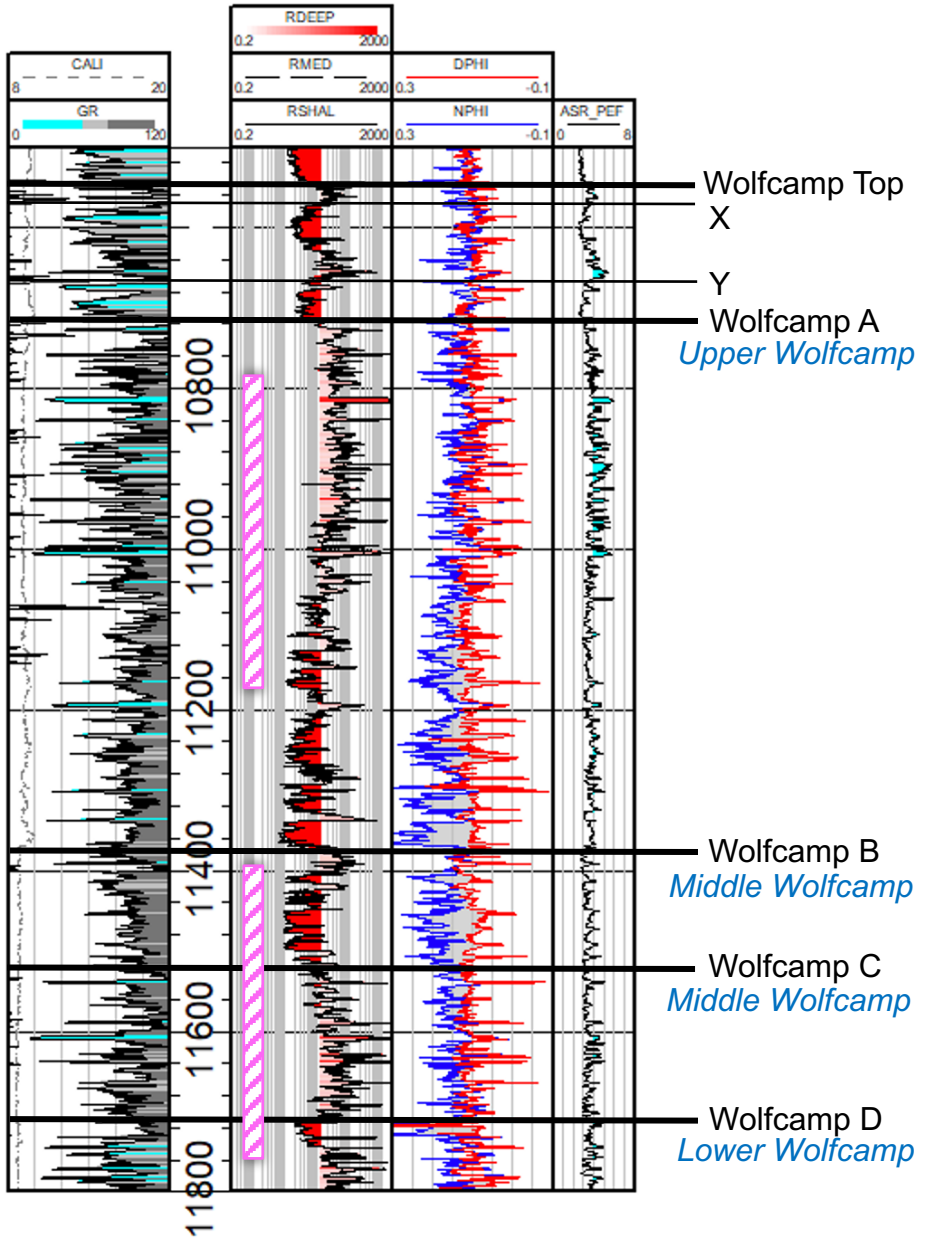
Integrated analysis of core, core associated data and well logs to investigate the vertical variability of the Upper, Middle and Lower Wolfcamp.

Presentation Outline

- Introduction to Dataset
- Stratigraphic Framework (Facies Analysis and Facies Distribution)
- Reservoir Quality Analysis (XRF Chemostratigraphy, RCA and Geomechanics)
- Source Rock Analysis
- Conclusions and Future Works

Core Location and Dataset

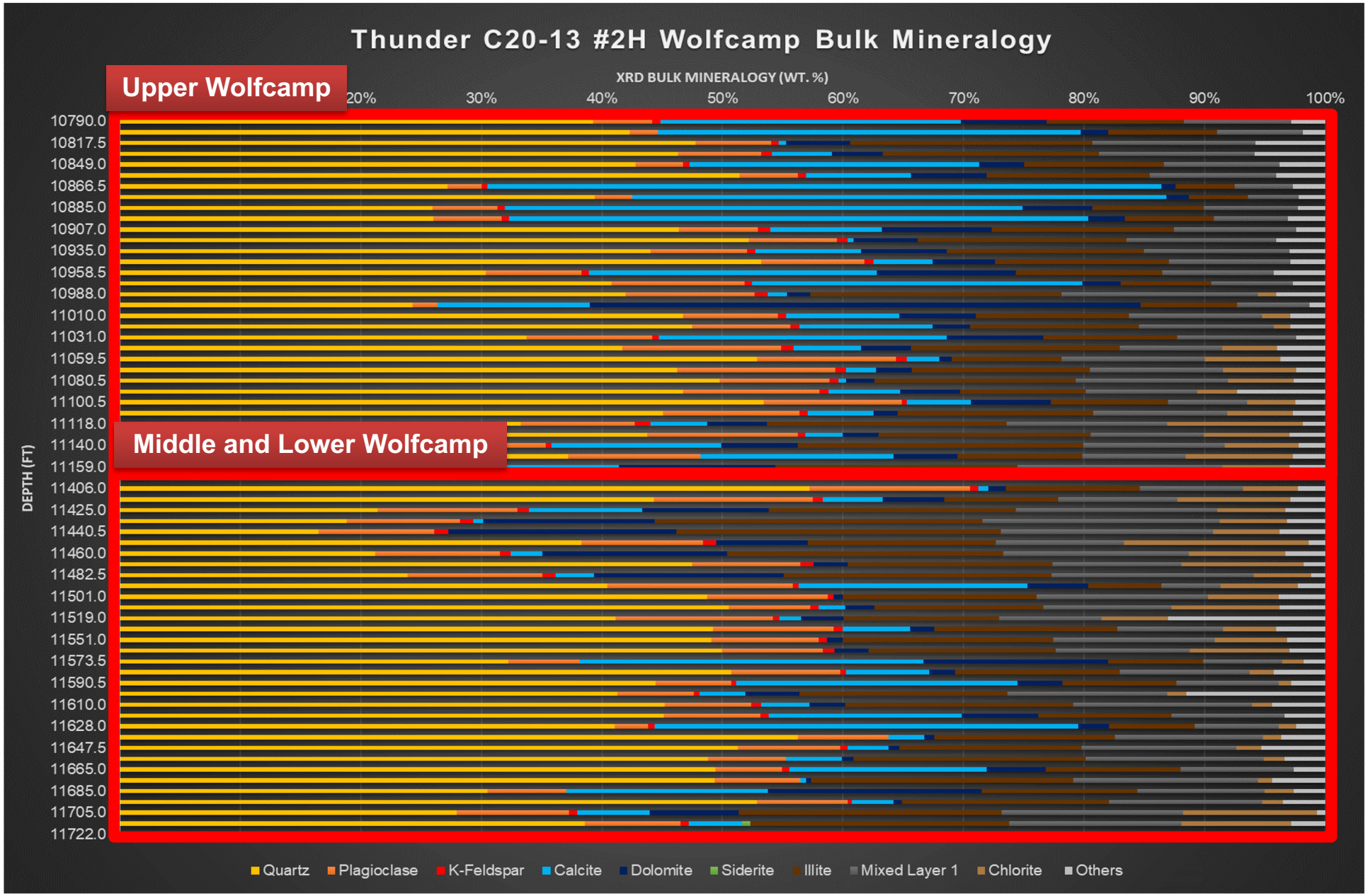




Multiscale Analysis

- Core totaling 739.5’
- Thin-section photomicrographs
- FE-SEM
- X-Ray Diffraction (XRD)
- X-Ray Fluorescence (XRF)
- Routine Core Analysis (RCA)
- Source Rock Analysis (SRA)
- Unconfined Compressive Strength (UCS)
- Wireline and Mudlog LAS

Bulk Mineralogy (XRD)



Lithofacies Ternary Diagram

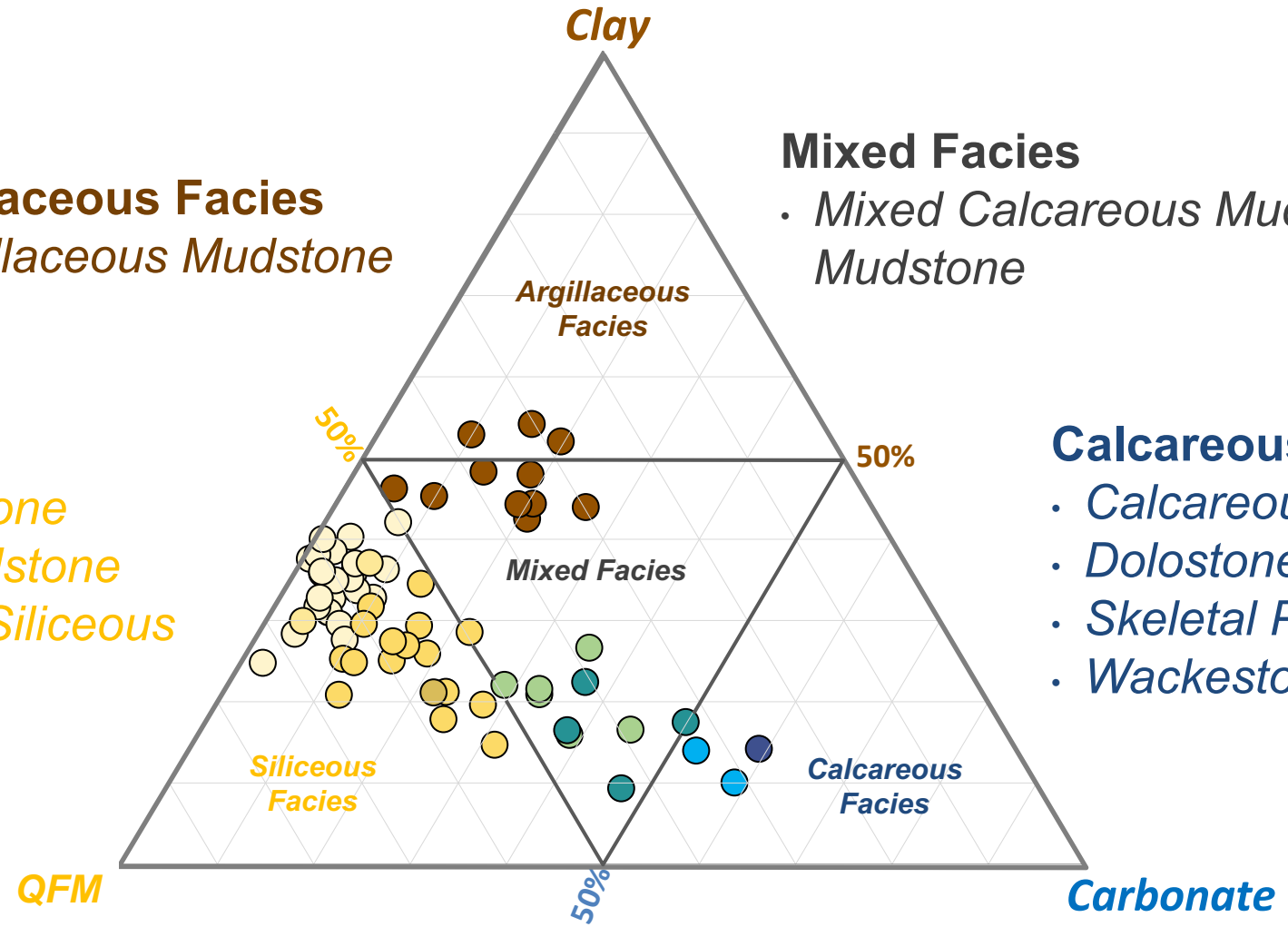
Four facies group subdivided into nine lithofacies

Argillaceous Facies
- *Argillaceous Mudstone*

Mixed Facies
- *Mixed Calcareous Mudstone to Silty Mudstone*

Siliceous Facies
- *Siliceous Mudstone*
- *Bioturbated Mudstone*
- *Carbonate-rich Siliceous Mudstone*

Calcareous Facies
- *Calcareous Siltstone*
- *Dolostone*
- *Skeletal Packstone**
- *Wackestone**



Argillaceous Mudstone

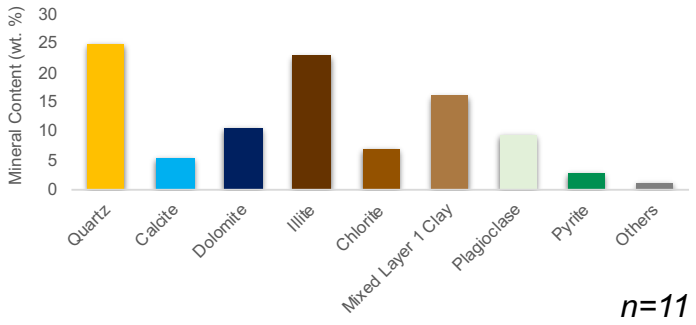
Argillaceous Mudstone



Observations

- Medium to dark green-gray, organic lean mudstone
- Massive with rip up clasts, pyrite, microfaults and some burrows
- Generally thin (cm-scale)
- *Most pronounced in Middle Wolfcamp*

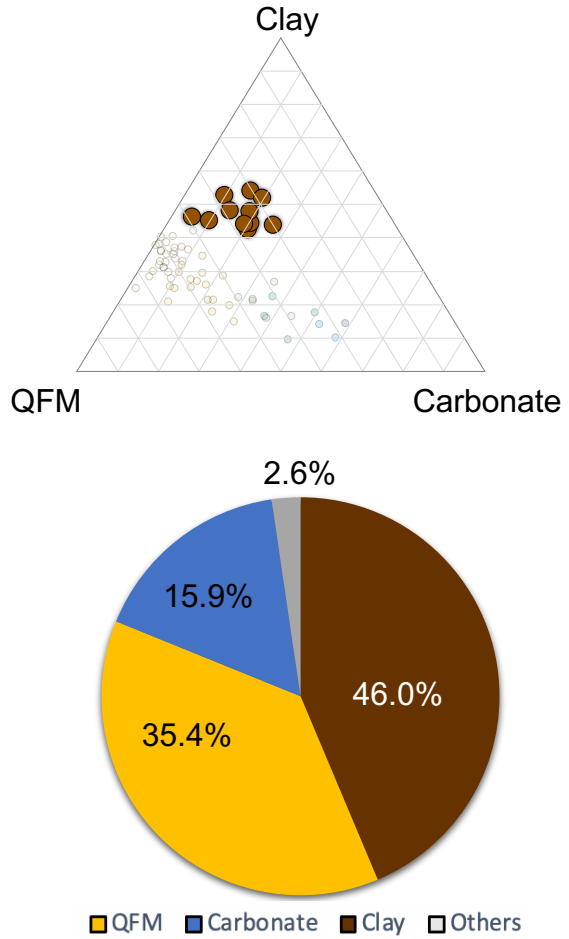
Bulk Mineralogy



Reservoir Properties (Average)

Porosity: 10.1 %
Permeability: 1.3 nD
TOC: 0.5 wt. %

Argillaceous Facies XRD (n=11)



Siliceous Mudstone

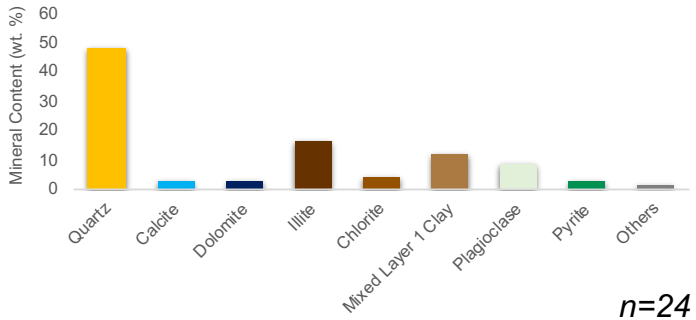
Siliceous Mudstone



Observations

- Dark gray to black mudstone
- Massive to faintly laminated
- Few to no silt sized specks
- Phosphatic nodules common
- Highest TOC up to 6.3 wt.% (OM disseminated in matrix and stringers)

Bulk Mineralogy

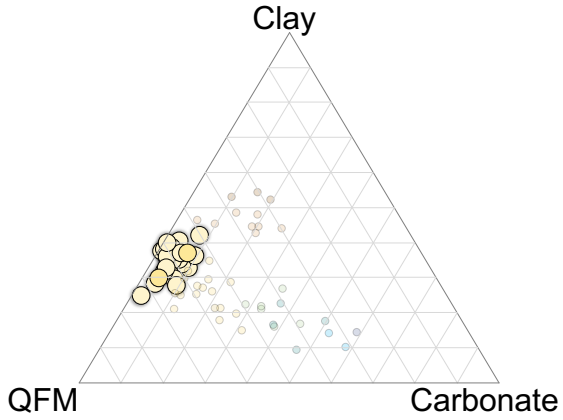


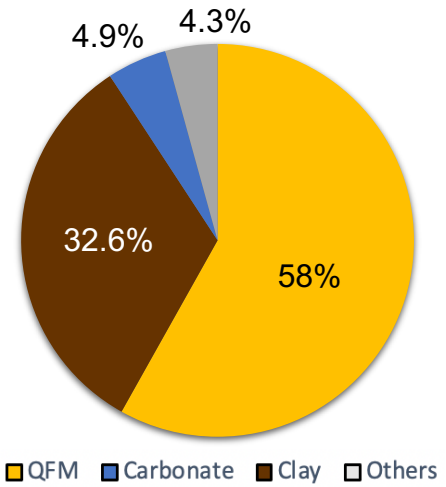
n=24

Reservoir Properties (Average)

Porosity: 9.3 %
Permeability: 48.6 nD
TOC: 2.6 wt. %

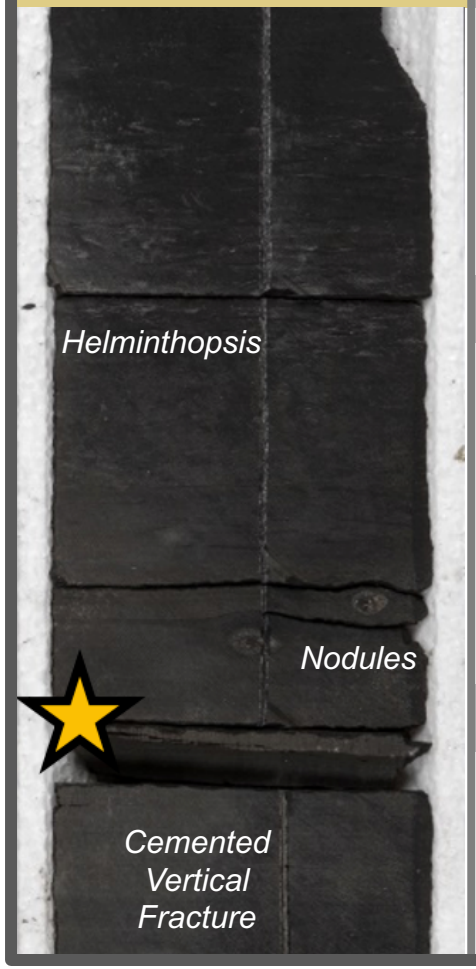
Siliceous Facies XRD (n=26)





Bioturbated Siliceous Mudstone

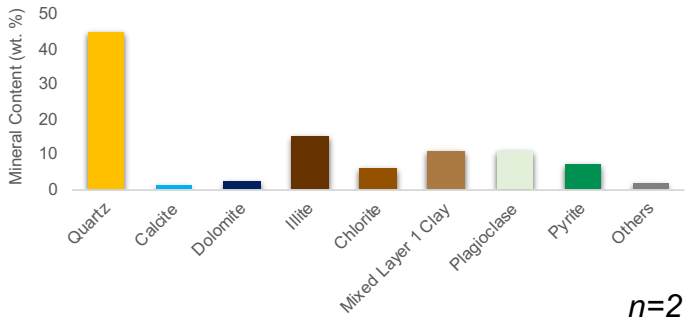
Bioturbated Siliceous Mudstone



Observations

- Burrowed intervals (subset) most commonly below Siliceous Mudstone
- Burrows seen in core and thin section
- Mud filled tubes
- Suggest slow sediment accumulation rates

Bulk Mineralogy

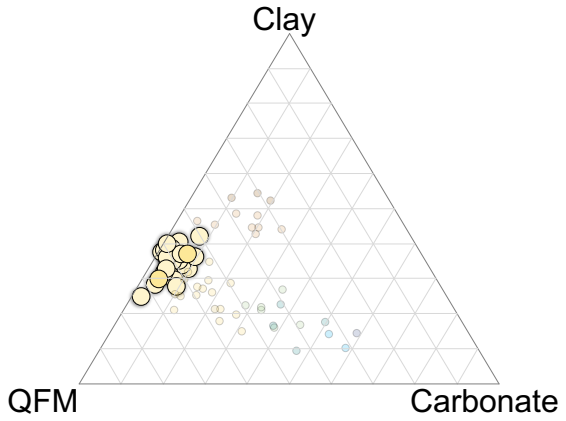


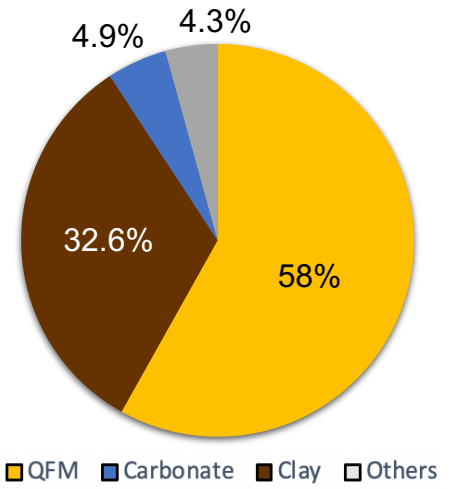
n=2

Reservoir Properties (Average)

Porosity: 9.1 %
Permeability: 72.2 nD
TOC: 1.6 wt. %

Siliceous Facies XRD (n=2)





Carbonate-rich Siliceous Mudstone

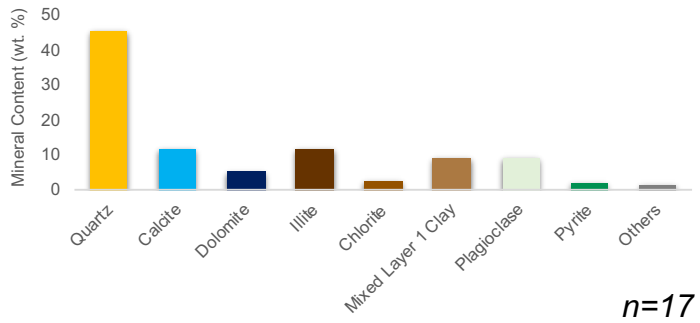
Carbonate-rich Siliceous Mudstone



Observations

- Massive mudstone matrix with calcareous fragments that are silt-sized to mm-scale
- Microfossil (radiolarians) and fractures replaced by calcite

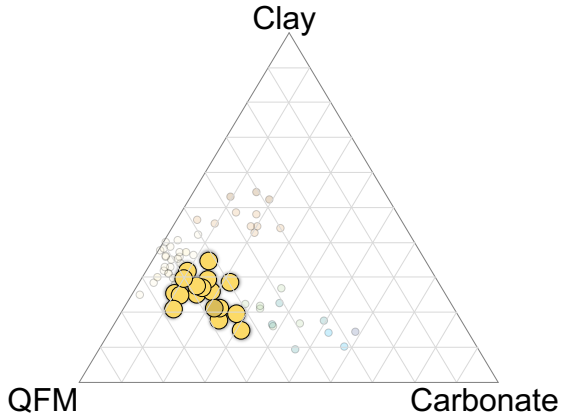
Bulk Mineralogy

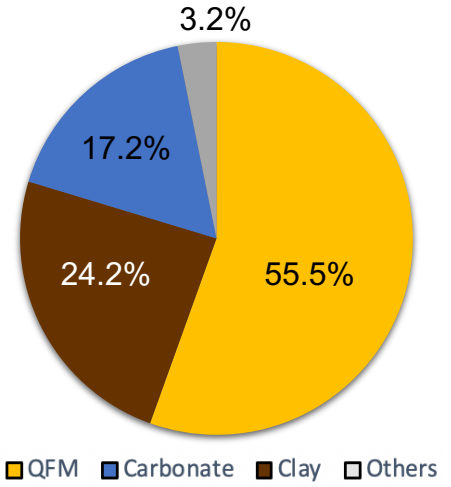


Reservoir Properties (Average)

Porosity: 8.2 %
Permeability: 59.9 nD
TOC: 2.3 wt. %

Carbonate-rich Siliceous Facies XRD (n=17)





Carbonate-rich Siliceous Mudstone

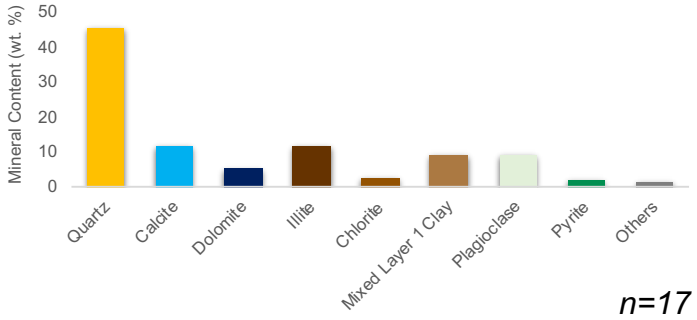
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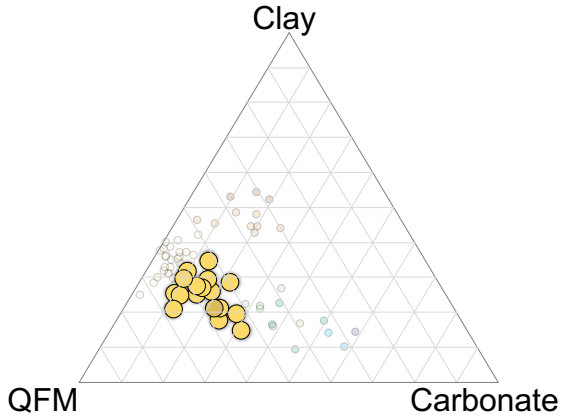
Bulk Mineralogy

