Sedimentary Lithofacies Classification in Wolfcamp A and B in Midland Basin from Supervised Machine Learning

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MS Spring 2023

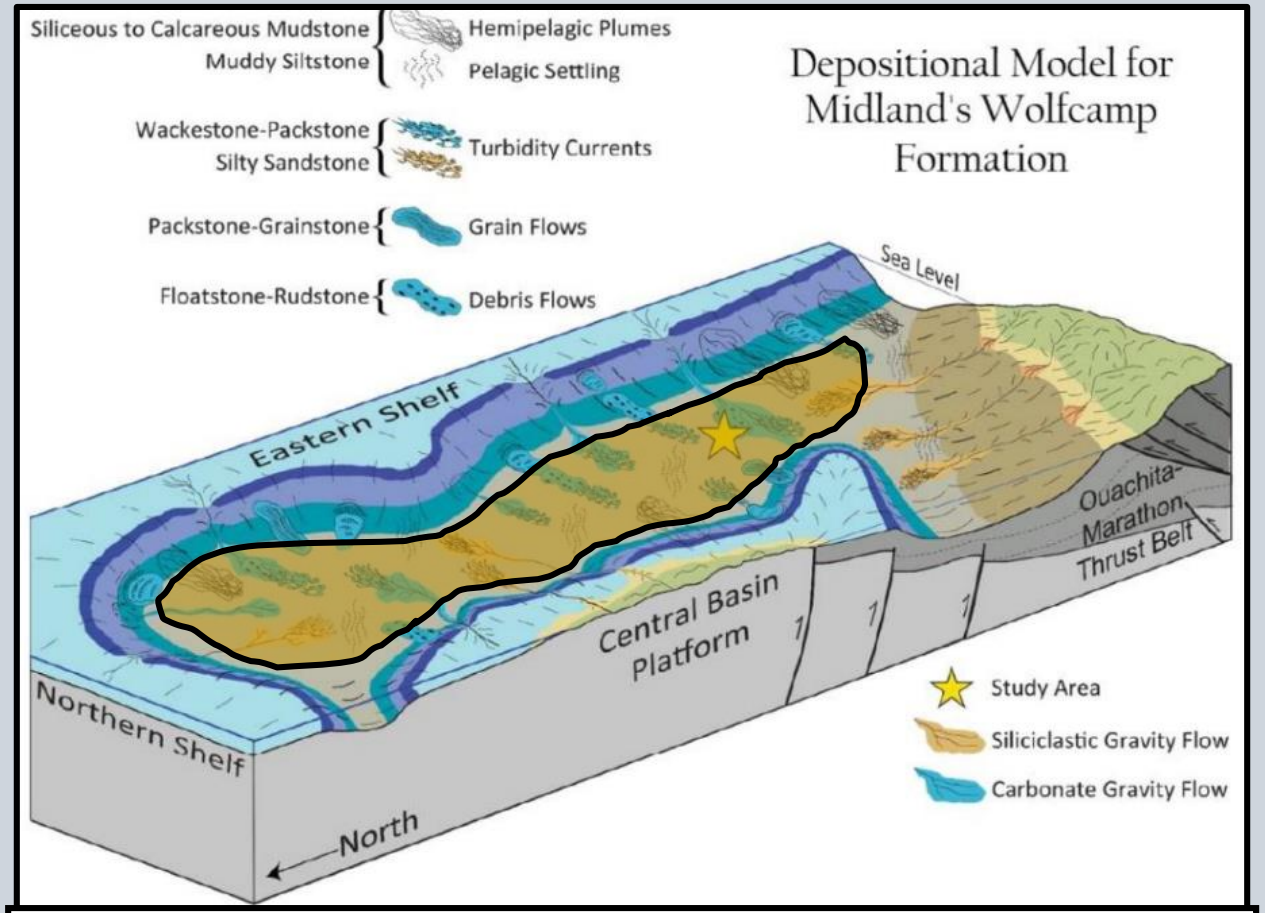
COLORADO SCHOOL OF MINES
MUDTOC

Overview

- Geologic Background of the Wolfcamp A and B of Midland Basin
- Importance of Carbonate Gravity Flows to the Hydrocarbon Industry
- Study Area and Data
- Producing a Lithofacies Predicting Model Schematic
  - Wrangling Vertical and Horizontal Well Data
  - Core-Based Lithofacies
  - What is a Multilayer Perceptron Algorithm?
  - Training and Testing the Algorithm
- Wolfcamp A Well with Predicted Lithofacies from Trained Model
- Wolfcamp B Well with Predicted Lithofacies from Trained Model
- Remaining Work

Geologic Background of Wolfcamp A and B

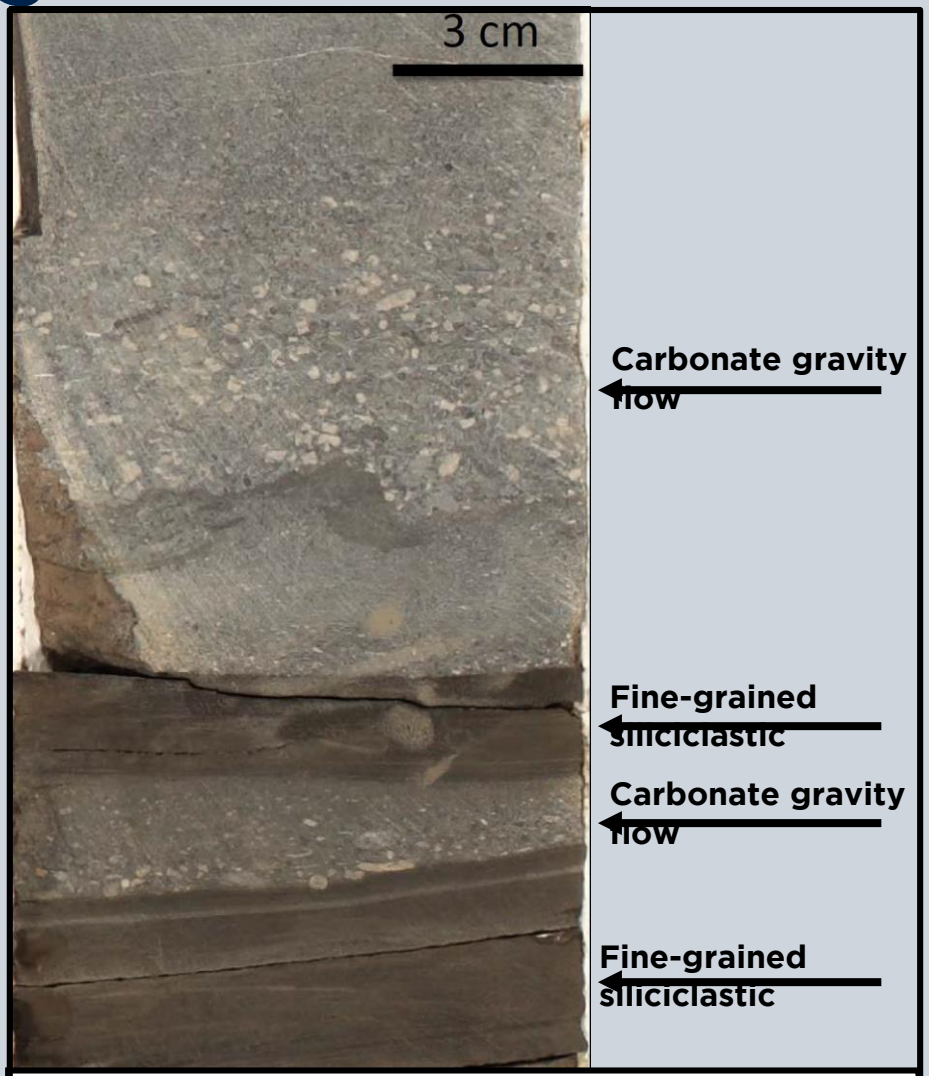
- The Wolfcamp A and B are comprised of interbedded siltstone, organic-rich mudrock, carbonate and mixed-lithology sediment gravity flows
- The Wolfcamp A tends to be more carbonate-rich while the Wolfcamp B is more siliciclastic-rich
- But both are riddled with carbonate gravity flows and these deposits play a major role in the basin's petroleum system



Modified from Ward (2017) and Pioneer Resources (2013).

