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Application of Poisson Impedance to Improve Reservoir Characterization, Sienna Field, West Delta Deep Marine Concession, Egypt.

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ABSTRACT

Many seismic interpretation techniques for reservoir characterization are depended on acoustic and shear impedances but in some cases the results of these impedances are not satisfied. Poisson impedance (PI) could be an effective attribute to solve the problems of lower contrast between sand and shale.

In this study, Poisson impedance attribute is calculated based on acoustic and shear impedances crossplot. The calculated Poisson impedance logs are matched very well with shale volume log in the correlation chart between them. Then Poisson impedance volume is generated by using EEI inversion technique.

Analysis the inverted Poisson impedance cross sections and extraction the amplitude maps represents the variation of reservoir sand and shale within the sienna channel that indicate PI is very promising attribute for sandstone reservoir characterization.

Keywords: Poisson impedance, Reservoir characterization, Sienna Field

INTRODUCTION

Discrimination between fluid and lithology is a vital step in reservoir characterization which is used to map hydrocarbon distribution. Reservoir characterization is a challenge to describe the physical properties of rock (lithology) and fluid content of reservoir by integrating the geophysical and petrophysical data. Lithology associated with the rock types are sandstone or carbonate contained in hydrocarbon reservoirs. While, the fluid content which will provide an overview of the reservoir fluid may be water, gas or oil. Many seismic interpretation techniques are used for this purpose as conventional seismic attributes, post and prestack seismic inversion. The success of these methods for reservoir characterization depends on using the suitable attribute or parameter that gives a good discrimination image between lithology and fluids.

One of the major problems found in the delta areas is low impedance contrast between the shale-sand units where shale layer surrounded the sand reservoir besides, especially if the reservoir is not clean sand. In these situations certain troubles occurs to characterize sand and shale layer.

The very important parameters to differentiate characteristic of fluid contained in medium is poisson's ratio. Poisson's ratio (σ) is expressed as a function of P wave velocity (Vp) and S wave velocity (Vs). Low value of the density and Poisson's ratio on a sand stone reservoir usually indicated there is an anomaly (hydrocarbon). So both of this parameter could combined into single attribute namely Poisson impedance attribute. This Attribute is one of physical parameters of rock that can be applied in practice to predict a reservoir and detect the existence of hydrocarbon. Poisson impedance is a solution to answer the difficulty in separate lithology and fluid distribution on the x and y coordinate on cross plot between Acoustic impedance (AI) and Shear impedance (SI) (Quakenbush et al, 2006).

Many researches used Poisson impedance as a seismic attribute to discriminate between different facies in the hydrocarbon reservoirs as (Prakash et. al, 2012; Direzza and Permana, 2012; Sharma and Chopra, 2013; Prasetyo et. al, 2017; Lantu et. al, 2017; Hutahaean et. al, 2018).

The main objective of this paper is to show at what extent Poisson impedance can enable to discriminate between sand and shale within the channel interval that in turn could be useful to better understanding and definition of hydrocarbon reservoir.

GEOLOGIC SETTING

The area of study is Sienna gas Field which is located in the eastern portion of the West Delta Deep Marine (WDDM) concession, approximately 120 km North-East of Alexandria, Egypt. It found between latitudes 32° 08' 47" N, 32° 21' 46" N and longitudes 30° 50' 46" E, 30° 57' 46" E (Figure 1).

Sienna channel is believed to be a slope channel complex deposited on the Nile delta slope in the Late- Pliocene within Kafr El Sheikh Formation. It consists of 123 m thick of thin shale, interbedded with siltstones, clay stones, and thick coarse sandstone beds. Sienna channel system is broadly oriented north-south and it pinches out at both eastern and western channels margins. The seal is the Kafr El Sheikh Formation claystone of the Late Pliocene age (Sharaf, et. al, 2014).