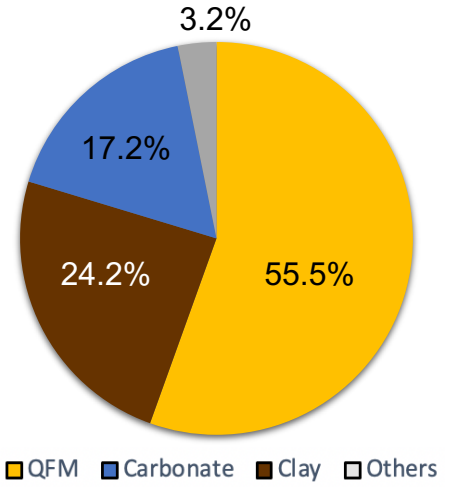


Reservoir Properties (Average)

Porosity: 8.2 %
Permeability: 59.9 nD
TOC: 2.2 wt. %

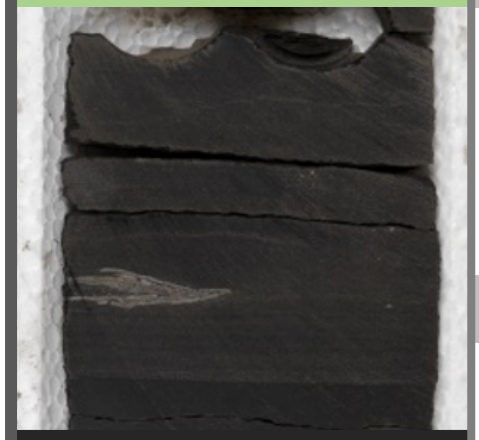
Carbonate-rich Siliceous Facies XRD (n=17)



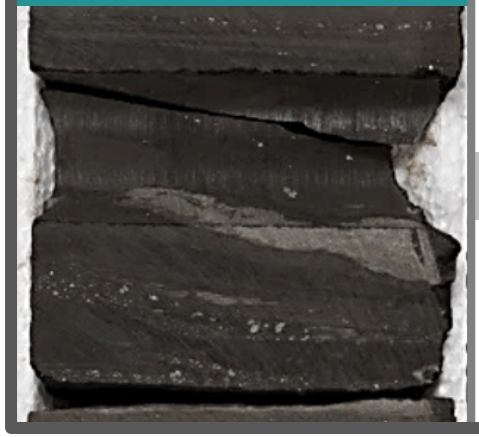


Mixed Carbonate Mudstone to Silty Mudstone

Mixed Calcareous Mudstone



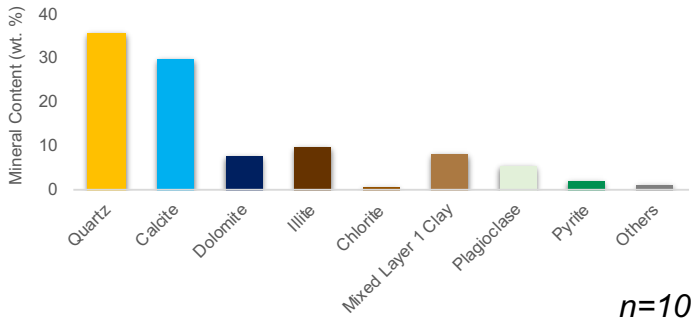
Mixed Calcareous Silty Mudstone



Observations

- Mixed facies largely composed of silicate and carbonate
- Increase in carbonate content attributed to calcite and dolomite diagenetic alteration

Bulk Mineralogy

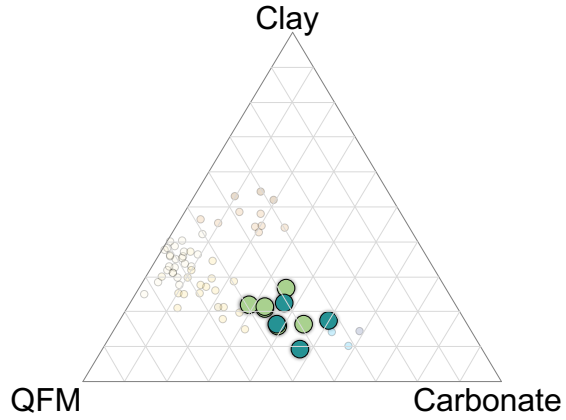


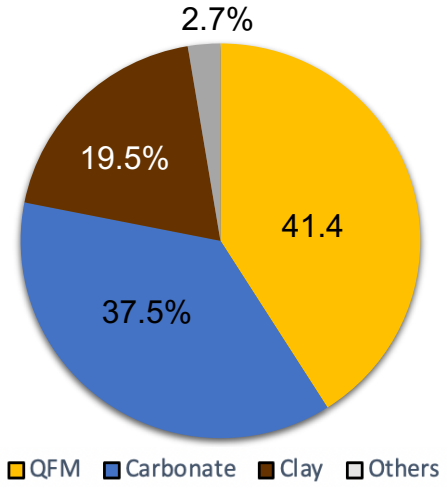
n=10

Reservoir Properties (Average)

Porosity: 7.0 %
Permeability: 97.8 nD
TOC: 2.3 wt. %

Mixed Calcareous Facies XRD (n=10)





Calcareous Siltstone

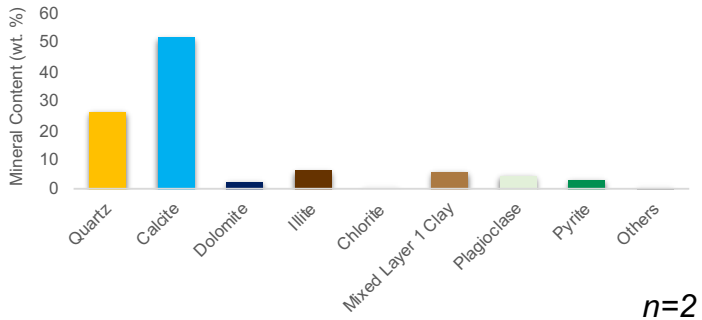
Calcareous Siltstone



Observations

- Light to medium gray siltstone composed of abundant silt sized calcareous fragments
- Massive to laminated
- Fluid escape structures
- Calcite component from cement and allochems replaced by calcite

Bulk Mineralogy

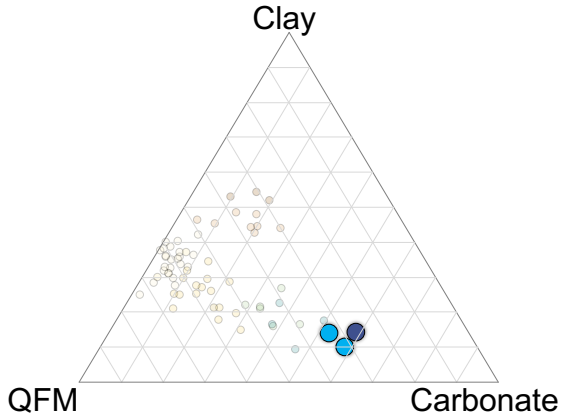


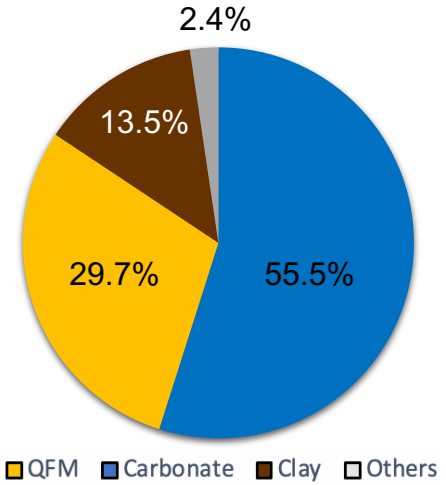
n=2

Reservoir Properties (Average)

Porosity: 5.7 %
Permeability: 59.7 nD
TOC: 1.8 wt. %

Calcareous Facies XRD (n=3)





Dolostone

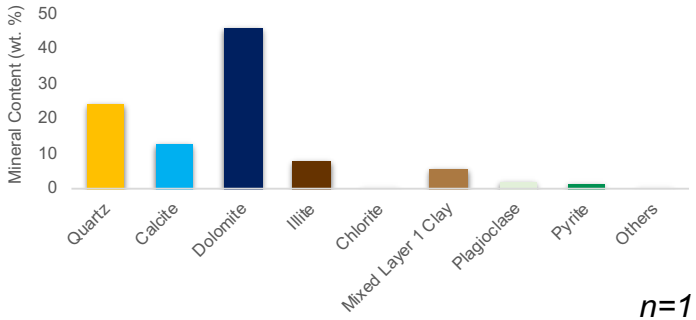
Dolostone



Observations

- Yellow-brown to gray dolostone
- Massive with sparse laminations
- Fluorescent under UV to dull orange
- Matrix of microcrystalline dolomite and recrystallized microfossils

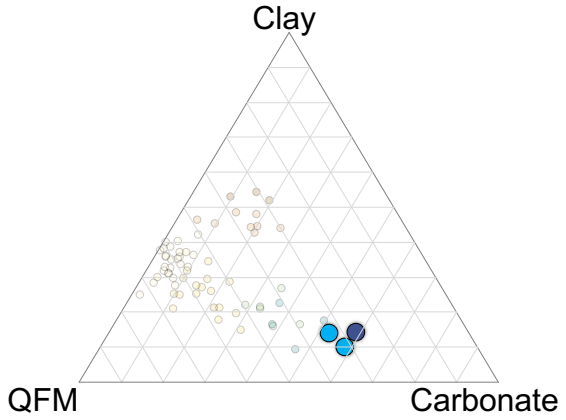
Bulk Mineralogy

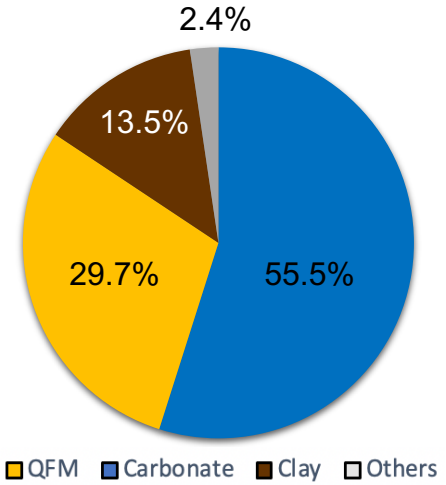


Reservoir Properties (Average)

Porosity: 6.1 %
Permeability: 11.2 nD
TOC: 0.7 wt. %

Calcareous Facies XRD (n=3)





Dolostone

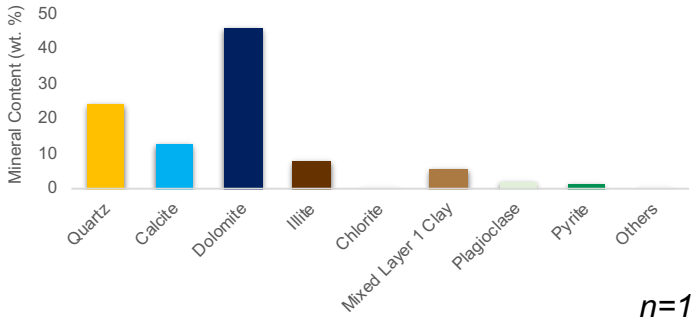
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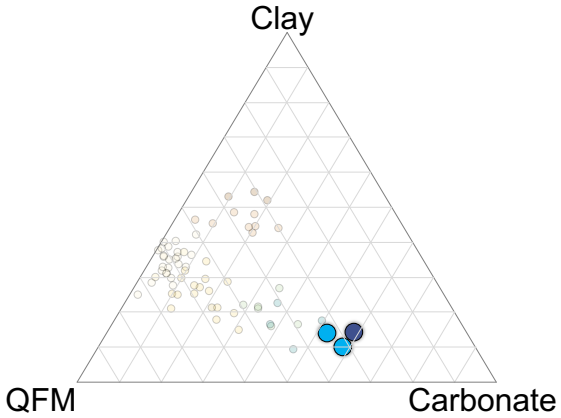


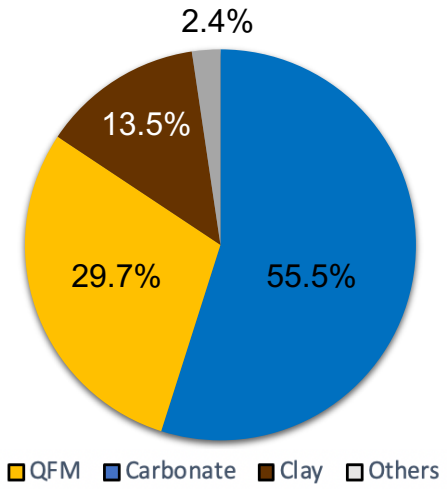
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Reservoir Properties (Average)

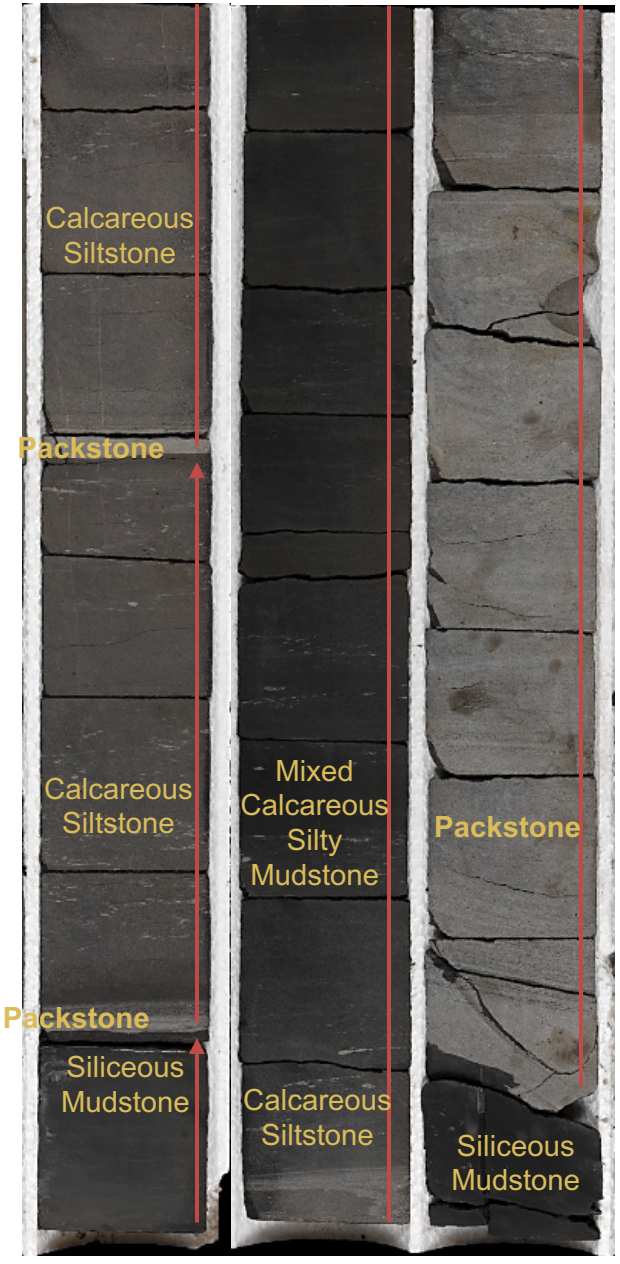
Porosity: 6.1 %
Permeability: 0.01 nD
TOC: 0.7 wt. %

Calcareous Facies XRD (n=3)



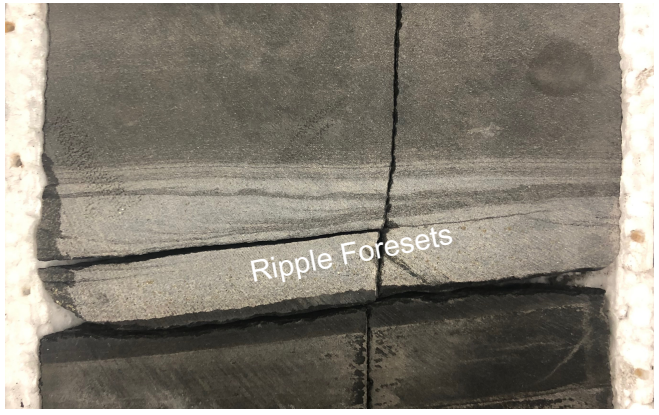


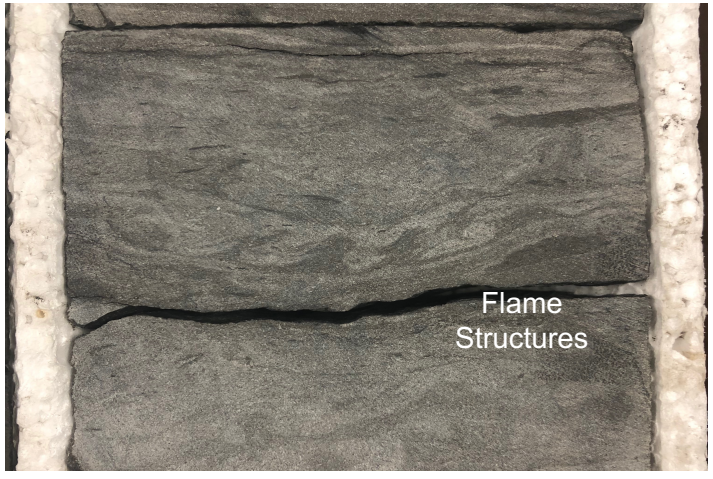
Skeletal Packstone



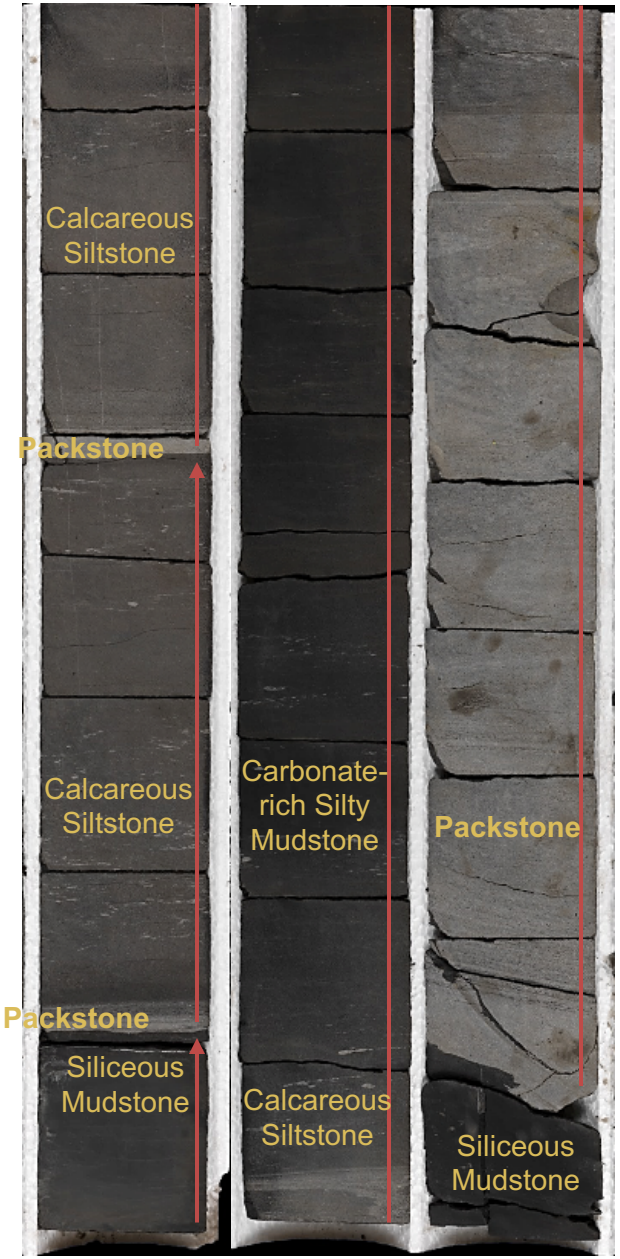


- Light to medium gray packstone
- Massive to laminated
- Sharp basal contact
- Normally graded
- Sedimentary structures: pyrite, mud clasts, soft sediment deformation features





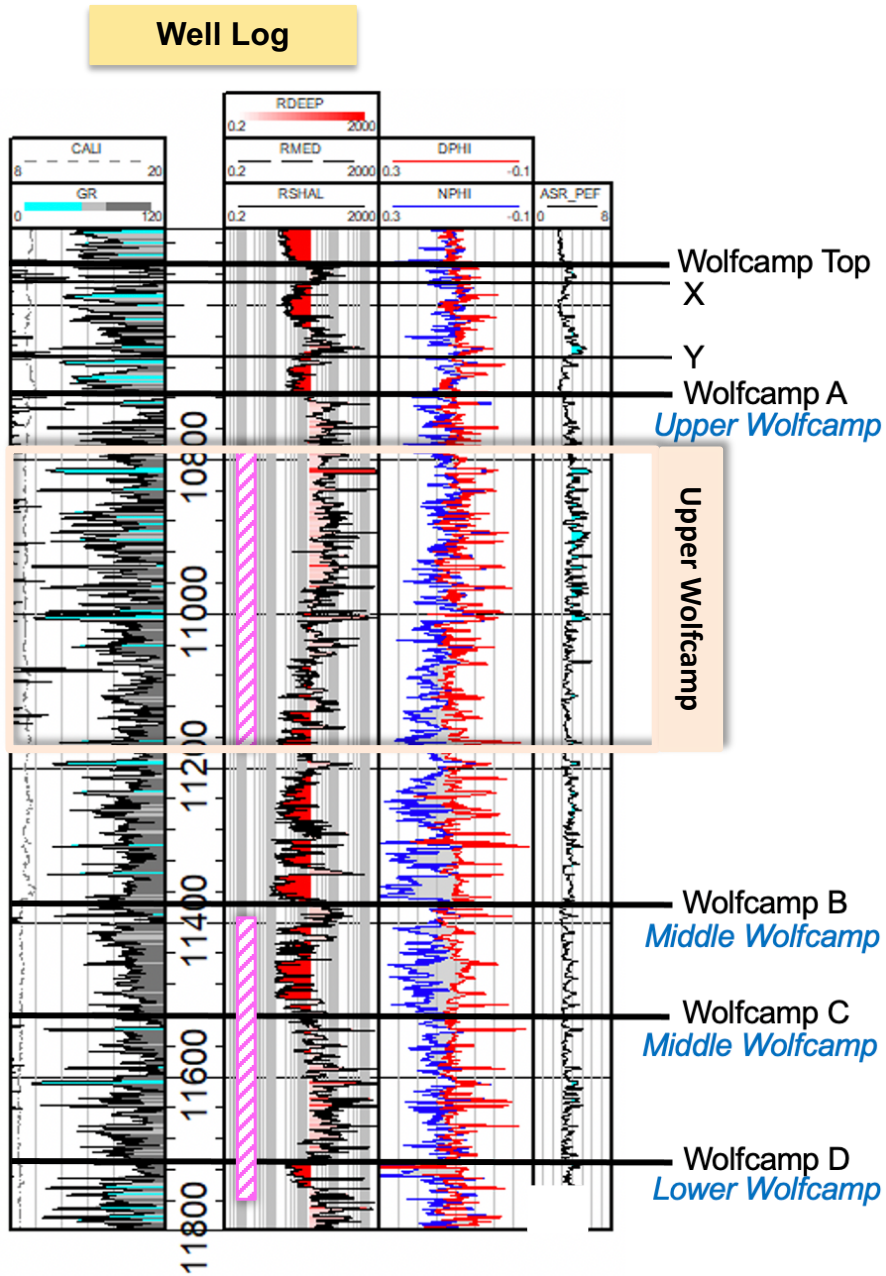
Wackestone

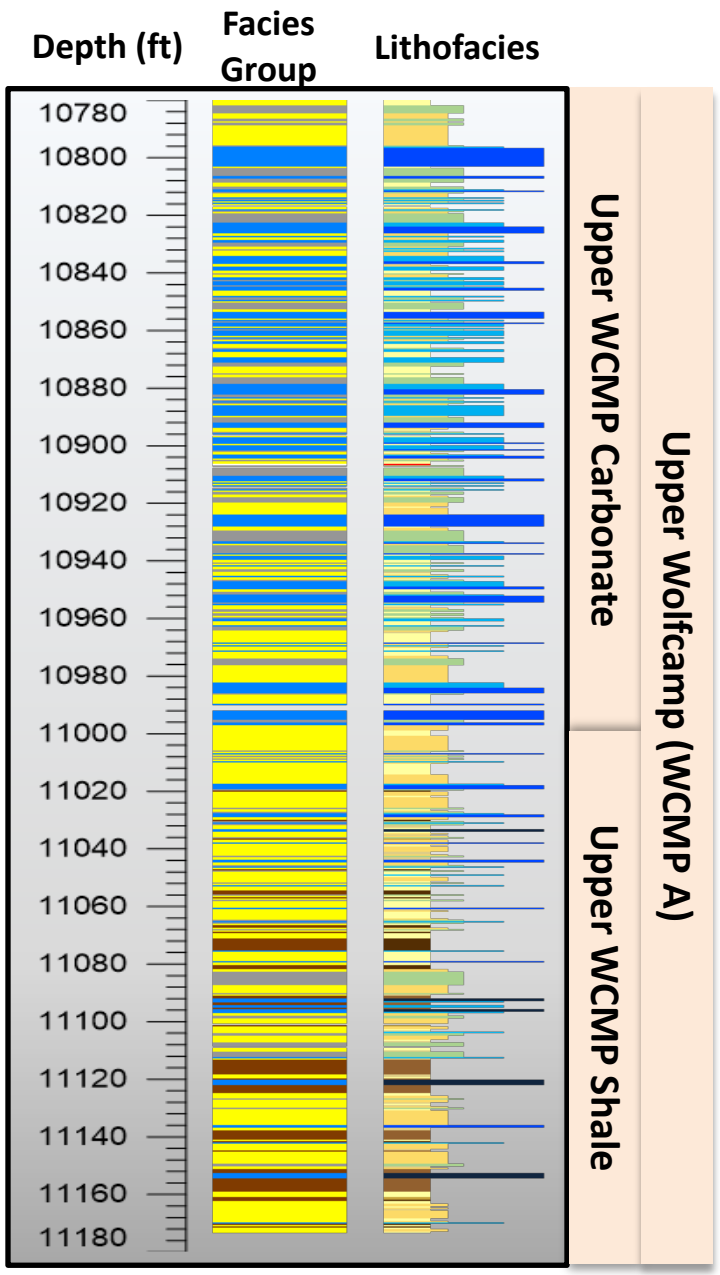

Calcareous Siltstone
Packstone
Calcareous Siltstone
Packstone
Siliceous Mudstone
Carbonate-rich Silty Mudstone
Calcareous Siltstone
Packstone
Siliceous Mudstone