Importance of Carbonate Gravity Flows

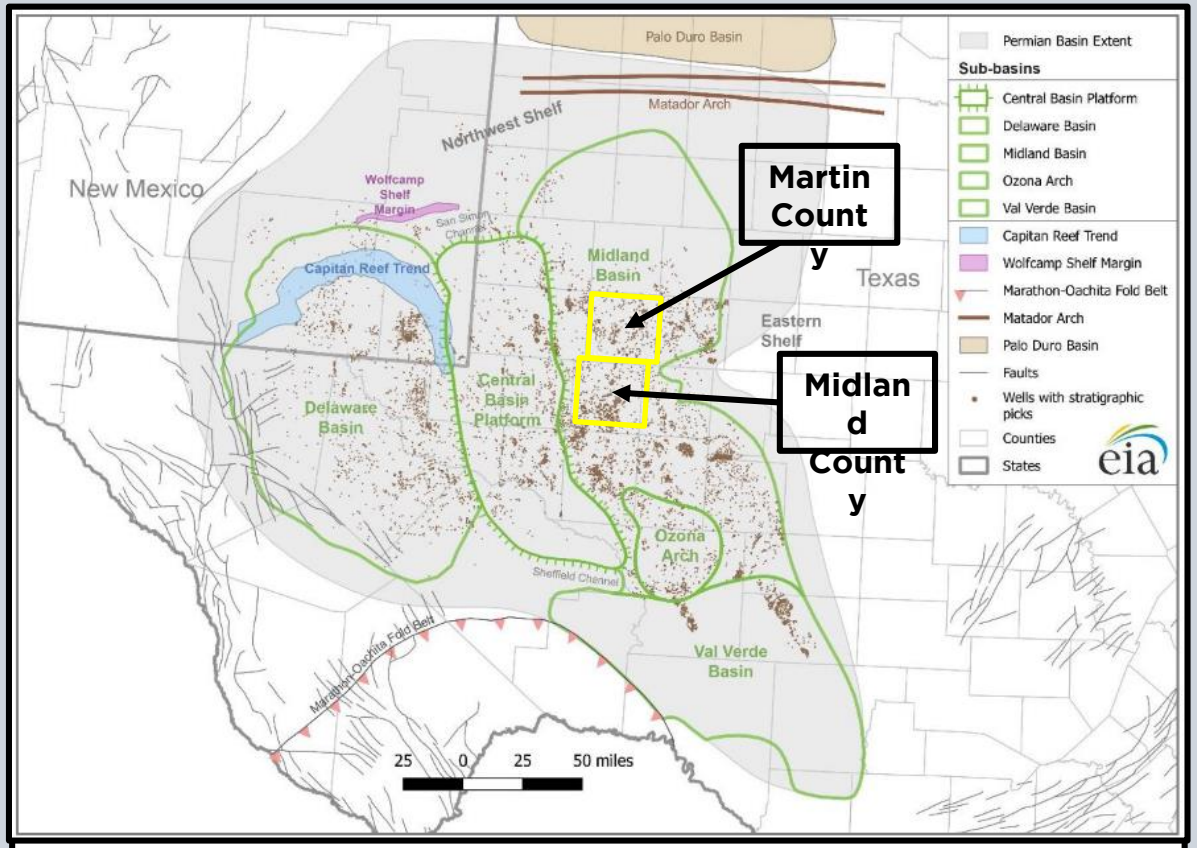
- Carbonate gravity flows in the Wolfcamp A and B benches may variously act as:
  - Drilling hazards
  - Frac barriers
  - Important parts of a petroleum system
  - Catalysts which lower the thermal stress required for kerogen to generation oil
- Knowing where these flows are located would be beneficial to the hydrocarbon industry



Modified from Zoeten and Goldstein (2017).

