PGE 383 - Stochastic Methods for Reservoir Modeling - Spring 2019

Project Update #4 by Team 8, Spatial Estimation Using Kriging

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Executive Summary

The purpose of this update is to apply spatial estimation analysis to assess the spatial uncertainties over our study area, given the available data and the models of spatial continuity previously built.

The work included:

- Calculating the probability of each facies across the reservoir
- Computing the Kriging estimate and variance for porosity and permeability over the entire prospect, for each facies
- Building a combined model (cookie cutter approach) with porosity and permeability for the most likely facies at all locations
- Calculating the values for porosity and permeability of most likely facies and reporting the local P10 and P90 map
- Picking two candidate well locations and providing a pre-drill porosity uncertainty distribution accounting for the probability of each facies

Simple kriging was used in our estimates and calculations due to its better performance in the under-sampled regions. The porosity and permeability maps were used to identify directionality and spatial continuity; for the porosity, the greatest continuity seems to occur along the channel's main axis, while a greater continuity in the permeability is observed in the orthogonal direction. The kriging models developed were finally used to identify and assess two locations for drilling new wells.

Description of Workflows and Methods

1. Declustering porosity and permeability data
2. Calculating experimental variograms and then modelling them
3. Modelling the facies probabilities with indicator kriging
4. Modelling the porosity and permeability (independently) for sand and shale separately and exhaustively, i.e. at all locations in the model
5. Assigning sand and shale locations based on the probabilities from step 3
6. Combining the porosity and permeability from sand and shale regions together
7. Calculating the 10th and 90th percentile for porosity and permeability for the most likely facies at all locations
8. Estimating the porosity uncertainty distribution for two selected candidate well locations

