PGE 383 - Stochastic Methods for Reservoir Modeling - Spring 2019

Project Update #1 – Dataset 12, Univariate, Spatial Data Analysis

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Executive Summary (1 Paragraph, 4 sentences)

The Moose Jaw reservoir subsurface team has just received delivery of 480 wells in a data table with X and Y coordinates (meters), Facies 0 and 1 (1 is sandstone and 0 interbedded sand and mudstone), Porosity (fraction), permeability as Perm (mD) and acoustic impedance as AI (kg/m2s*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 initial subsurface hypotheses.

The work included:

- visualization of data distributions and location maps, including combined and by-facies
- calculation of summary statistics
- outlier detection
- comparison of at-well and mapped acoustic impedance
- initial interpretations of the depositional setting

The data coverage includes the entire area of interest, but there are indications of biased well placement. Also, there appears to be strong directionality in the reservoir property spatial distributions. The property distributions, and geometries are consistent with a weakly confined deepwater channel system. Future modeling work should integrate facies, debiased well-based sample statistics and account for directionality and trends.

Description of Workflows and Methods (1 Paragraph)

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

1. loaded csv data files to Pandas DataFrame and gridded ndarray
2. checked summary statistics for invalid values, e.g. nulls and negatives
3. plotting of data distributions and spatial location maps (by-facies and combined)
4. outlier detection (Tukey 1.5 x IQR method, with no distribution assumption)
5. comparison of well and map-based seismic data (Student's t-test for difference in means, with pool variance)
6. initial interpretation of reservoir depositional setting and architectural elements

Results and Discussion

Location Maps – indicate exhaustive well coverage over the area of interest, without the need for spatial extrapolation, visual inspection indicates well samples may be denser in high porosity regions, there are clear directional trends and geometries associated with all properties. Facies may provide strong control on reservoir properties, and porosity and permeability are directly related, and acoustic impedance and porosity are inversely related.

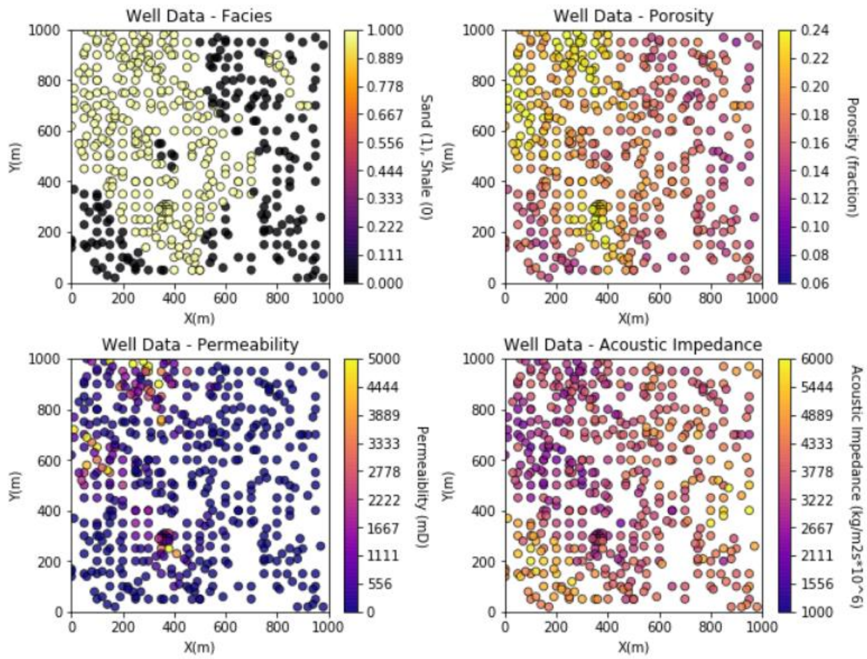

Figure 1 – location maps for facies, porosity, permeability and acoustic impedance at all 480 wells.

Univariate distributions / binned PDFs by Facies – indicate a strong porosity, permeability and acoustic impedance dependence on facies. Summary statistics by facies indicate there are no null values, nor non-physical values.

