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RESEARCH ARTICLE

Cross plot Analysis of Rock Properties from Well Log Data for gas detection in Soku Field, Coastal Swamp Depobelt, Niger Delta Basin

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Abstract

The cross plotting of rock properties for fluid and lithology discrimination was carried out in a Niger Delta oil field using well data X-26 from a given oil field in the coastal swamp depobelt. The data used for the analysis consisted of suites of logs, including gamma ray, resistivity, sonic and density logs only. The reservoir of interest Horizon 1, was identified using the available suite of logs on the interval where we have low gamma ray, high resistivity, and low acoustic impedance specifically at depths 10,424 ft (3177.24 m) to 10 724 ft (3268 m). We first obtained other rock attributes from the available logs before cross plotting. The inverse of the interval transit times of the sonic logs were used to generate the compressional velocities and the S-wave data was generated from Castagna´s relation. Employing rock physics algorithm on Hampson Russell software (HRS), rock attributes including Vp/Vs ratio, Lambda-Rho and Mu-Rho were also extracted from the well data. Cross-plotting was carried out and Lambda Rho (λρ) versus MuRho (μρ) cross-plots proved to be more robust for lithology identification than Vp versus Vs crossplots, while λρ Versus Poisson impedance was more robust than Vp/Vs versus Acoustic impedance for fluid discrimination, as well as identification of gas sands. The crossplots were consistent with Rock Physics Templates (RPTs). This implies the possibility of further using the technique on data points of inverted sections of various AVO attributes within the field in areas not penetrated by wells within the area covered by the seismic.

Keywords: Compressional Velocities, Coastal Swamp Depobelt, Impedance, LambdaRho, MuRho

1. Introduction

Cross plots are visual representations of the relationship between two or more attributes, and they are used to visually identify or detect anomalies which could be interpreted as the presence of hydrocarbon or other fluids and lithologies. Cross plot analysis are carried out to determine the attributes that better discriminate the reservoir (Omudu et al., 2007). Cross plotting appropriate pairs of attributes so that common lithologies and fluid types generally cluster together allows for straightforward interpretation. The off-trend aggregations can then be more elaborately evaluated as potential hydrocarbon indicators (Chopra et al., 2003).
Rock physics describes a reservoir by physical properties such as porosity, rigidity, compressibility; properties that would affect how seismic waves physically travel through the rocks. It, thus, seeks to establish relations between these material properties and the observed seismic response thereby developing a predictive theory so that these properties may be detected seismically (Dewar, 2001).
Velocities and elastic parameters are basically what link these physical rock properties to seismic expression, and to establish this relationship, we need;

i) Knowledge about the elastic properties of the pore fluid and rock frame.
ii) Models for the rock-fluid interactions. These are initially obtained from well-log data (Dewar 2001).

The first step in Rock Physics analysis is to obtain these elastic properties from well logs within select geologic units and cross-plot them. The knowledge of the crossplot cluster pattern at known well location would be used to investigate other locations without well penetration covered by the seismic. In interpretational practice, modeling and well templating help to define the type of trends an interpreter should be looking for (Burianyk and Pickford, 2000).

Rock physics is usually integrated with AVO analysis for a better understanding of lithology and fluid differentiation. Rock physics creates a link between geophysical observable to geological parameters and nowadays becomes an important part of reservoir characterization (Golyan, 2012). Various rock physics models have their benefits and limitations. Fluid and lithology discrimination are carried out for reservoir by applying different rock physics templates (RPTs). By plotting acoustic impedance (AI) versus Vp/Vs ratio (where Vp and Vs are Velocities of primary waves and Velocity of secondary waves respectively), data points concentrate within a narrow zone indicating high AI and Vp/Vs ratio suggest that application of rock physics template in the study area needs significant modification compared to generalized RPTs. As typically used in the oil and gas industry, the term rock physics is usually applied to the measurement, modeling, and interpretation of elastic wave propagation in sedimentary rocks (Golyan, 2012).

This article shows the application of cross plotting of rock properties for fluid and lithology discrimination based on trends established from the Rock Physics Templates in a field in the coastal swamp depobelt. An important question to be answered would be, which attributes would be most helpful in discriminating gas sand?