Skeletal Packstone

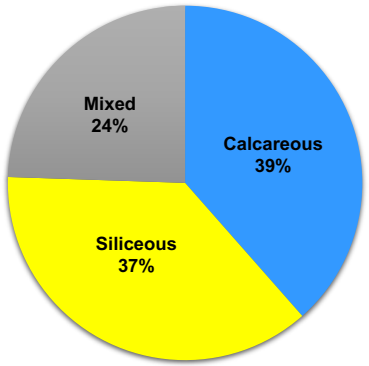

Wackestone
Clast protrusion
Poorly sorted clasts in mud matrix
Sub-angular to sub-rounded
Sharp basal contact

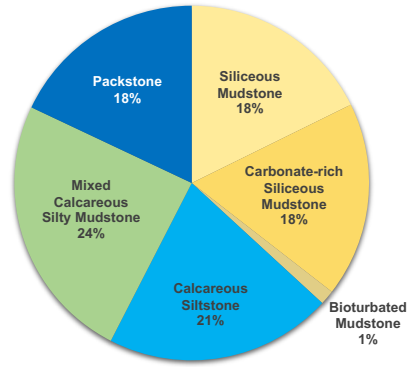
Upper Wolfcamp Facies Distribution



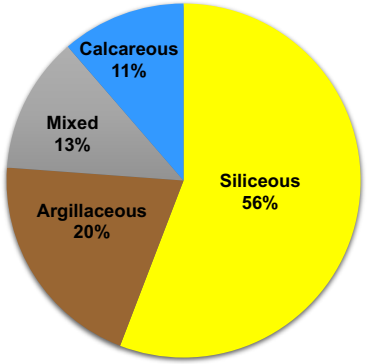


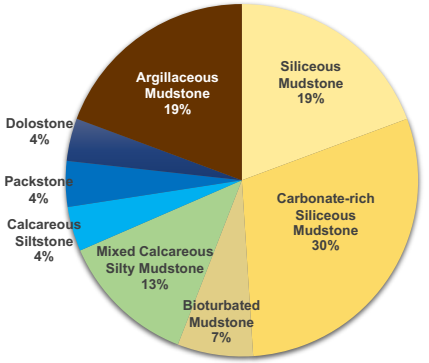
Upper Wolfcamp Carbonate



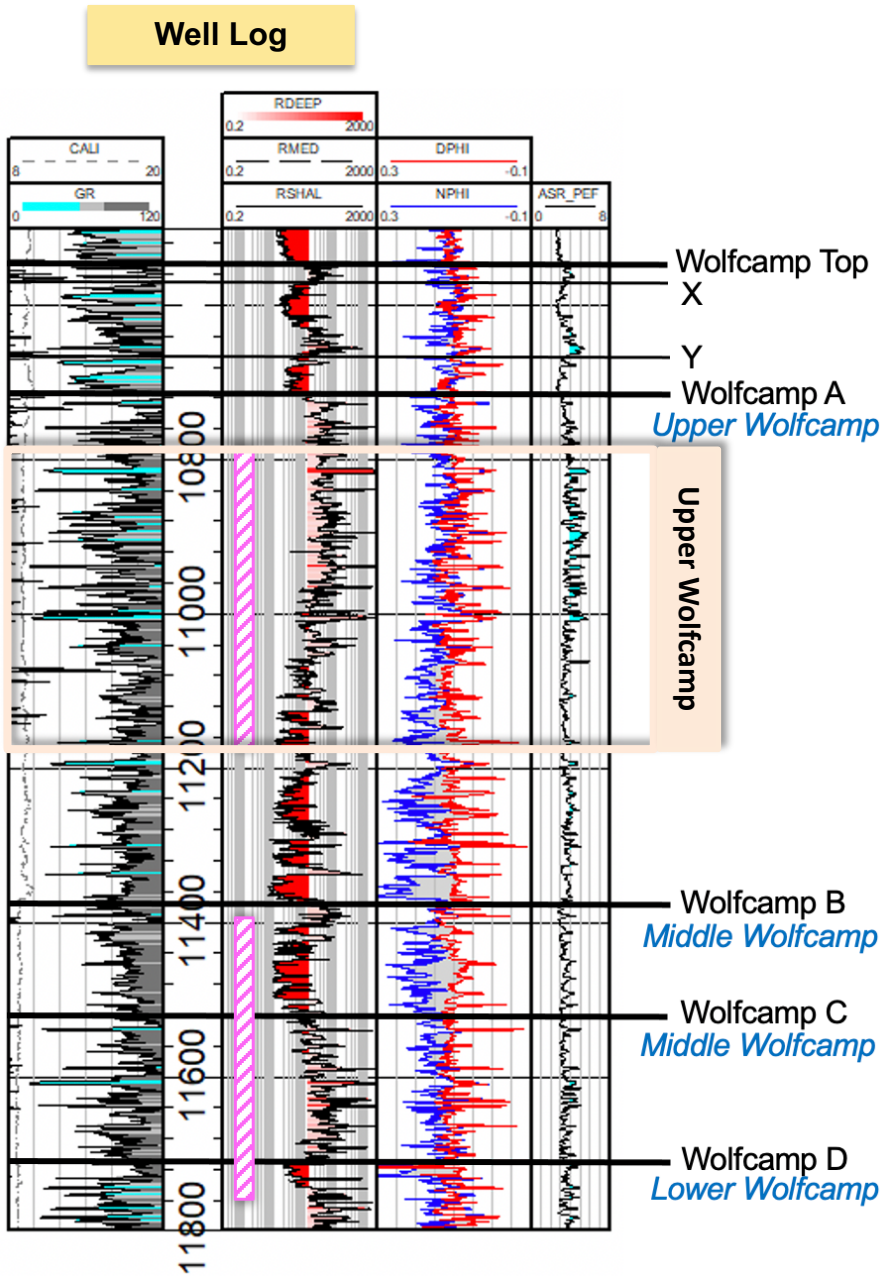


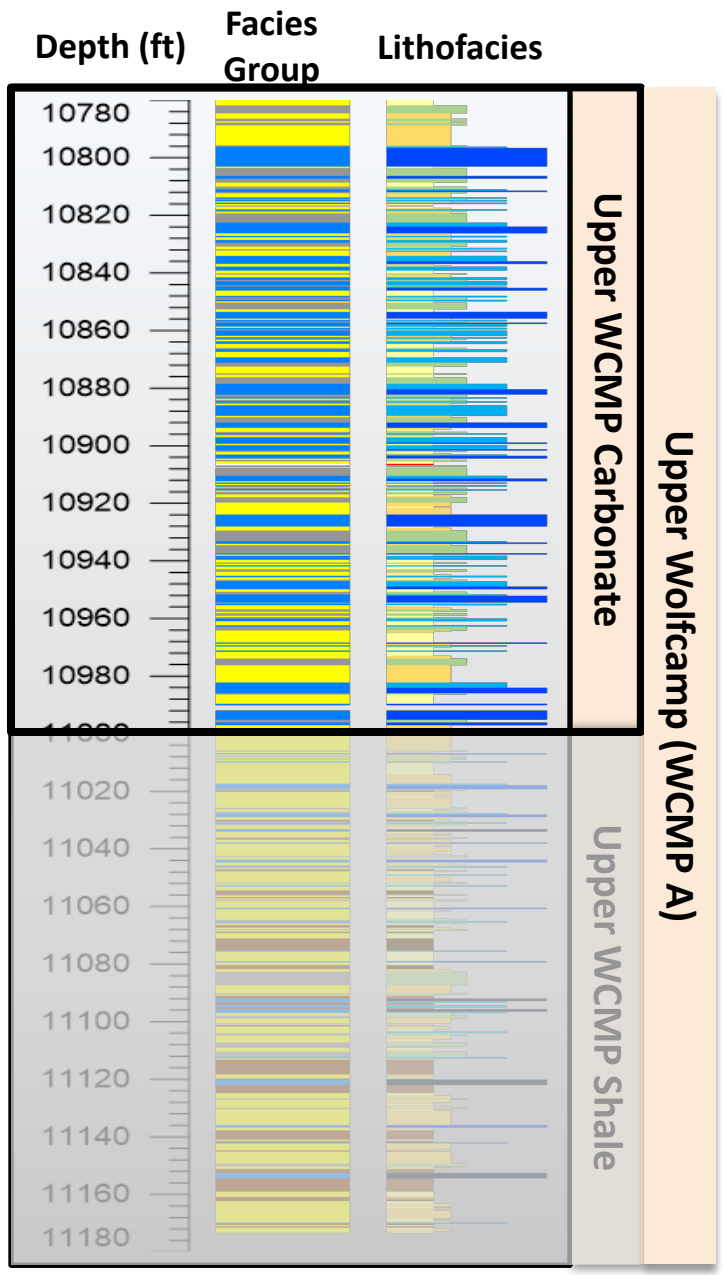
Upper Wolfcamp Shale





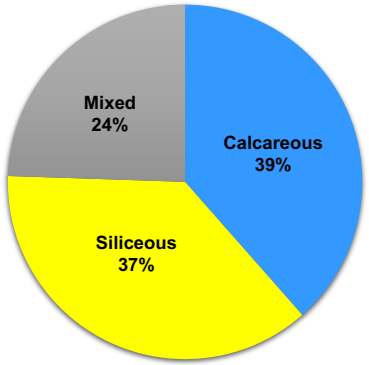
Upper Wolfcamp Carbonate



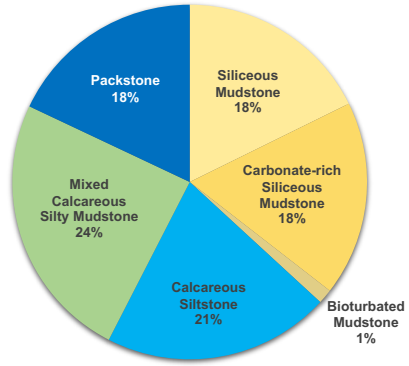


Upper Wolfcamp Carbonate

Facies Group

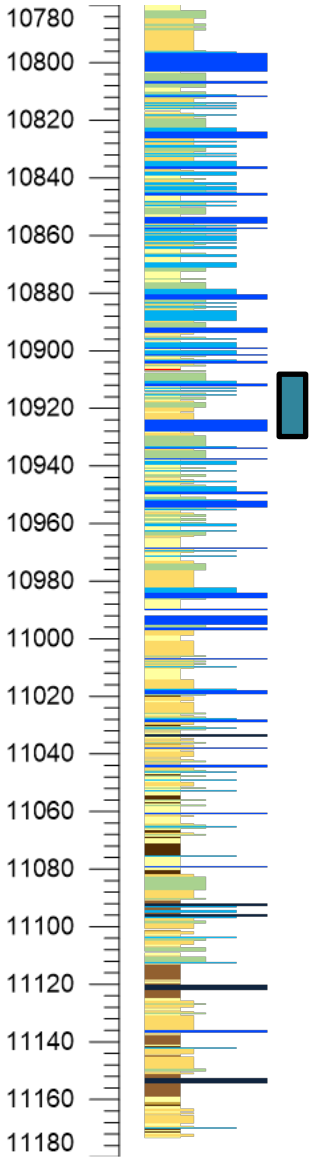


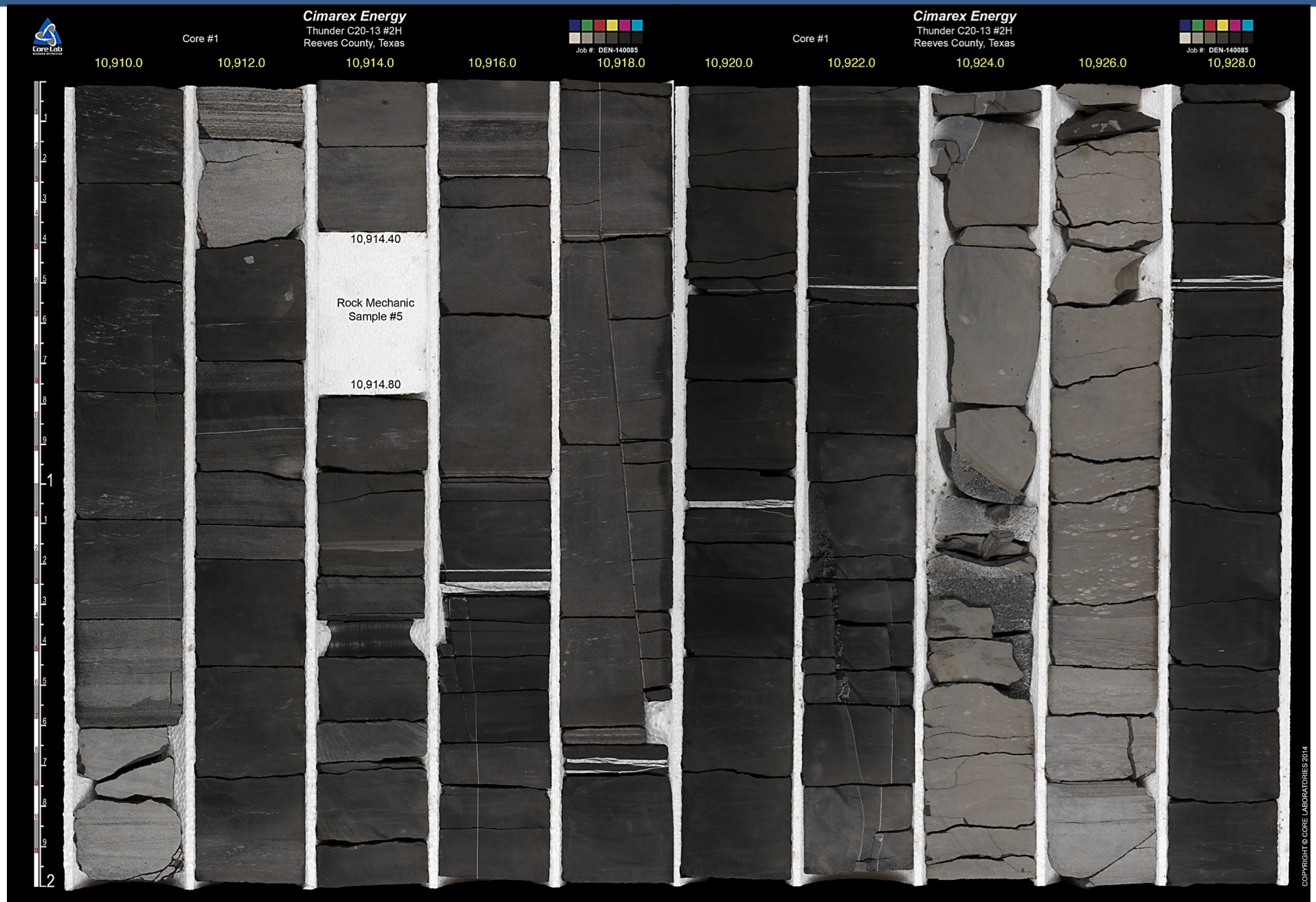
Lithofacies



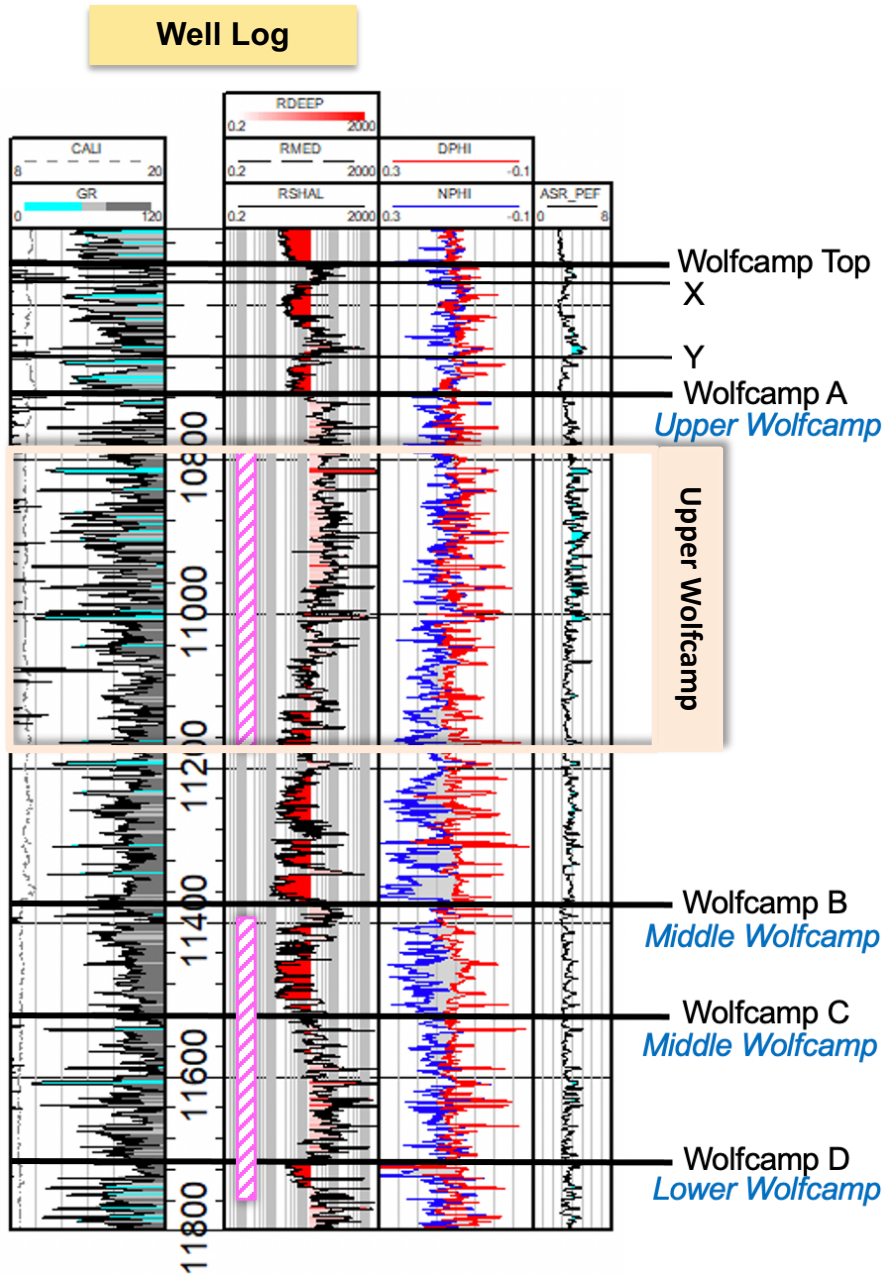
- Calcareous, siliceous and mixed facies group
- Dominant lithofacies associated with sediment gravity flows → Hybrid Event Beds (HEBs)
- Compositionally stratified beds (cyclicity) of fining upward sequences

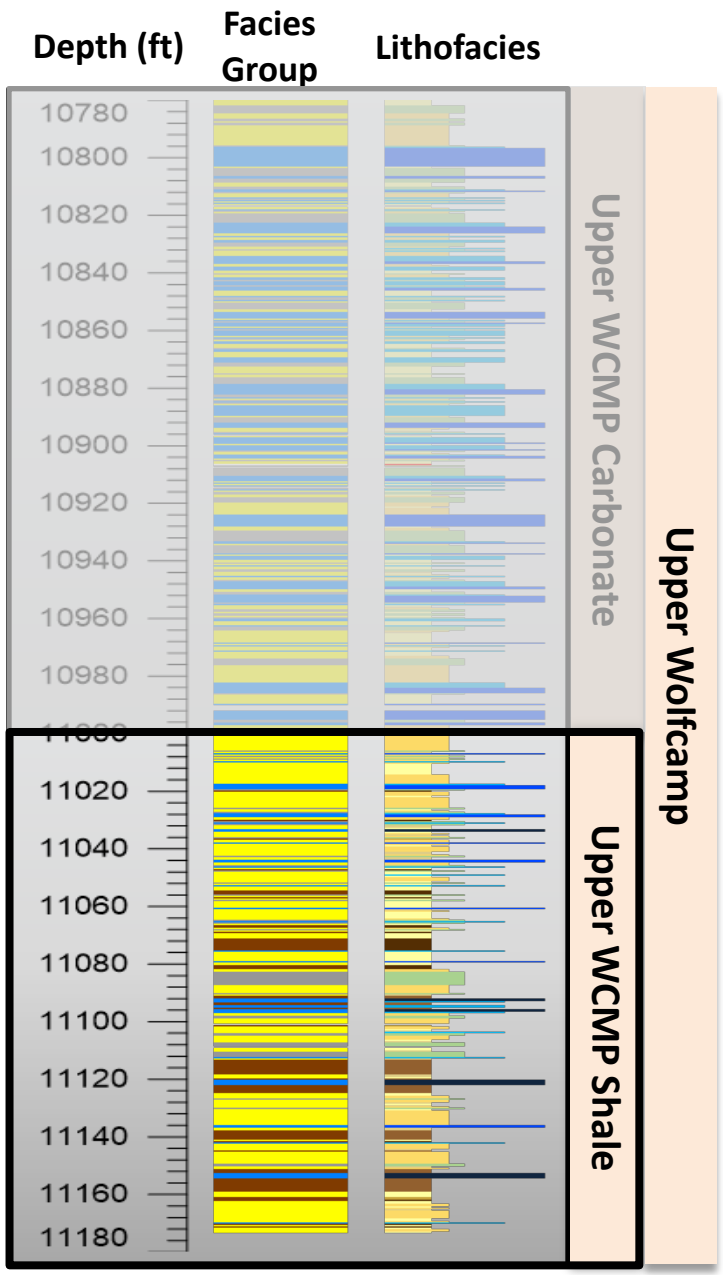
Upper Wolfcamp Carbonate (Core)