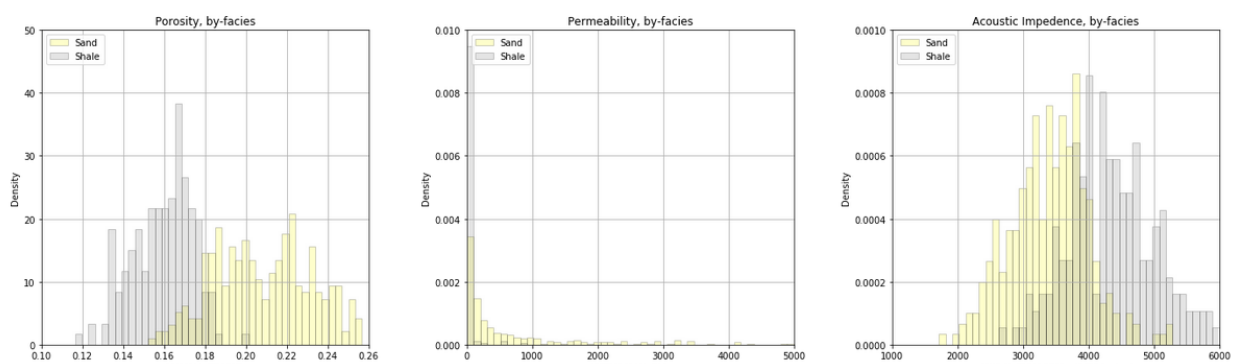

Figure 2 – univariate binned PDFs by-facies for porosity, permeability and acoustic impedance.

	count	mean	std	min	25%	50%	75%	max
X	296.0	334.493243	190.943456	0.000000	200.000000	330.000000	450.000000	920.000000
Y	296.0	578.442568	255.631707	49.000000	356.750000	599.000000	800.000000	999.000000
Facies	296.0	1.000000	0.000000	1.000000	1.000000	1.000000	1.000000	1.000000
Porosity	296.0	0.208288	0.023880	0.152834	0.189499	0.207314	0.225885	0.261091
Perm	296.0	829.621970	1478.987862	0.417761	57.632564	217.892561	842.443423	10319.904850
AI	296.0	3389.696587	594.918055	1746.387548	3002.729163	3413.063944	3797.924538	5257.846464

Figure 3 – summary statistics for sand facies well data.

	count	mean	std	min	25%	50%	75%	max
X	184.0	584.130435	291.176818	0.000000	350.000000	650.000000	810.000000	980.000000
Y	184.0	431.635870	304.709004	19.000000	150.000000	350.000000	714.000000	969.000000
Facies	184.0	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Porosity	184.0	0.159119	0.014573	0.117562	0.148313	0.161547	0.169884	0.198044
Perm	184.0	24.344030	85.961235	0.005776	1.068144	5.620795	15.131359	840.234243
AI	184.0	4352.782848	668.427855	2660.776406	3911.486161	4321.452309	4771.533780	6194.573653

Figure 4 – summary statistics for shale facies well data.

Outlier Detection – outlier detection was performed with the Tukey, 1.5 x interquartile range method over porosity, permeability and acoustic impedance. The results are shown below.

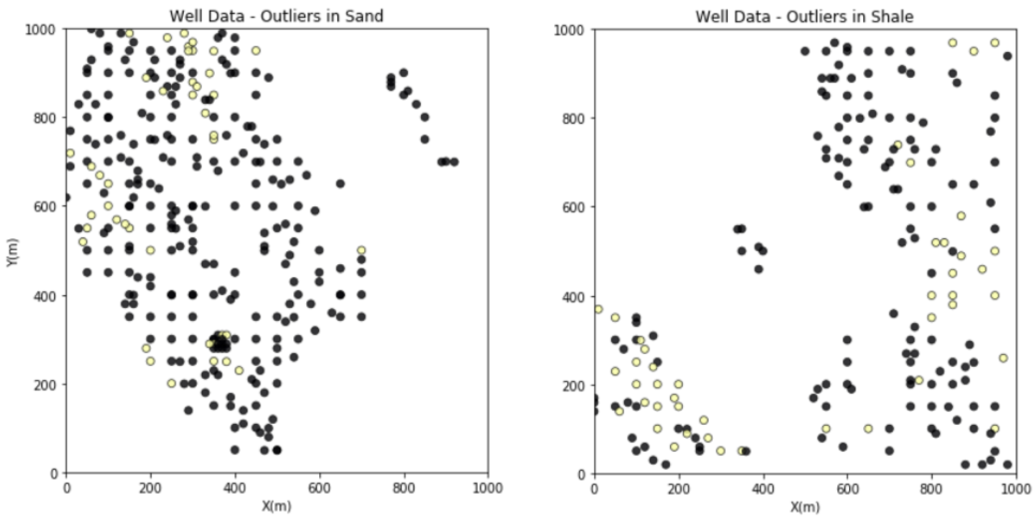

Figure 5 – outlier detection by-facies over porosity, permeability and acoustic impedance. Outliers wells are in yellow.

From the location maps and data distributions we observe that the wells flagged as 'outliers' are not spatially discontinuous nor isolated from the remainder of the PDFs; therefore, they may not be indicative of a data issue. I assess that they are distinctly high acoustic impedance locations deemed outliers by the Tukey method due to the 'fat tails' in the acoustic impedance distributions. These may be considered locations of interest during the remainder of the subsurface study.