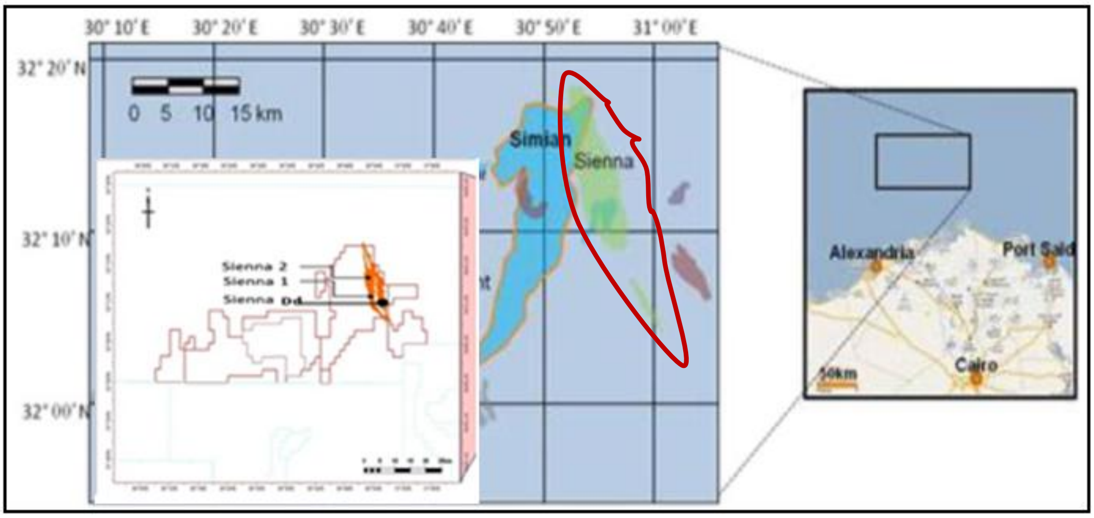

Figure (1): Location Map of WDDM concession with focusing on the study area (Sienna channel field, specified by red circle).

MATERIALS AND METHOD

Available dataset used for this study include the pre-stack time migrated seismic volumes and three wells (Sienna-1, Sienna-2, and Sienna Dd). The data were quality-checked (QC) and prepared for seismic inversion process, before loading them into the petrel software. Log data available for calculation of Poisson impedance and the inversion workflow are P-wave sonic, S-wave sonic, density logs. Beside that petrophysical logs (shale volume and resistivitylogs) are available for comparison for the three wells.

Basics of Poisson Impedance

Poisson Impedance, PI was introduced by Quackenbush et. al, (2006) as a rotation of the cross plot of acoustic impedance (AI) versus shear impedance (SI). Mathematically, this relation is called Poisson impedance and can be demonstrated as PI =AI – (C) SI, where “C” is rotation parameter of impedances data or inverse of cross plot trending lithology and fluid. The idea of PI calculation is illustrated in the Figure (2). Also, it is defined as an attribute that joins both Poisson's ratio and density information into a single attribute. This attribute optimizes desired separation for different litho-fluid types by choosing an axis of rotation in acoustic impedance versus shear impedance cross-plot space. The constant term "C" optimizes the rotation. As shown in Figure (2) data clouds are not discriminated along the AI or SI axes alone but with a rotation of the axis represented by the dotted line, the data clouds in this case can be perfectly discriminated. This rotation can be achieved by computing Poisson Impedance.

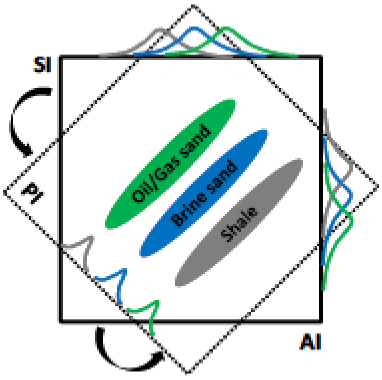

Figure (2): Illustration of Poisson Impedance (after Quakenbush et al., 2006).

In this paper, Poisson impedance is calculated and then used as discrimination attribute between lithology (sand and shale within the channel) depending on extended elastic impedance (EEI) inversion technique.

Calculation of Poisson Impedance

Firstly, acoustic impedance AI (the product of density and compressional wave velocity) and shear impedance SI (the product of density and shear wave velocity) are calculated by using the density, the compressional transit time and the shear transit time logs for the three wells in the Sienna channel interval. Then cross plot between AI and SI is constructed (Figure 3). PI is defined by simple equation as PI =AI – C SI. The “C” term derived from the regression line of the cross-plot of the AI and SI logs for the wet trend. The inverse of the slope (equal 0.713047) is used as the "C" value (equal 1.4). By calculating the rotation parameter "c” of impedances data, Poisson impedance log are constructed for the three wells in the study area.

The behavior of the Poisson impedance attribute within the channel interval is studied depending on the correlation between it and shale volume within the channel interval for the three wells in the study area (Figure 4). The correlation exhibits a good matching (the same manner of variation) between the Poisson impedance logs and the shale volume logs. The Poisson impedance has high value in shale zone while in the sand zone its value is low so the Poisson impedance can be used as discrimination attribute between sand and shale.

