PGE 383 Project Update #1 - Team 01

Preston Fussee-Durham, Ningjie Hu, Jayaram Hariharan, Jorge Navas

1 Executive Summary

Reservoir Subsurface Team 1 has just received delivery of 271 wells in a data table with X and Y coordinates (meters), Facies 0 and 1 (1 is sandstone and 0 is shale), Porosity (fraction), permeability as Perm (mD) and acoustic impedance as AI ($\frac{kg}{m^2 s} \cdot 10^6$) along with an acoustic impedance map with exhaustive coverage at 10 x 10m resolution over the 1 x 1km area of interest. This update includes the team's initial univariate, spatial analysis for the purpose of data checking and to formulate an initial subsurface hypotheses.

The work includes:

- Visualization of data distributions, data coverage, sampling and location maps, including combined and by-facies
- Sampling bias detection
- Calculation of summary statistics
- Outlier detection
- Comparison of at-well and mapped acoustic impedance
- Initial interpretations of the depositional setting

The area of interest has an acceptable data coverage, however, there are large swaths of land near the boundaries of the study area that were not sampled. This lack of sampling in conjunction with a high density of wells in promising regions of the reservoir indicate biased spatial sampling. The property distributions and geometries are consistent with a meandering channel interpretation.

2 Description of Workflows and Methods

The following steps were conducted in an annotated Python Jupyter Notebook:

1. Loaded csv data files to a DataFrame and ndarray.
2. Checked summary statistics for invalid values, e.g. nulls and negatives.
3. Plotted data distributions and spatial location maps (by-facies and combined).
4. Detected outliers (Tukey method with no distribution assumption)
5. Compared well and map-based seismic data (hypothesis testing)
6. Developed an initial interpretation of reservoir depositional setting and architectural elements.

3 Results

3.1 Data coverage and bias detection

Visual inspection indicates a fair coverage over the interest area, but in the north-east and south-west areas, irregular sampling suggests biased well locations. In addition, the north-west area indicates biased sampling in the best property zone showing a denser sampling in very high permeability regions. There are not clear directional trends and geometries associated with all properties. The outliers may provide a better resolution in some properties due to the broad range in permeability data. Nevertheless, porosity and permeability are directly related, and acoustic impedance and porosity are inversely related.