2. Field Location and Geology

The Tertiary Niger Delta is geologically divided into three formations representing prograding depositional facies distinguished mostly on the basis of sand-shale ratio (Inyang, et al 2015; Short, et al 1967; Kulke, 1995). These three formations are the Benin Formation or Continental Alluvial Sands, the paralic Agbada Formation and the prodelta marine Akata Formation (Akpabio, et al 2014: Agbasi, et al 2017).

The Akata Formation is the basal part or unit of the Tertiary Niger Delta complex (Agbasi, et al 2013; Mode, and Anyiam, 2007). It is of marine origin and composed of thick shale sequences which on the basis of geochemistry are believed to be the source rock of the Niger Delta petroleum system (Ubong, et al 2017). In the deepwater region of the Niger Delta such as the Bonga field, turbidite sandstone with minor amount of clay and silt compose the major reservoir units. The Akata Formation is believed to have formed during low stands when terrestrial organic matter and clays were transported to deep-sea waters characterized by low energy conditions and oxygen deficiency (Inyang, et al 2015; Inyang, et al 2017; Starcher, 1995).

The formations in the Niger Delta, Nigeria consist of sands and shale with the former ranging from fluvial (channel) to fluvial-marine (Barrier Bar), while the later are generally fluvial-marine or lagoon. These Formations are mostly unconsolidated and it is often not feasible to take core samples or make drill stem tests (Agbasi, et al 2017).

X-field is located some few kilometers southwest of Port Harcourt within the Niger Delta Basin as shown in Fig. 1. The Niger Delta lies between latitudes 3° N and 6° N and longitudes 5° E and 8° E. The structure in X-field is a complex collapsed crest, rollover anticline, elongated in an East-West direction. The zone of interest is typically a sand/shale/sand sequence. The well is located at the northwestern region of the field and used for the cross plot analysis.