Comparison of Acoustic Impedance over the Map and at Wells – the acoustic impedance distributions were compared between the wells and over the entire map. The wells are significantly shifted to lower values suggested preferential well site selection in low acoustic impedance, high porosity regions. A two tailed, pooled Student's t-test for difference in means rejected the null hypothesis that the means are the same at a 95% confidence level. This sampling bias must be addressed with future work.

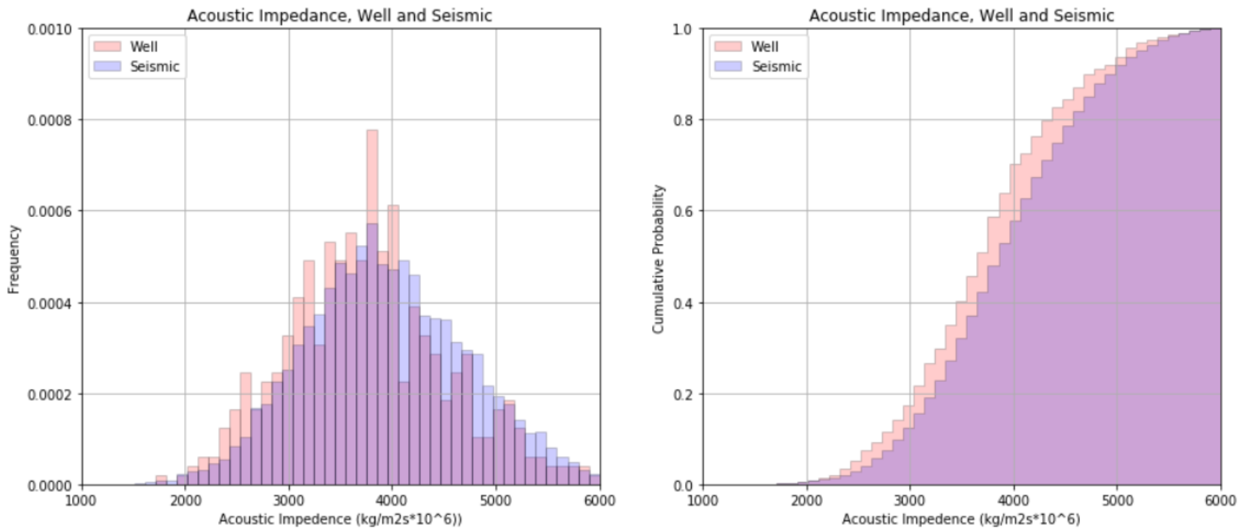

Figure 6 – acoustic impedance distributions at wells and over exhaustive seismic map.

Initial Interpretation – The property distributions, and geometries are consistent with a weakly confined deepwater channel system. This interpretation is quite preliminary at this early stage and there are significant uncertainties to resolve and quantify during the entire subsurface modeling project.

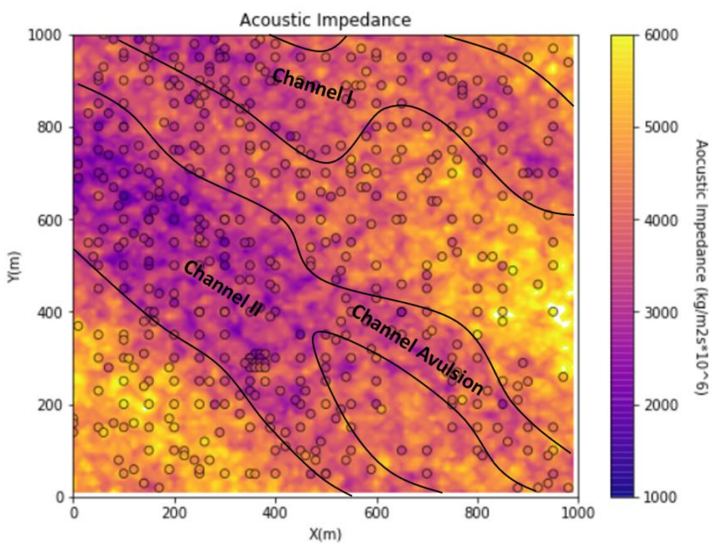

Figure 7 – map of acoustic impedance with well data and initial reservoir interpretation included.

Conclusions

Conclusions from the initial univariate, spatial investigation include:

1. by-facies workflows are required
2. data debiasing should be investigated
3. directionality and trends must be included in the subsurface model
4. the reservoir may be a weakly confined deepwater channel system