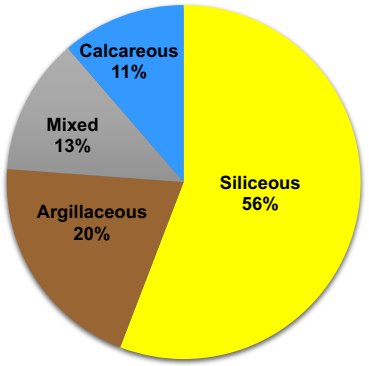
Upper Wolfcamp Shale



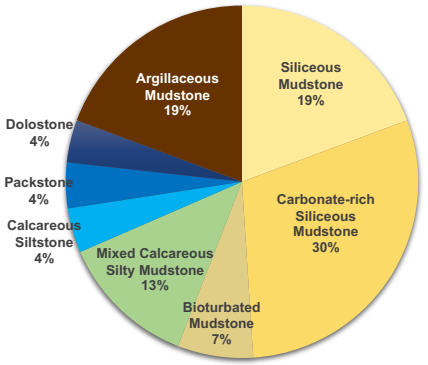


Upper Wolfcamp Shale

Facies Group

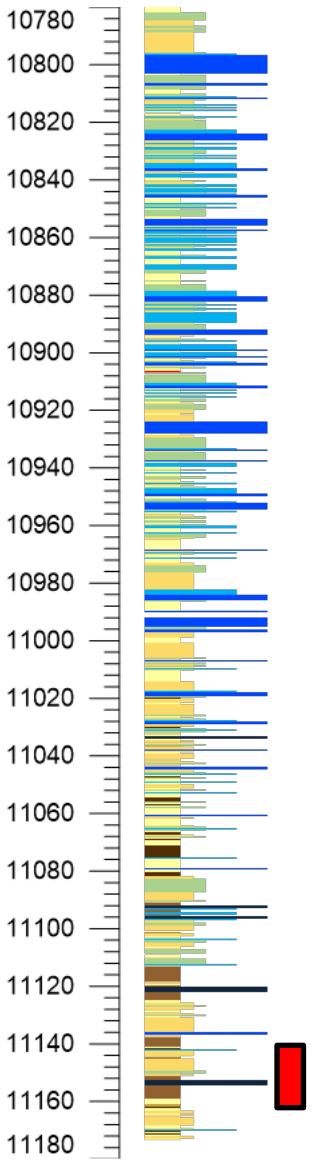


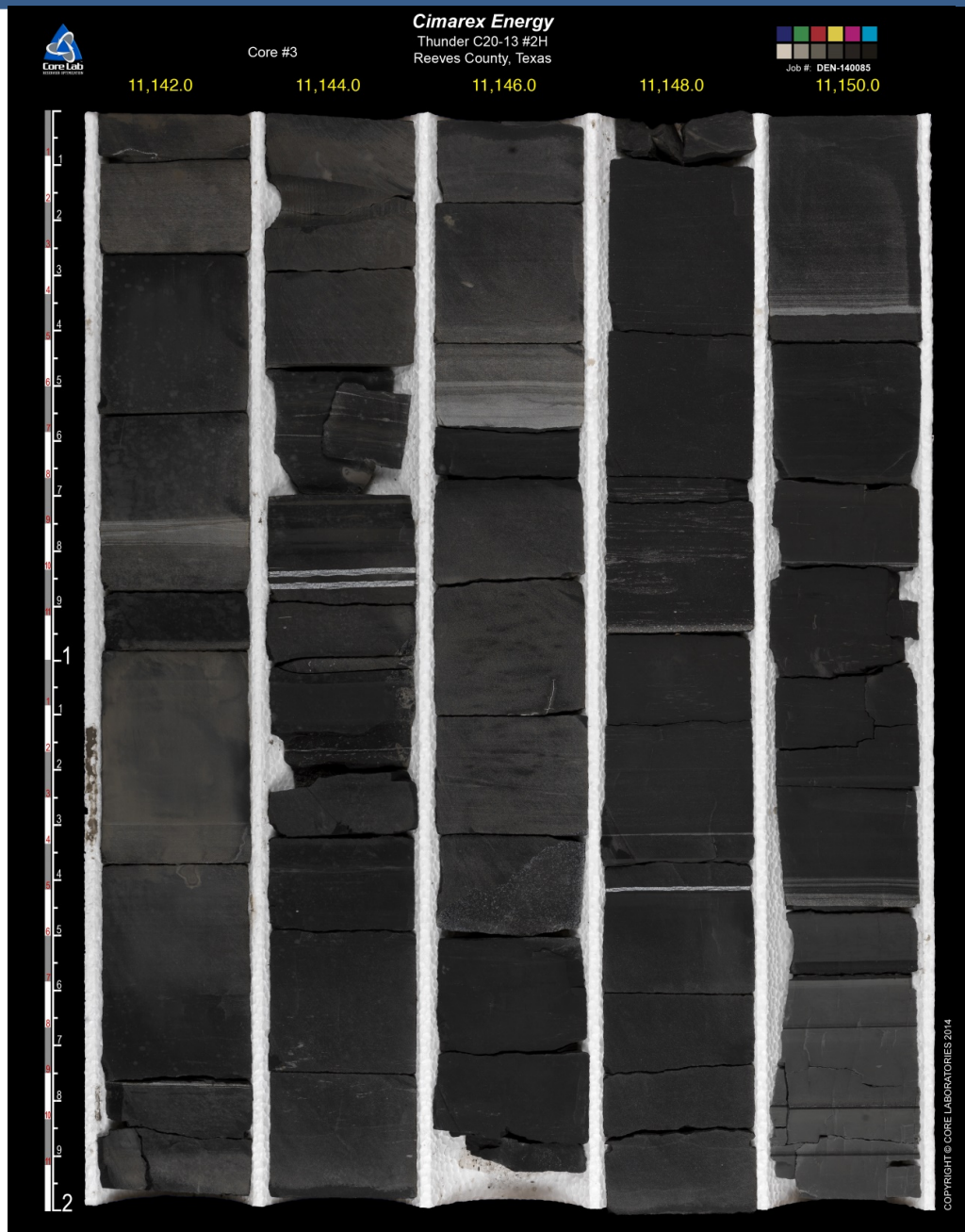
Lithofacies

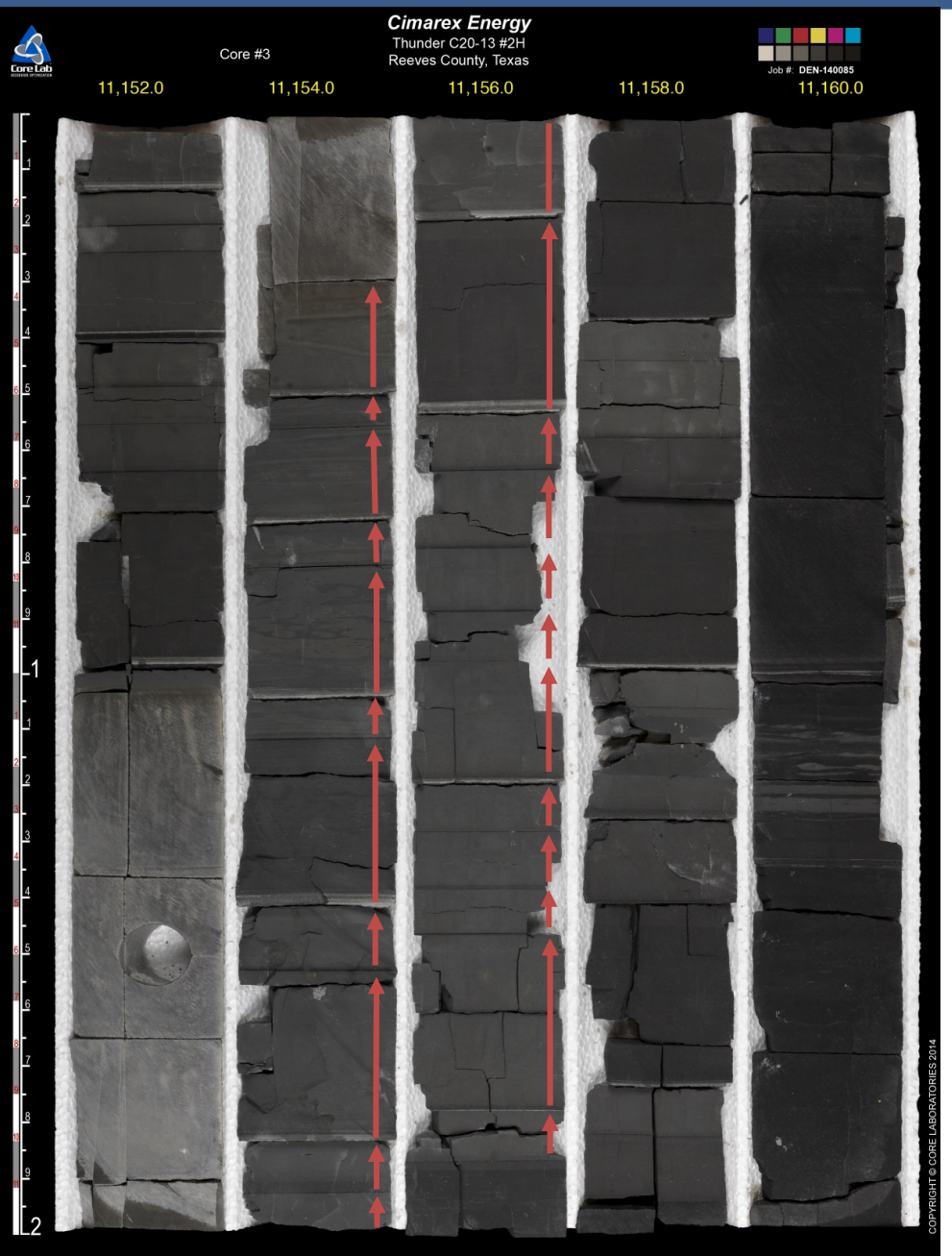


- Dominantly siliceous and argillaceous facies group
- Decrease in calcareous facies
- Some HEBs
- Dominant facies associations are thin, distal turbidites
- Series of organic-lean, green, argillaceous mudstone capped with dark gray to black mudstone with between fluorescent dolostone

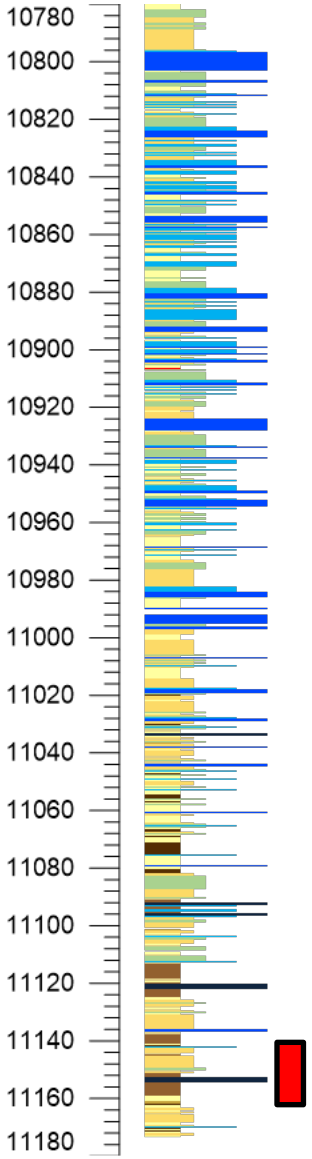
Upper Wolfcamp Shale (Core)

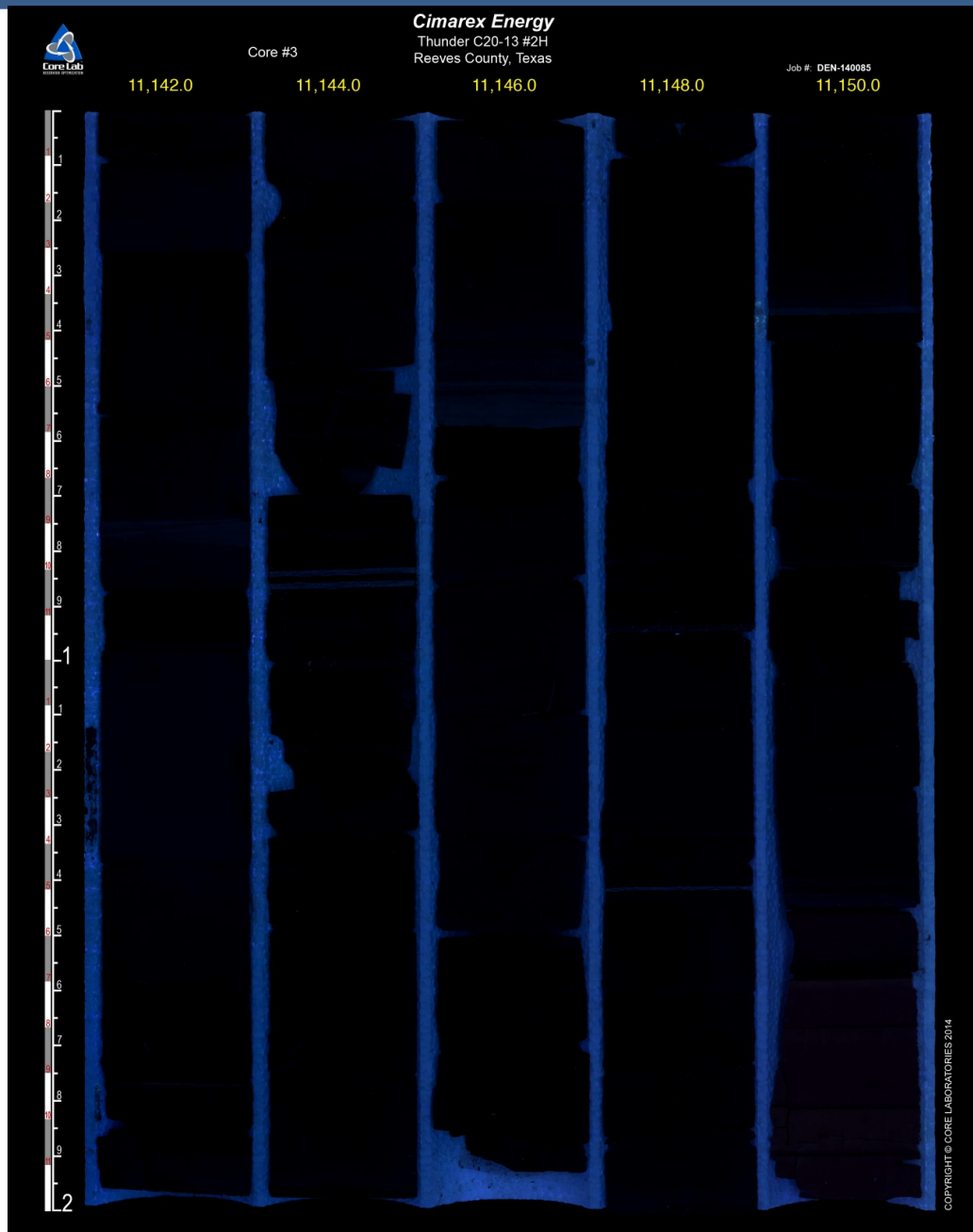


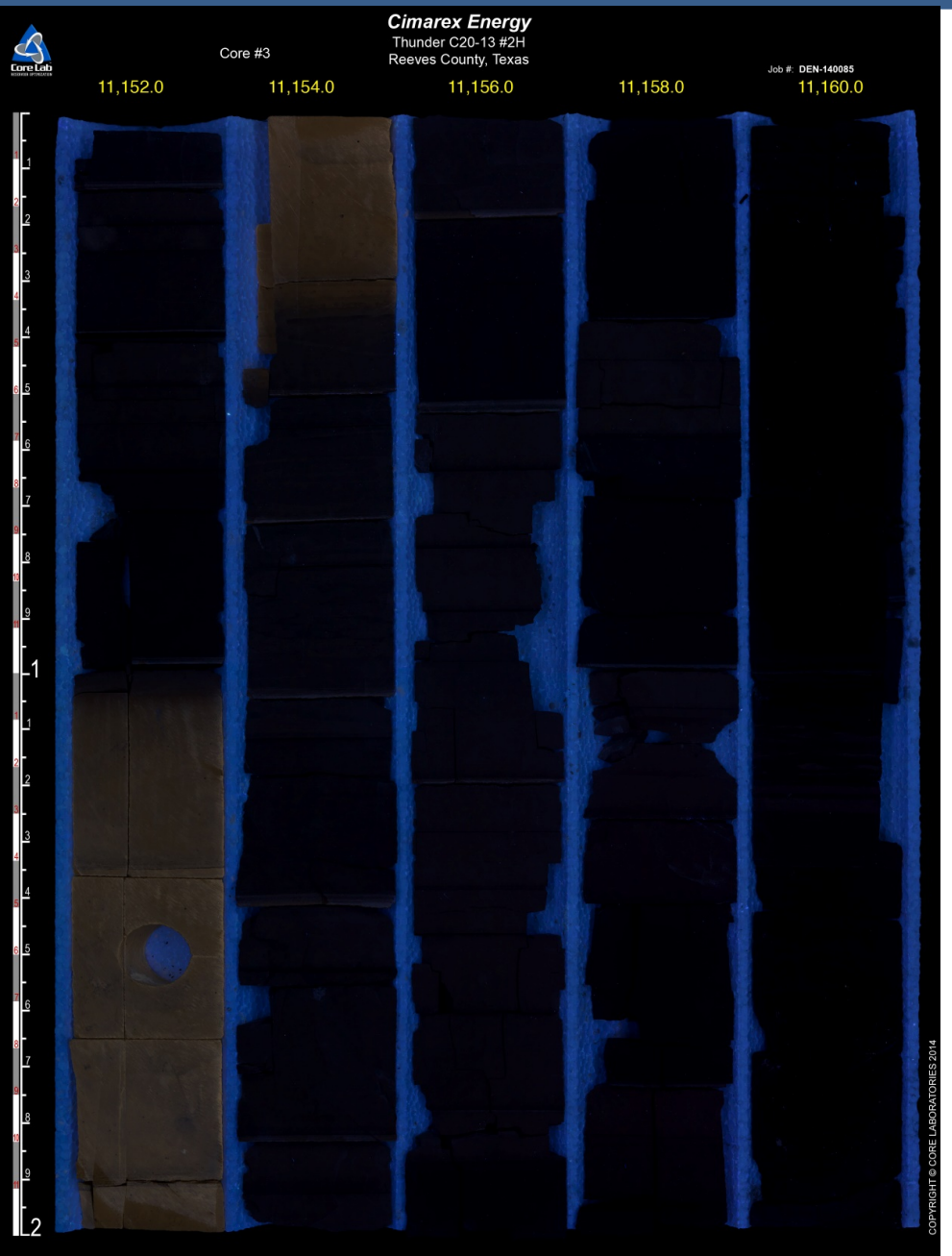




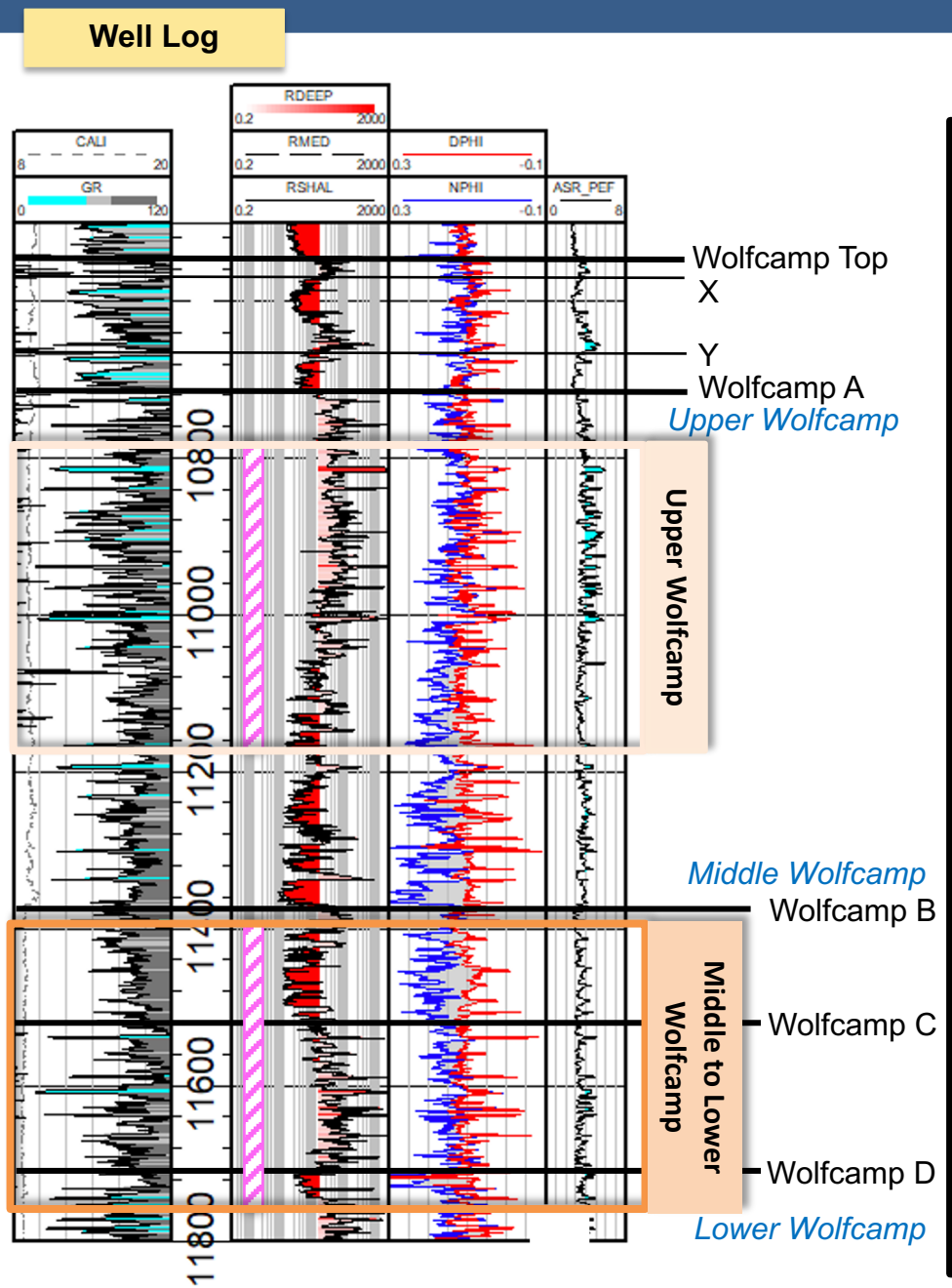
Upper Wolfcamp Shale (Core)