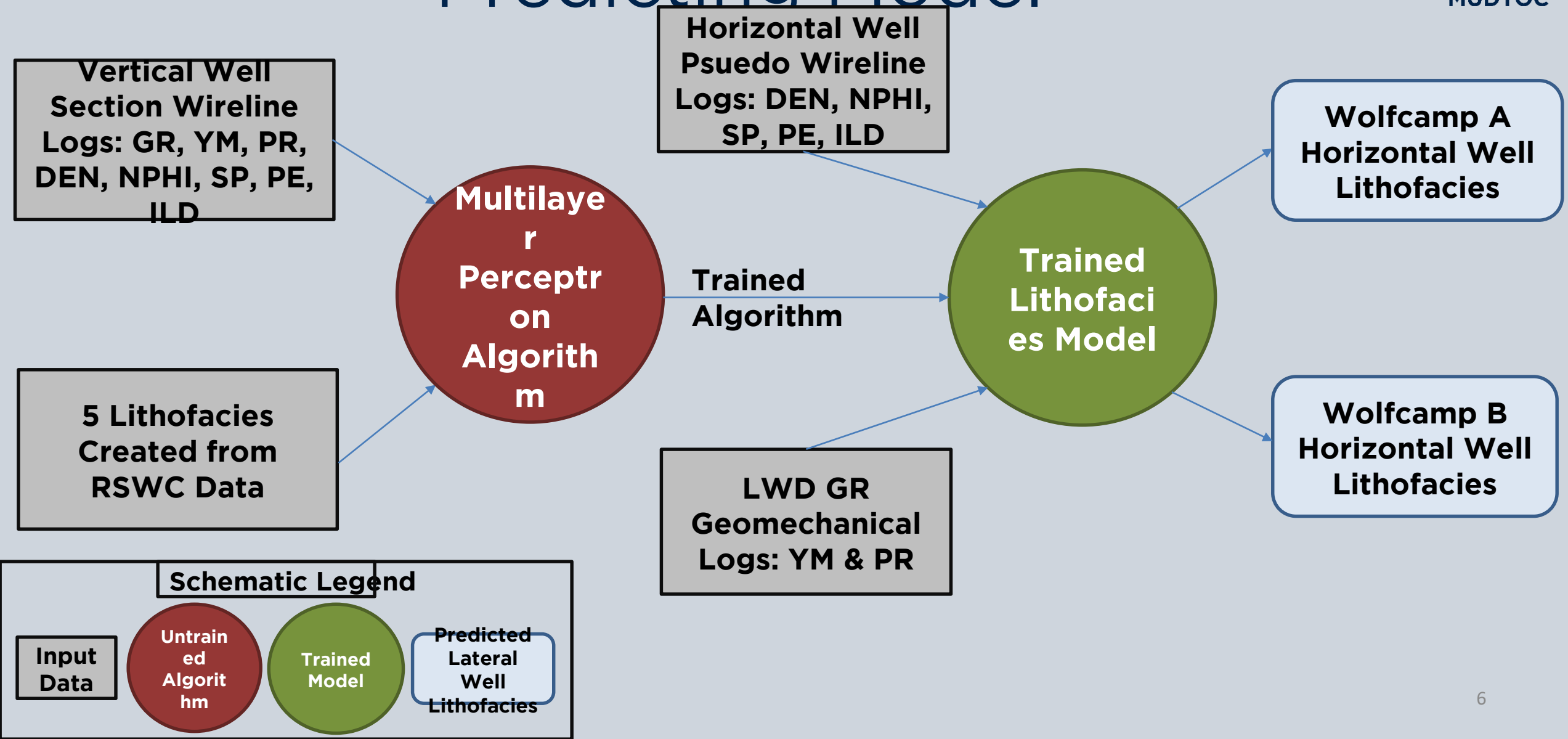
Study Area and Data

- Midland and Martin Counties in west Texas comprise study area
- Thesis Data:
  - Donated by generous operator
  - 3 vertical wells
  - 8 Wolfcamp A horizontal wells
  - 18 Wolfcamp B horizontal wells
- Vertical well data used:
  - Wireline
  - 31 rotary side wall core (RSWC) plugs, core descriptions, thin section photomicrograph images
- Horizontal well data used:
  - LWD GR
  - YM & PR



Modified from the EIA (2020).

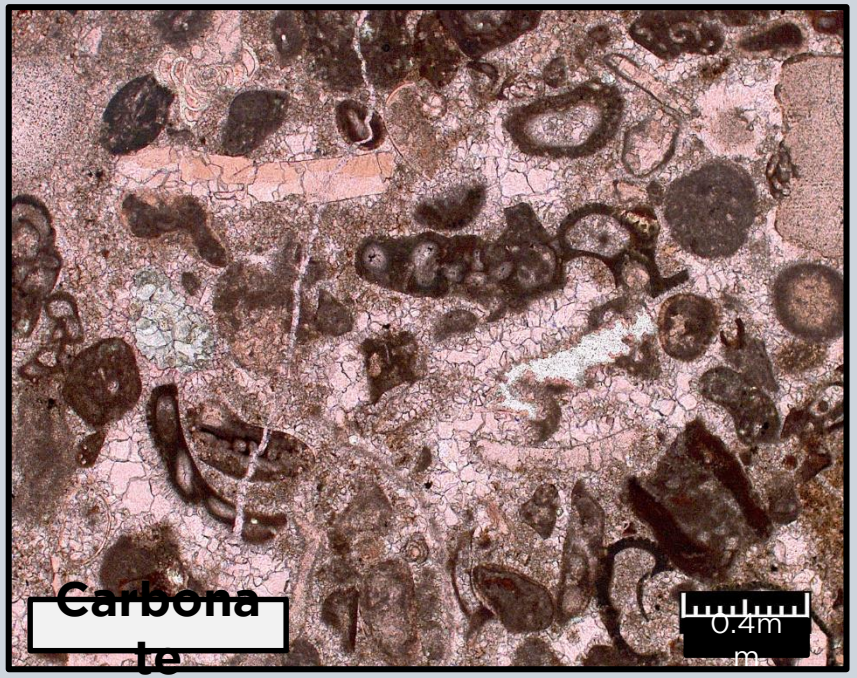
How to Produce a Lithofacies Predicting Model



End Member Lithofacies

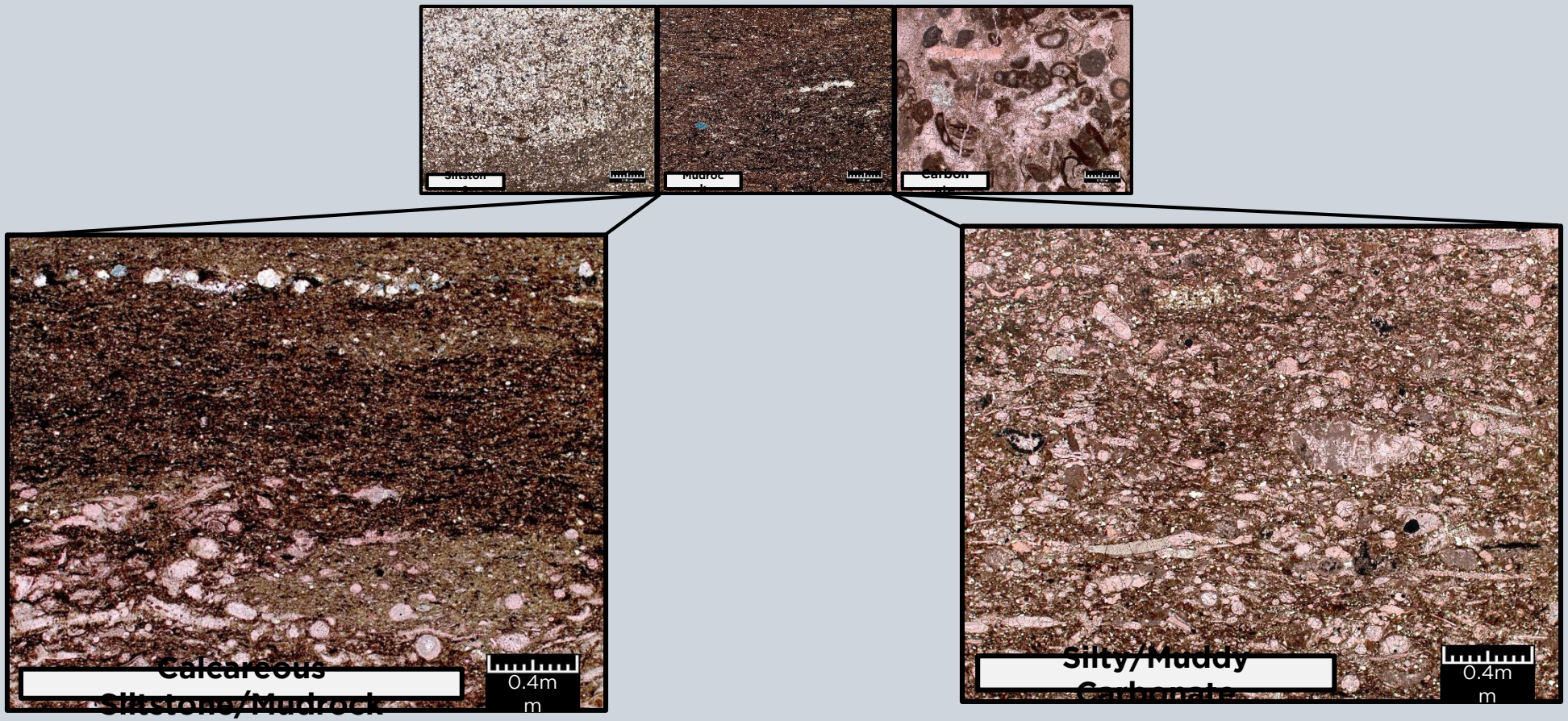
- **Average grains:** angular to subrounded coarse silt
- **Average minerals:** quartz, muscovite, feldspar, compacted silty mudrock and mudrock clasts
- **Matrix:** detrital illite/mica clay mixed with very fine organic particles
- 8 lithofacies samples or 25% of total

