# PGE 383 Project Update #4 - Team 01

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## 1 Executive Summary

The Reservoir Subsurface Team 1 has continued with the spatial estimation of this reservoir. This update includes efforts taken to assess the spatial uncertainties over the reservoir in continuous variables such as porosity and permeability.

Spatial continuity found via variogram modeling in the previous update was applied to perform spatial kriging. We found that kriging maps for permeability and porosity are well correlated with each other. These findings support the hypothesis that the most productive area of the reservoir is in the middle of the channel identified in previous updates. In addition, the percentile maps also confirm the presence of the zones with the highest reservoir properties in the center of the sinuous channel. We picked two potential well locations which have high porosity and permeability values, and calculated their porosity uncertainty distributions. Moving forward, it is the belief of our asset team that the spatial estimation contained within this report should be used throughout the simulation process.

## 2 Description of Workflows and Methods

The following steps were carried out in a Jupyter Notebook workflow:

1. Indicator kriging was applied to the indicator-transformed facies data to estimate the probability of occurrence for each facies across the reservoir

2. Using the variogram models from Update #3, ordinary kriging was performed on the porosity and permeability data on a per-facies basis

3. A combined cookie-cutter approach was used to estimate the permeability and porosity across the field by taking the kriged estimates for the most likely facies at each location

4. The 10th and 90th percentile estimates were calculated for permeability and porosity at each location on the cookie-cutter maps

5. 2 candidate well locations were identified and predrill porosity uncertainty distributions for the facies probabilities were calculated

# 3 Results

## 3.1 Indicator Kriging of Facies

After applying an indicator transform to move from categorical facies classifications to numerical classes, model variograms were fit to the facies data. Indicator kriging was performed using the spatial ranges derived from the model variograms to estimate the facies probabilities across the reservoir; these probability maps are shown in Figure 1.

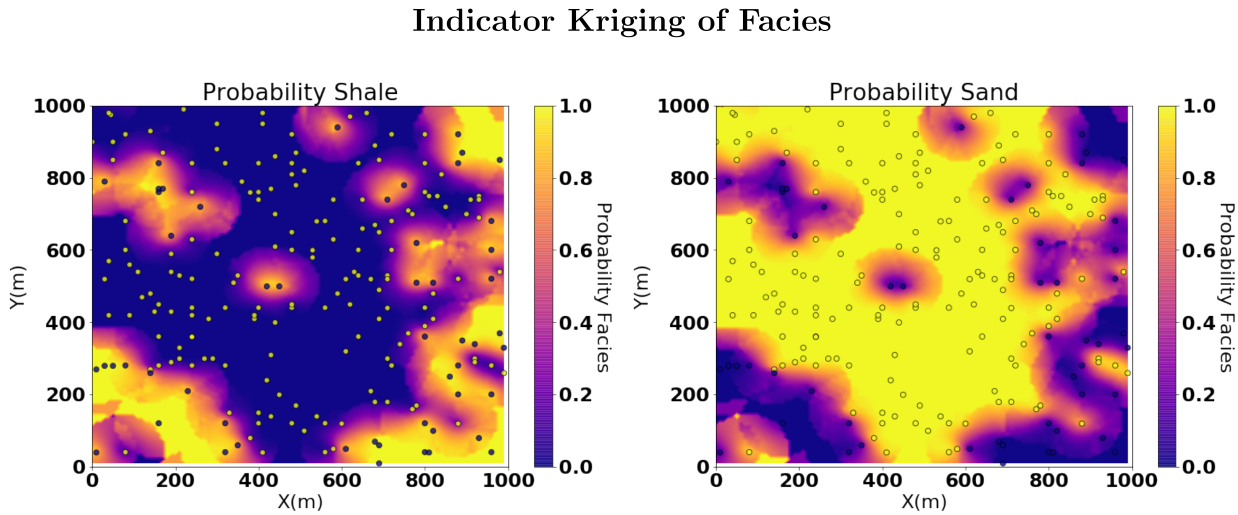



Figure 1: Facies probability maps found via indicator kriging

## 3.2 Ordinary Kriging of Porosity and Permeability Data

The permeability and porosity data was kriged on a per-facies basis. Prior to kriging, the data was tested for trends by plotting the property of interest against the primary X and Y axes. No significant trends in the data were apparent, and so variogram modeling proceeded without any trend modeling or removal.