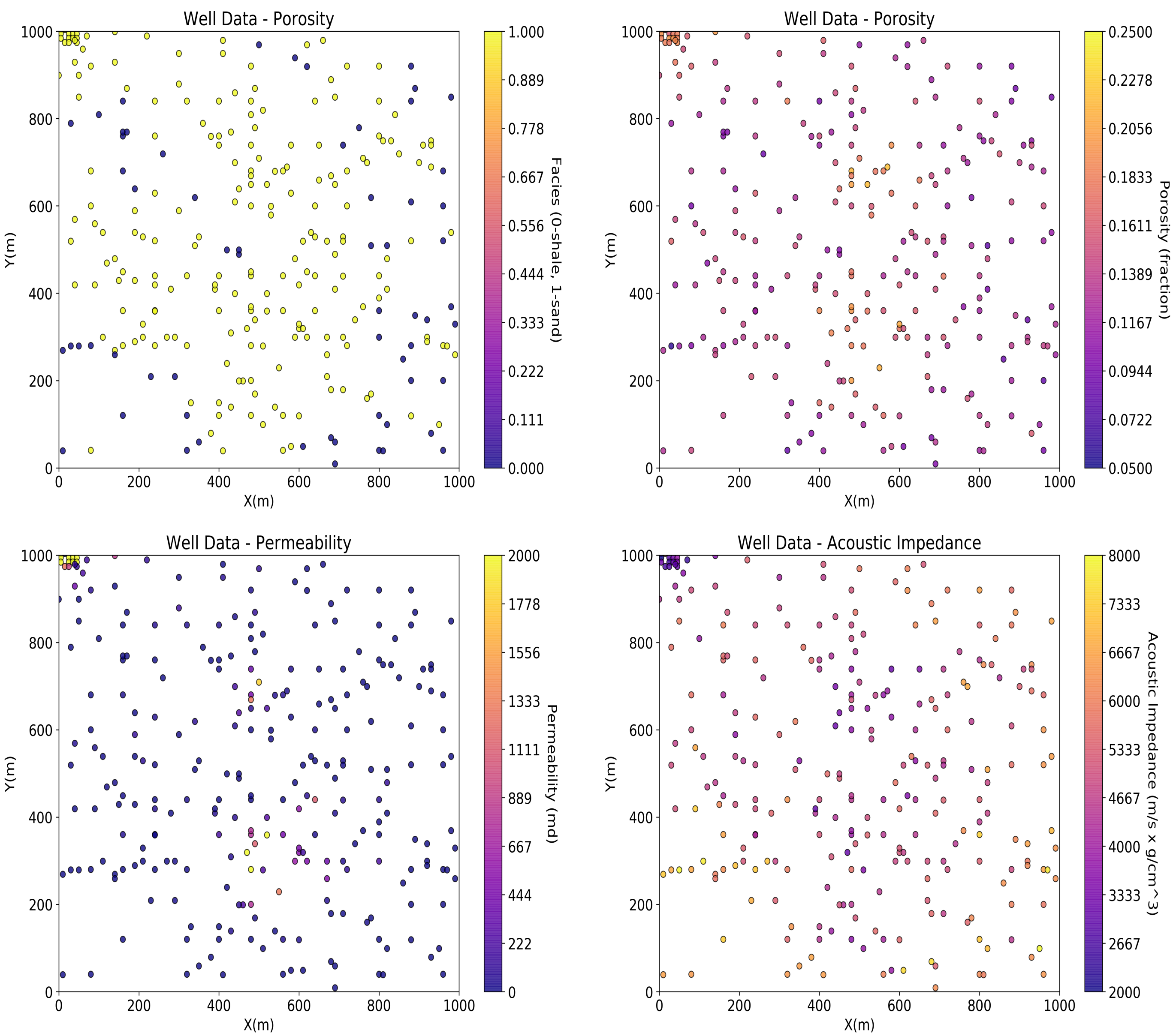

Figure 1: Location maps for facies, porosity, permeability and acoustic impedance at all 271 wells.

3.2 Univariate Analysis

Analyses indicate strong porosity, permeability and acoustic impedance dependence on facies. Facies provide good control on reservoir properties and their spatial distribution. Reservoir properties are key to making informed production estimates. The summary statistics below are based on data with outliers removed and represent 217 of the 271 wells in the data set.

Univariate Distributions

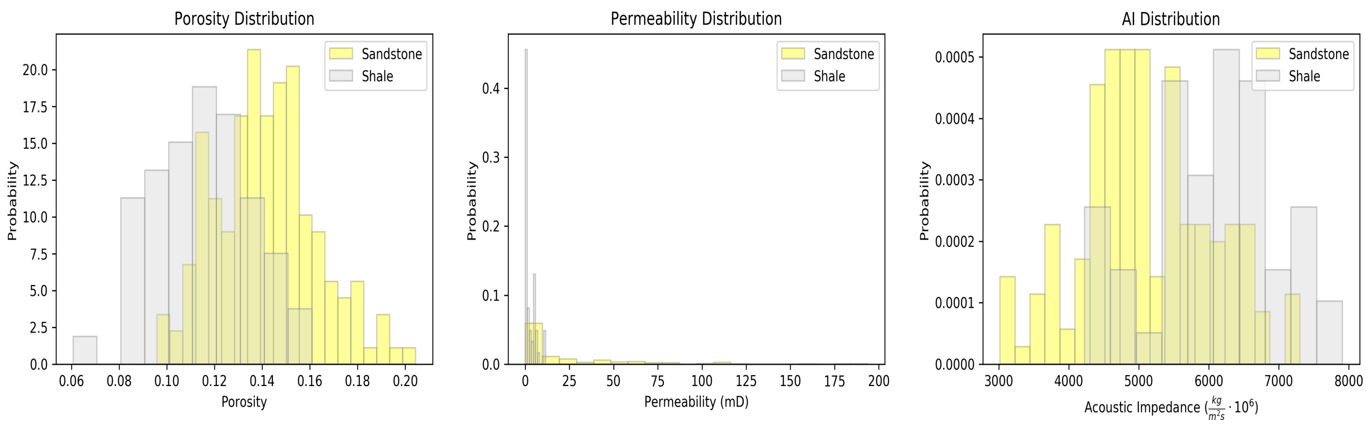

Figure 2: Univariate binned PDFs by facies for porosity, permeability and acoustic impedance.

