



Stochastic Methods for Reservoir Simulation

Project Update 5

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Initial Interpretation - Channel Meander

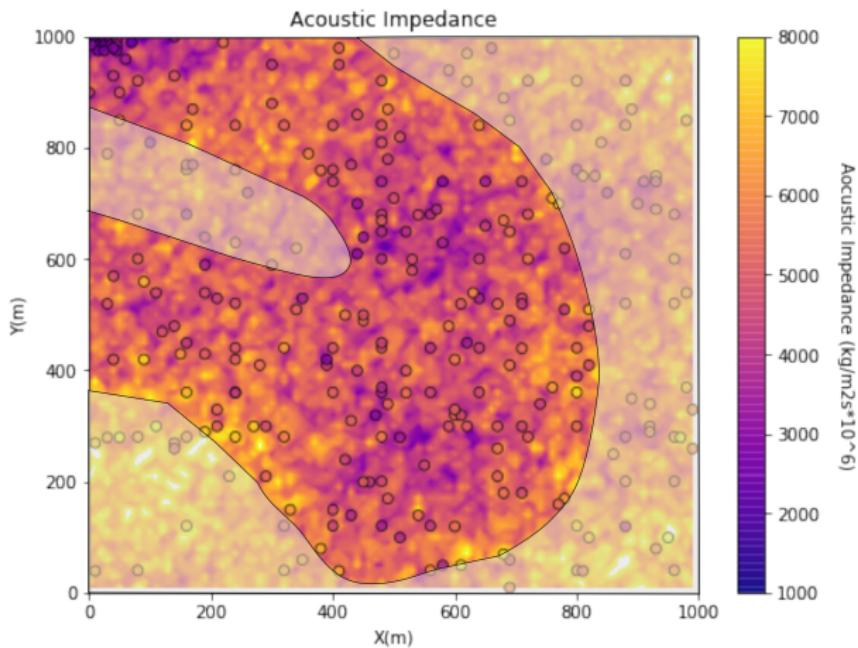


Figure: Geologic interpretation overlaid on acoustic impedance data

Workflow

1. Facies spatial distributions estimated using sequential indicator simulation (from well data and prior spatial continuity analyses)
2. Variogram models were fit to the porosity residuals (after removal of trends)
3. Sequential gaussian simulation (using simple kriging estimator) conducted for porosity values by-facies
4. Colocated cokriging performed to estimate permeability by-facies (using simulated porosity fields, well data correlation between porosity and permeability, and prior permeability variogram models)
5. Cookie-cutter approach for facies porosity and permeability simulation realizations conducted by using sequential indicator simulated facies information

Sequential Indicator Simulation of Facies

Using the facies proportions present in the original data, sequential facies simulation was performed to generate potential distributions of the facies.

