

THE APPLICATION OF POISSON IMPEDANCE USING TARGET CORRELATION COEFFICIENT ANALYSIS (TCCA) METHOD FOR LITHOLOGY DISCRIMINATION AND FLUID IDENTIFICATION IN AN OILFIELD, NIGER DELTA

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ABSTRACT

In this study we have shown the use of Poisson Impedance (PI) in the separation of sandstone reservoir from shale where the reservoir sandstone has similar P-, S-impedance contrast. We have adopted the Target Correlation Coefficient Analysis (TCCA) method introduced by Tian, *et al.* (2010) to calculate c . The correlation coefficients between PI curve with different c values versus Gamma ray (GR) curve and Water Saturation (Sw) curve are computed. The c value which gave the maximum correlation coefficient for GR and Sw were used to derive two new attributes namely Lithology impedance (LI) and Fluid Impedance (FI) respectively. The c value for LI is 1.324 at maximum correlation of 0.7580 and that for FI is 1.296 at maximum correlation of 0.6329. These new attributes are used specifically with its sensitivity with the LI, GR crossplot discriminating lithology and the FI, Sw crossplot identifying fluid effect. The derived volumes of the LI and FI from the prestack data have similar trend with their well counterpart hence attesting to PI being a favorable tool in reservoir characterization in the study field.

Keywords: Attributes, crossplot, c value, Poisson Impedance.

INTRODUCTION

The increase in demand for oil and gas has motivated geoscientists to search for new reservoirs. This can only be possible if the lithology and fluids can be differentiated in the reservoir before exploration, development and production can begin. Several attributes exist for a robust discrimination of lithology and fluid content by crossplotting a pair of these attributes. Notable among these attributes is the combination $\lambda\rho$, $\mu\rho$ whose crossplot shows an enhanced separation between gas sand and background shale. On these crossplots, it may be difficult to discriminate the litho-fluid distribution where clusters are not completely separated. But in such cases, rotating the axes to be parallel with the trends would ensure a distinct discrimination of the litho-fluid distribution. (Riesch and Satinder, 2013) This underscores the importance of Poisson Impedance.

The term "Poisson Impedance" (PI) is an attribute that is derived from a combination of the P- and S-impedance values and is a good hydrocarbon indicator (Quakenbush, *et al.*, 2006).

Figure 1 shows a schematic representation of P-impedance versus S-impedance crossplot with shale, brine sand and oil sand distributions. The data clusters are not discriminated along the P-impedance or S-impedance axes alone, but with rotation of the axes (represented by the dotted lines) parallel with the trends, the data clusters in this case can be perfectly discriminated into the various litho-fluid distributions.

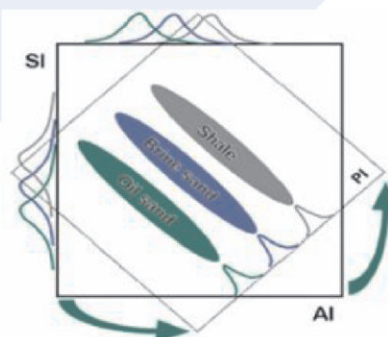


Figure 1: Illustration of Poisson Impedance (Quakenbush *et al.*, 2006)

Mathematically, Poisson Impedance (PI) is given in terms of the P-impedance (AI) and S-impedance (SI)

and can be shown as:

$$PI = AI - c \cdot SI \quad \text{Equation [1]}$$

Where c is the term that optimizes the rotation.

THEORY AND METHODS

We have adopted the Target Correlation Coefficient Analysis (TCCA) method introduced by Tian, *et al* (2010) to calculate c . This process is iterative and requires calculating the correlation coefficients between PI curve with different values of c versus GammaRay (GR) curve and Water Saturation (Sw) curve. The maximum correlation coefficient reached for GR and Sw is then used. Hence, we can derive two attribute of Poisson Impedance namely Lithology Impedance (LI) and Fluid Impedance (FI). Direzza *et al.*, 2012, computed his fluid impedance (FI) using a c value that corresponds to the maximum correlation coefficient for the porosity curve.

Crossplot of LI versus GR is expected to discriminate between sandstone and shale while crossplot of FI versus Sw is expected to identify the Hydrocarbon.

Fluid Replacement Modeling (FRM) will be performed on the logs to validate the strength of the FI log.

Finally, the prestack seismic data will be inverted for the AI and SI volumes from which the PI attributes volumes will be derived, tested and interpreted for a match with that from the logs.

RESULTS

Figure 2 shows the P-impedance versus S-impedance crossplot where the sandstone can not be clearly separated from shale as seen from the almost linear P- and S-Impedance crossplot.