After variogram modeling, ordinary kriging was applied to the datasets. Ordinary kriging was chosen instead of simple kriging because we did not want to assume that the field is statistically stationary. Additionally, we note that the low number of shale values (53) made the shale variograms quite noisy, and as a result the spatial continuity was assumed to be very small. As a result, the kriged maps for the shale data are not highly informative, and so we have omitted them from this report. Figure 2 displays the ordinary kriging maps for the estimates of sandstone porosity and permeability as well as the kriging variance maps.

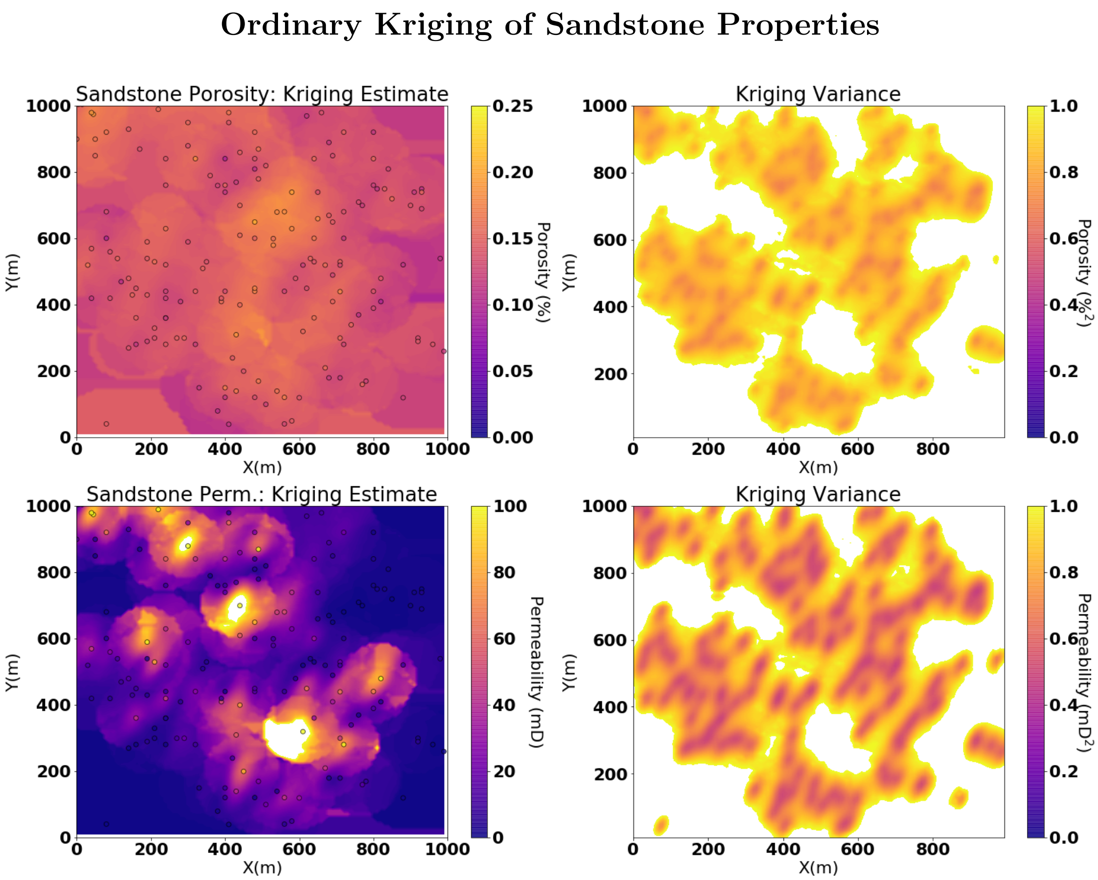



Figure 2: Sandstone porosity and permeability kriging maps and kriging variance

## 3.3 Combined Model (Cookie Cutter Approach)

From the ordinary kriging results we calculated the kriging spatial estimates and kriging estimation variance of porosity and permeability for both facies. Based on the indicator kriging results, separate kriging maps of each facies for porosity and permeability were generated. Finally, these maps were joined to create a combined model as shown in Figure 3. The categorical variables distribution represented in the kriging facies maps agree with the work done in past updates. Our initial interpretation identified a sandstone channel bordered by shale. In addition, the kriging maps for permeability and porosity are well correlated with each other and further suggest that the most prospective area is the middle of the channel.