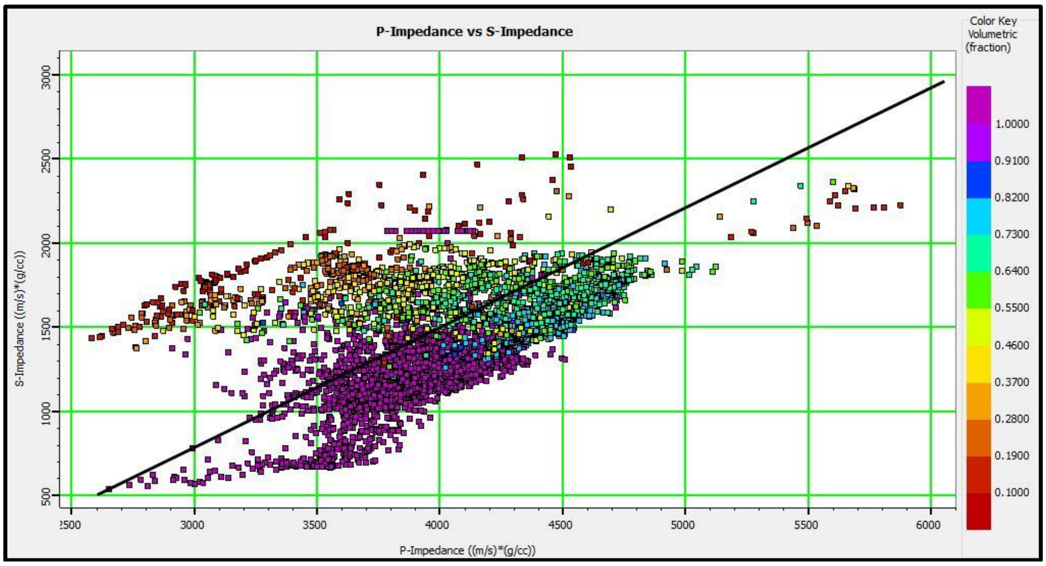

Figure (3): Crossplot between Acoustic impedance AI and Shear impedance SI.

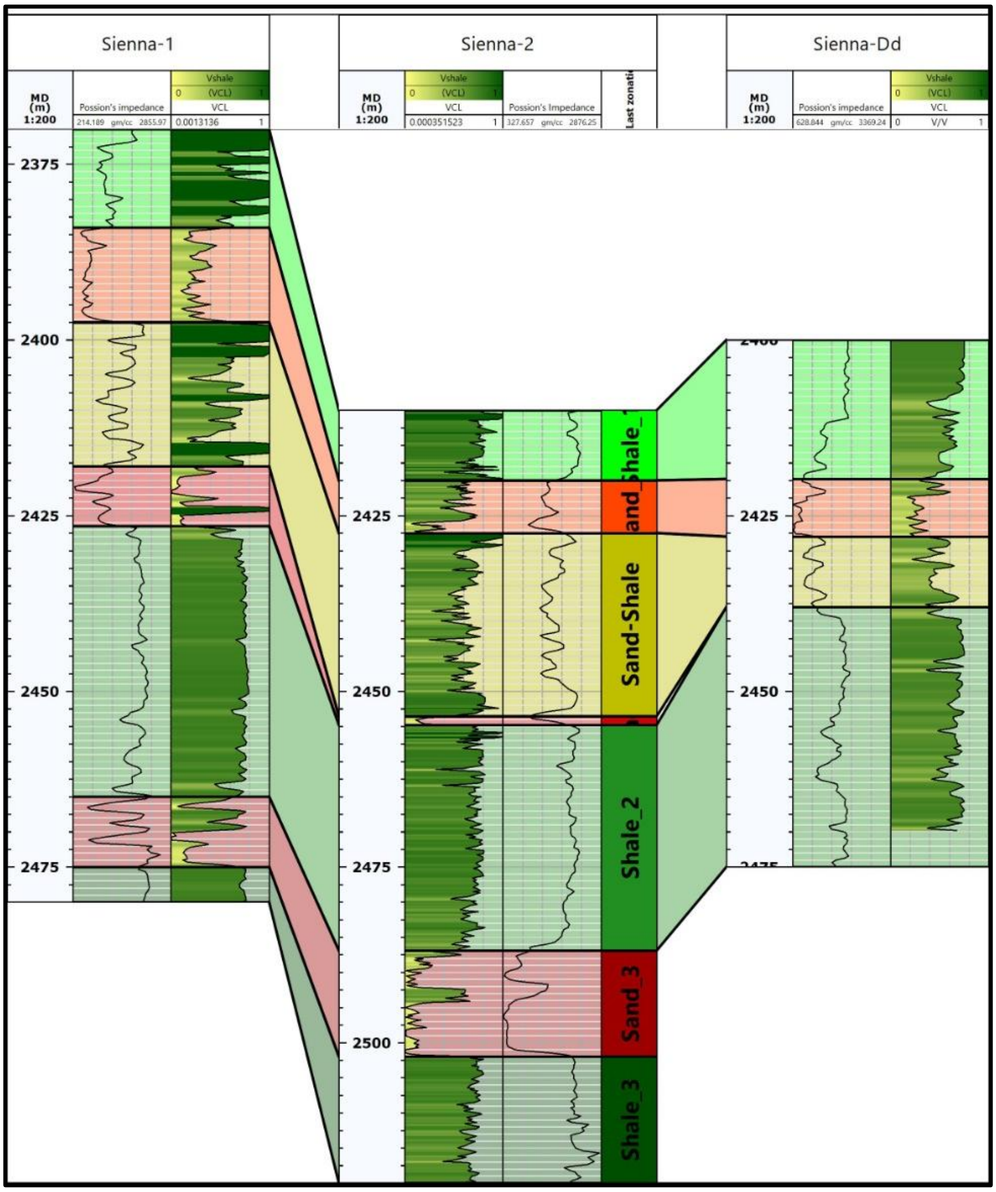

Figure (4): Correlation between Poisson impedance and shale volume for the three wells.