- **Average grains:** clay-sized particles, very-fine organic particles
- **Average minerals:** illite/mica clay, quartz, radiolarians, very fine calcareous bioclasts
- **Matrix:** illite/mica clay mixed with very fine organic particles
- 9 lithofacies samples or 30% of total



- **Dunham classification:** bioclast packstone
- **Average grains:** ooids/coated grains, forams, gastropods, echinoderms, and brachiopods
- **Average minerals:** calcite
- **Matrix:** very minor recrystallized micritic calcite and trace clay minerals
- 2 lithofacies samples or 7% of total

Mixed Lithology Lithofacies

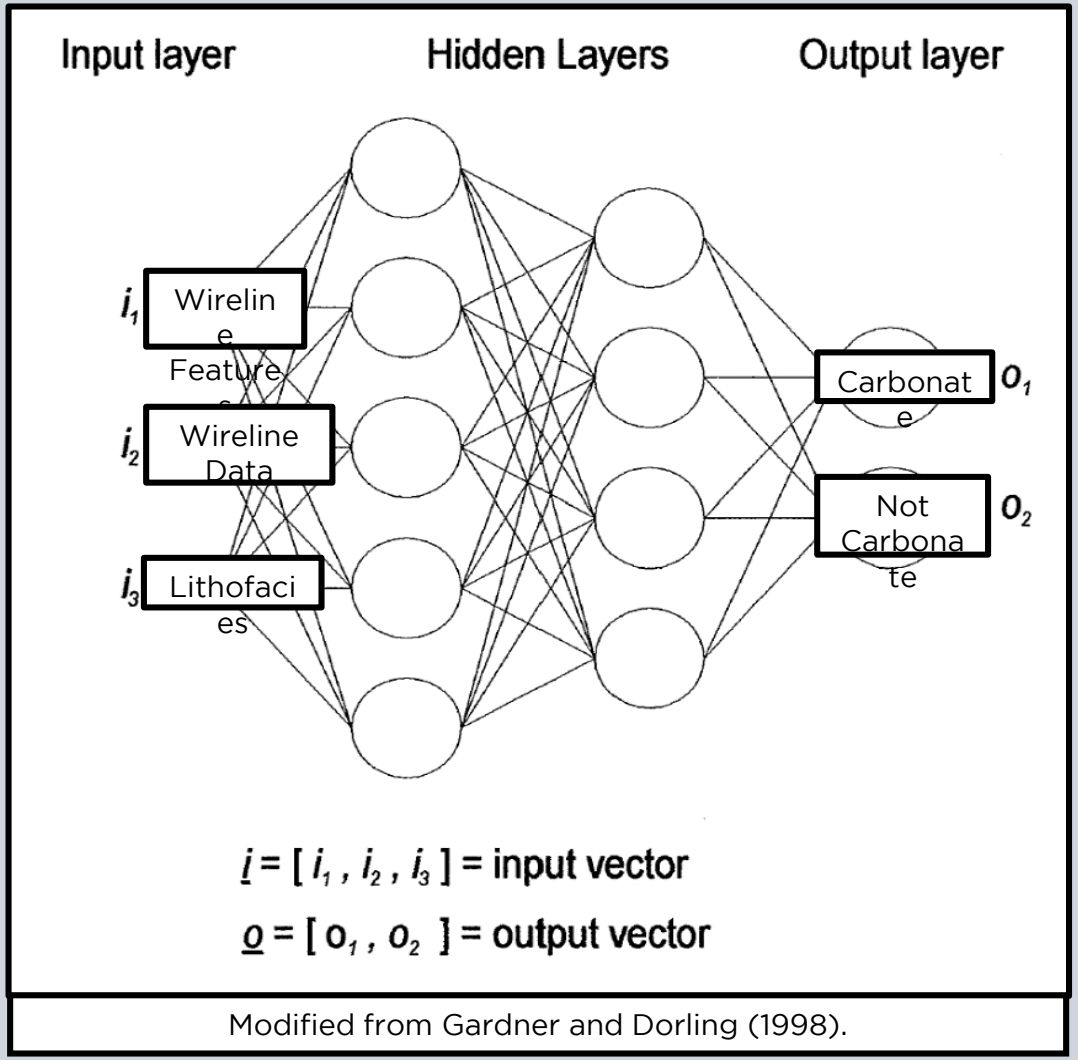


- **Average siliciclastic grains:** angular to subrounded medium silt
- **Average calcareous grains:** bioclasts, calcite-replaced grains, micritic limestone clasts
- **Average minerals:** quartz, calcite, feldspar, and muscovite
- **Matrix:** detrital illite/mica clay with commonly interspersed organic material, occasional calcite

- **Dunham classification:** bioclast wackestone
- **Average calcareous grains:** round to subrounded sponge spicules, radiolarian tests, small micritic limestone clasts, echinoderms, and forams
- **Average siliceous grains:** angular to subrounded medium silt
- **Average minerals:** calcite, quartz, muscovite, and feldspar
- **Matrix:** detrital illite/mix intermixed with organic material or impregnated with bitumen

Multilayer Perceptron Algorithm

- A multilayer perceptron is a class of feedforward artificial neural network information in the network moves forward from the input nodes, through the hidden nodes, and to the output nodes
- Hyperparameters used to tune the algorithm:
  - Solver
  - Hidden layer sizes
  - Batch size
  - Max iteration
- Validity of model determined by accuracy score



Modified from Gardner and Dorling (1998).

Training the Algorithm

- Wolfcamp A and B combined in one algorithm
  - Similar lithologies
  - Lithofacies data too sparse if split
- 5 lithofacies and 8 wireline features
  - Lithofacies: siltstone, mudrock, calcareous siltstone/mudrock, silty/muddy carbonate, and carbonate
  - Features: GR, YM, PR, DEN, NPHI, SP, PE, and ILD
- Hyperparameters used to tune algorithm:
  - Hidden layer size
  - Batch size
  - Max iteration
- Model's performance validated using an accuracy score