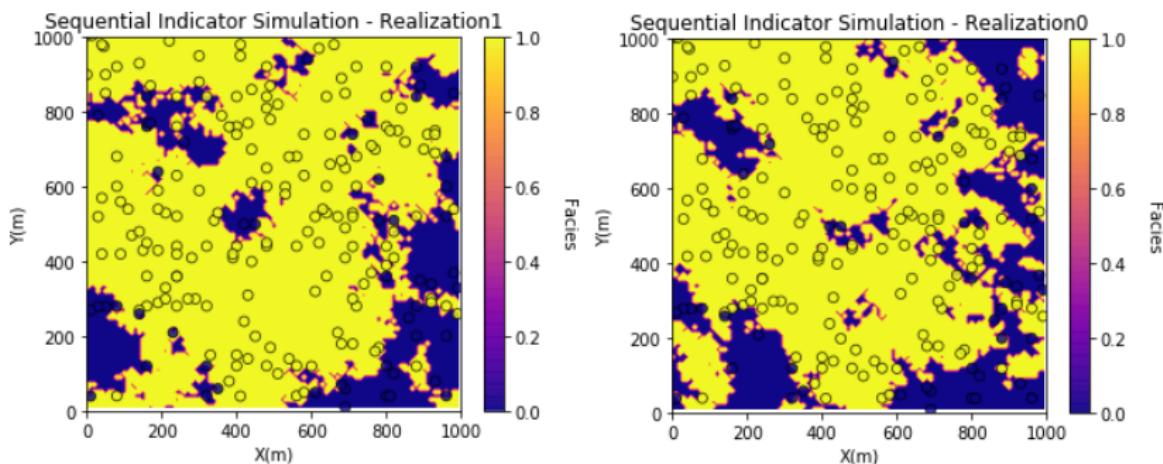
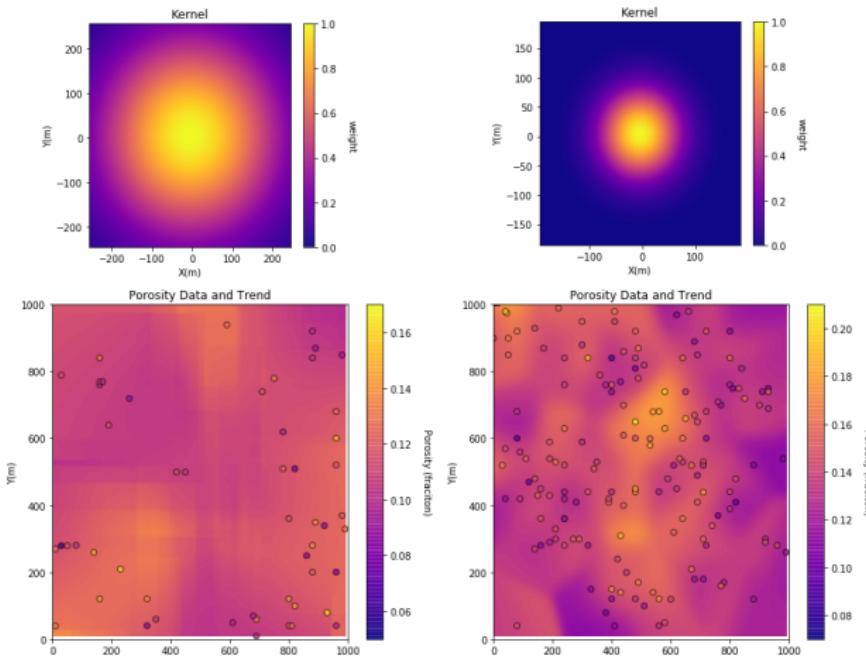


Figure: Facies Sequential Indicator Simulation - Sandstone shown as yellow,

Modeling Trends in Porosity

- ▶ 10% variance modeled in shale (left)
- ▶ 34% variance modeled in sandstone (right)



Model Variogram

- ▶ Model variogram to porosity residuals
- ▶ Hypothesize the cyclicity in shale due to data sparsity

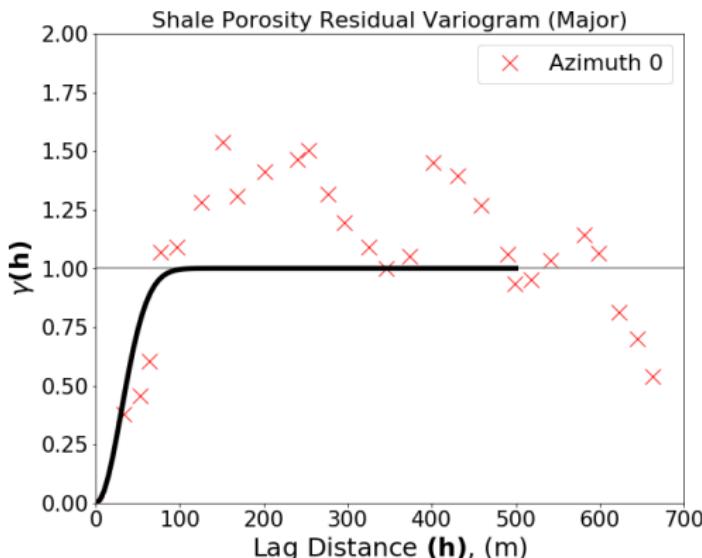


Figure: Example of variogram modeled to the porosity residuals

Porosity Simulations

- ▶ Sequential Gaussian Simulation for porosity (by-facies)
- ▶ Sandstone on left, Shale on right