Extended Elastic Impedance (Generation of Poisson impedance volume)

In this paper, the seismic volume of Poisson impedance is derived to characterize the sienna channel reservoir and enhance fluid and lithology imaging based on extended elastic impedance (EEI) inversion technique (Whitcombe et. al, 2002; Arsalan and Yadav, 2009).

Extended elastic impedance provides a framework to work with pre-stack AVO but in terms of impedance instead of reflectivity. For the EEI analysis, EEI logs are generated for each well as a function of angle χ and correlated with the target logs. For each target log, cross-correlation of EEI logs at different angle is computed and a plot is then made for the correlation coefficient as a function of angle. EEI can be defined as

$$\mathrm{EEI}(\chi) = \alpha_{\circ}\mathrm{p}_{\circ}\left[\left(\frac{\alpha}{\alpha_{\circ}}\right)^{\mathrm{p}} * \left(\frac{\beta}{\beta_{\circ}}\right)^{\mathrm{q}} * \left(\frac{\rho}{\rho_{\circ}}\right)^{\mathrm{r}}\right] \quad (1)$$

where α = P-wave velocity, ρ = density, β = S-wave velocity, p = cos χ + sin χ, q = -8K sin χ, and r = cos χ -4K sin χ. α0, β0, and ρ0 are the average of the respective property used as normalization factors for P velocity, S velocity, and density, respectively. K is the average of $(VS/VP)^2$.

EEI Workflow

The EEI inversion is run based on a model-based algorithm with time intervals of 2600 msec and 3100 msec, three wells with sonic (P-wave velocity log, and S-wave velocity log), density logs and interpreted seismic horizons (top and base of the channel) as the major input data. Then EEI analysis for the χ angle is performed to determine the best application angle for reservoir target parameter. Detailed required steps are introduced as follow:

Step 1: Generate Intercept and Gradient data

Intercept (A) and gradient (B) volumes are generated from a linear regression of the amplitudes across near-mid-far stacks.

Step 2: Obtaining the best implementation angle for reservoir target parameter (PI)

The EEI log for different χ angles is computed using equation (1). The optimum angles are estimated based on the best correlation (positive or negative) between the EEI and the target parameter (Poisson impedance). The targeted EEI reflectivities for the selected optimum χ angles were separately generated using a combination of the calculated intercept and gradient stack volumes through AVO analysis. Figure (5) shows the maximum correlation at angle equal 44^o (average value for the three wells).

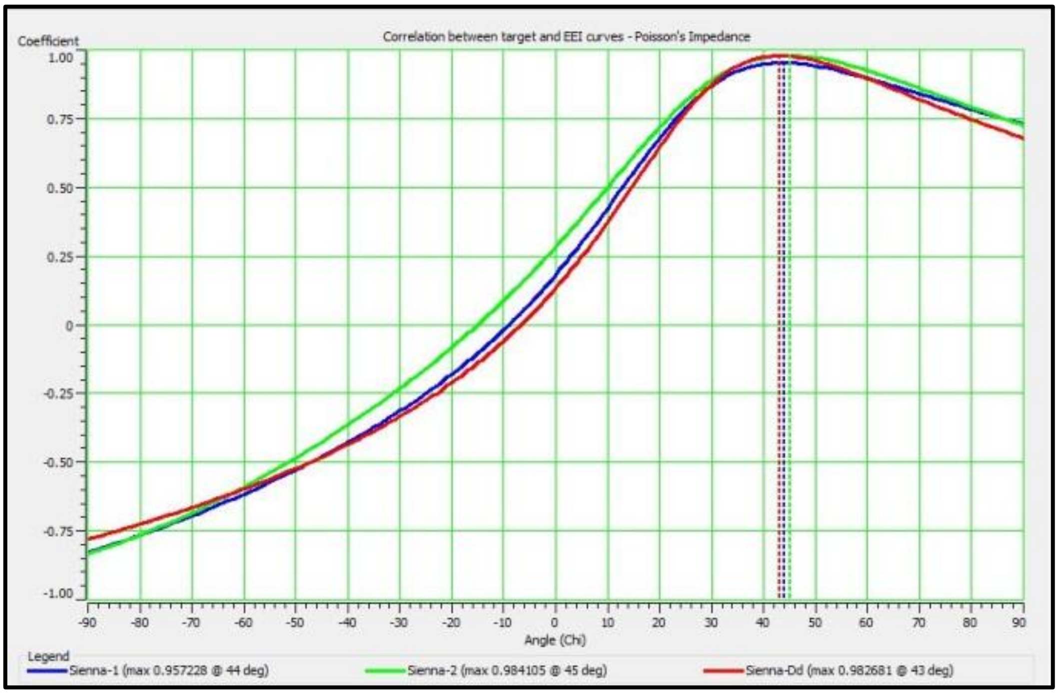

Figure (5): Crossplot represents the maximum correlation coefficient angle for the Poisson impedance at three wells.