Wolf A Lateral Well

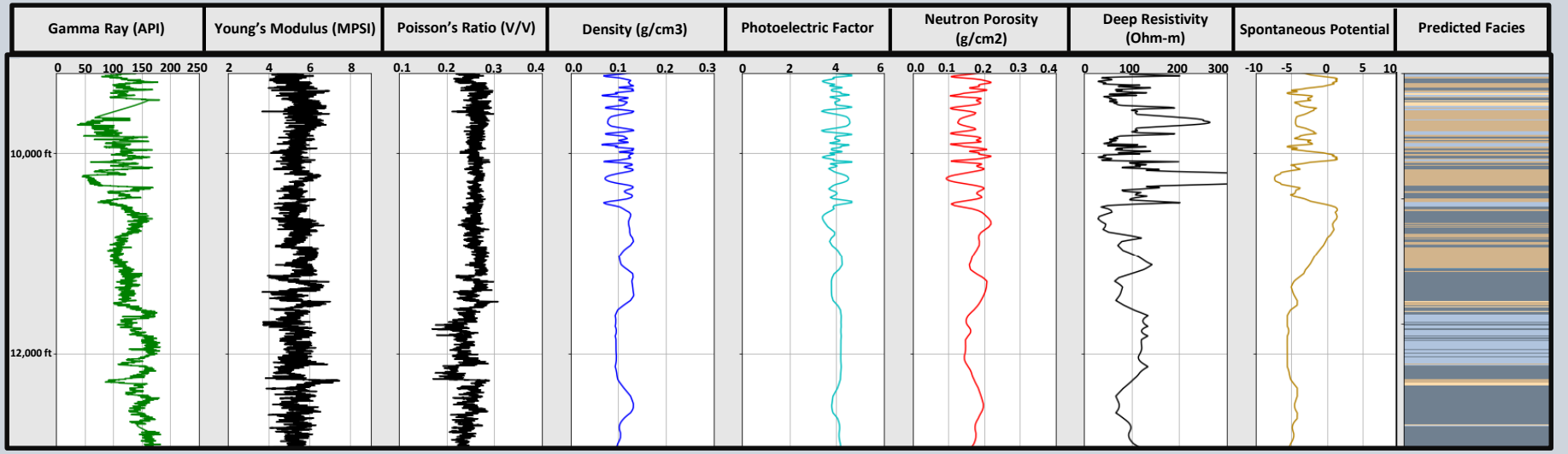
Siltstone

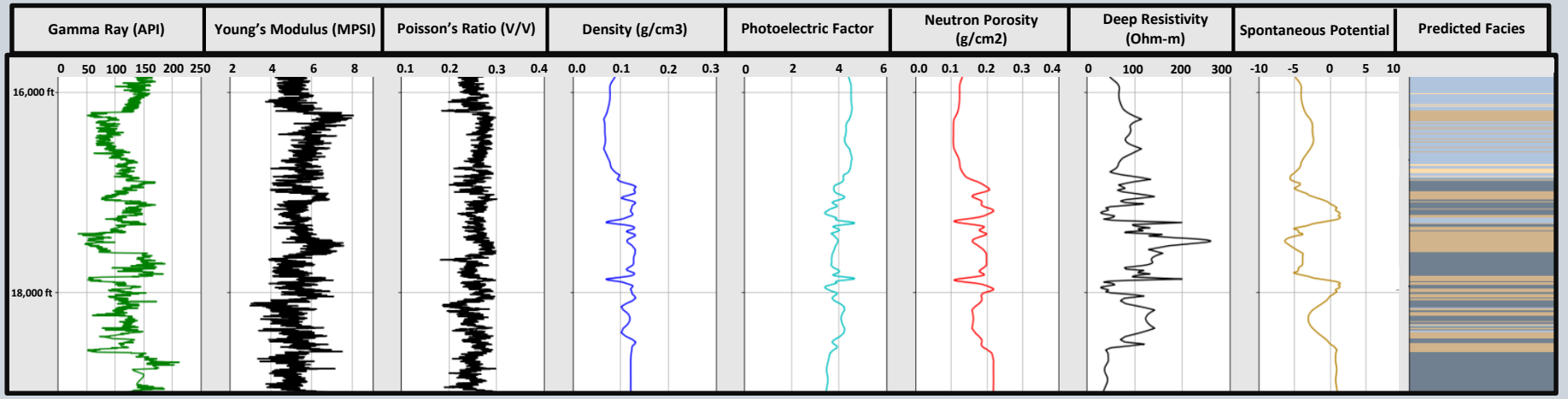
Calcareous Siltstone/Mudrock

Mudrock

Silty/Muddy Carbonate

Carbonate





Wolf B Lateral Well

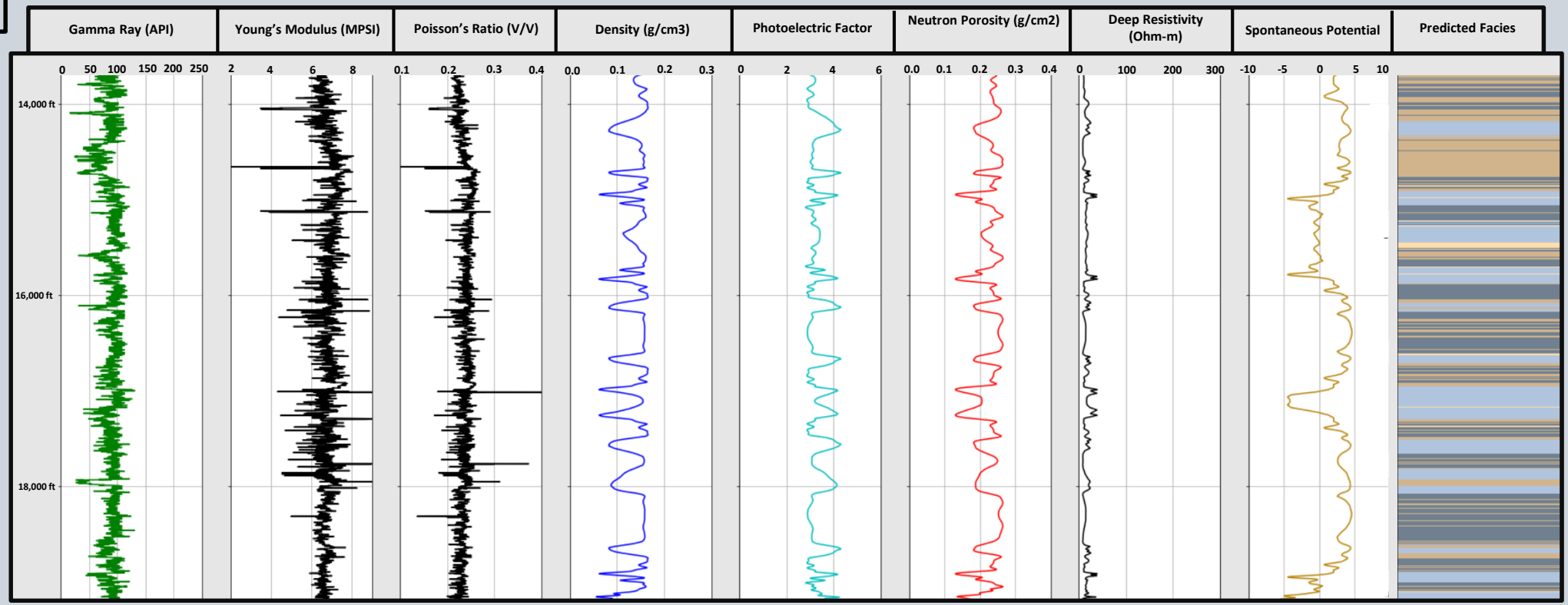
Siltstone

Calcareous Siltstone/Mudrock

Mudrock

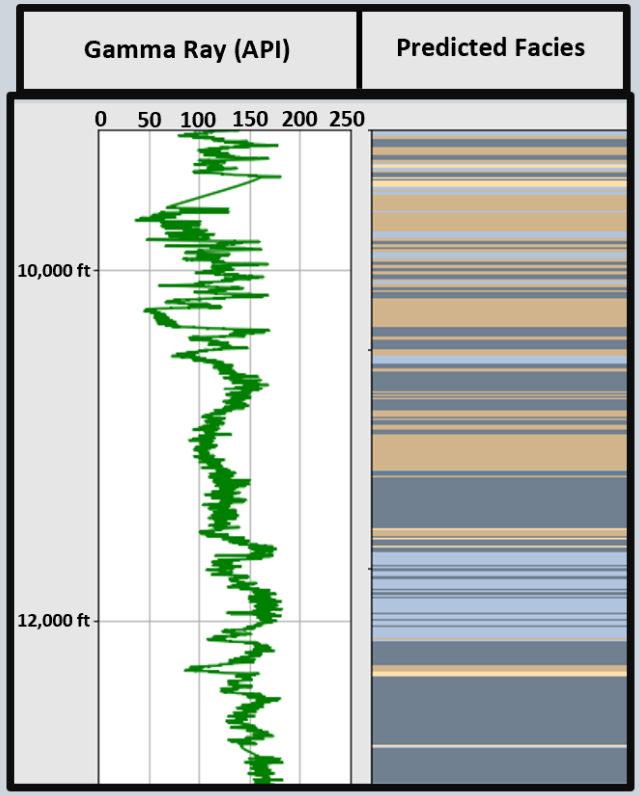
Silty/Muddy Carbonate

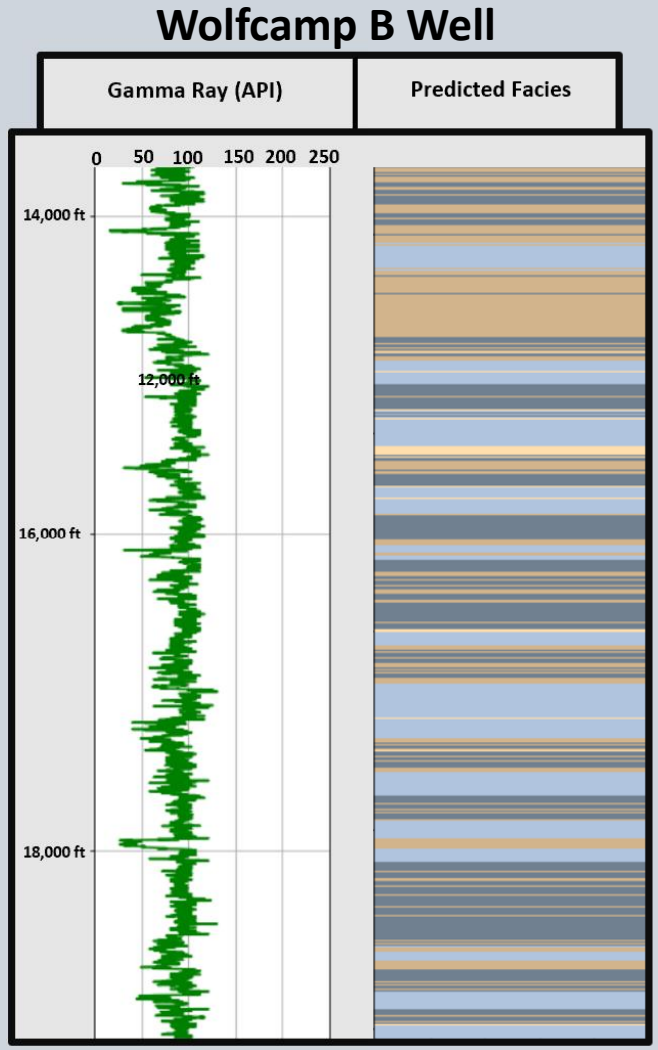
Carbonate



Conclusions

- The Horizonal Well Lithofacies Predicting Model can successfully predict the facies of siltstone, mudrock, carbonate, calcareous siltstone/mudrock, and silty/muddy carbonate along the majority of a lateral well
- The model can predict where there is a higher concentration of background carbonate
- The model can differentiate between siltstone and carbonate
- The model excels at predicting the heterogeneity of the Wolfcamp A and B





Future Work

- Apply trained model to remaining Wolfcamp A and B horizontal wells
- Stratigraphically map extent and thicknesses of major carbonate gravity flows through Wolfcamp A and B using 3 vertical wells, 8 Wolfcamp A horizontal wells, and 18 Wolfcamp B horizontal wells
- Write thesis
- Graduate
- Start full-time position at COP in Midland next summer