**Combined Model With Porosity and Permeability for Both Facies in Each Map**

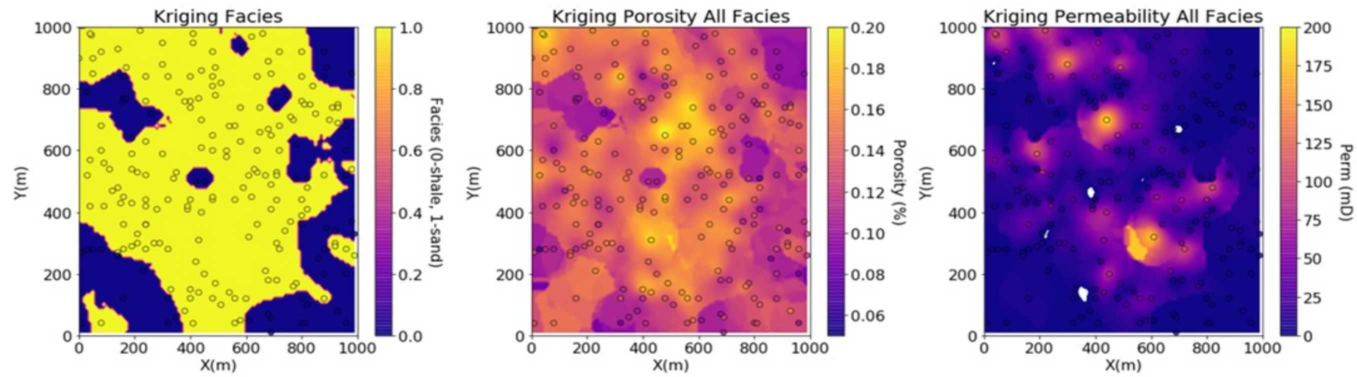



Figure 3: Cookie Cutter Approach

## 3.4 Local P10 and P90 Maps

The P10 and P90 percentiles are obtained from a Gaussian distribution. In order to generate a Gaussian Distribution at each location, the kriging estimate and kriging variance maps were used to calculated the mean and the variance respectively, depending on the facies at each location. However, the local mean is re-estimated, so the model has greater uncertainty. The local variance was calculated by multiplying the kriging variance with the variance of the property to re-scale the local variance.

Using the estimated mean and variance values, the 10th and 90th percentiles (P10 and P90) for porosity and permeability were calculated. The P90 for both properties confirm the presence of a potential high-value area in the center of the channel shown in Figure 4. The P10 will help to define the possible new locations of two proposed wells because the zones with high reservoir properties in the 10th percentile are potentially prospective with only a 10 percent of uncertainty for drilling a well.