Results and Discussion

1. Indicator Kriging for Facies

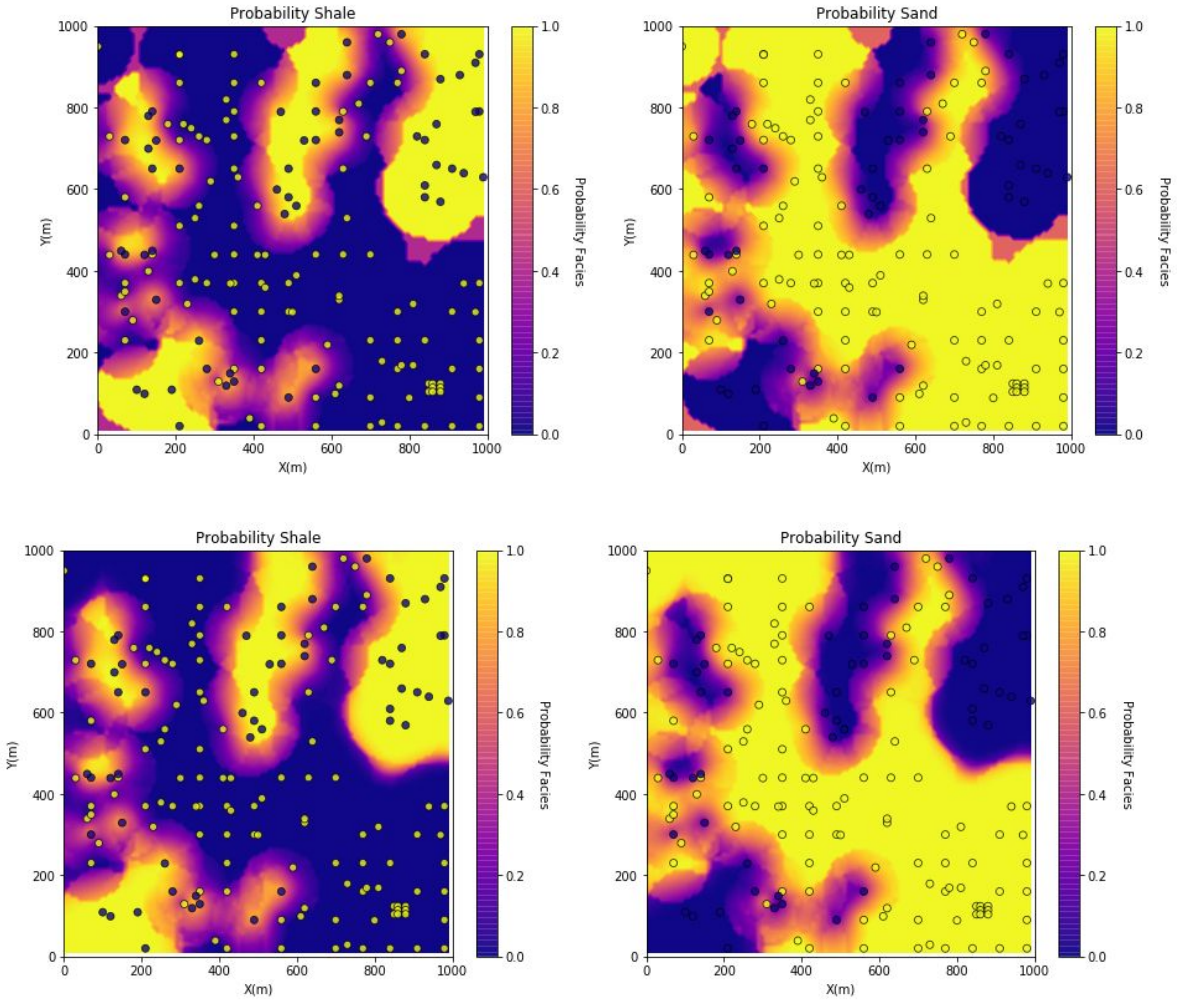

Figure 1. Indicator Kriging for facies (above:ordinary kriging, below: simple kriging)

The maps displayed were generated using both simple and ordinary Kriging. Although the resulting maps are similar, in regions that are under-sampled (upper left corner, for instance) estimates based on the global mean are more appropriate. Therefore, simple kriging delivers better results. Based on these results, simple kriging was used in subsequent estimates and calculations.

2. Kriging estimate for porosity and permeability

The Kriging estimates and variance for porosity and permeability were calculated over the entire prospect for each facies separately. The resulting maps reflect the directionality identified in the spatial continuity model we had previously built and that was shown in the last update. It is particularly evident in the porosity map, that the greatest spatial continuity seems to occur in the

direction of what we interpret as the channel's main axis. Conversely, in the permeability map we observe greater continuity in an orthogonal direction (SW-NE roughly).