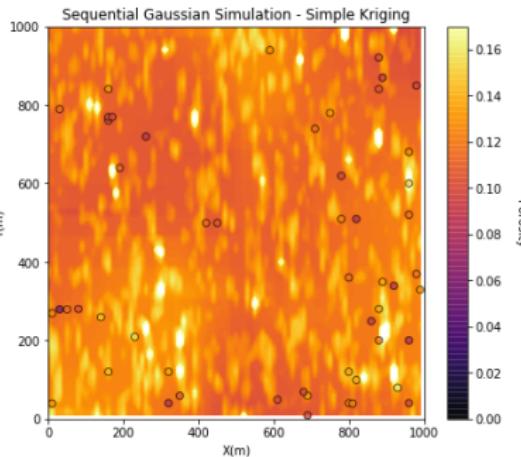
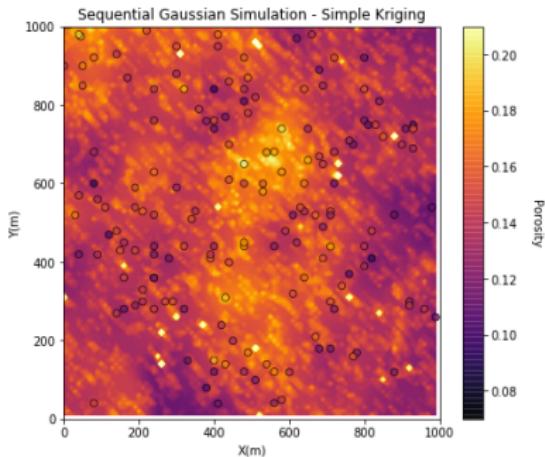
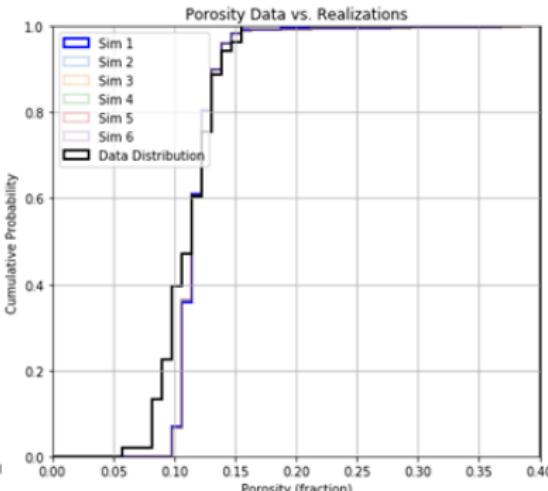
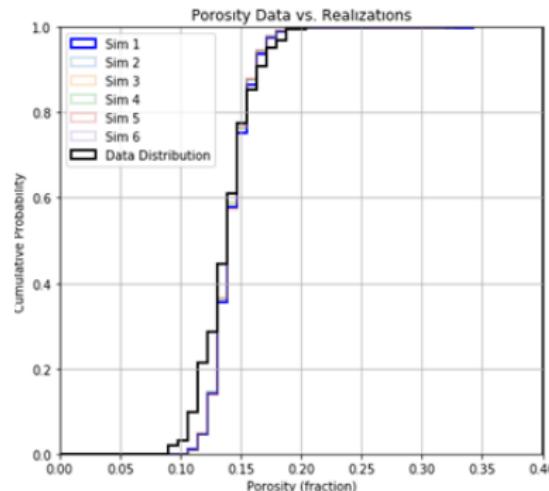


Figure: Example of simulated porosity fields (Sandstone on left, Shale on right)

Porosity Simulation CDFs

- ▶ Comparing simulated porosity fields to original porosity data distributions
- ▶ Under-representation of the tails - Likely due to overfitting of trend
- ▶ Sandstone on left, Shale on right





Collocated Cokriging Permeability

- ▶ Use correlations between porosity and permeability from the well data for collocated cokriging
- ▶ Correlation of about 0.35 in sandstone and 0.2 in shale
- ▶ Sandstone on left, Shale on right