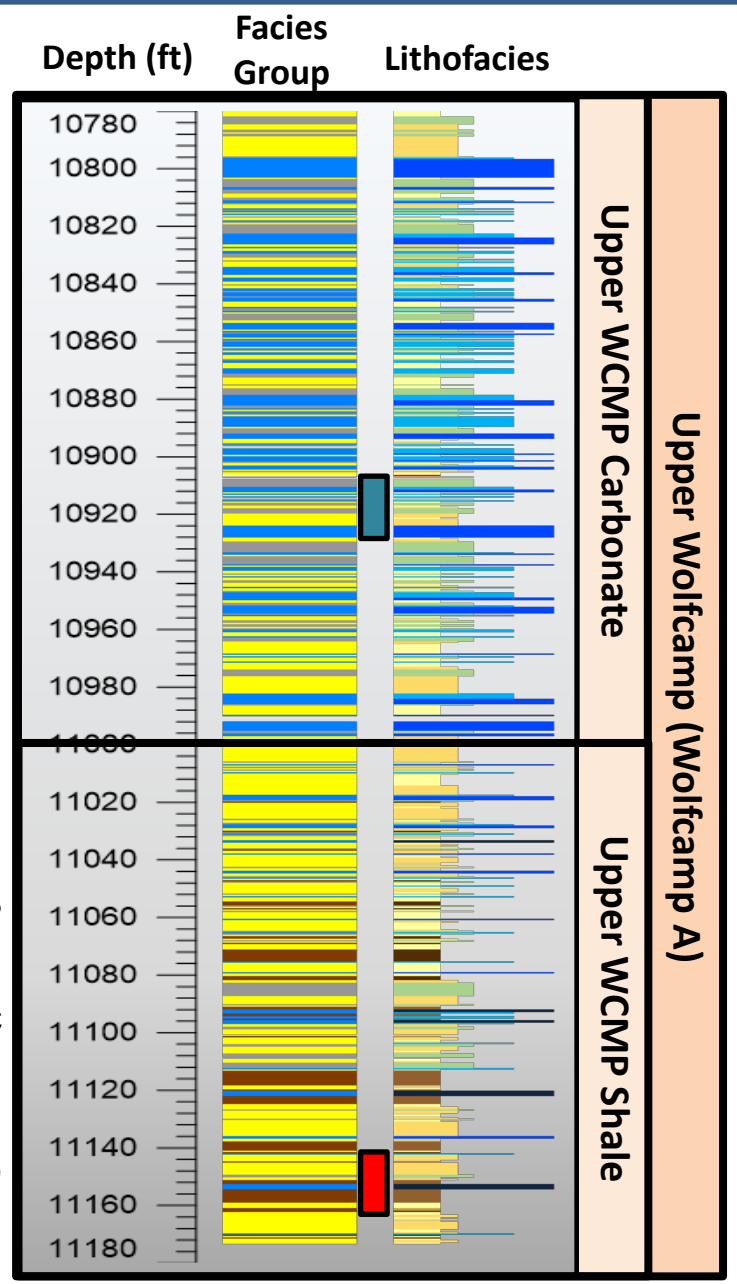


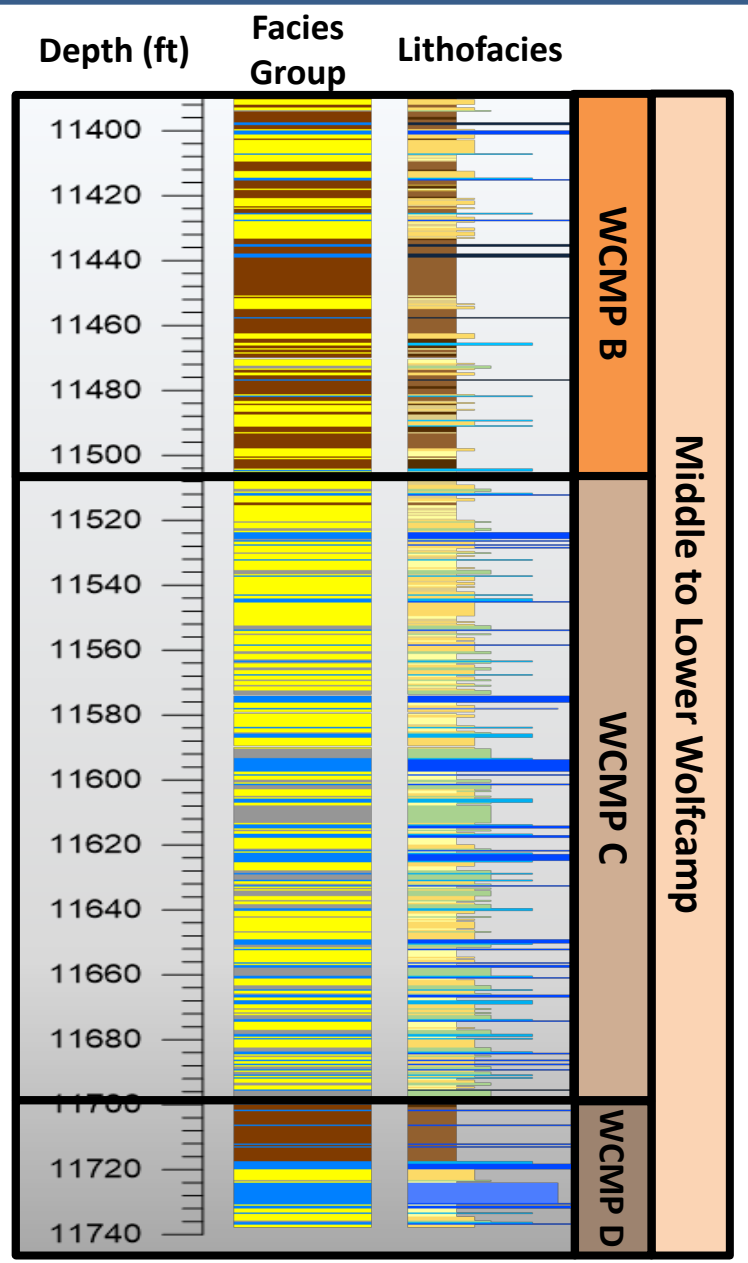




Middle and Lower Facies Distribution

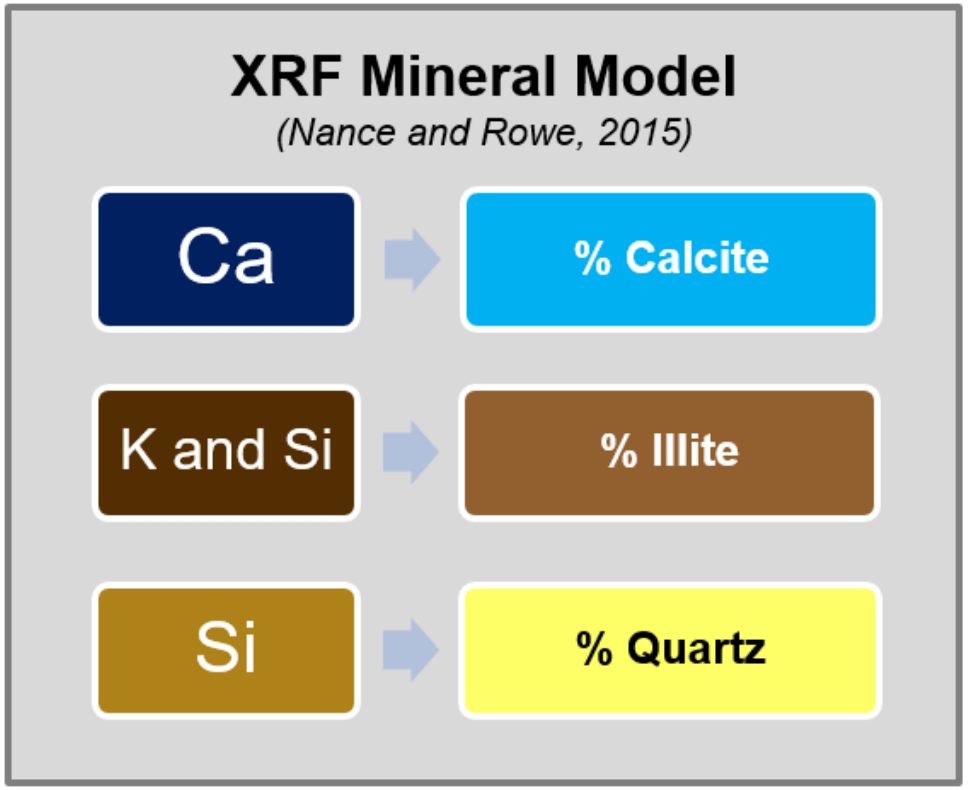


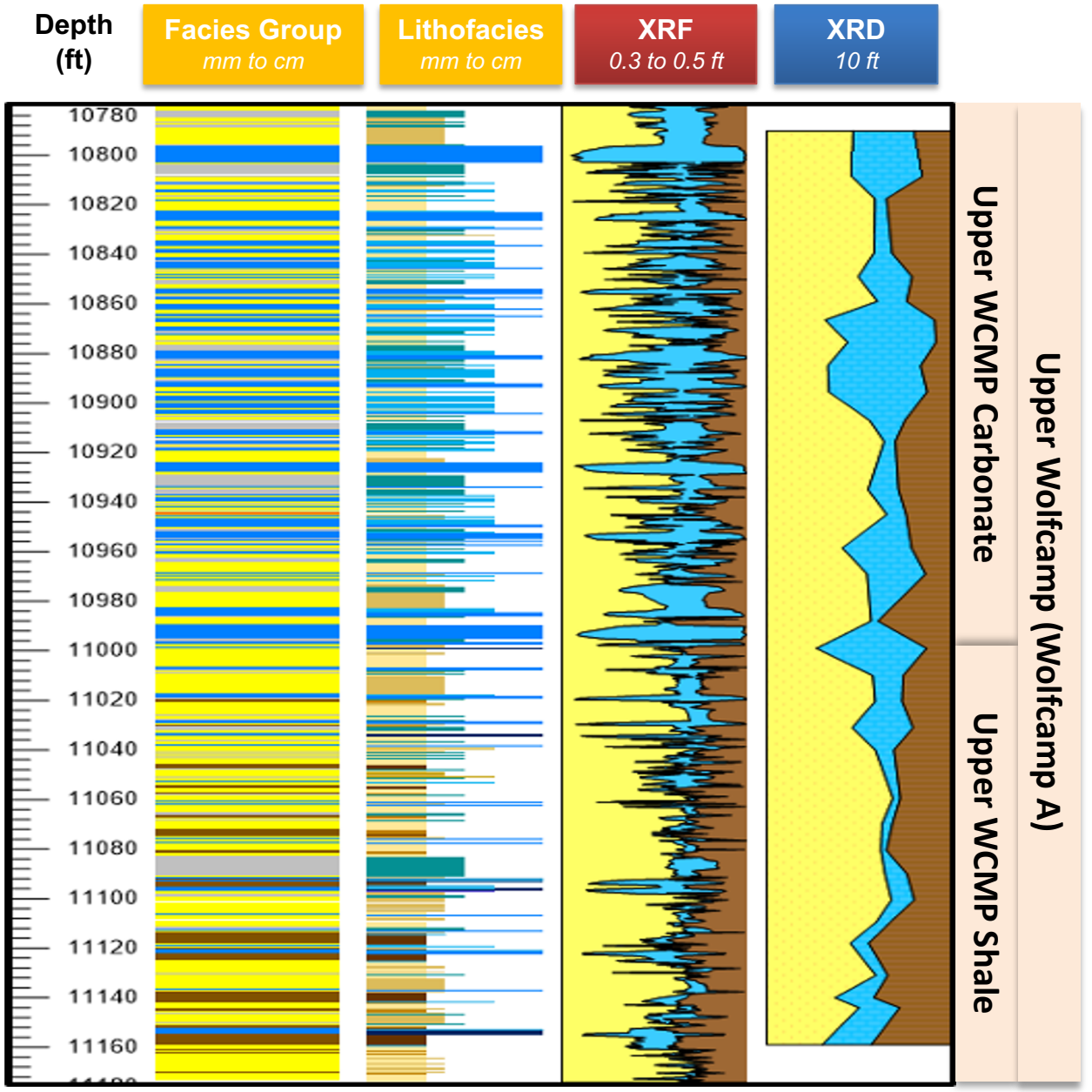




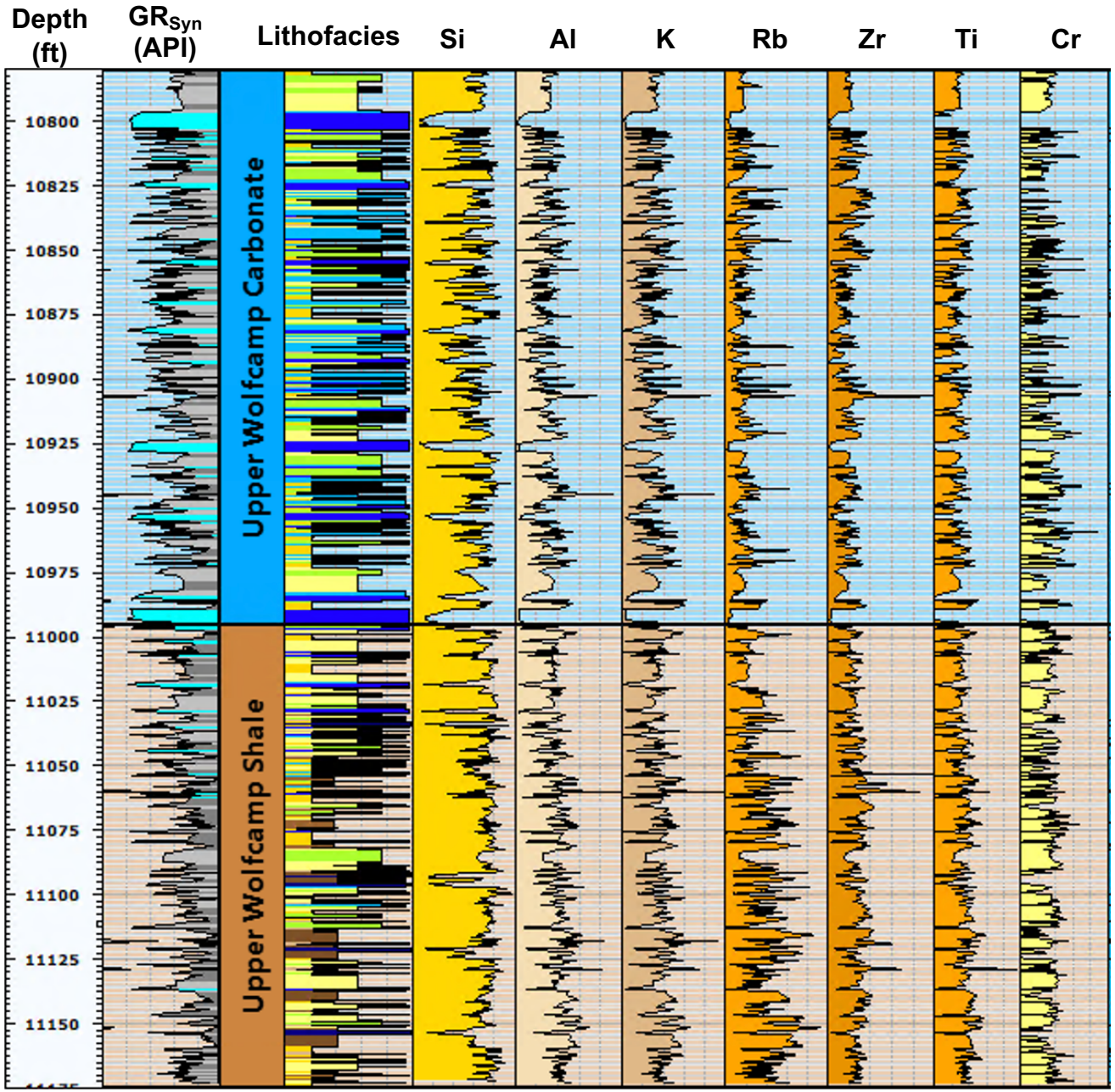
XRF Highlighting Wolfcamp Heterogeneity

High resolution XRF available for Upper Wolfcamp Cored Section

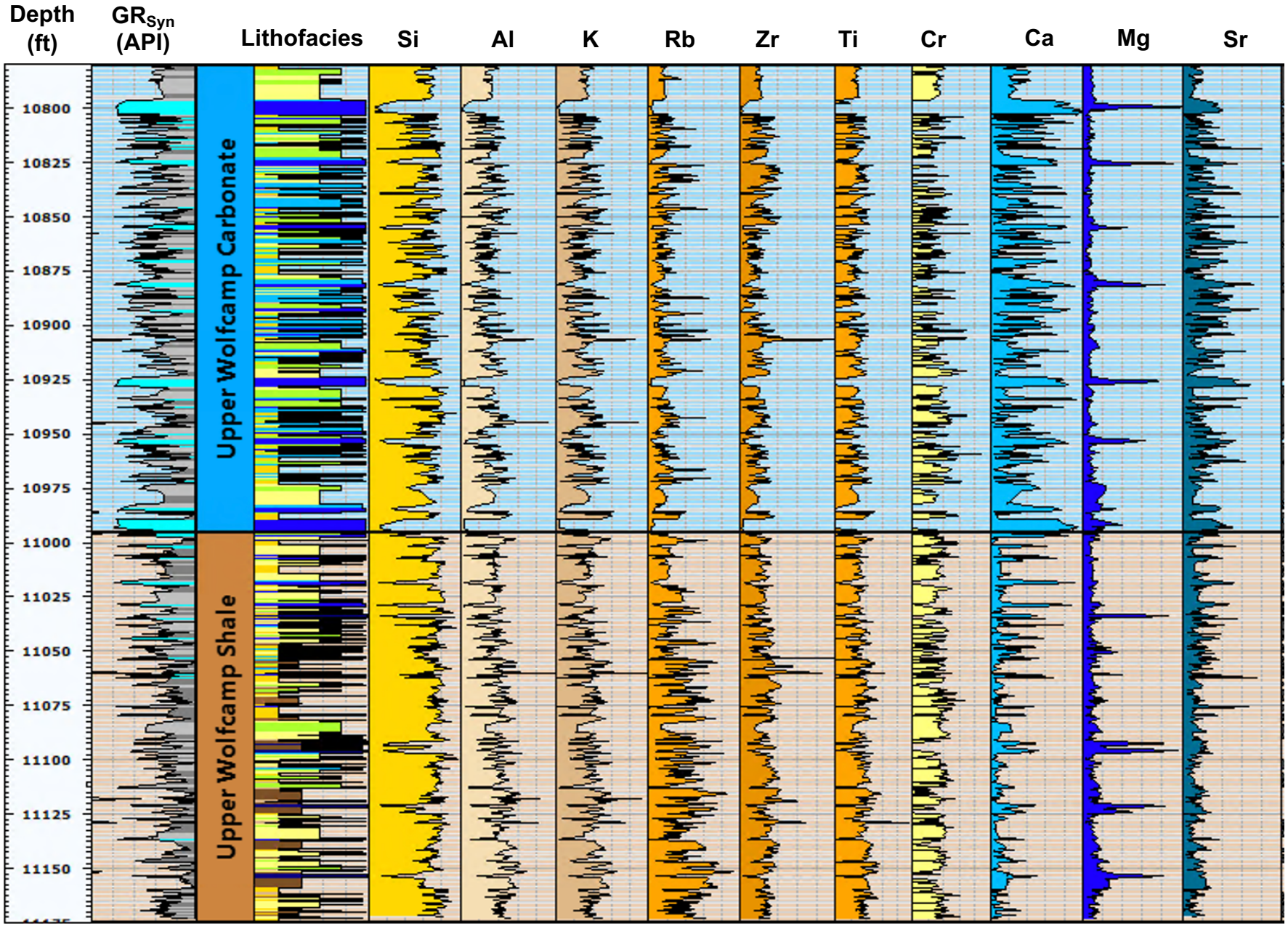




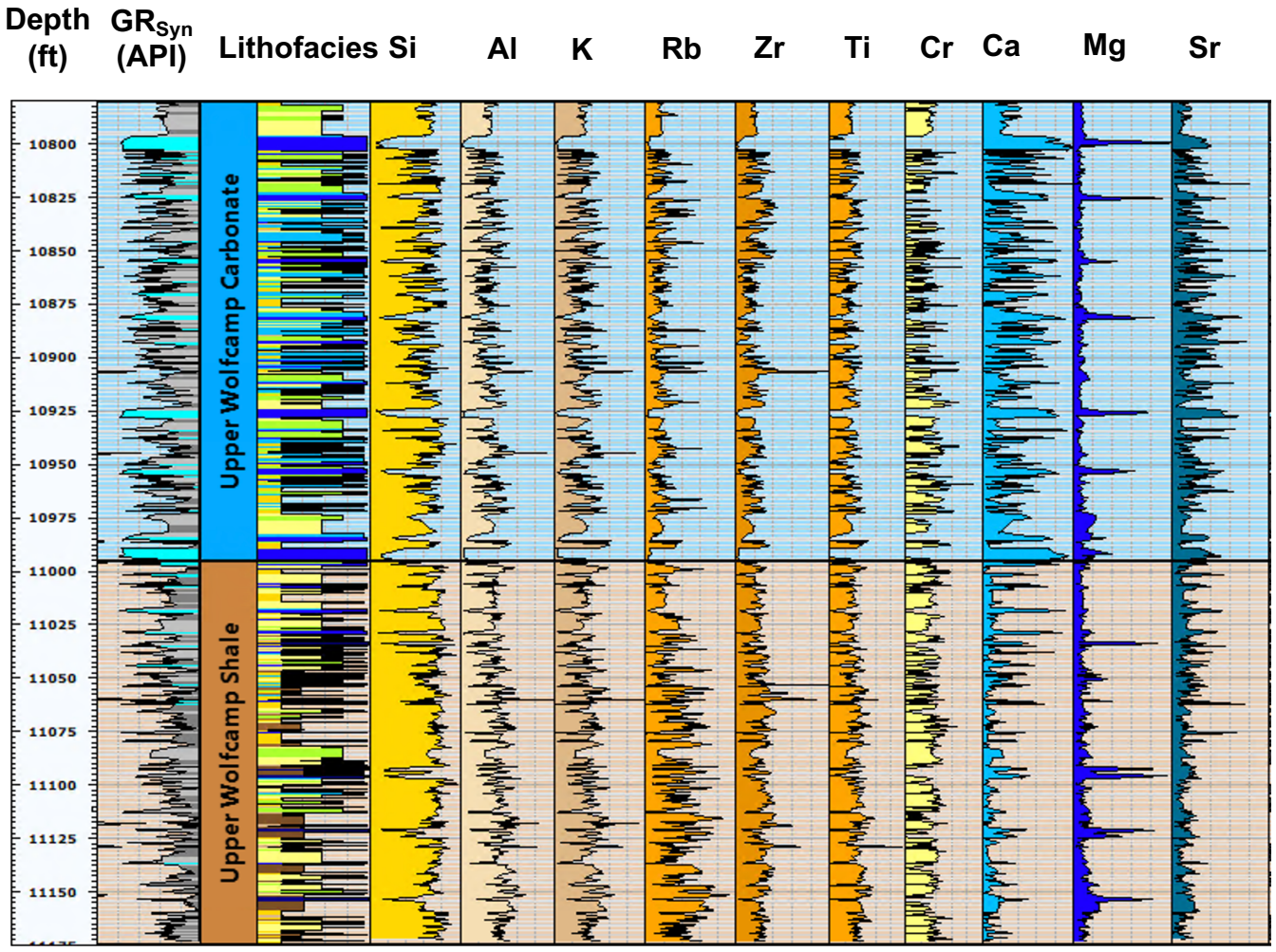
Terrestrial Indicators

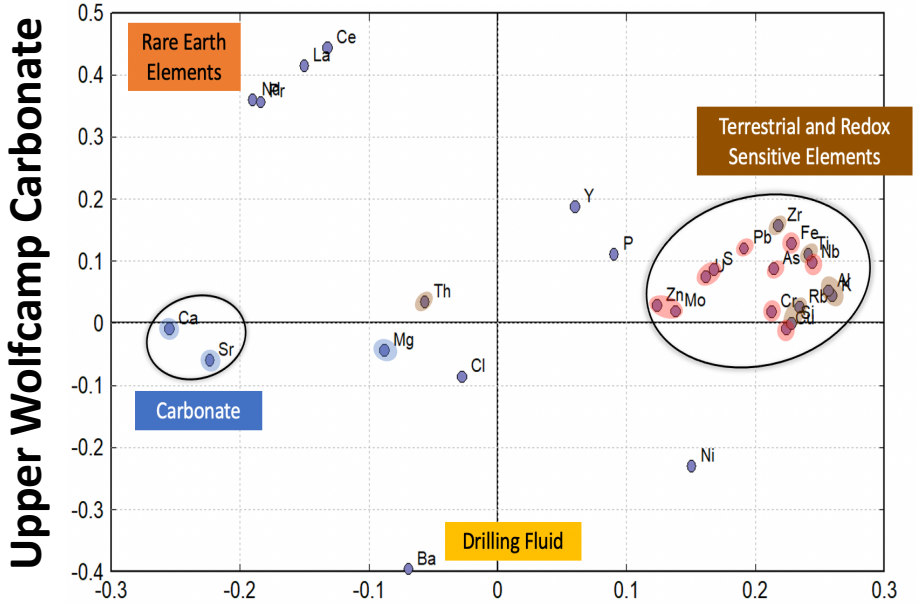


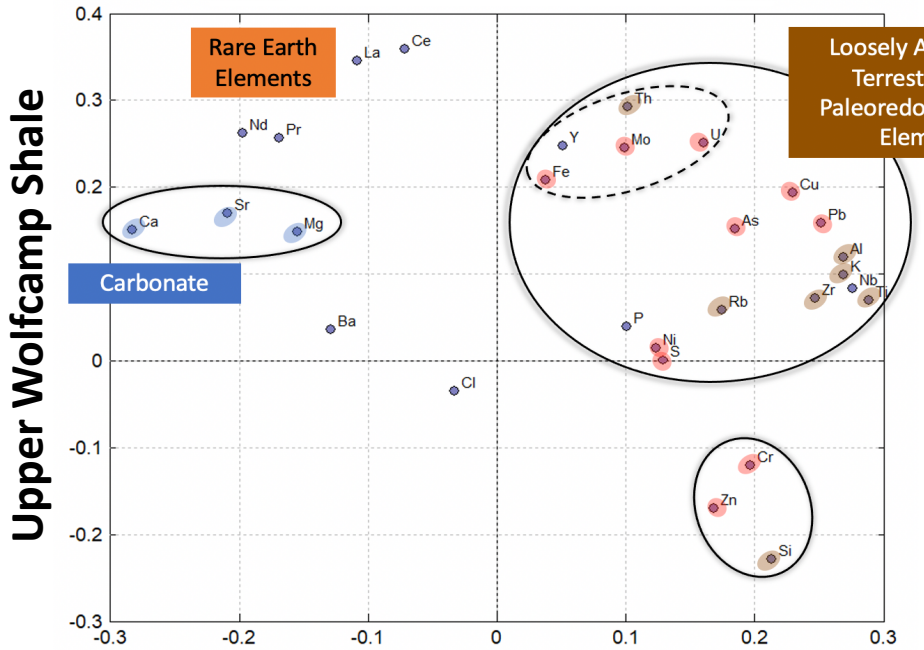
Carbonate Indicators



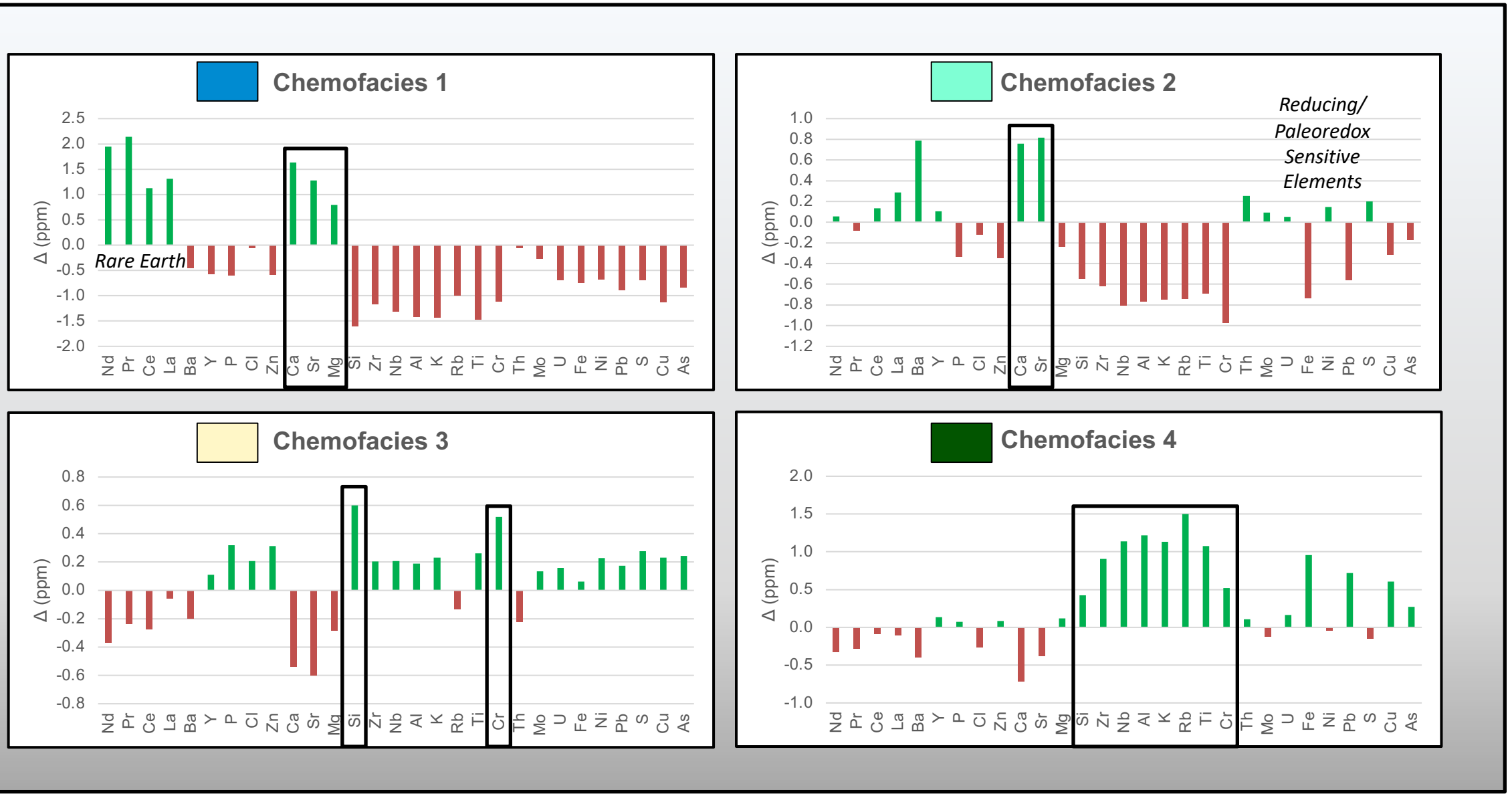
Principal Component Analysis (PCA)