Step 3: Generate reflectivity of extended elastic impedance (REEI) for target parameter

The equivalent EEI volume (REEI) was computed through equation (1) for Poisson impedance by using the implementation angle (44^o) to transform such EEI volume into quantitative target parameter (Poisson impedance volume).

Step 4: Build initial model of the target property

The construction of a low-frequency model is one important step for seismic inversion of REEI to remove the wavelet effect on seismic data. The initial EEI model was made using the low-frequency component of 10 to 15 HZ, the P-wave, S-wave, density and EEI target logs and interpreted seismic horizons (top and base of the channel) with the application of a modeling algorithm; inverse distance weighting..

Step 5: post-stack model-based inversion

Finally, optimal wavelet parameters of the post-stack inversion were selected through parameter testing, before actual inversion application. After finalizing inversion parameters through extensive testing, the derived parameters were applied for the related EEI reflectivity volume to run the inversion algorithm to generate the target EEI volume. The post-stack model-based inversion was iteratively updated, and the calculated seismic data was compared with the real seismic data and the misfit was computed to minimize.

Results

Using the optimum inversion parameters, the Poisson impedance volume is generated. The volume has been checked at well locations and it shows a very good match and also away from the well it exhibits a very reasonable geological shape. Figures (6 and7) illustrate the lithology variations, on the green-yellow color scale; a low PI value indicates the presence sand reservoir at the interest zone is confirmed by high resistivity and low shale value. The blue-purple color scale shows the shale lithology. While, sandy shale may be represented by intermediate PI value (red color scale).

Lateral distribution of these different facies is illustrated by extraction of maximum negative amplitude maps from the Poisson impedance volume (Figures 8 through 12) through the interested zone (Senna channel).

Figure (8), maximum negative amplitude map at 2880 msec with a window of 20 msec, shows the lateral distribution of sand; minimum Poisson impedance value (green color), then red and yellow color represent the sandy shale, while blue and purple represent the shale. By increasing the time window from 20 to 40 msec, the same manner of variation is shown but with slight disappears of the extension sand area (Figure 9). With increasing the time window (Figures 10 and 11), it is noticed that the presence of sand disappears totally on these maps.

CONCLUSIONS

Discrimination between sand reservoir and shale and delineate their extension within the channels is the primary objective for any reservoir characterization techniques. Also, the selection of the optimum parameter for the discrimination is very vital.

In this study Poisson impedance attribute is calculated based on acoustic and shear impedances crossplot for three wells penetrated Sienna channel complex. The calculated Poisson impedance logs are matched very well with shale volume logs in the correlation chart between them. Then Poisson impedance volume is generated by using EEI inversion technique. Low values of Poisson impedance reflect sand while the high values reflect shale and the intermediate values indicate sandy shale zones.

Analysis inverted cross sections and the amplitude maps of Poisson impedance reveal the variation between reservoir sand and shale within the sienna channel and display their lateral extension that confirmed well with resistivity and shale volume.