The LI versus GR crossplot (Figures 3a and 3b) show the advantage of LI in distinguishing sandstone from shale as seen from the different clusters. The $LI < 6400$ ft/s*g/cc indicate the cutoff of its separation. The FI versus Sw crossplot show that we can predict the fluid content from its almost linear relationship. The low FI correlates with low water saturation and vice versa (Figures 4a and 4b).

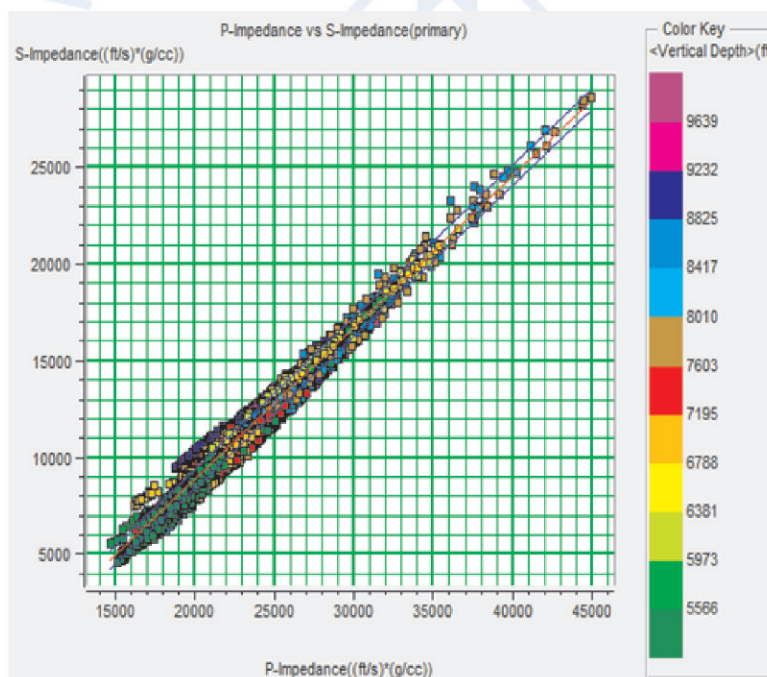


Figure 2: P-impedance vs S-impedance crossplot

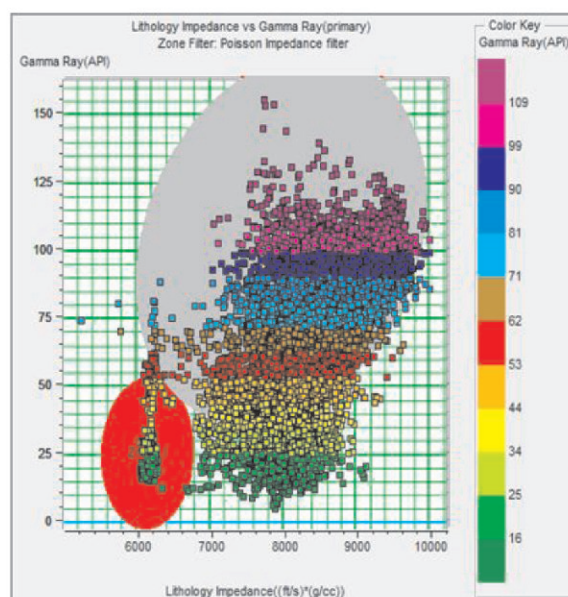


Figure 3a: LI vs GR crossplot

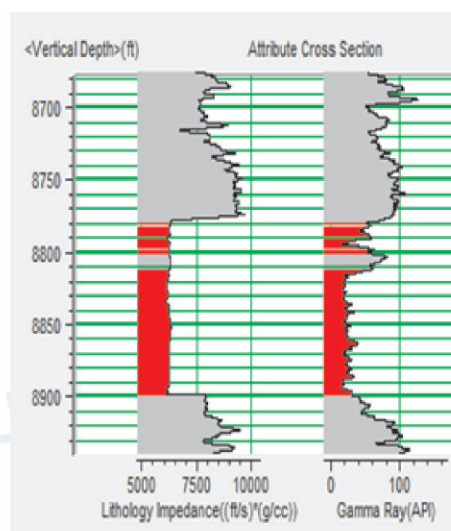


Figure 3b: Depth cross section of LI and GR

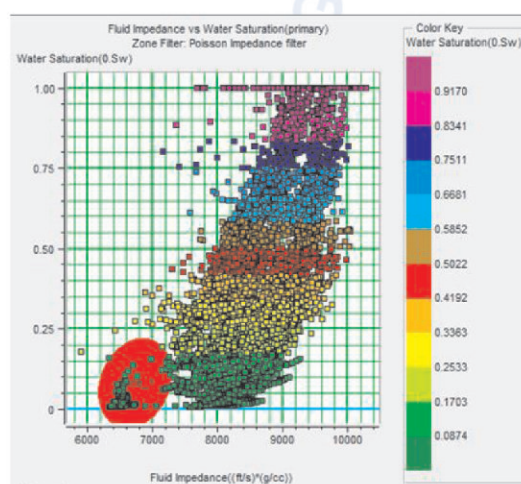


Figure 4a: FI vs Sw crossplot

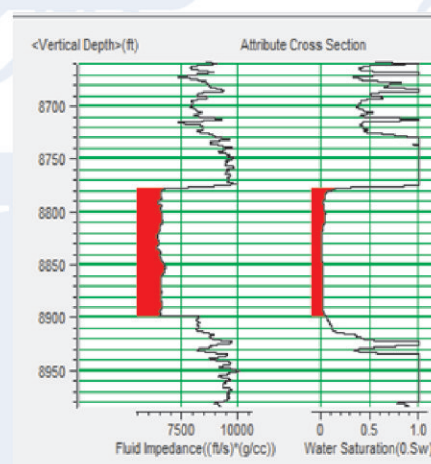


Figure 4b: Depth cross section of FI and Sw

Fluid Replacement Modeling (FRM)

The FRM allows us to derive logs output for different quantities or type of saturation especially compressional sonic (V_p), shear sonic (V_s), and Density (ρ). The Biot-Gassman equations as given by Gregory (1977) is used to convert the actual P-wave log within the mapped reservoir in Well A to fully water saturated (wet). Then, FI-wet is calculated by using the FRM logs; V_p -wet, V_s -wet and ρ -wet as shown in Figure 5.