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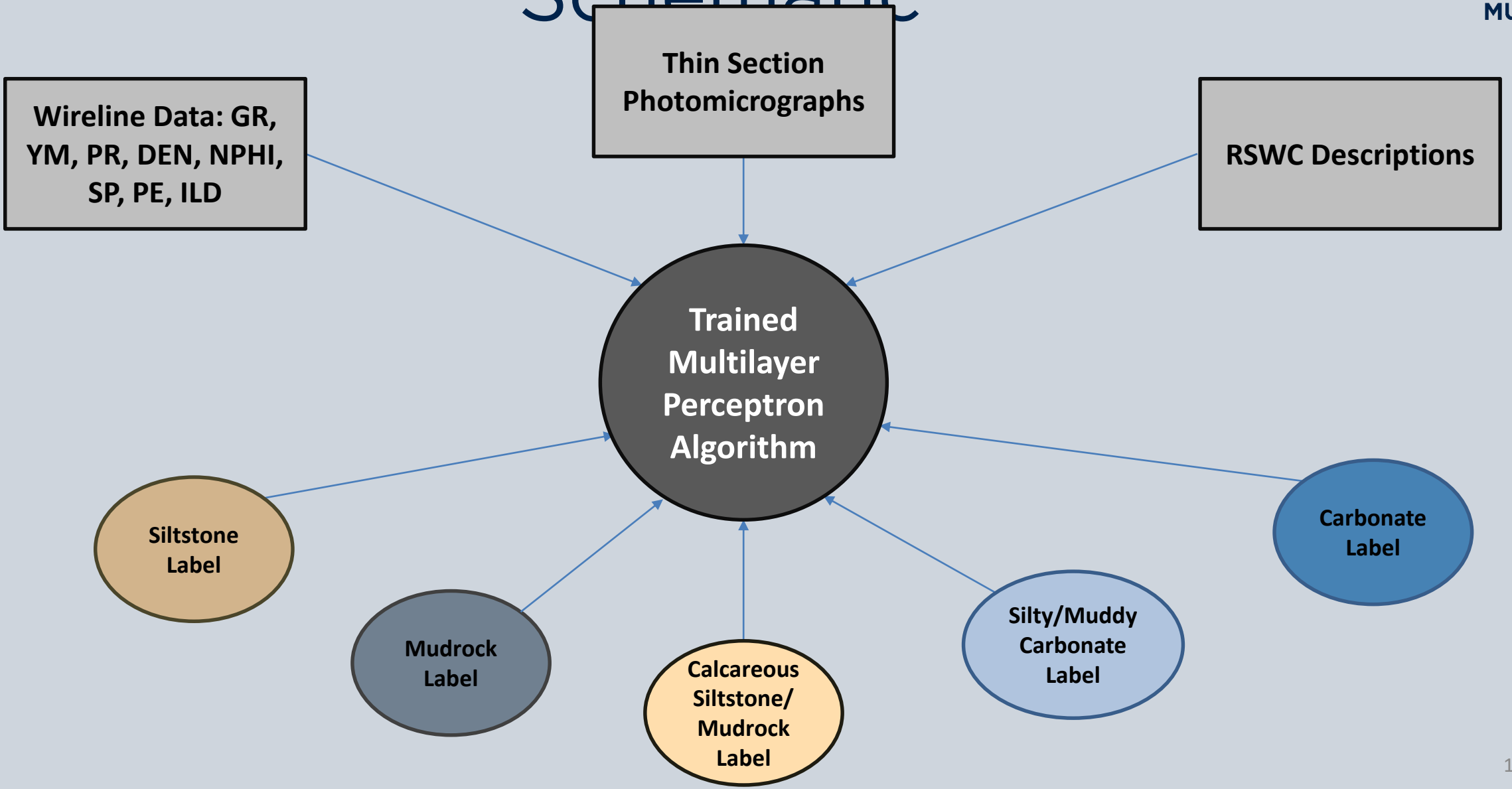
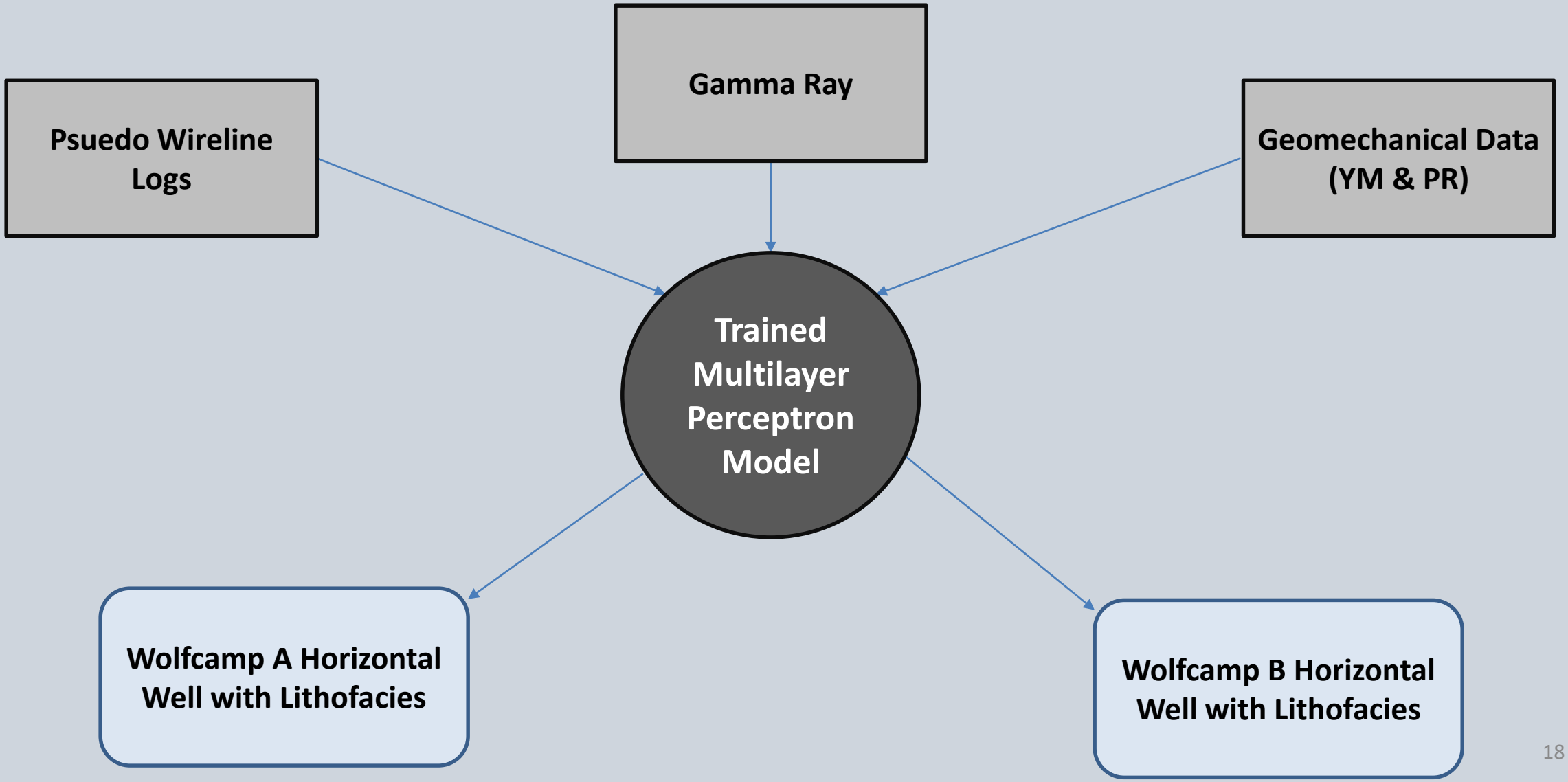
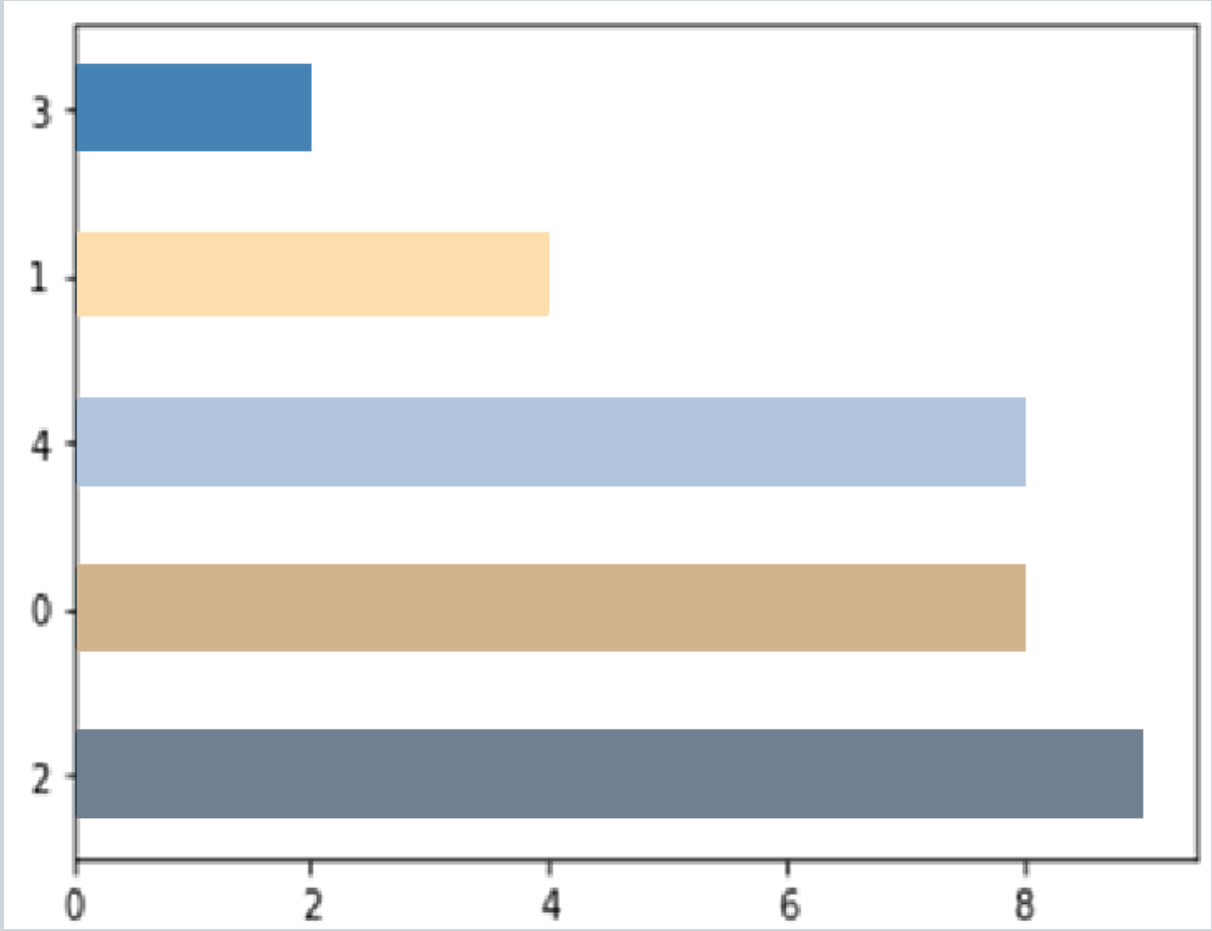
Training a Lithofacies Predicting Model Schematic