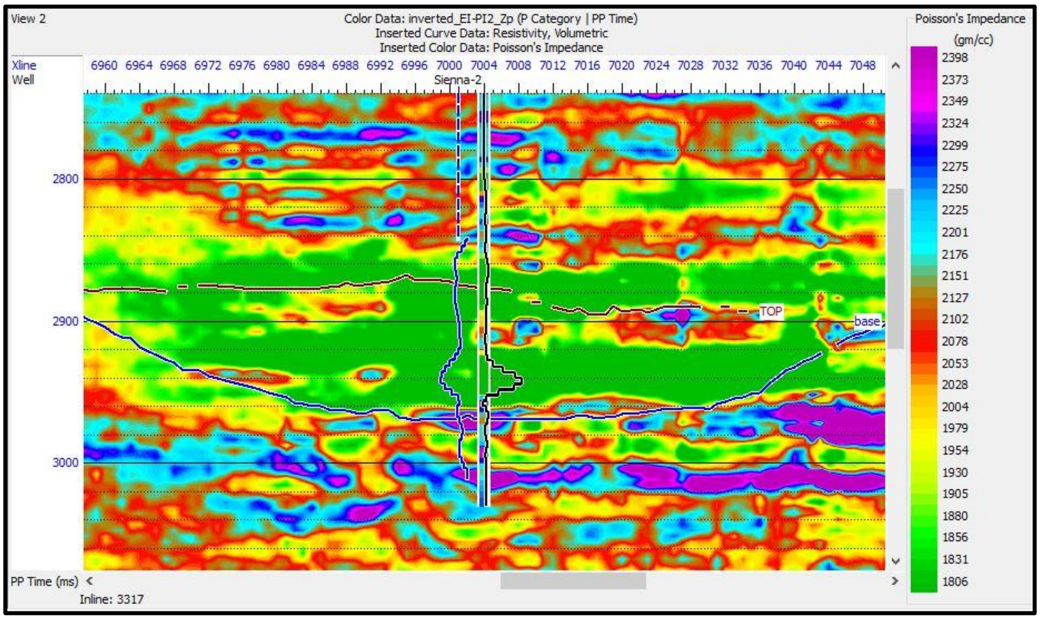

Figure (6): Inverted Poisson impedance section at Sennia-2 well location (Black log is resistivity and blue log is shale volume).

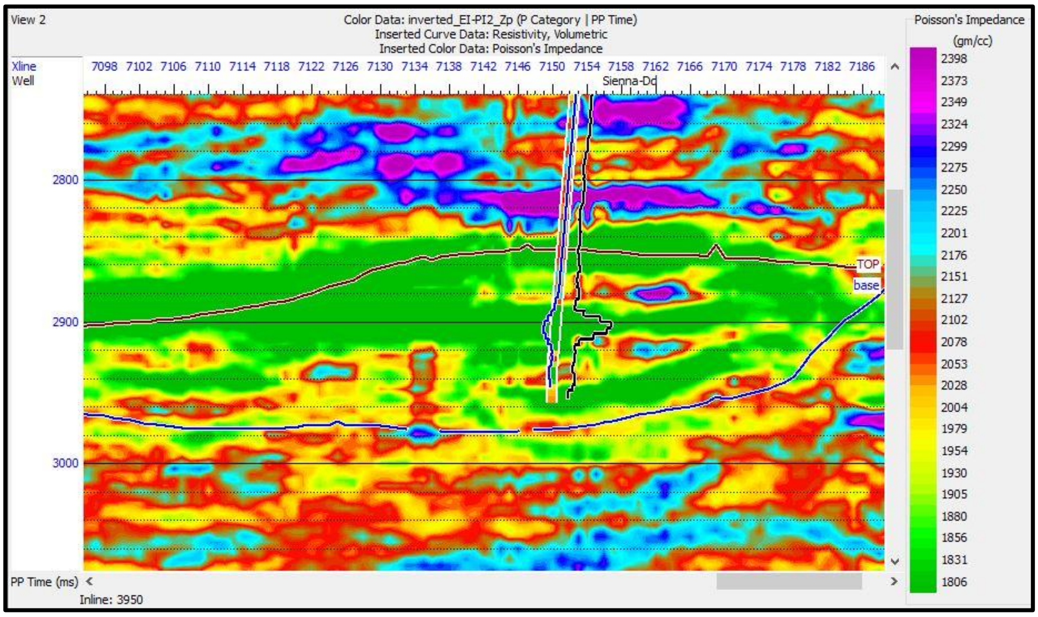

Figure (7): Inverted Poisson impedance section at Sennia-Dd well (Black log is resistivity and blue log is shale volume).

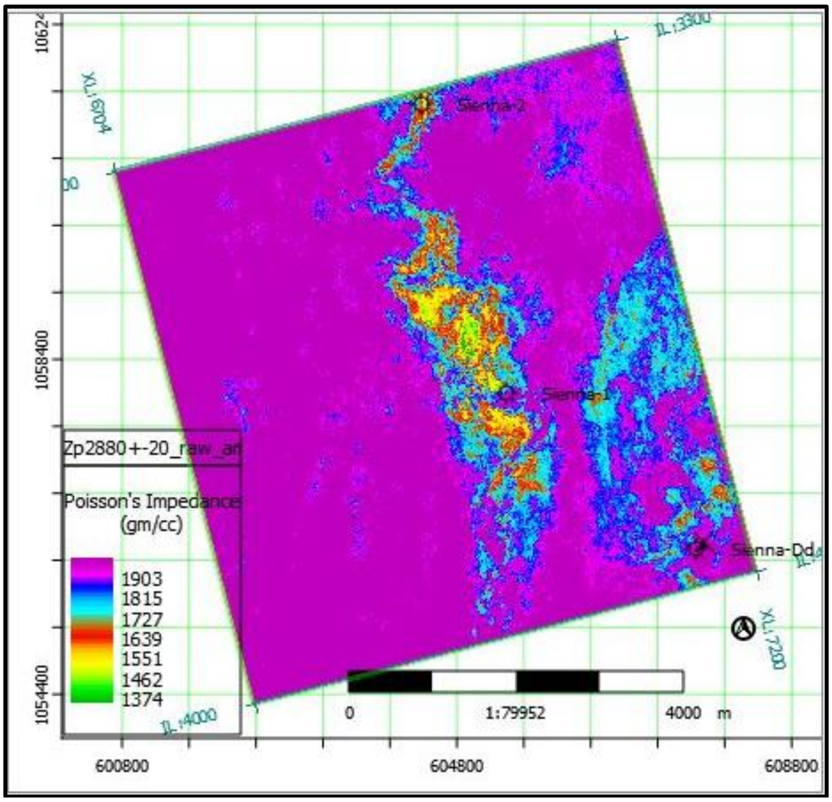

Figure (8): Maximum negative amplitude extracted map from the Poisson impedance volume at 2880 msec with a window of 20 msec (chi angle=44◦).