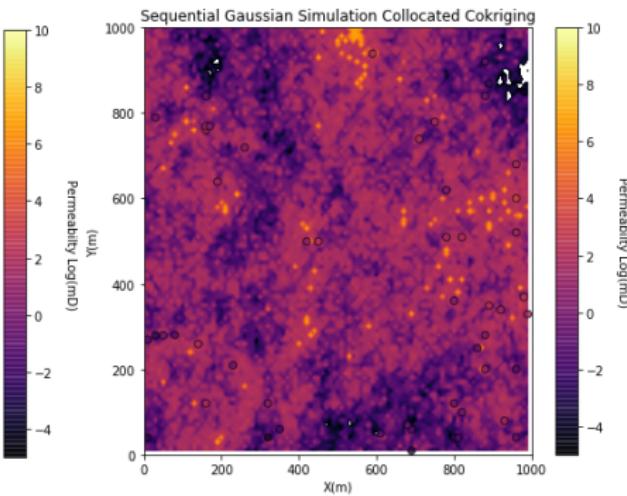
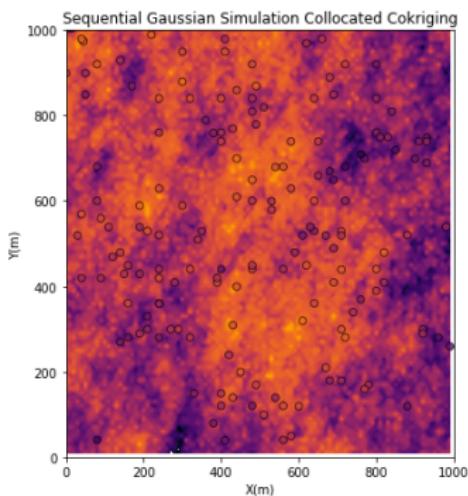


Figure: Simulated Permeability Fields (Sandstone on left, Shale on right)



Permeability Simulation CDFs

- ▶ Plotting simulated CDF of permeability and the CDF from the data - CDFs of $\log(\text{permeability})$ are plotted
- ▶ Sandstone on left, Shale on right

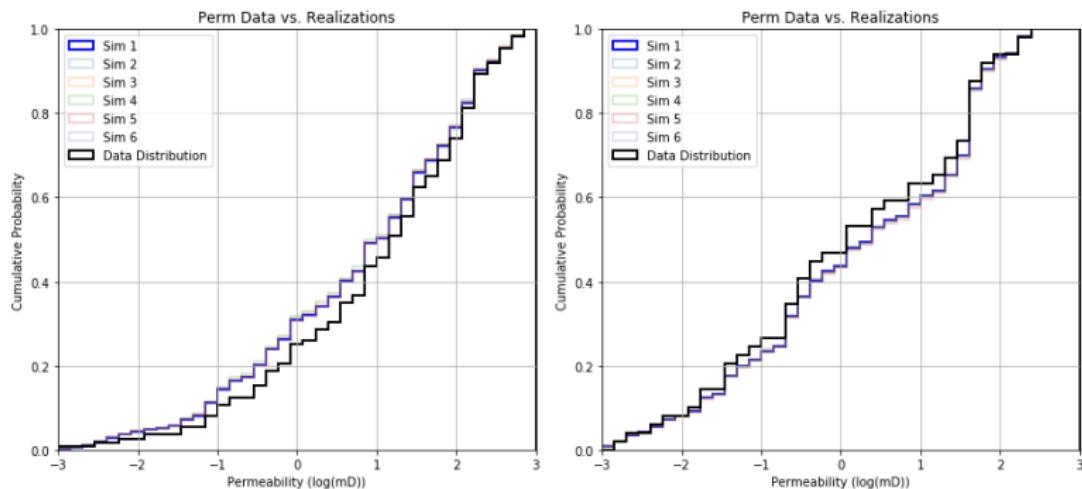


Figure: Permeability CDFs (Sandstone on left, Shale on right)

Cookie-Cutter Results

- ▶ Apply indicator values from sequential indicator simulation to fill in field with values by facies from the sequential gaussian simulations
- ▶ Porosity on left, Permeability on right