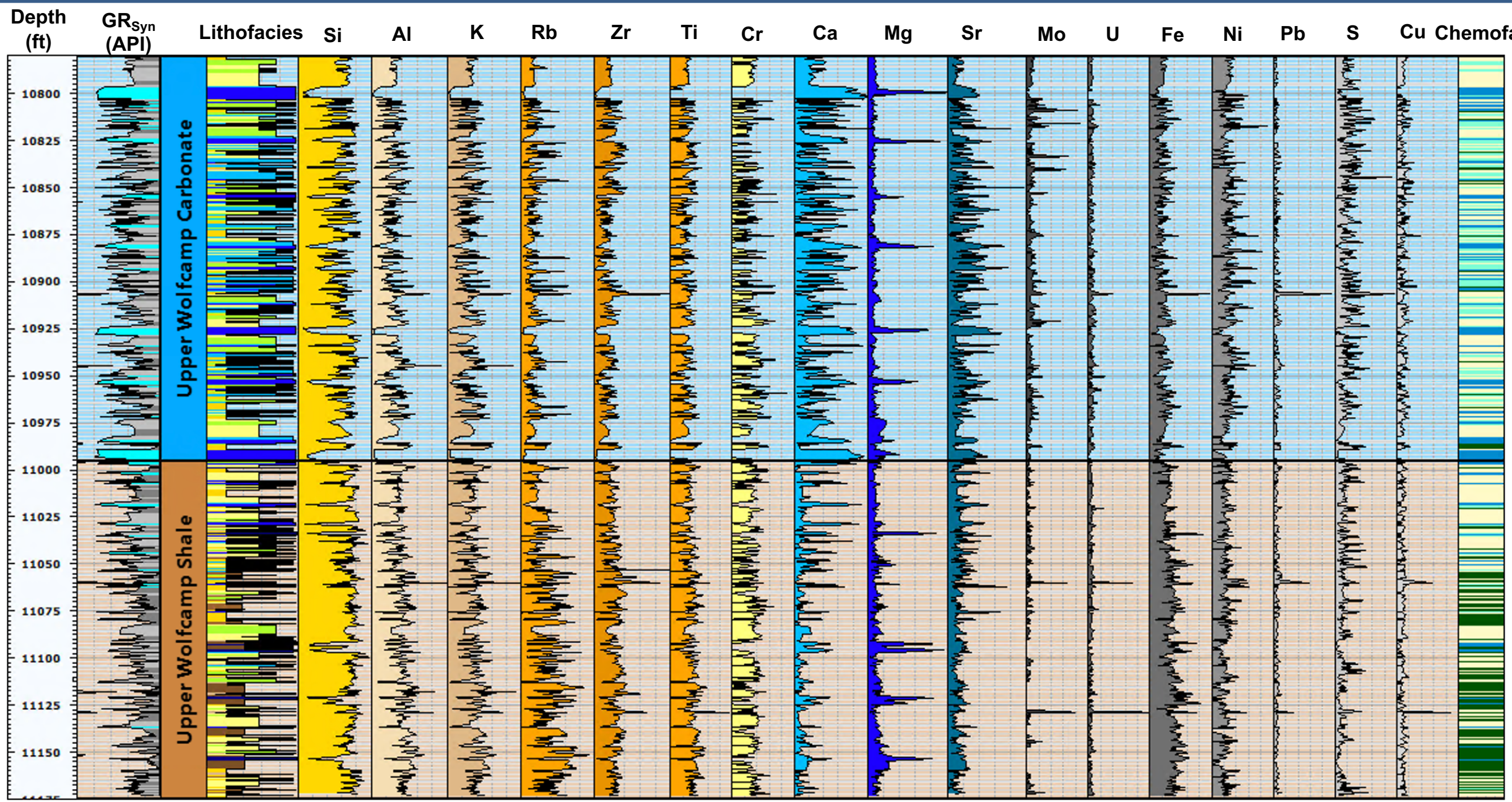




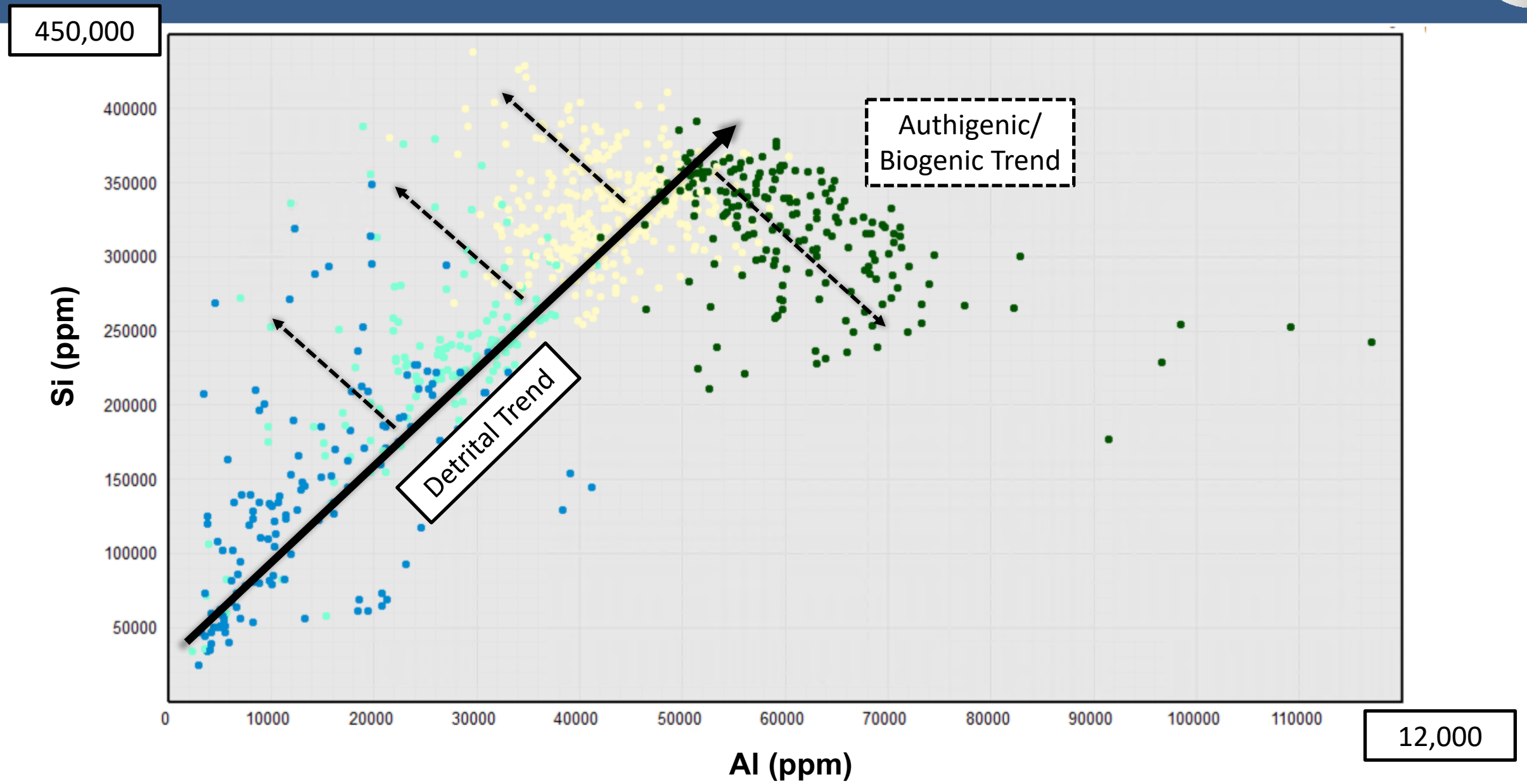
XRF Chemofacies through Cluster Analysis