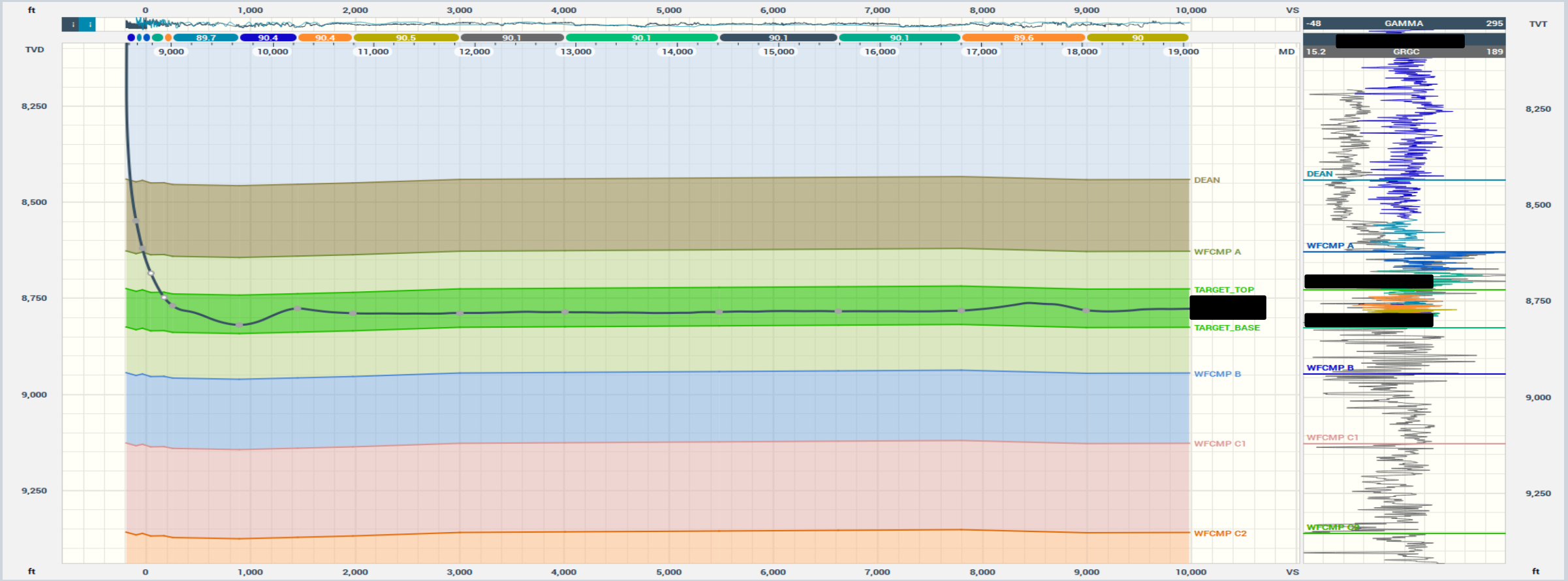
Horizontal Wells with Lithofacies Prediction Schematic



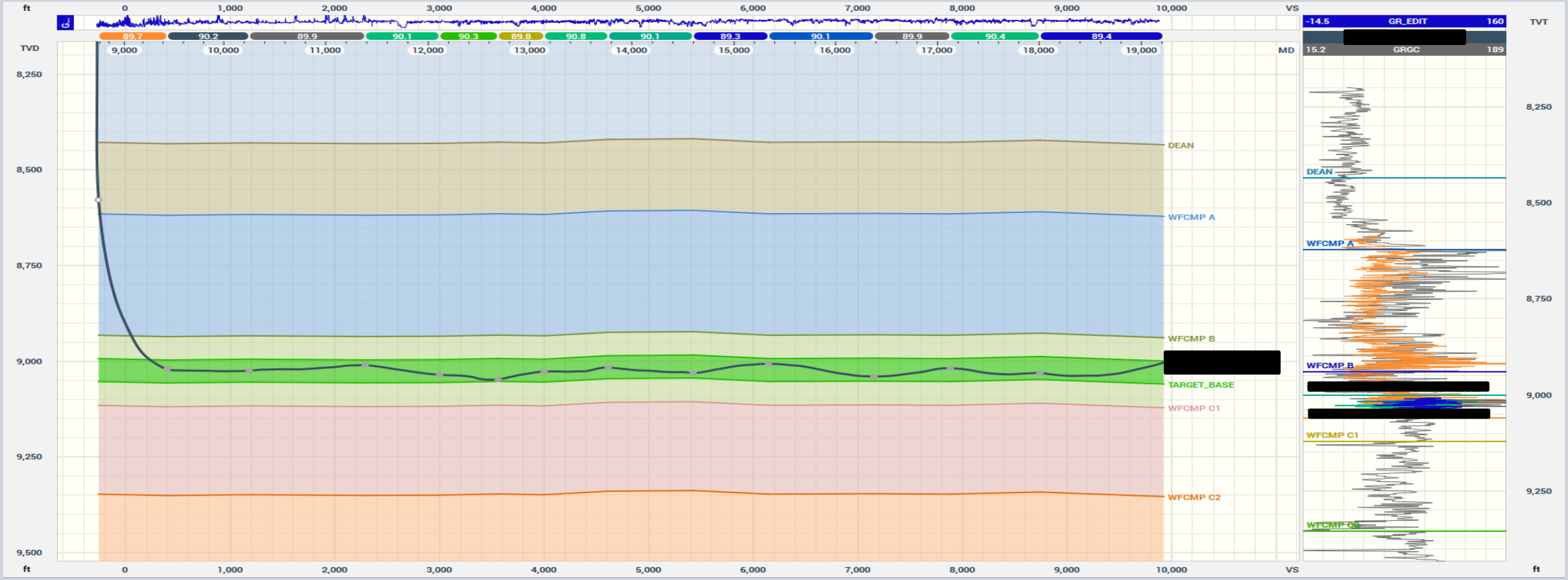
Facies Labels Count



Wolfcamp A Lateral Well Backsteer Plot



Wolfcamp B Lateral Well Backsteer Plot



Combined Wolfcamp A and B Lateral Well BackSteer