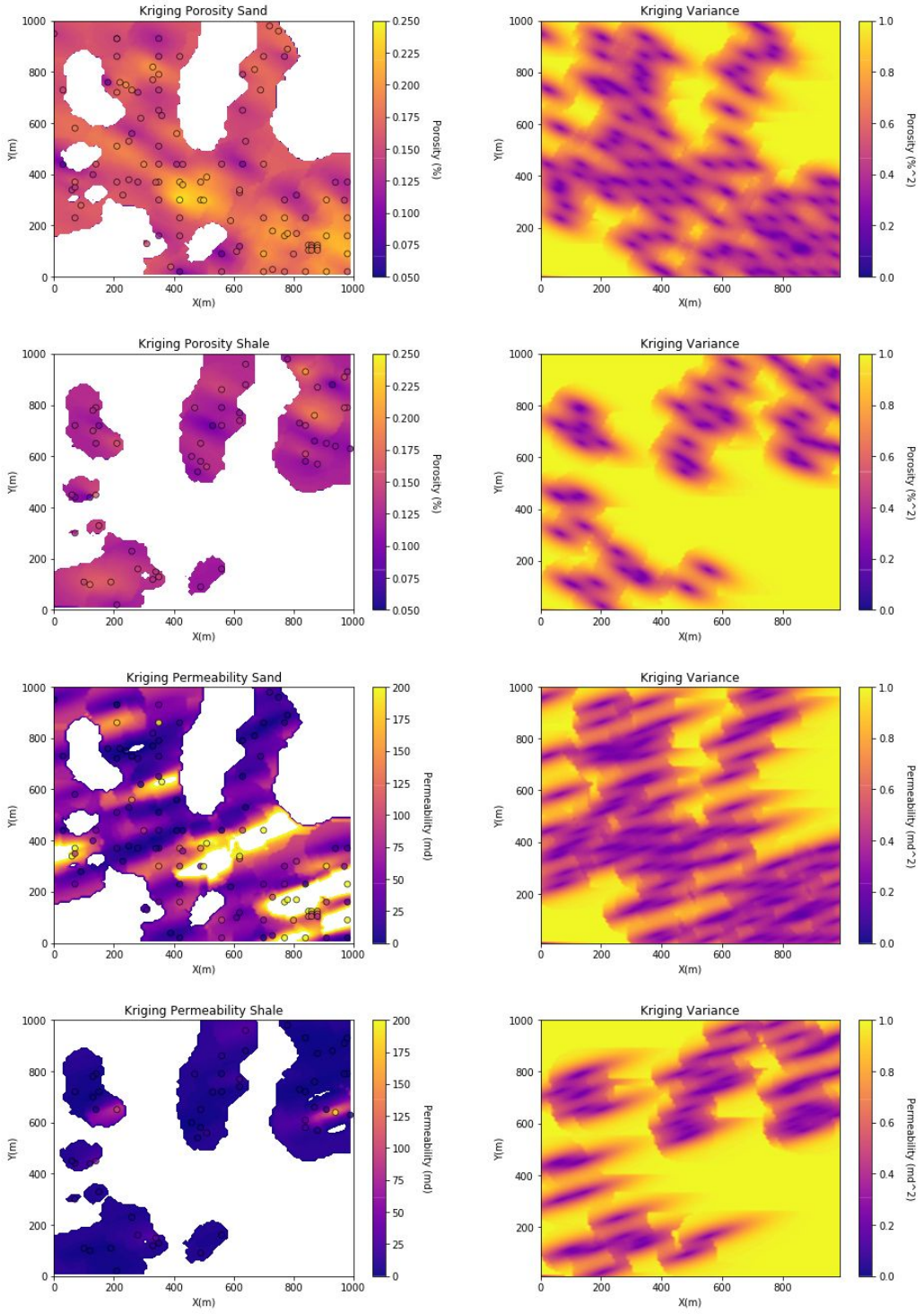

Figure 2. Estimated porosity and permeability and their variance map for sand and shale facies using Simple Kriging

3. Combined model for porosity and permeability for the two facies

By using the cookie cutter approach we generated the porosity and permeability maps for the most likely facies at all locations. In both the porosity and permeability maps, the contrast in the values clearly separates one facies from another. However, it is more evident in the porosity map.

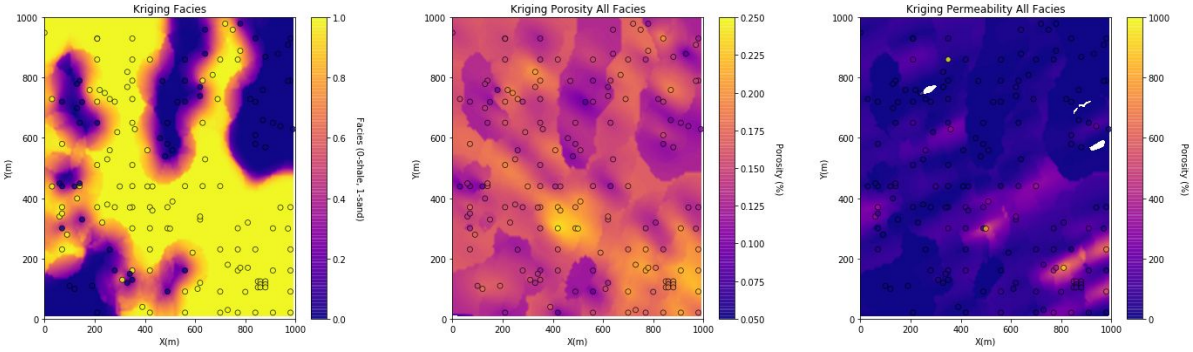

Figure 3. Combined models of estimated facies probability porosity, and permeability for all facies