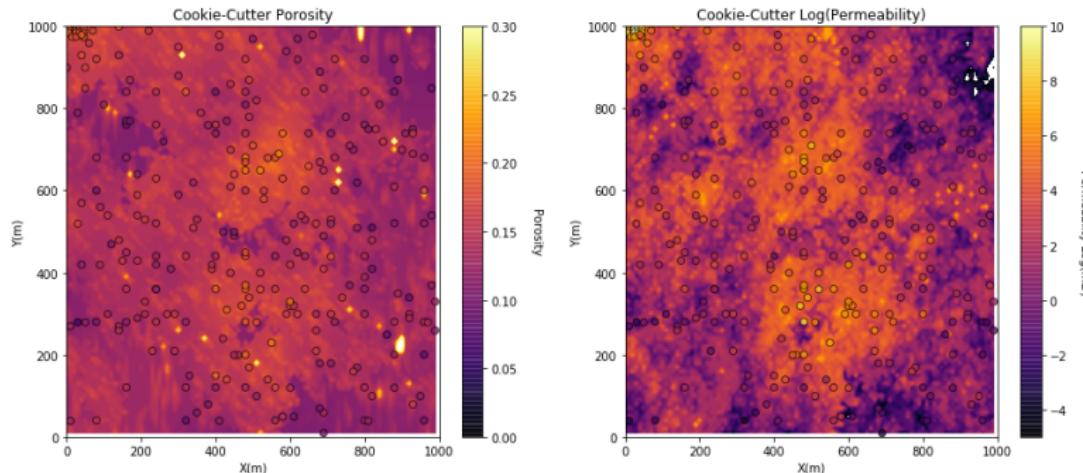


Figure: Cookie-Cutter Results (Porosity on left, Permeability on right)

Cookie-Cutter Results and Acoustic Impedance

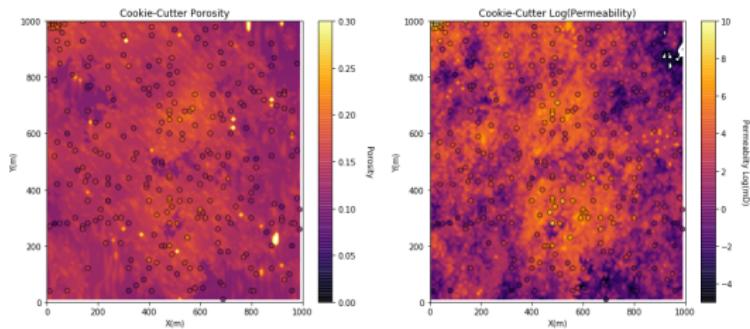
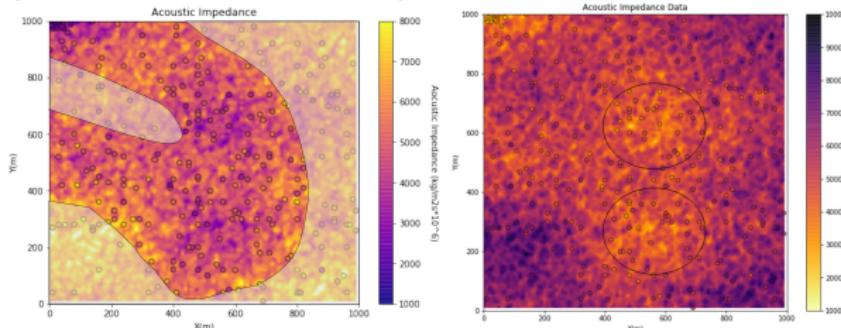


Figure: Cookie-Cutter Results Above (Porosity on left, Permeability on right); Initial Interpretation and Acoustic Impedance Data Below



Conclusions

- ▶ Trends were overfit leading to underprediction in tails
 - Potentially little/no trend
 - Only modeled 10% and 34% of variance as it was
- ▶ Overfitting also enhanced spatial continuity beyond truth
 - Consequence of underpredicting tail/extreme values
- ▶ However overall simulations representative of original data
 - Comparison to acoustic impedance data is good
- ▶ See features that resemble lobes - challenges our initial interpretation of channel depositional setting