**10th and 90th Percentiles for Porosity and Permeability for Both Facies**

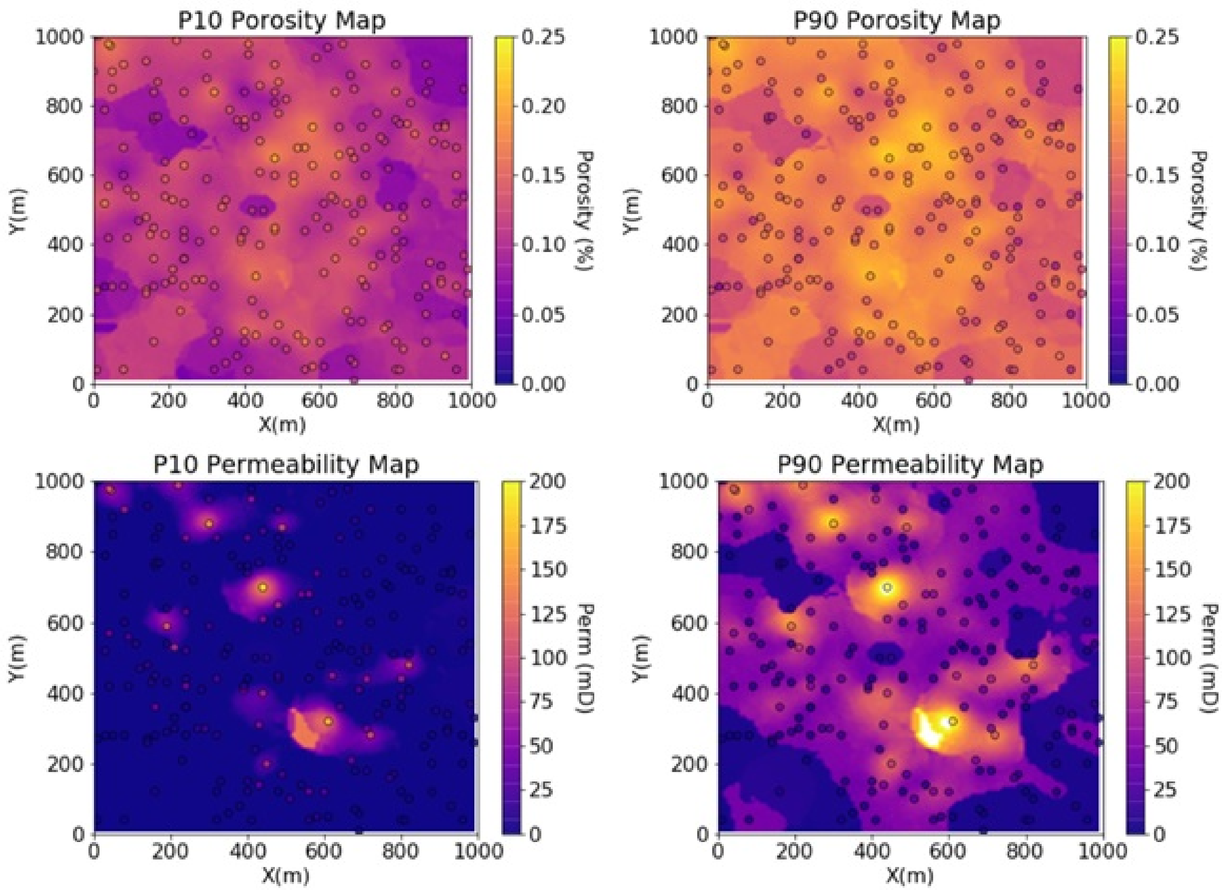
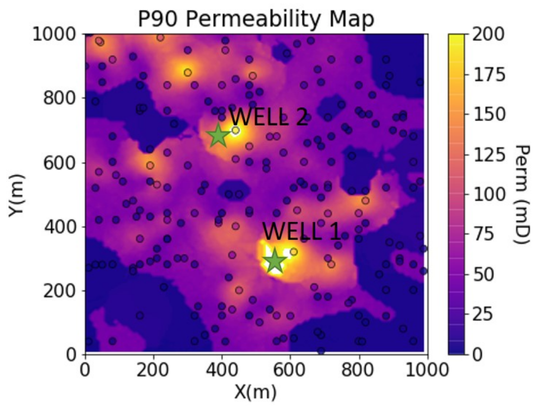
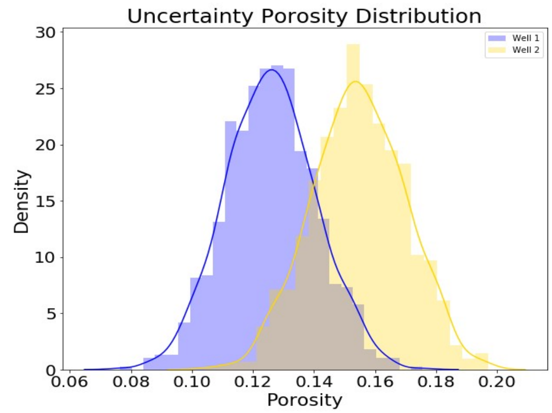



Figure 4: P10 and P90 for Permeability and Porosity

## 3.5 Candidate Well Locations and Predrill Porosity Uncertainty

We chose two candidate well locations on the basis of porosity and permeability. Both of the two proposed well locations show high permeability and porosity values on both P10 and P90 maps. Moreover, the proposed well locations target channel-fill sandstone within the interpreted channel-belt. We also considered the spacing of the proposed wells to the existing wells to avoid interference during production. Based on the porosity uncertainty distribution, Well 2 is more likely to hit high porosity rock than Well 1. Therefore, we recommend drilling Well 2 first based on our current knowledge.




# 4 Conclusions

The kriging map and percentile maps of porosity and permeability suggest that there is a potential drainage area of hydrocarbon in the middle of the previously-interpreted. channel-belt. The two proposed well locations are within the channel-belt and aim to hit the channel-fill sandstone reservoirs with high porosity and permeability. We prioritized well 2 for drilling because it is more likely to hit reservoirs with good porosity.