4. Local P10 and P90 maps

Using a gaussian distribution assumption for porosity and permeability, the kriging estimate means and kriging variances were used to identify the 10th and 90th percentile values for the area of interest. This was then used to build the P10 and P90 maps for the two properties, based on the most likely facies at a given location.

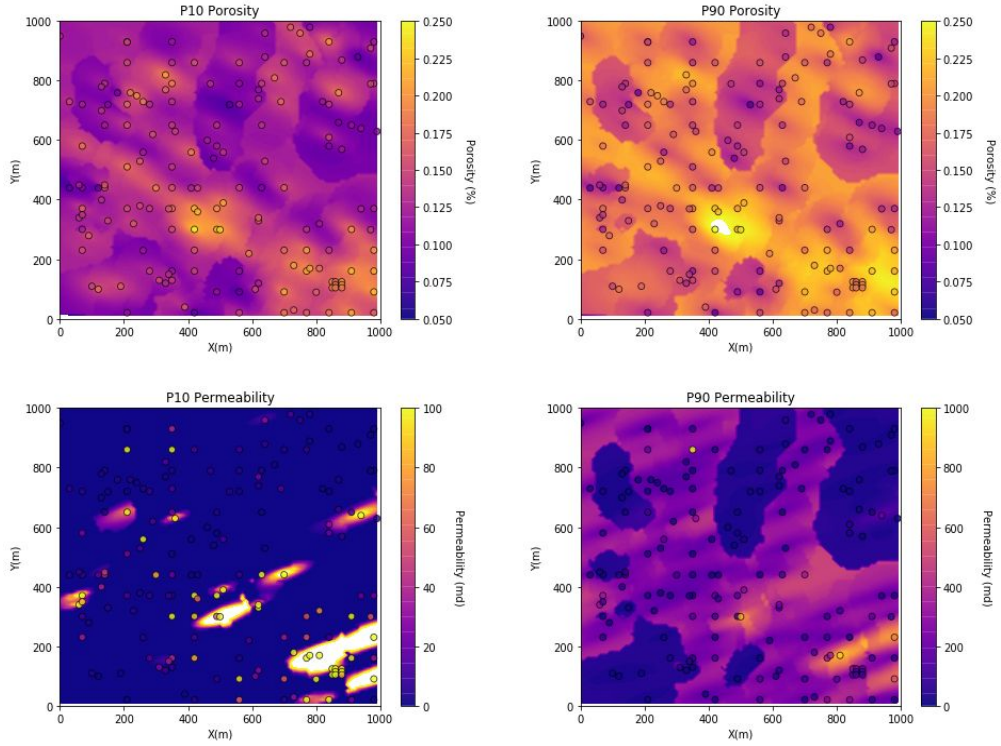

Figure 4.Local estimated P10 and P90 map of porosity and permeability for all facies

5. Two proposed well locations and porosity uncertainty

The two proposed well locations are: (725,605) and (825,425). The corresponding indices in the kmap are (39,72) and (57,82). These two locations are chosen because they lie in a relatively under-sampled area and drilling at these two locations can best help identify the boundary between the sand and shale facies. Furthermore, porosity and permeability values in the selected locations are likely to be favorable, as the P90 maps show (Figure 4). This is confirmed for porosity by the porosity uncertainty distribution plot displayed in Figure 6.