Summary Statistics - Sandstone

	count	mean	std	min	25%	50%	75%	max
Facies	164.0	1.000000	0.000000	1.000000	1.000000	1.000000	1.000000	1.000000
Porosity	164.0	0.141945	0.021228	0.095861	0.126620	0.141629	0.153456	0.204388
Perm	164.0	23.033024	34.867885	0.051426	2.321887	7.817239	28.539127	193.746824
AI	164.0	5101.614178	933.384251	3017.611167	4510.886339	5005.947121	5733.632011	7305.189368

Summary Statistics - Shale

	count	mean	std	min	25%	50%	75%	max
Facies	53.0	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Porosity	53.0	0.115015	0.020962	0.060693	0.100367	0.114894	0.128914	0.160937
Perm	53.0	2.573466	3.058961	0.018054	0.268076	0.888961	4.979026	11.605383
AI	53.0	6099.268353	886.103245	4227.070196	5574.433666	6174.244316	6684.167663	7911.757046

3.3 Outlier Detection

Using data from the 271 wells, outlier detection was performed based on Tukey's $1.5 \cdot (IQR)$. Outliers were removed based on porosity, permeability and acoustic impedance values. If any property was classified as an outlier, all results from that well were discarded. The results are shown in Figure 3.

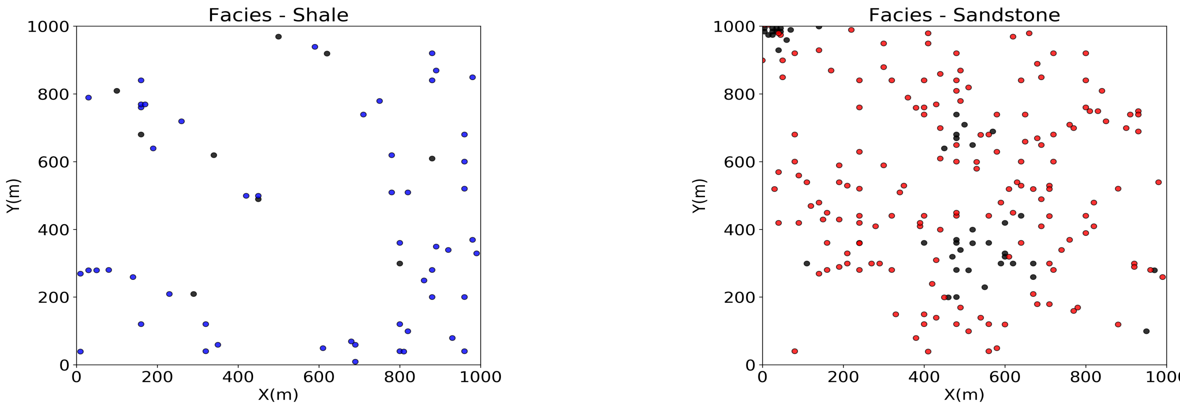

Figure 3: Location map for shale (blue) and sandstone (red) facies. Black dots indicate outliers in the dataset.

From the location maps and data distributions, we observe that the wells flagged as 'outliers' are relatively spatially discontinuous. Many of the outliers are isolated from other regions of the reservoir. The high concentration of outliers in the northwestern corner of the reservoir have permeability values on the order of 10-25 Darcy's. We presume that they are distinctly high due to natural fractures in this region. These outlier locations may be of interest during the remainder of the subsurface study.

3.4 Comparison of Acoustic Impedance over the Map and at the Wells

The discrete PDF and CDF of the acoustic impedance values collected via the seismic and well data are shown in Figure 4. Assuming a null hypothesis, $H_0 : \mu_{\text{Wells}} = \mu_{\text{Acoustic}}$, a two sample t-test, rank-sum test, ANOVA test and Kruskal-Wallace test were performed; all tests reported p-values substantially greater than 0.05 ($\sim$0.18-0.2) suggesting that the null hypothesis could not be refuted.