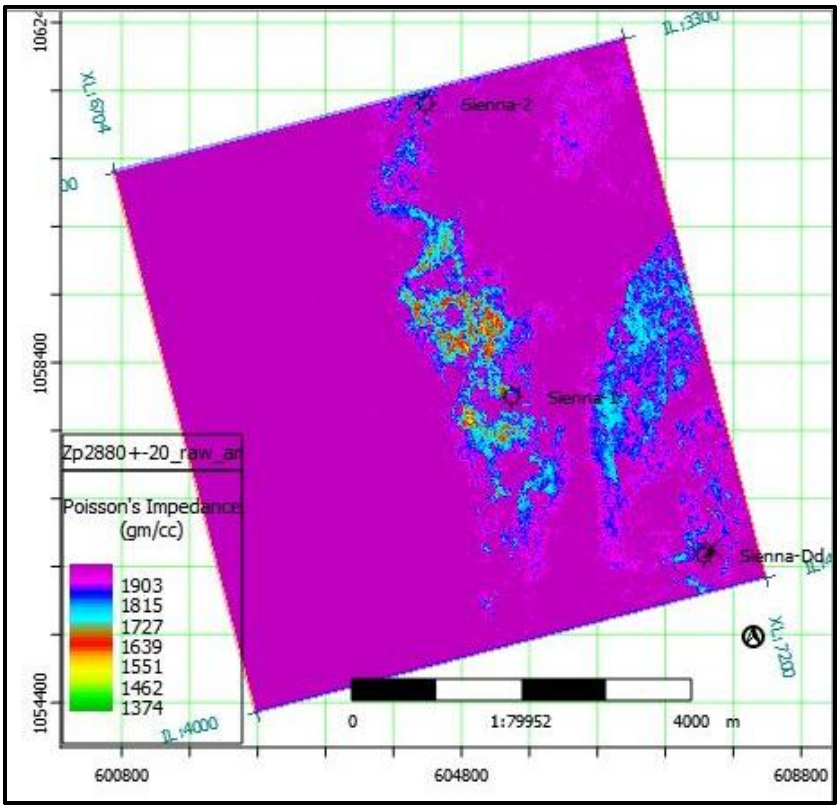

Figure (9): Maximum negative amplitude extracted map from the Poisson impedance volume at 2880 msec with a window of 40 msec (chi angle=44◦).

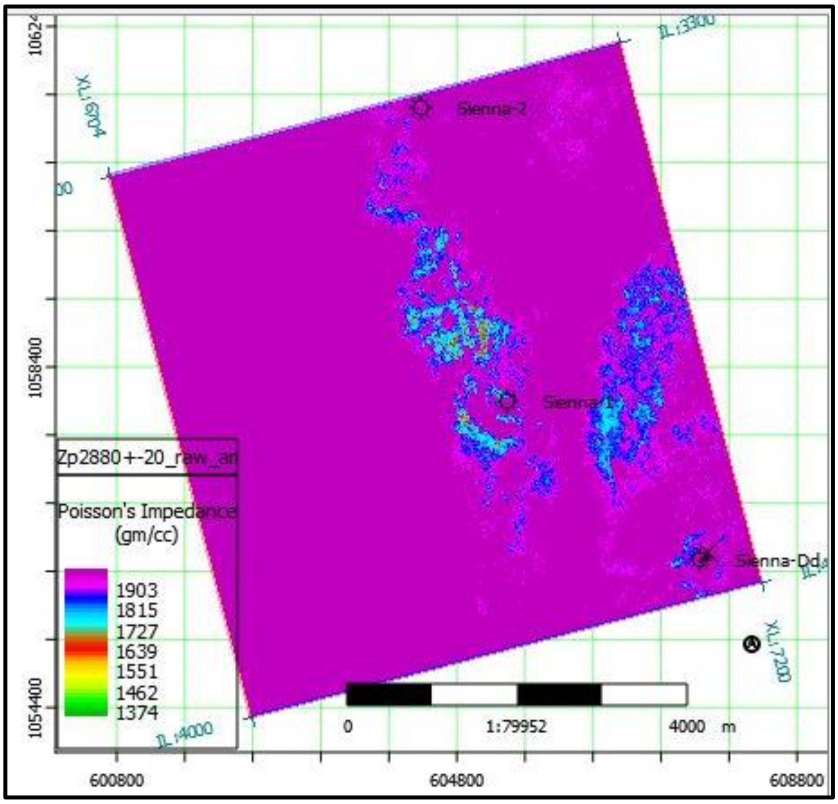

Figure (10): Maximum negative amplitude extracted map from the Poisson impedance volume at 2880 msec with a window of 60 msec (chi angle=44◦).