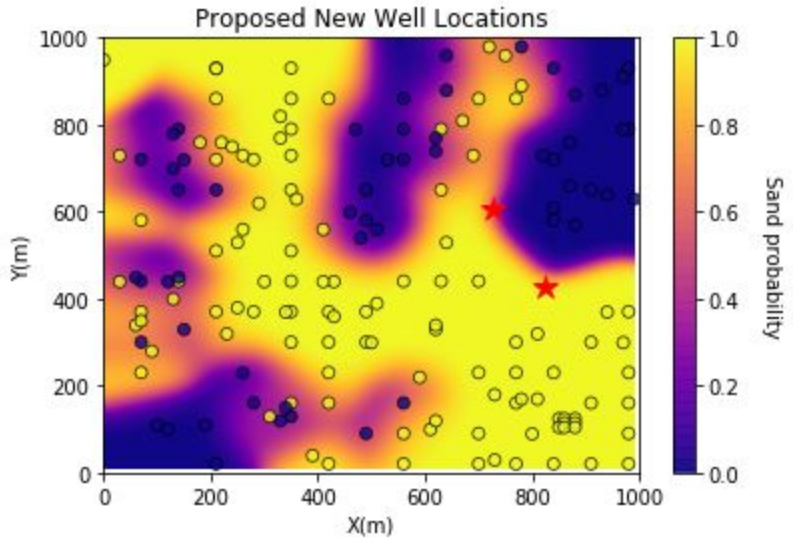

Figure 5. Proposed well locations (stars) displayed in estimated sand probability map

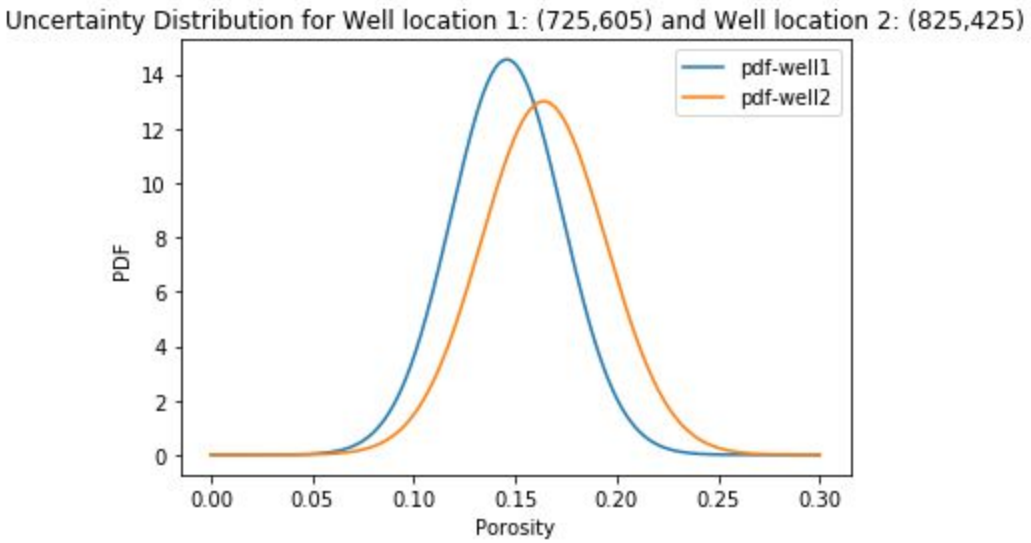

Figure 6. Porosity PDFs for proposed well locations

Limitations of Kriging estimates for Porosity and Permeability:

- Kriging is too smooth, the spatial continuity is too high
- Kriging does not reproduce the continuous property distributions
- It does not account for the correlation between porosity and permeability

Conclusions

- The geometry of the facies probability model, using Kriging indicator, enhances our interpretation of a deep-water channelized system as the paleoenvironment of deposition of our reservoir
- Kriging estimates are a good way to assess spatial uncertainties, although the smoothing effect is considerable and should be tackled in the future
- Using the maps generated by kriging can help identify viable locations for drilling subsequent wells, and the generated kriging maps can help perform pre-drill assessments

Future Work

- Mitigate the over smoothing of Kriging porosity and permeability estimates when performing simulation