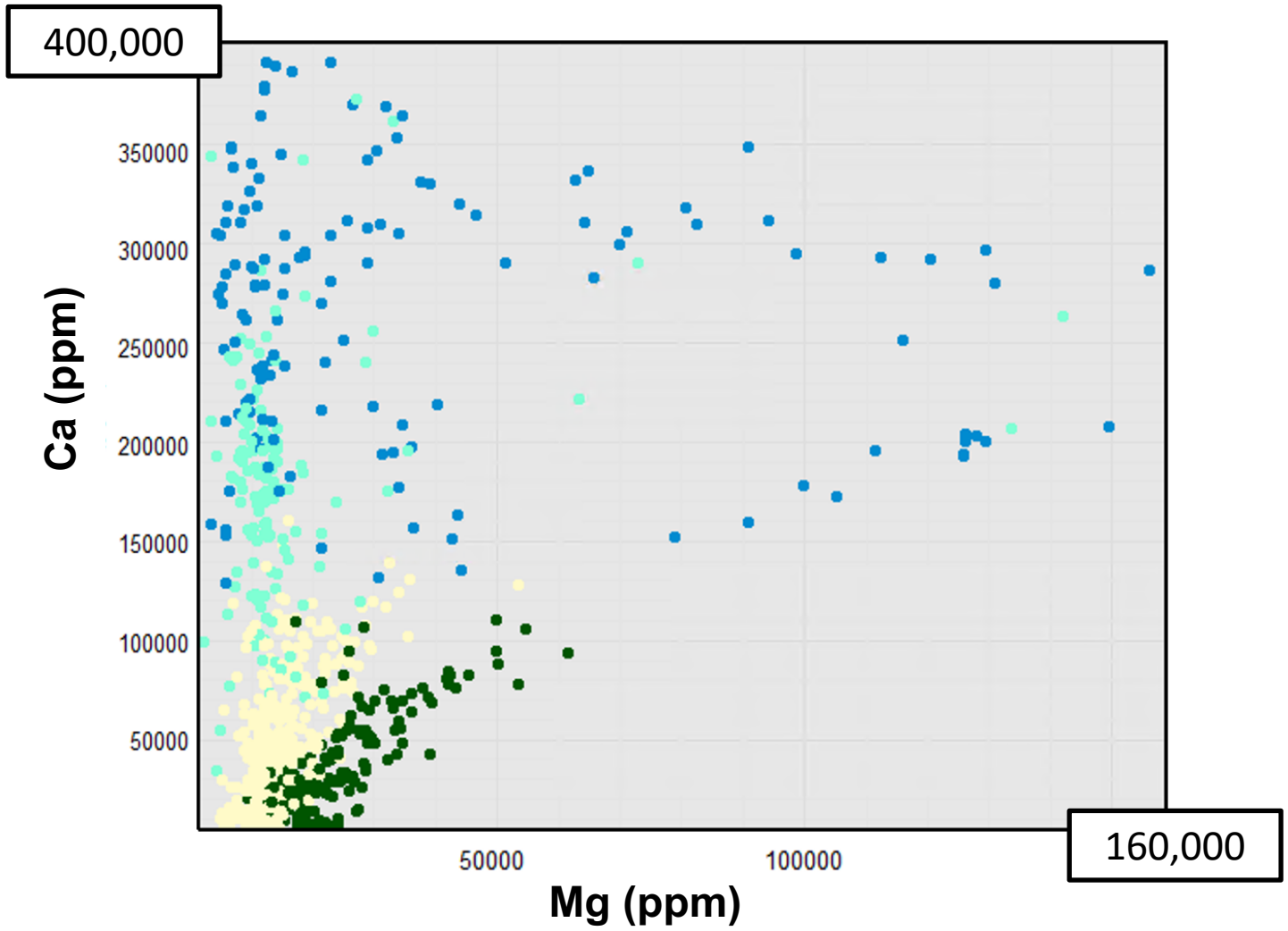
Wolfcamp Chemofacies

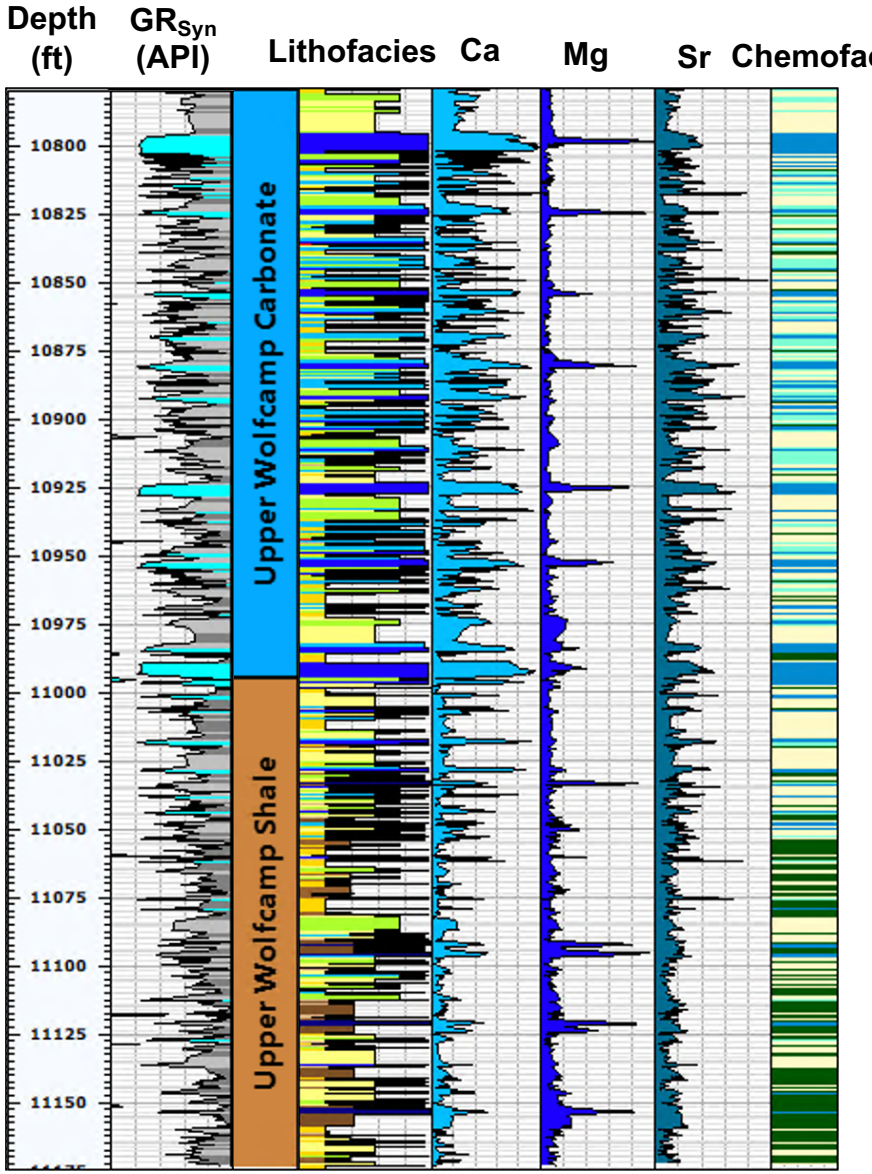


Silica Sources



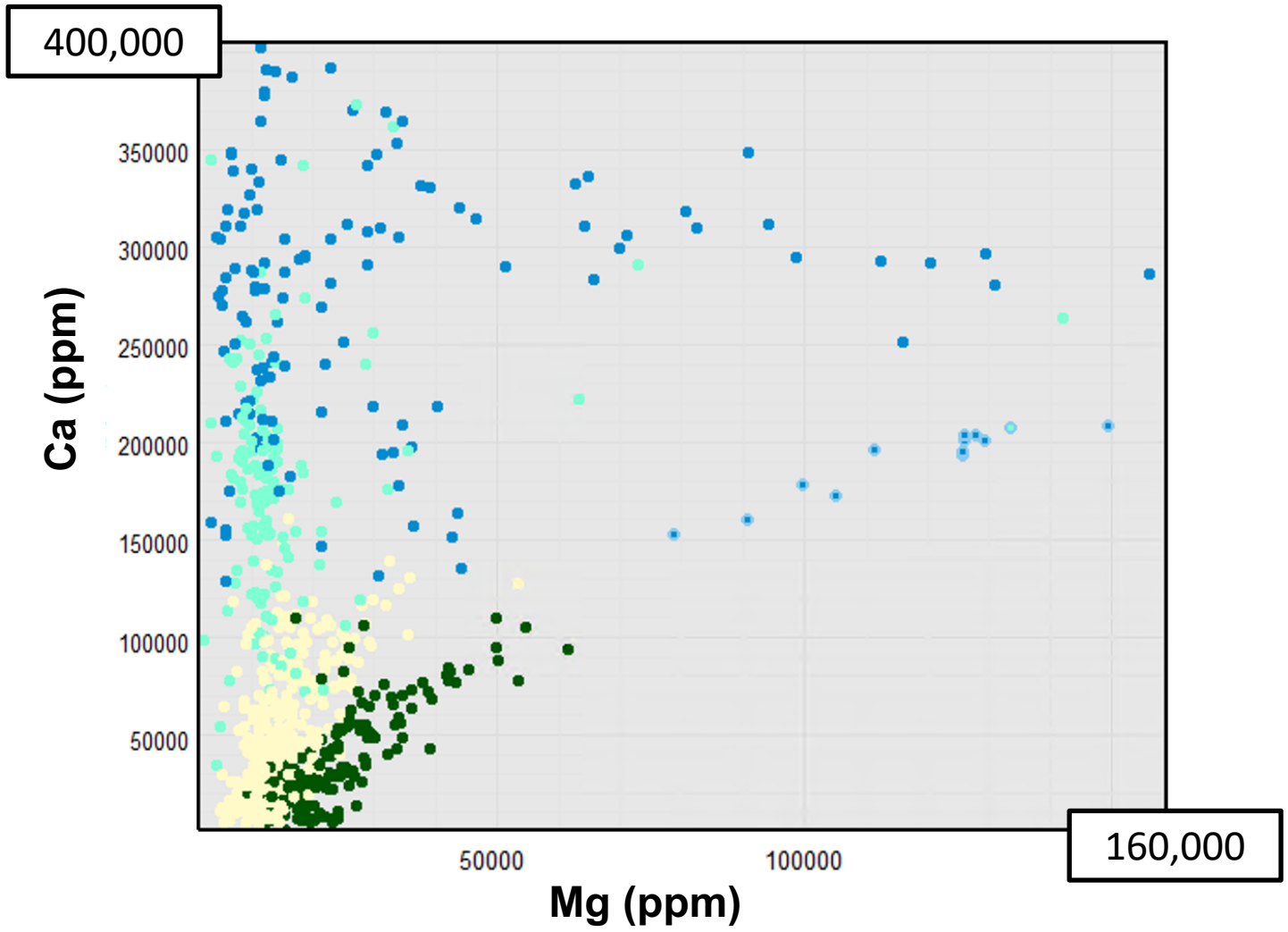
Calcium Magnesium Relationship

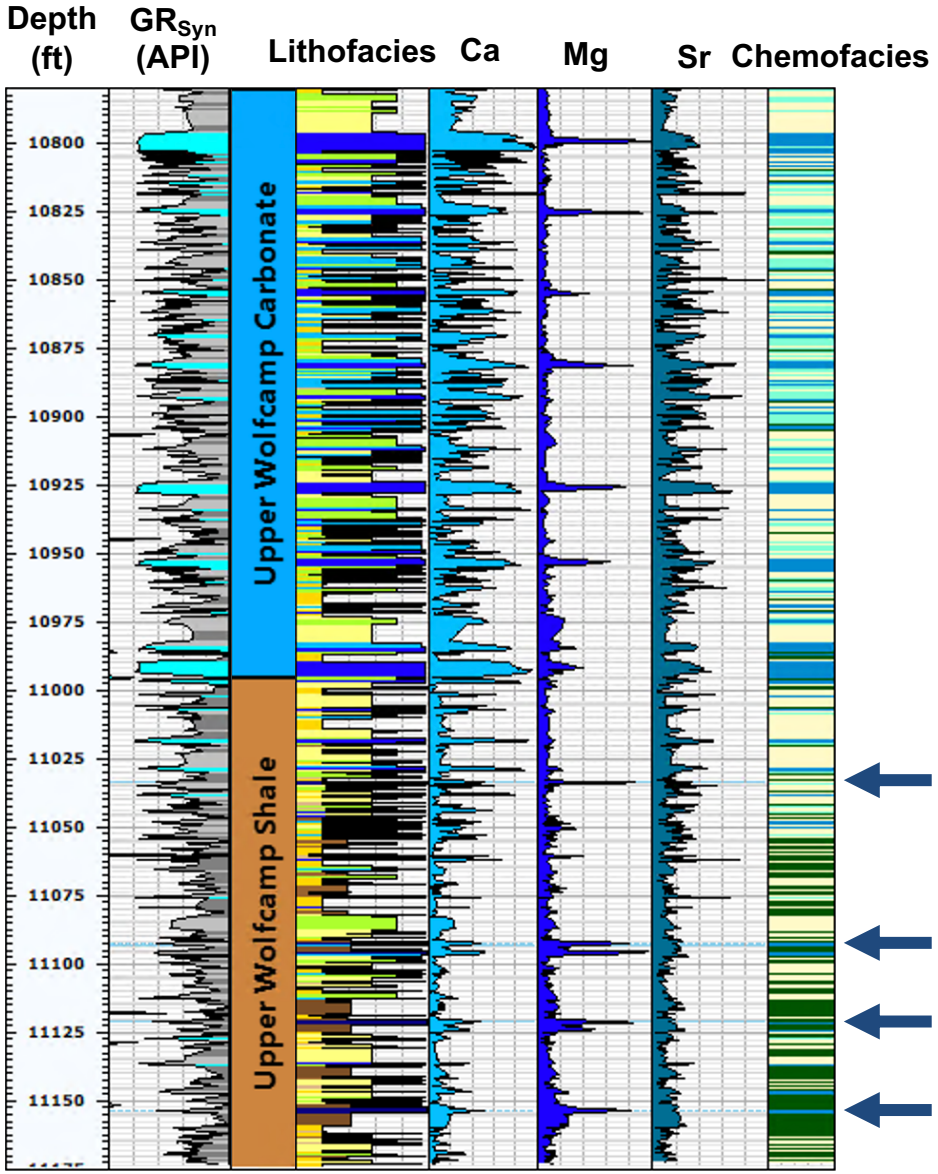




Chemofacies 1 Chemofacies 2 Chemofacies 3 Chemofacies 4

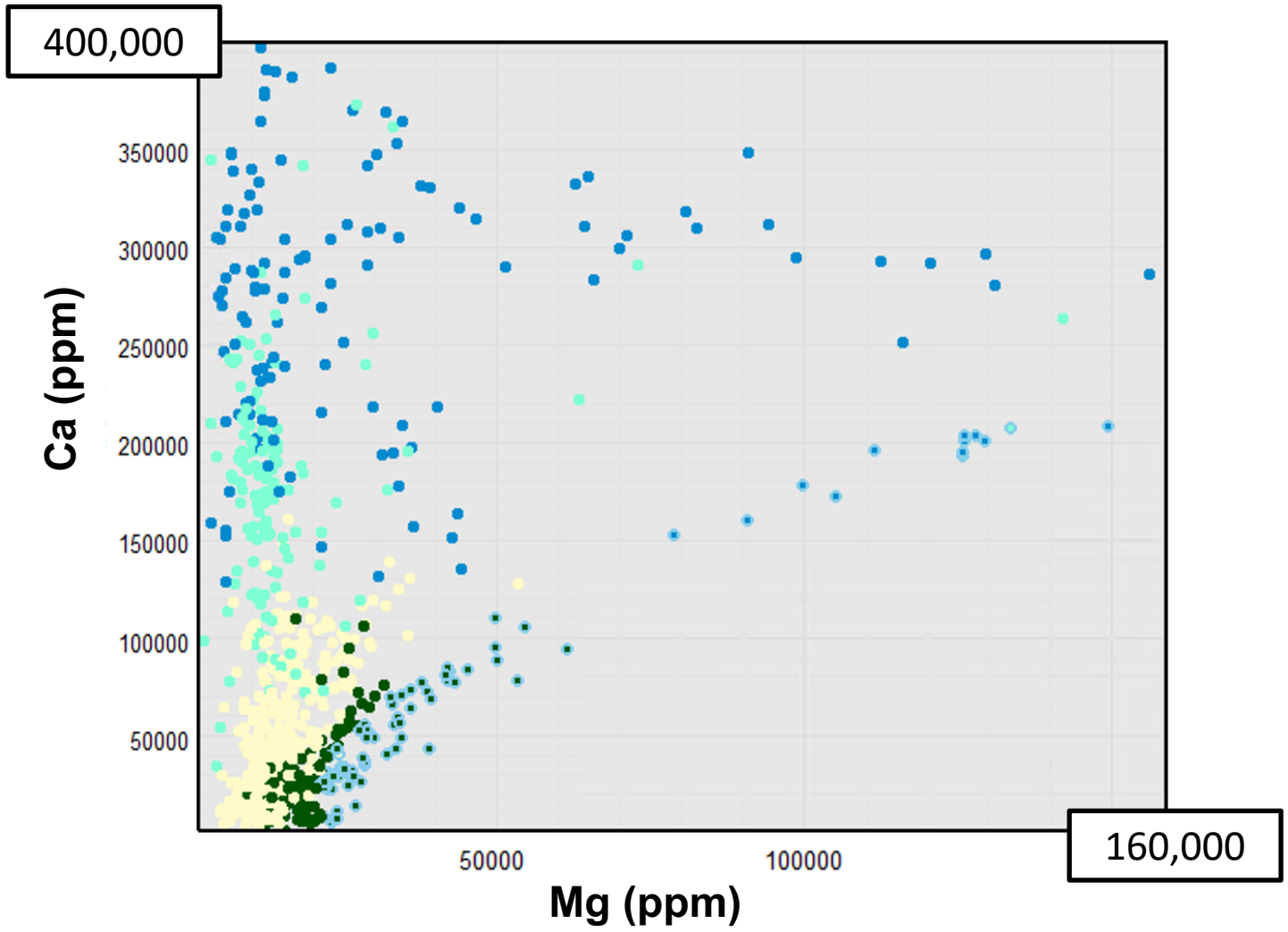
Calcium Magnesium Relationship

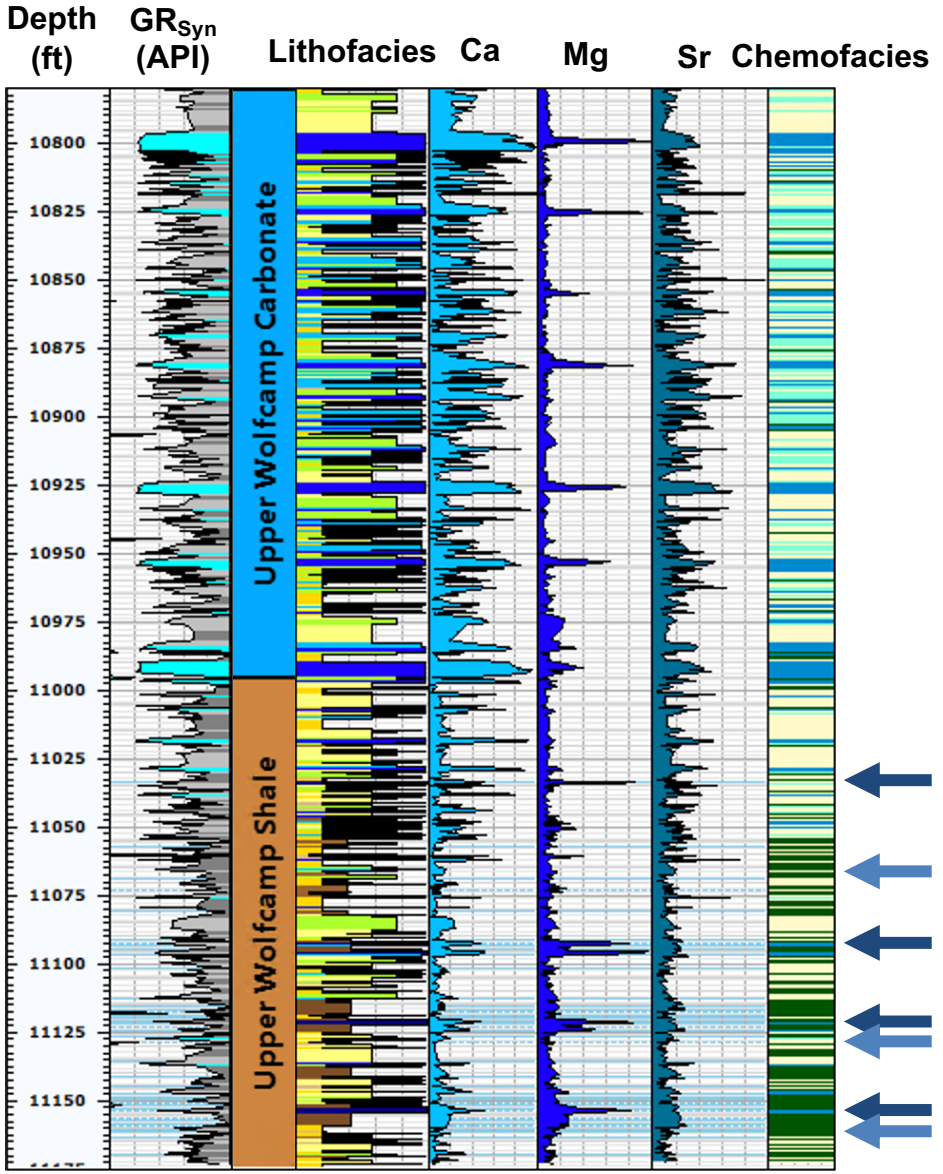




Chemofacies 1 Chemofacies 2 Chemofacies 3 Chemofacies 4

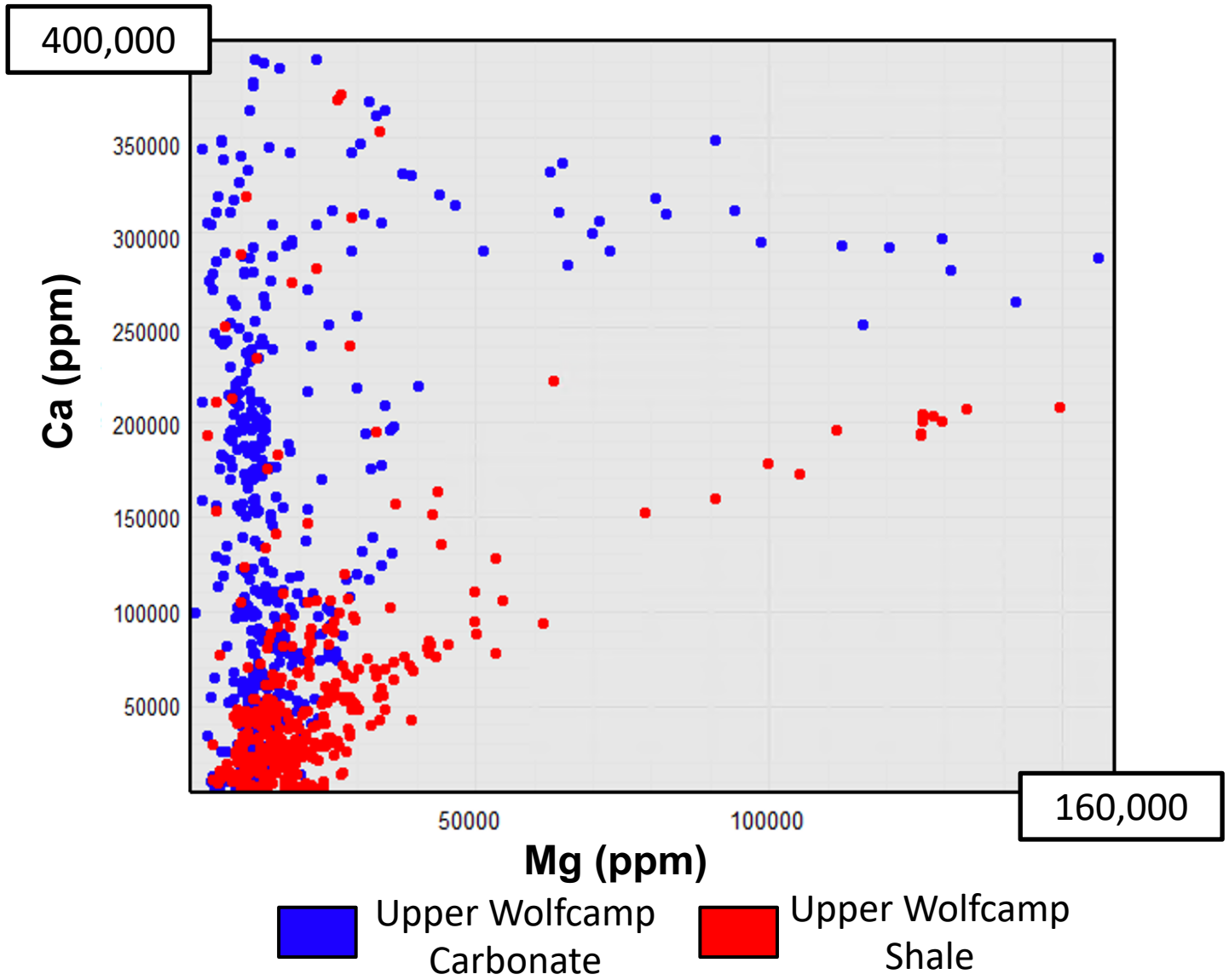
Calcium Magnesium Relationship

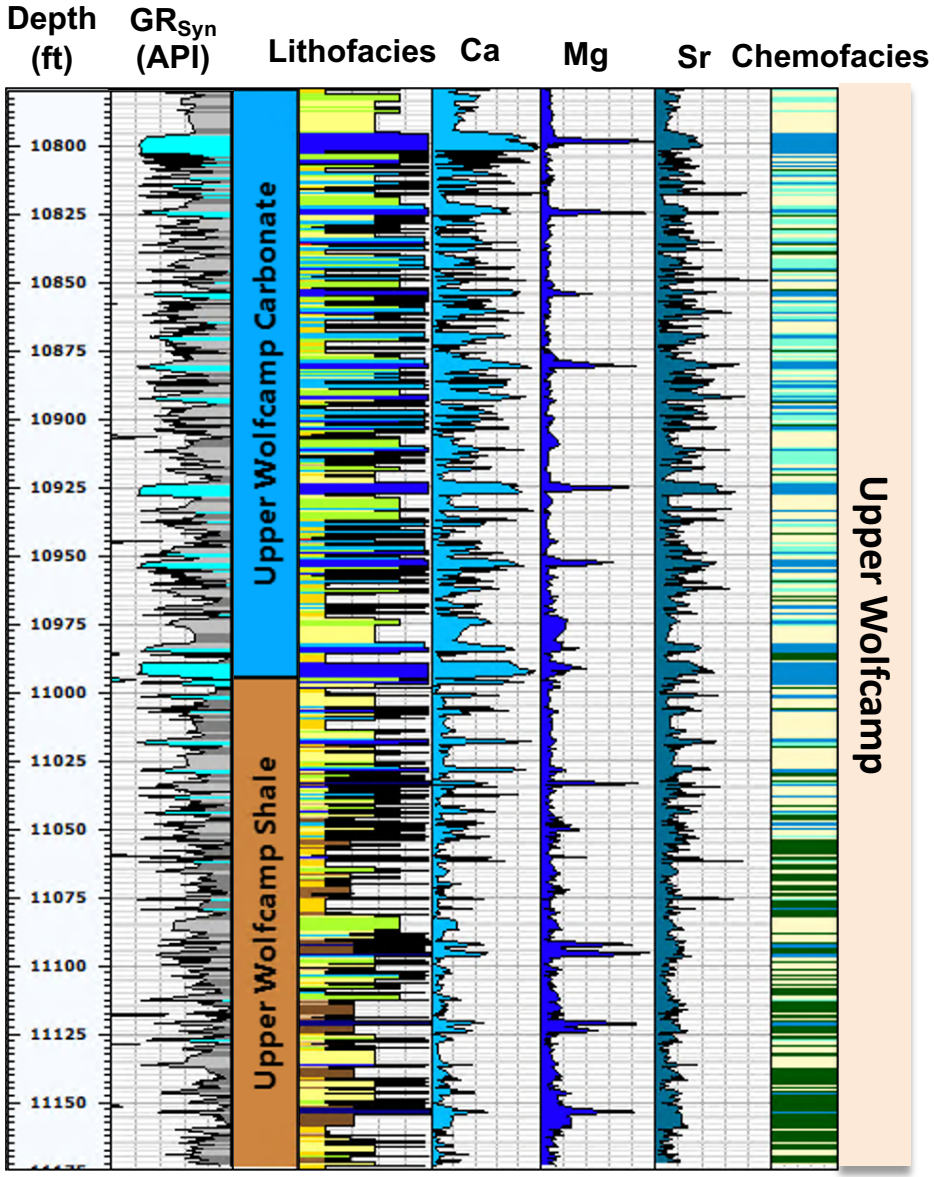




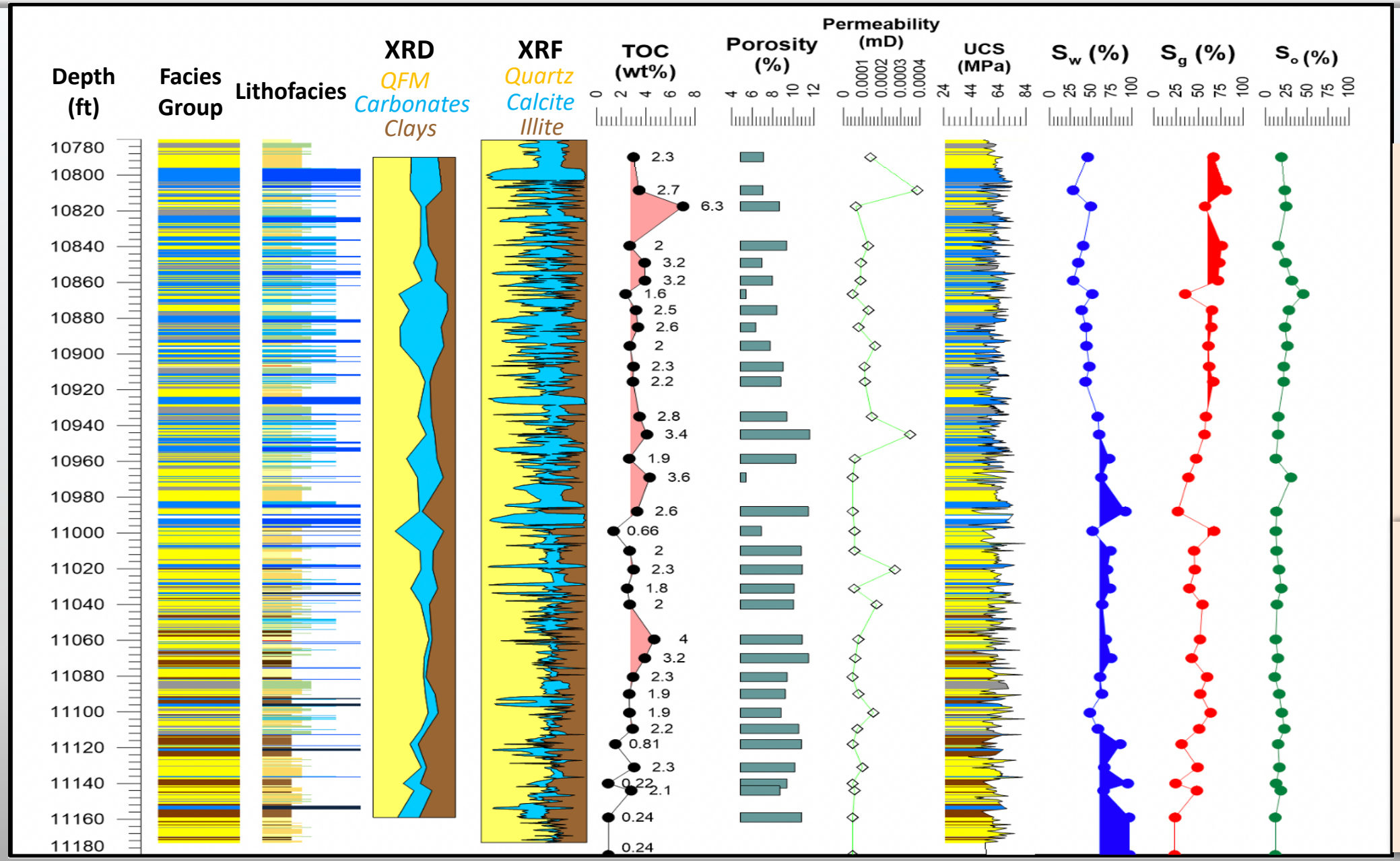
Chemofacies 1 Chemofacies 2 Chemofacies 3 Chemofacies 4

Calcium Magnesium Relationship

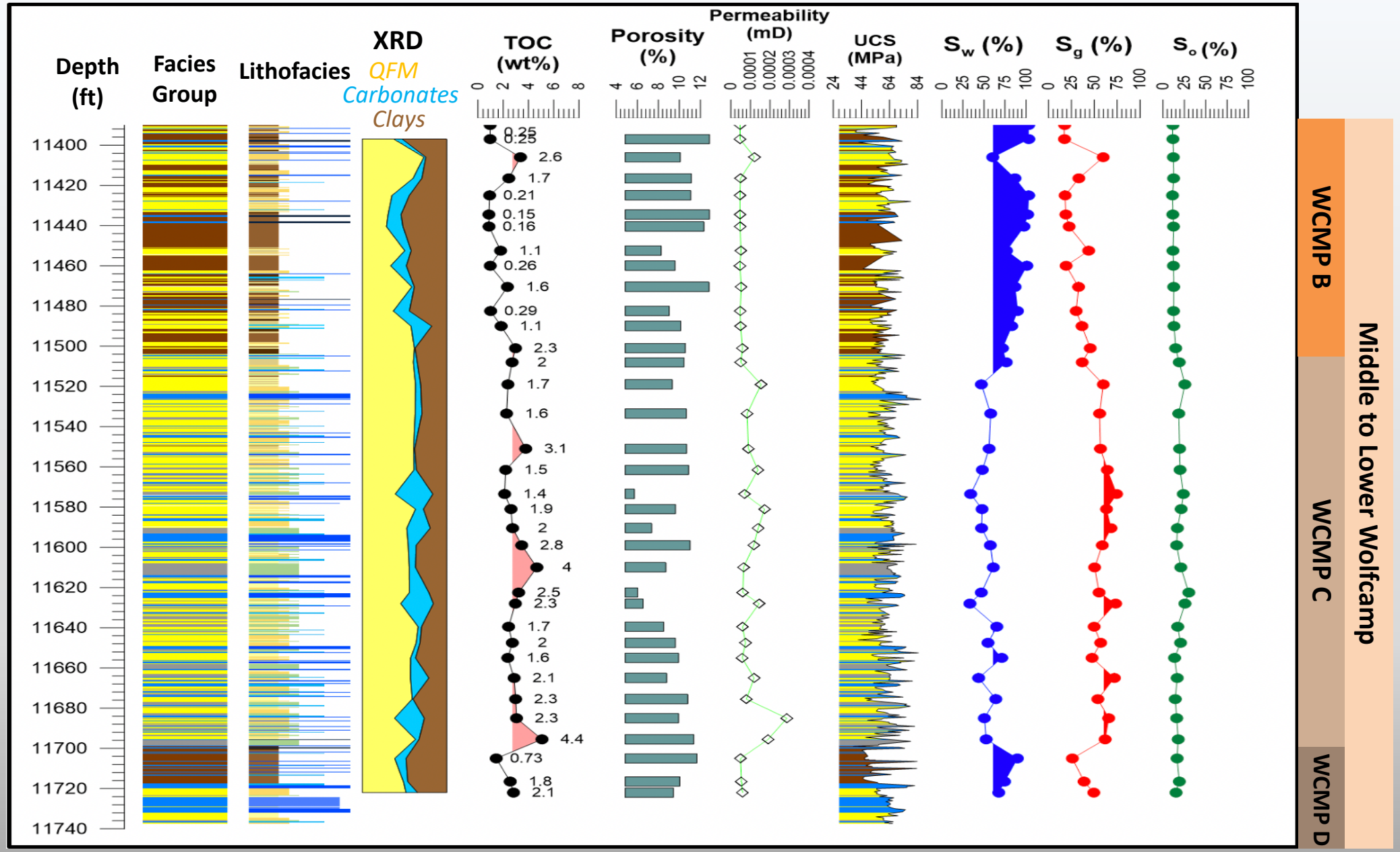




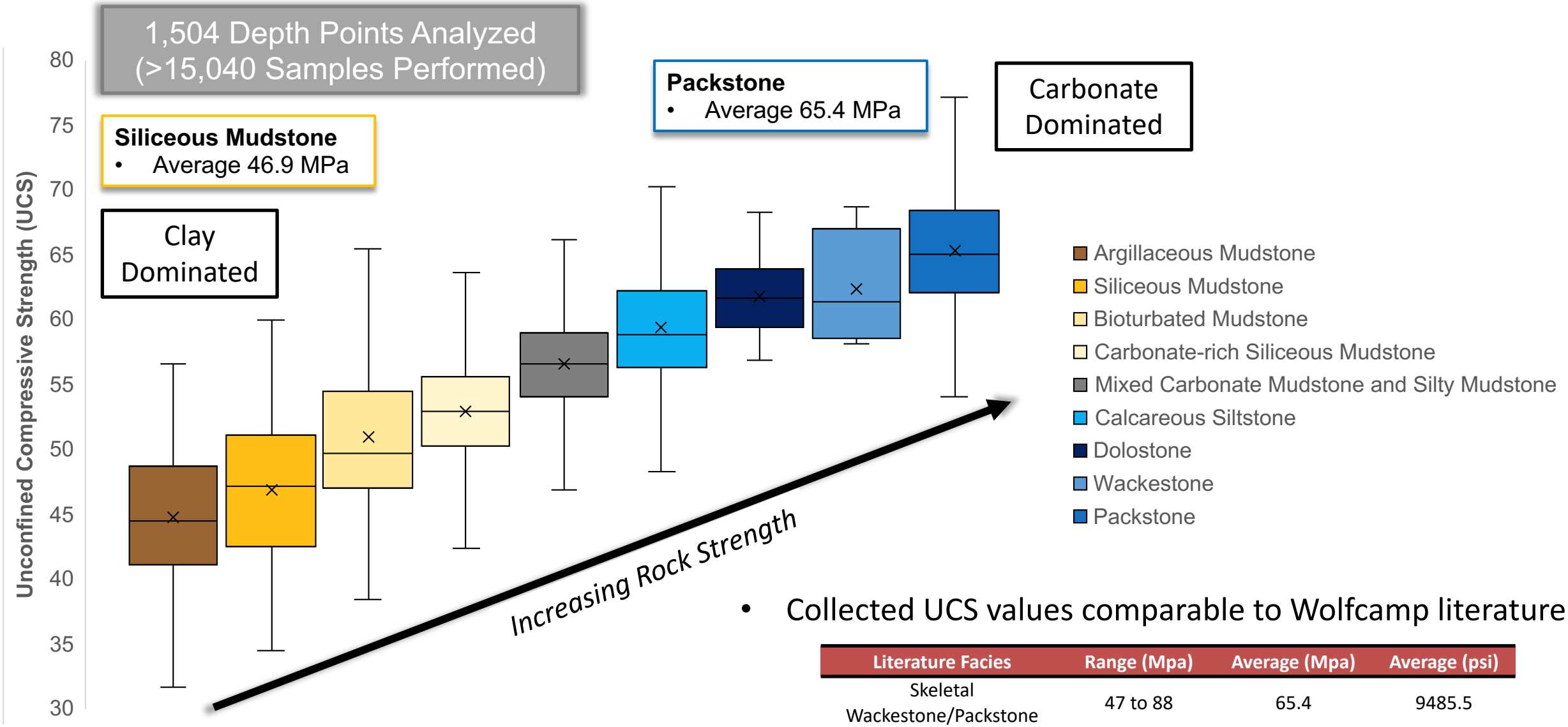
Upper Wolfcamp Reservoir Properties



Middle and Lower Wolfcamp Reservoir Properties



Unconfined Compressive Strength

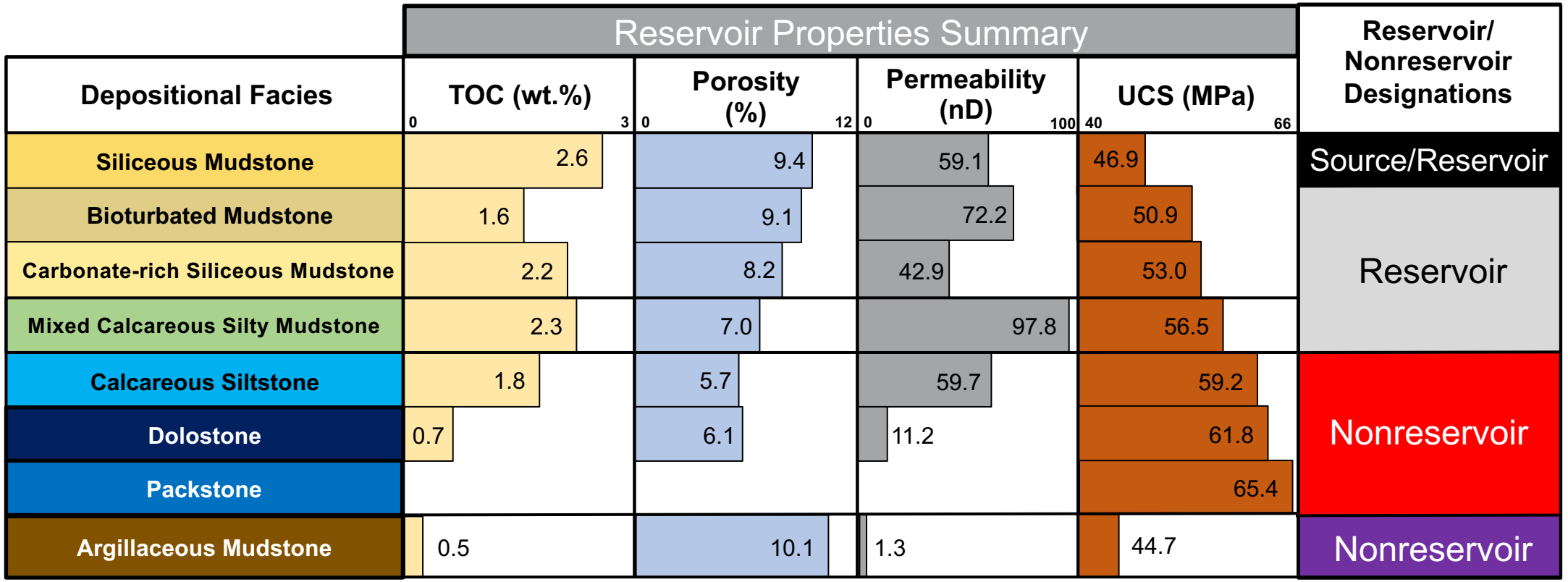


- Collected UCS values comparable to Wolfcamp literature

Literature Facies	Range (Mpa)	Average (Mpa)	Average (psi)
Skeletal Wackestone/Packstone	47 to 88	65.4	9485.5
Siliceous Mudrocks	30 to 59	44.1	6396.2

Baumgardner and Others (2016)

Reservoir Quality by Facies



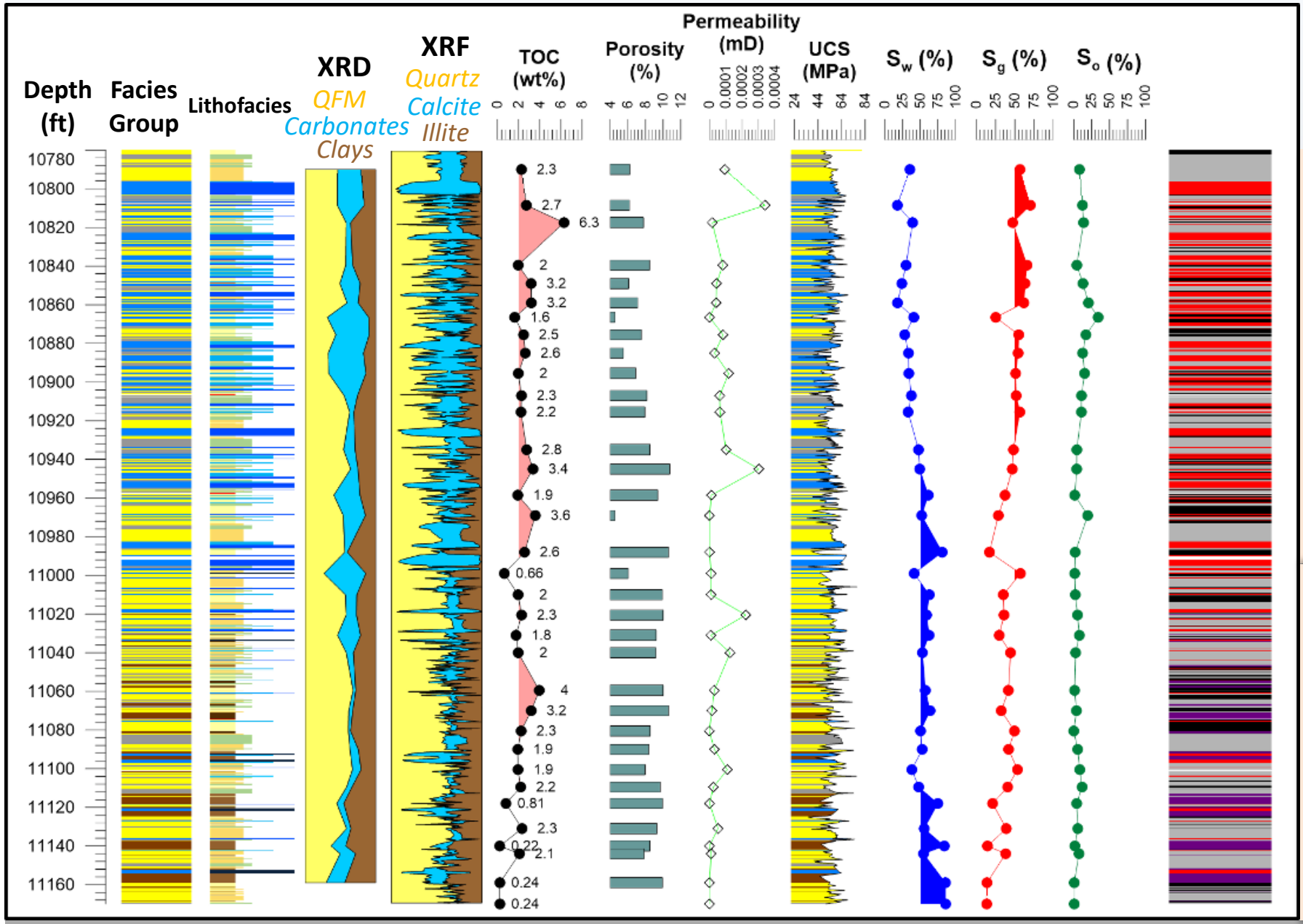
Source/Reservoir
- Highest TOC (up to 6.3 wt.%)
- Low UCS
- High porosity