It can be seen that there is an alteration of the FI-wet log signature as compared to the FI log signature within the mapped zone (track 4). This confirms the FI attribute as a viable tool in identifying fluid content.

Generally, the LI log have similar trend with the GR log (track 5) as well as the FI log with the Sw log (track 6). Qualitatively, the presence of hydrocarbon sandstone reservoir can be represented by both low LI and FI (Figure 5).

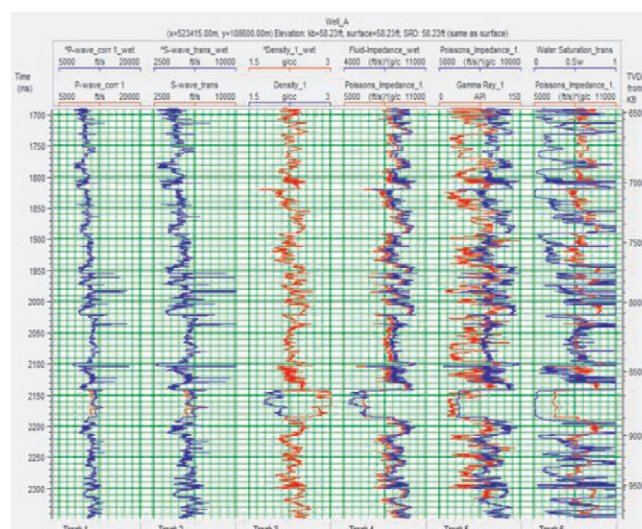


Figure 5: Fluid Replacement Modeling and Poisson Impedance (PI) attributes comparisons at Well A

Poisson Impedance Volume

The P- and S-Impedance volume which were gotten through inversion were used as input parameters to derive LI and FI. The LI volume (Figure 6) shows striking low values on the mapped time window that corresponds to the depth on the well likewise the FI volume (Figure 7). This output Poisson Impedance attributes with the low blue values indicates the hydrocarbon sand zone. This was further validated on an amplitude slice on both attributes volumes where the wells correspond to both low LI and FI values (Figures 8 and 9).