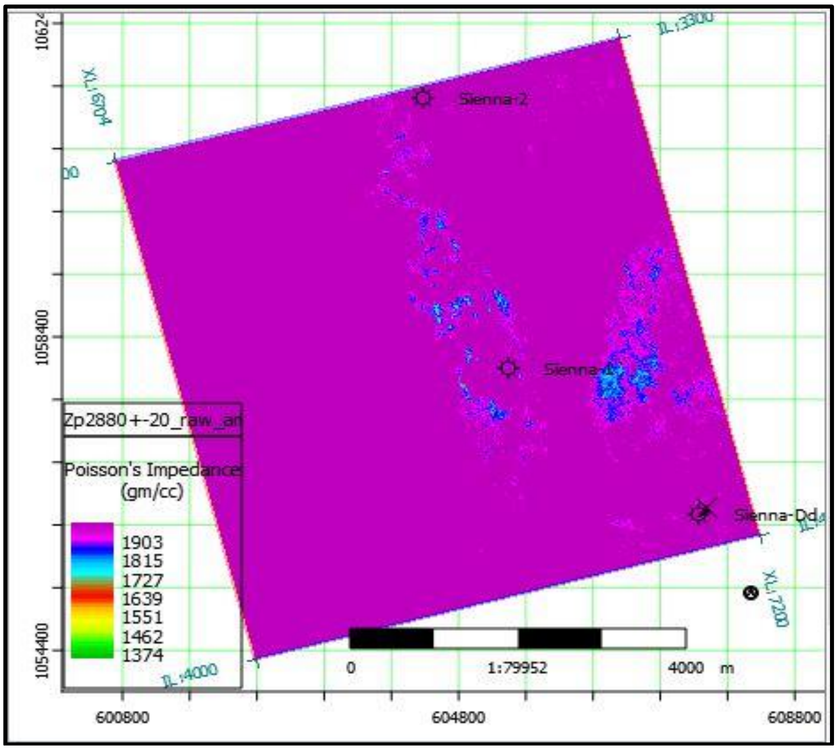

Figure (11): Maximum negative amplitude extracted map from the Poisson impedance volume at 2880 msec with a window of 80 msec (chi angle=44◦).

REFERENCE

Arsalan S., YadavA. (2009): Application of extended elastic impedance: A case study from Krishna-Godavari Basin, India.

Direzza1 A. and Permana K. (2012): The Application of Poisson Impedance Inversion for Sandstone Reservoir Characterization in the Lower Talang Akar Formation, Case Study Melandong-West Java. AAPG International Convention and Exhibition.

Hutahaean R., Rosid M., Guntoro J and Ajie H. (2018): Poisson Impedance Analysis to Identify Sweet Spot Shale, Gas Reservoir in Field "X". AIP Conference Proceedings

Lantu, Sabrianto and Wahidah (2017): Attribute Model For Poisson Impedance (PI) Using Inversion Simultaneous AVO to Estimation of the Spreading Gas at Wa Basin South Sumatra. ARPN Journal of Engineering and Applied Sciences, 12, No. 22, 6407-6413.

Prakash P, Singh S, Chetia B , Chaudhuri P. , Mohan S and Das, S (2012): Application of Advanced Tools for Reservoir Characterization - EEI and Poisson's Impedance : A Case Study. GEOHORIZONS

Prasetyo B., Rosid M., TriviantyJ. and Purba H. (2017): Implementation of Poisson Impedance Inversion to Characterize Hydrocarbon Reservoirs at Field "B", South Sumatra. Proceedings, Indonesian Petroleum Association. 41 Annual Convention & Exhibition.

Quakenbush, M., Shang B., and Tuttle C. (2006): Poisson impedance: The Leading Edge, 25, 128–138.

Sharaf, E., Korrat, I., Seisa, H. and Esmaiel, E., 2014: Seismic Imaging and Reservoir Architecture of Sub-Marine Channel Systems Offshore West Nile Delta of Egypt. Open Journal of Geology, 4, 718-737.

Sharma R. and Chopra S. (2013): Poisson impedance inversion for characterization of sandstone reservoirs, SEG Technical Program Expanded Abstracts, 2549–2553.

Whitcombe, D. N., Connoly, P., Reagan, P. L., and Redshaw, T. C., (2002): Extended elastic impedance for fluid and lithology prediction, Geophysics, 67, 63-67.