Reservoir
- Good TOC (mostly >2 wt.%)
- Good porosity
- Intermediate UCS

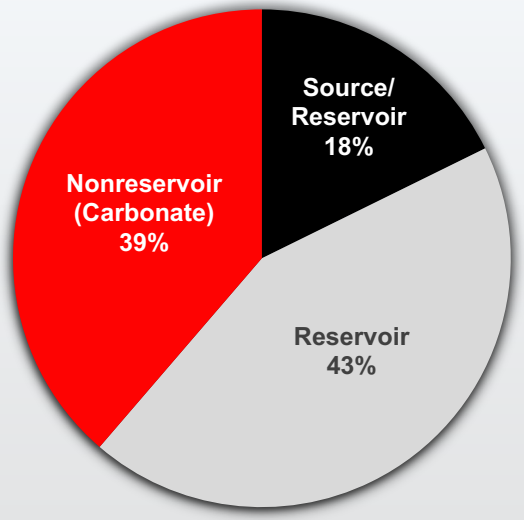
Nonreservoir (Carbonate)
- Low TOC
- High UCS
- Potential seal/baffle

Nonreservoir (Argillaceous)
- Lowest TOC and permeability
- Low UCS
- High Water Saturation

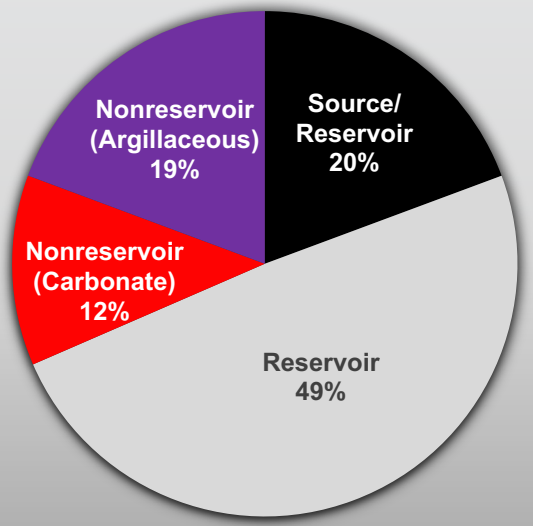
Upper Wolfcamp



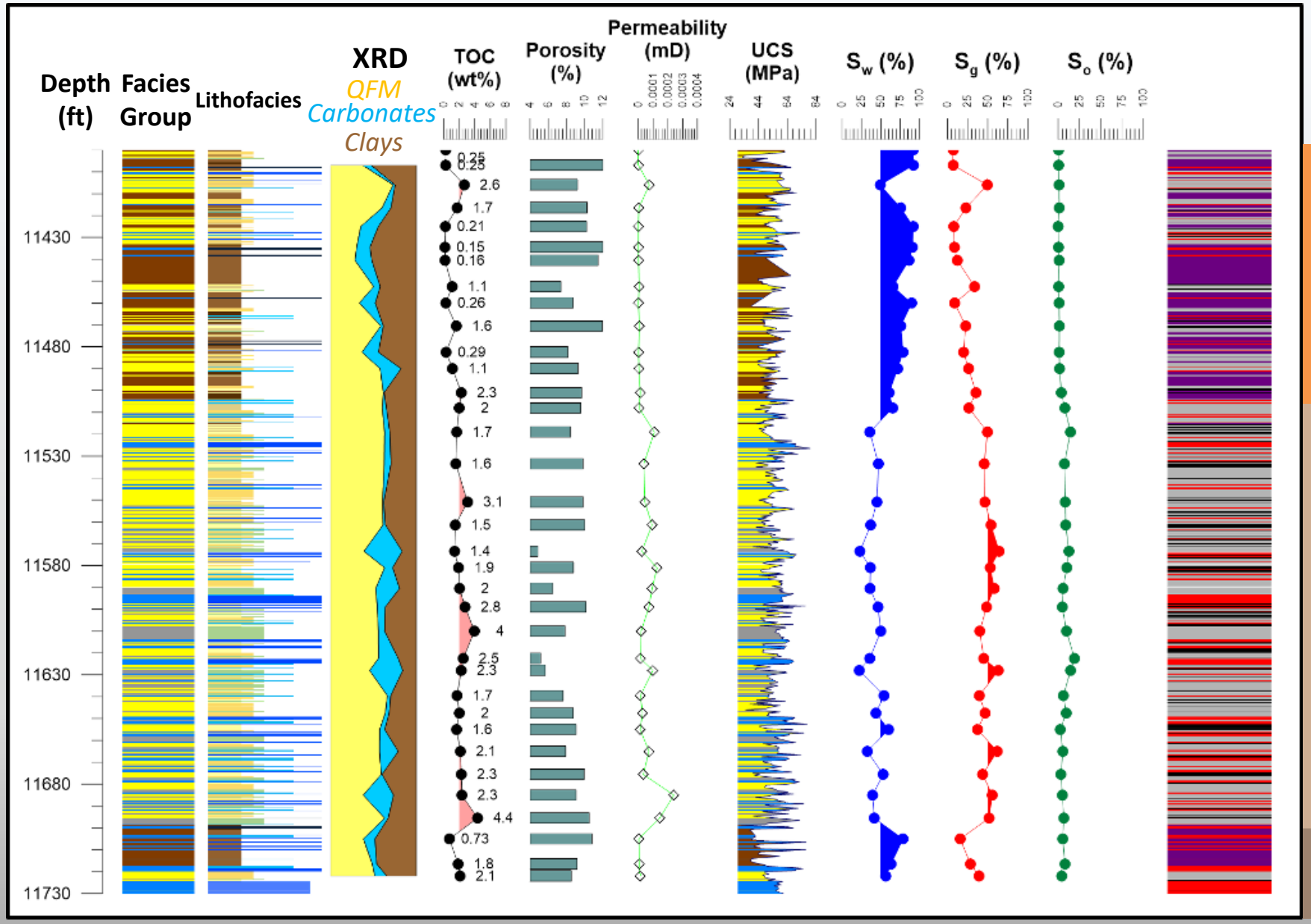
Upper Wolfcamp Carbonate

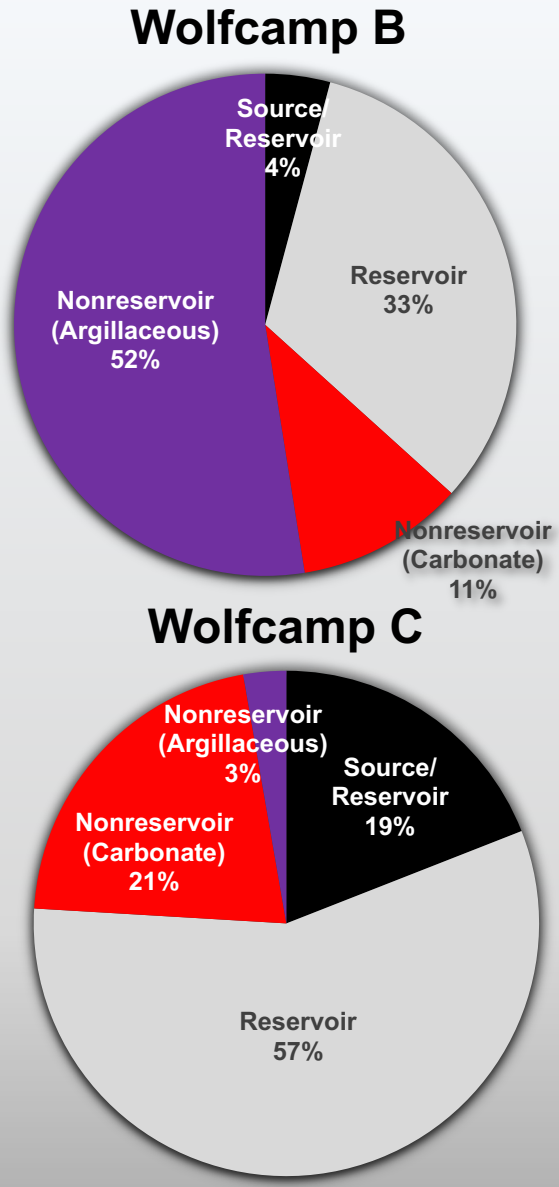


Upper Wolfcamp Shale

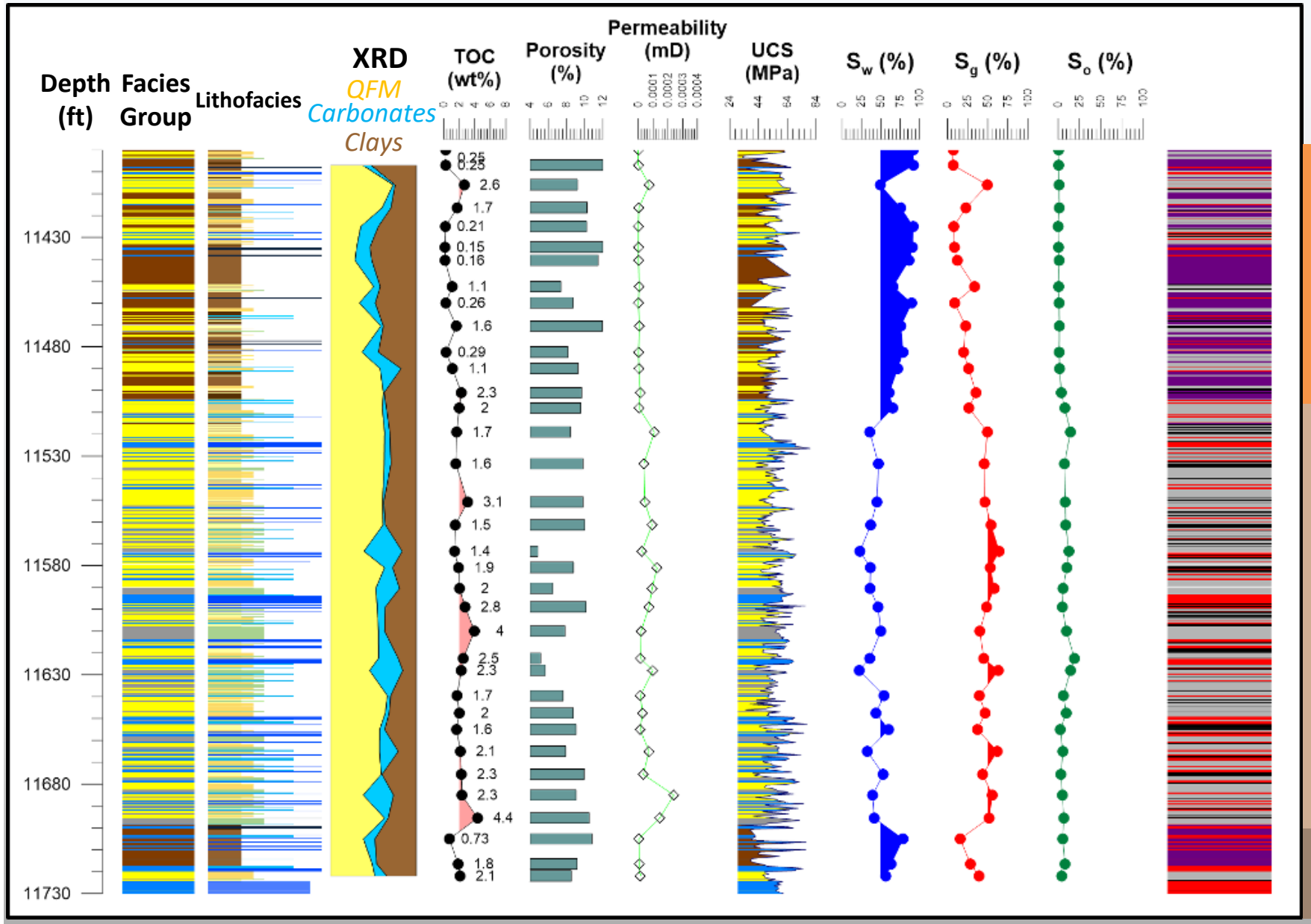


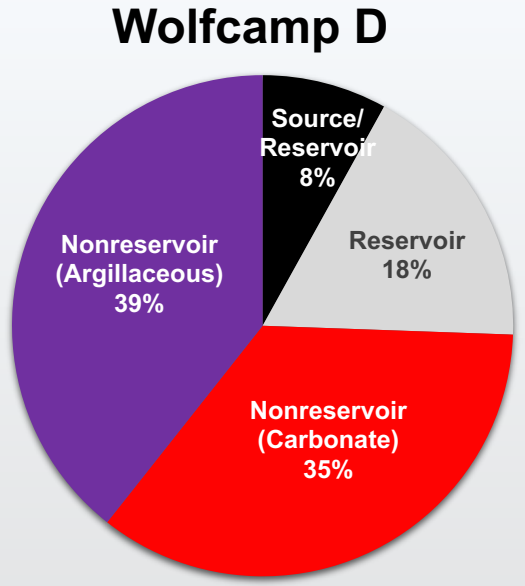
Middle and Lower Wolfcamp





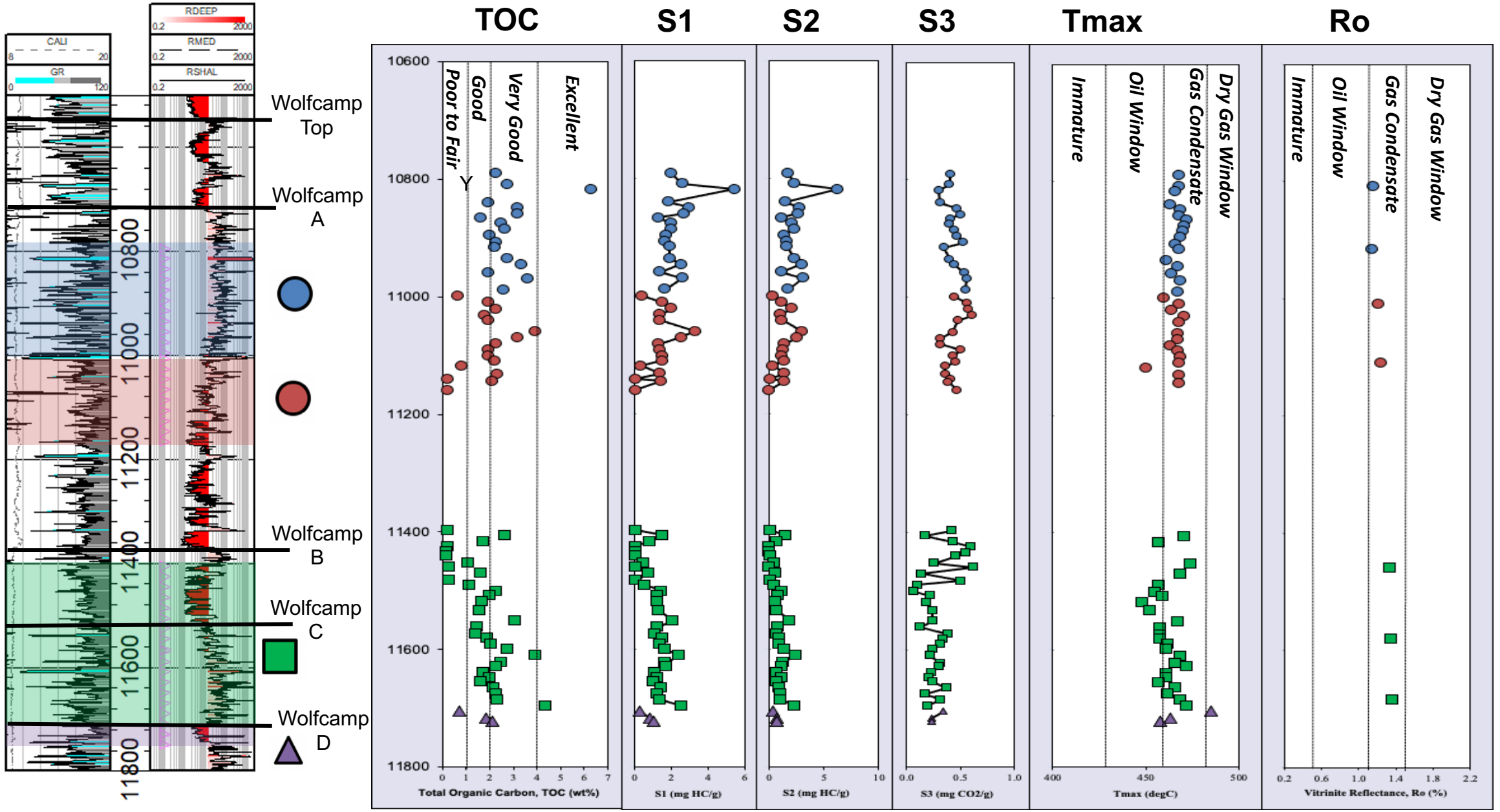
Middle and Lower Wolfcamp



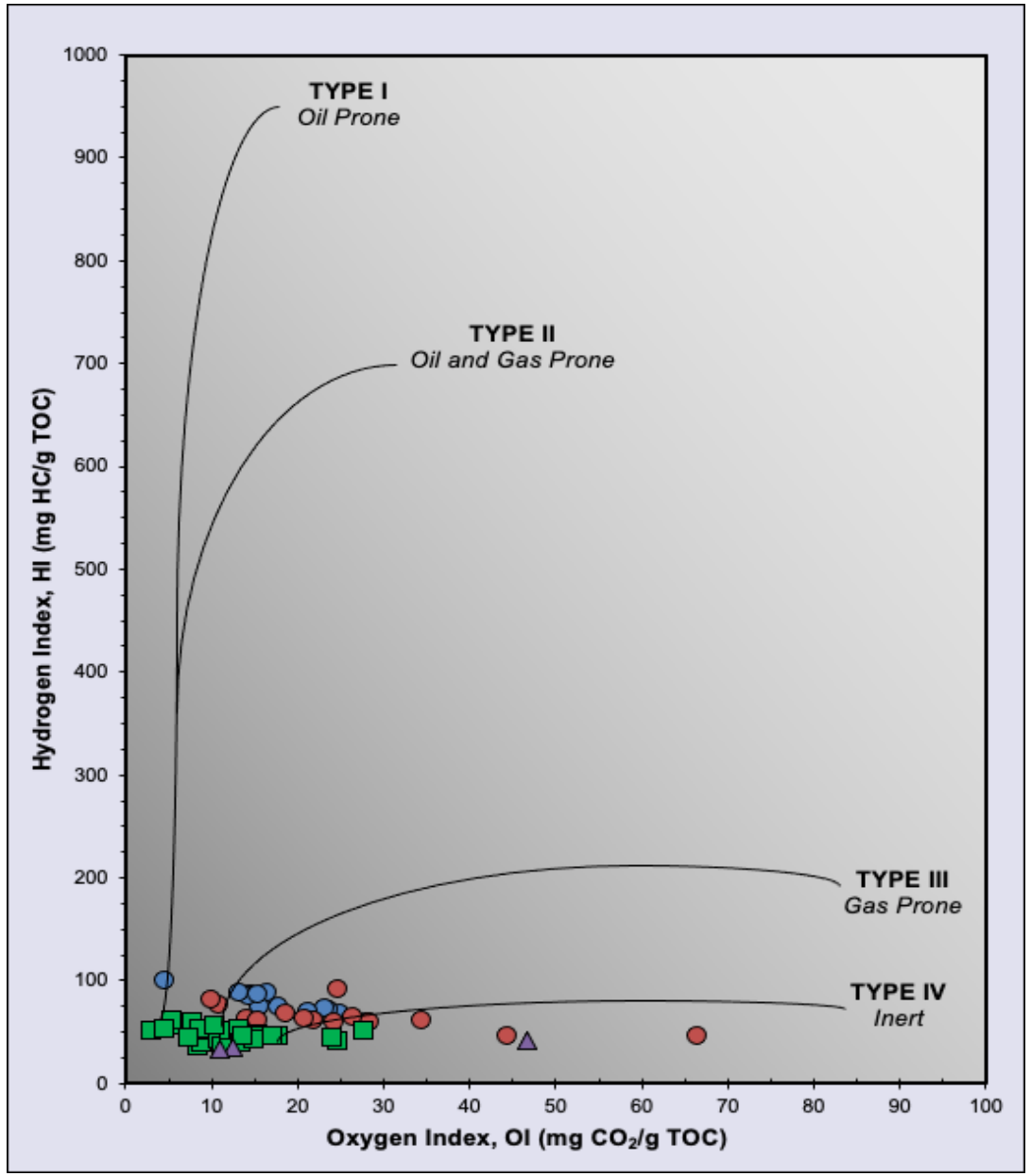


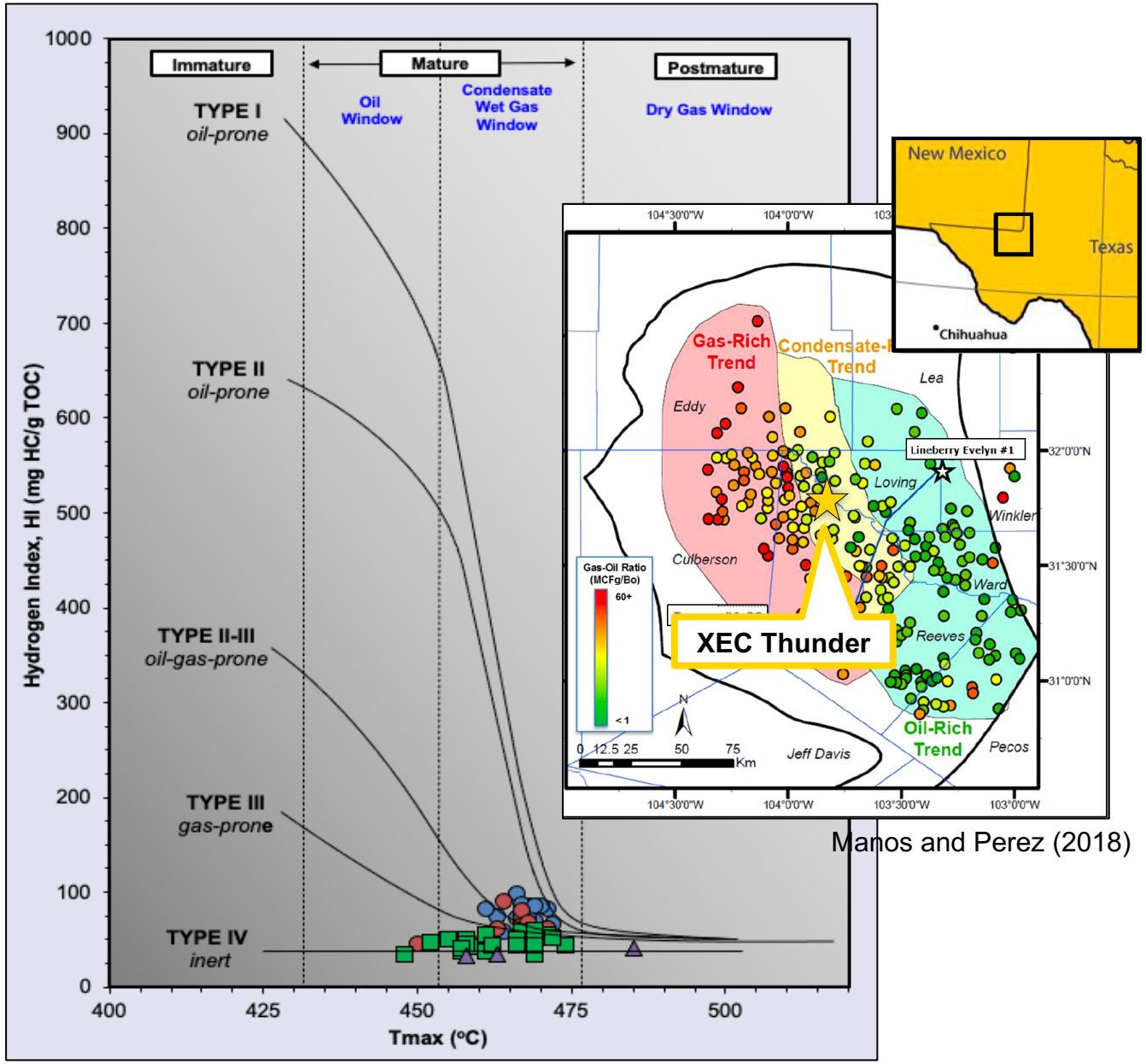
- Highly stratified
- Reservoir facies abundant
  - WCMP A Carbonate (61%)
  - WCMP A Shale (70%)
  - WCMP C (76%)
  - WCMP B (37%) *
  - WCMP D (26%) **
- Variation in nonreservoir facies

Source Rock Analysis



Kerogen Type and Maturity





Manos and Perez (2018)

Conclusion and Future Works

Completed:

- Lithofacies and analysis of associated rock properties
- Facies distribution
- Initial XRF analysis
- Unconfined compressive strength (rock strength) testing
- Source rock analysis

Future Works:

- Finalize chemostratigraphy (XRF)
- FE-SEM analysis
- Log analysis (extending beyond cored section)

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