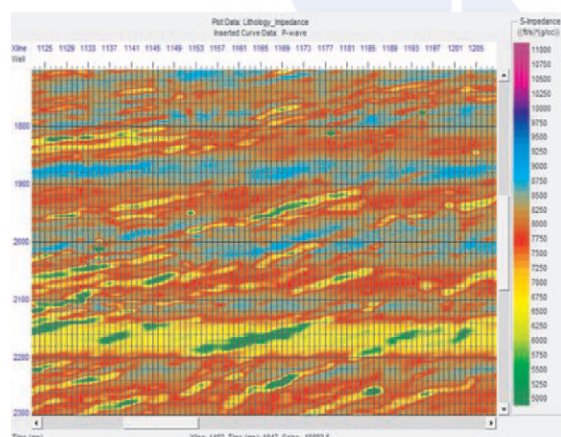


Figure 6: Lithology impedance volume with low values indicating sandstone

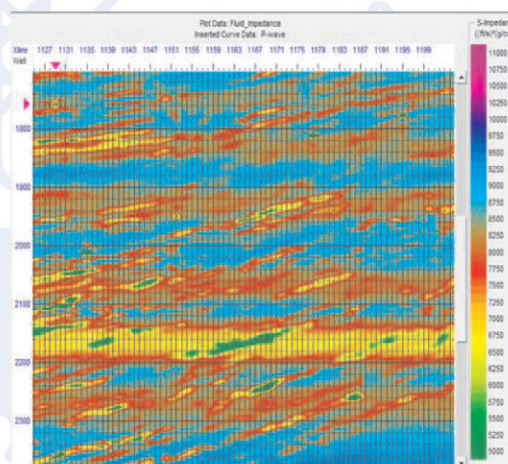


Figure 7: Fluid impedance volume with low values indicating hydrocarbon

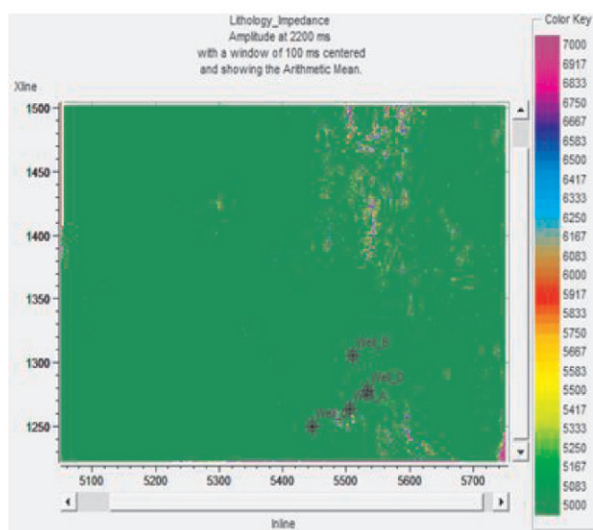


Figure 8: Amplitude sliced Lithology Impedance (LI) map

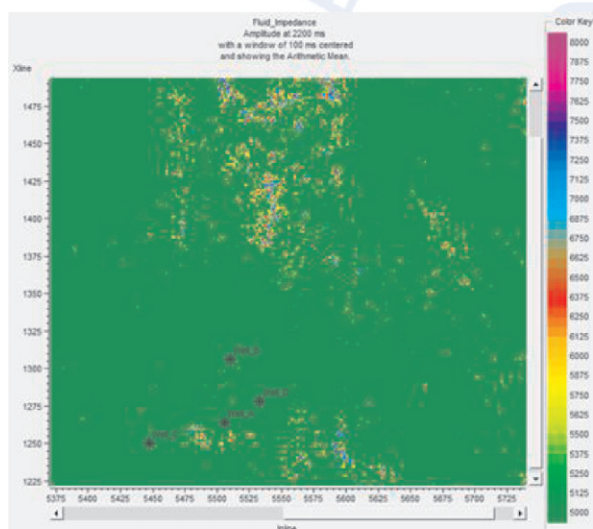


Figure 9: Amplitude sliced Fluid Impedance (FI) map.

CONCLUSION

This study has confirmed the TCCA method viability in deriving two attributes of Poissons Impedance (PI) within the study area which are Lithology Impedance (LI) and Fluid Impedance (FI). The results of the log curve show that the LI can well discriminate sandstone and shale while, FI provide a potential fluid content identification. These results are consistent with the FI and LI volumes gotten from the prestack seismic data which gives better visualization and provides good interpretation for our reservoir.

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APPENDIX

SUMMARY OUTPUT					
Regression Statistics					
Multiple R	0.758024				
R Square	0.574601				
Adjusted R Square	0.57453				
Standard Error	0.200784				
Observations	6062				
ANOVA					
	df	SS	MS	F	Significance F
Regression	1	329.9886	329.9886	8185.437	0
Residual	6060	244.3035	0.040314		
Total	6061	574.2921			

Figure 10: Correlation analysis report for c value of 1.324

SUMMARY OUTPUT					
Regression Statistics					
Multiple R	0.632944				
R Square	0.400618				
Adjusted R Square	0.400519				
Standard Error	21.70779				
Observations	6062				
ANOVA					
	df	SS	MS	F	Significance F
Regression	1	1908666	1908666	4050.408	0
Residual	6060	2855643	471.2281		
Total	6061	4764309			

Figure 11: Correlation analysis report for c value of 1.296