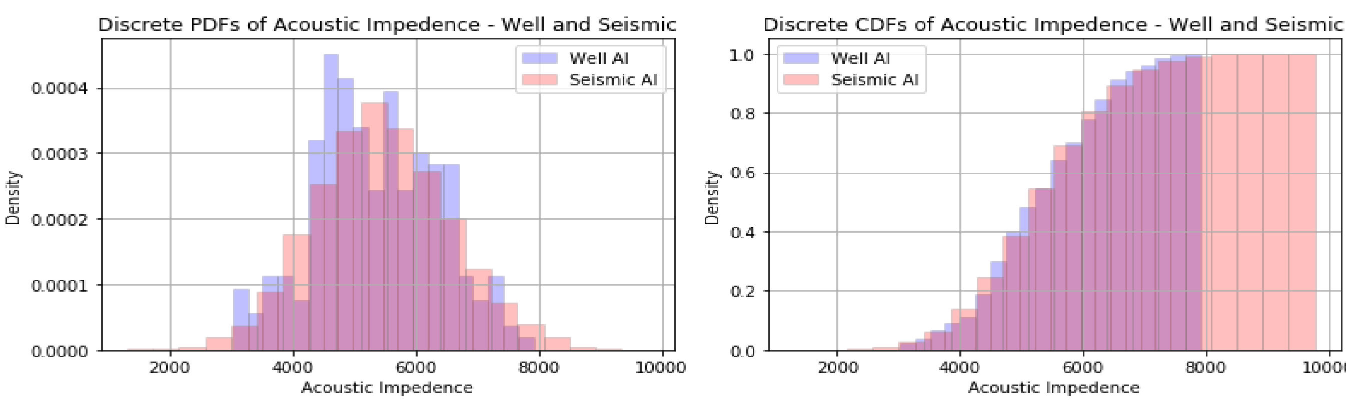

Figure 4: PDF and CDF of Acoustic Impedance from well data (blue) and from seismic data (red)

4 Initial Interpretations

The property distributions and geometries are consistent with a meandering channel interpretation (Figure 5). The channel geometry is less distinct in the acoustic impedance map, which lead to an alternative interpretation of a less-confined system, such as a deltaic or submarine fan environment. The preliminary interpretation attempts to capture the uncertainties of subsurface geological interpretation. To reduce the uncertainty of the interpretation, we recommend conducting a more comprehensive geological analysis, such as regional seismic interpretation of the basin, detailed seismic interpretation on a 3D seismic volume, drill-core description, to inform the environment of deposition and predict reservoir distributions.

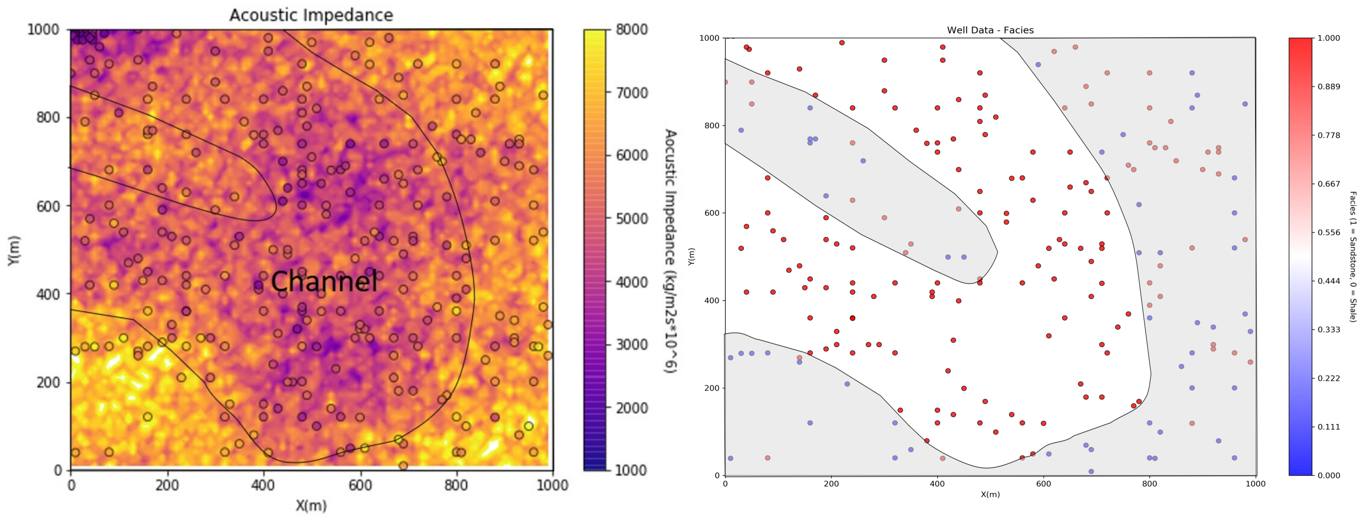

Figure 5: Interpretation of depositional environment from field based acoustic impedance (left) and well-based facies records (right).

5 Conclusions

Conclusions from the initial univariate, spatial investigation include:

1. The sampling of 271 wells shows some bias according to the facies location
2. Outlier analysis account for 54/271 of the data set and reveal 10-25 Darcy reservoir rock at the northwestern corner of the reservoir
3. Directionality and trends should be included in the model
4. Preliminary geological interpretation suggests that the reservoir is sandy channel-fills of a fluvial system
5. Future analyses should include observations from recovered core, namely in search of cross bed features in wells near the interpreted point bar located at (500m,500m)