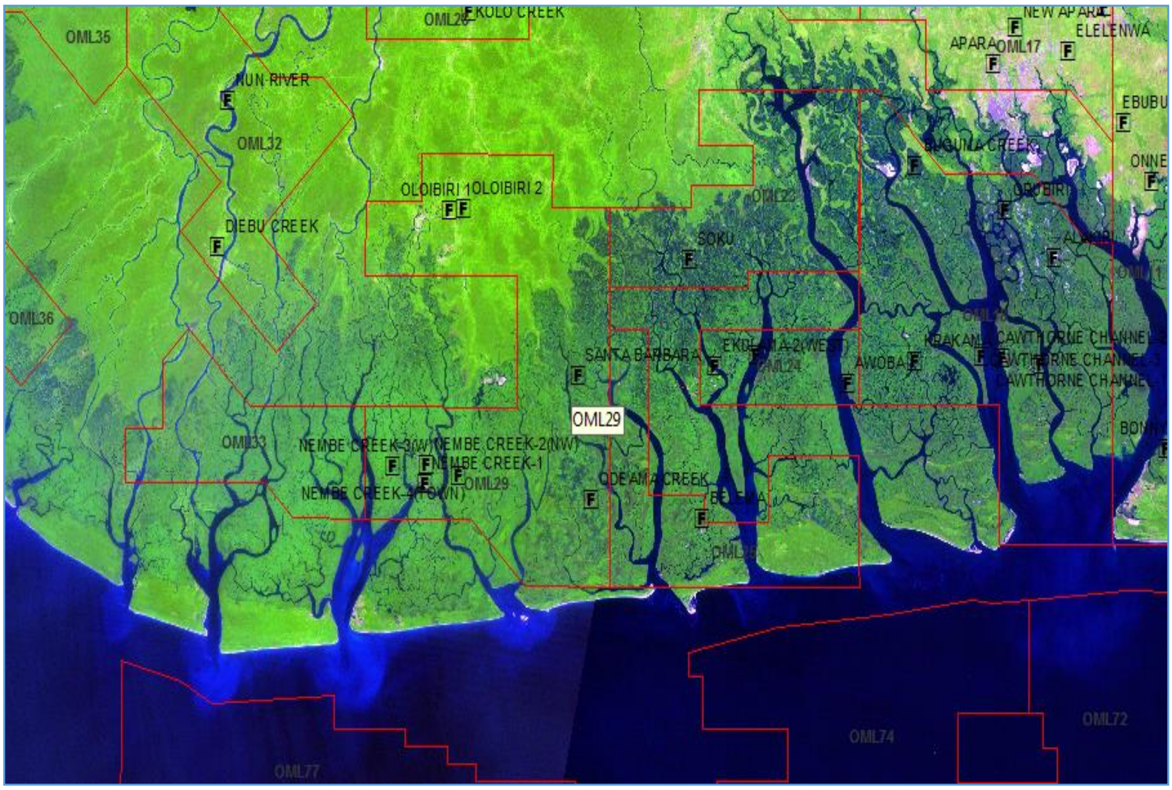

Fig 1. Location map showing X-Field in the Niger Delta

3. Data and Methodology

The data used in this work is a well log data (Fig. 2) and a 3D full stack seismic data from "X" field in the Coastal Swamp depobelt within the Niger Delta Basin. The data consist of a suite of well logs from X-26. This data was analyzed using Hampson Russell software (HRS).

The suite of wireline log data comprises density log, caliper log, gamma ray log, resistivity log, and sonic log. The inverse of the interval transit times of the sonic logs were used to generate the compressional velocities for the well. We generated S-wave data from Castagna´s relation since shear log data are not available. Lambda-Rho and Mu-Rho were extracted from the well data using rock physics algorithm, rock attributes, including Vp/Vs ratios as shown in Fig. 3. This available suite of logs can be grouped into two categories, namely, properties that affect seismic wave propagation (e.g., compressional- and shear- velocity log and density log) and properties of interest for reservoir description but which indirectly affect seismic-wave propagation (e.g., porosity, water saturation, Vp/Vs ratio and Poisson's ratio). Petrophysical analysis through conventional cross plot was used in this work as the key to relating the two groups.

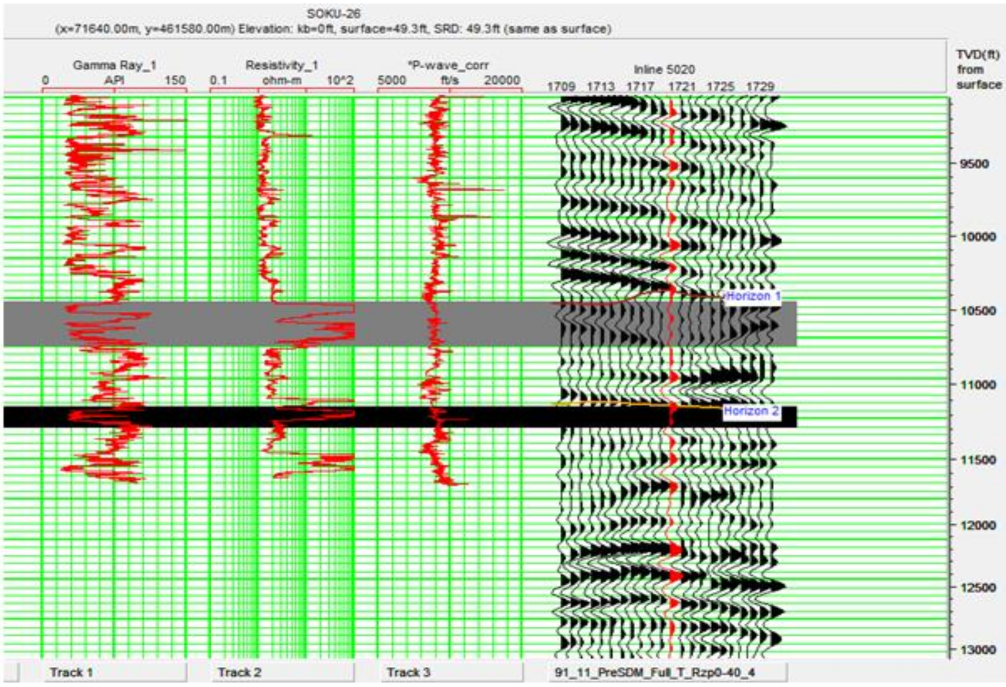

Fig. 2 Flow chart diagram of the method of study.

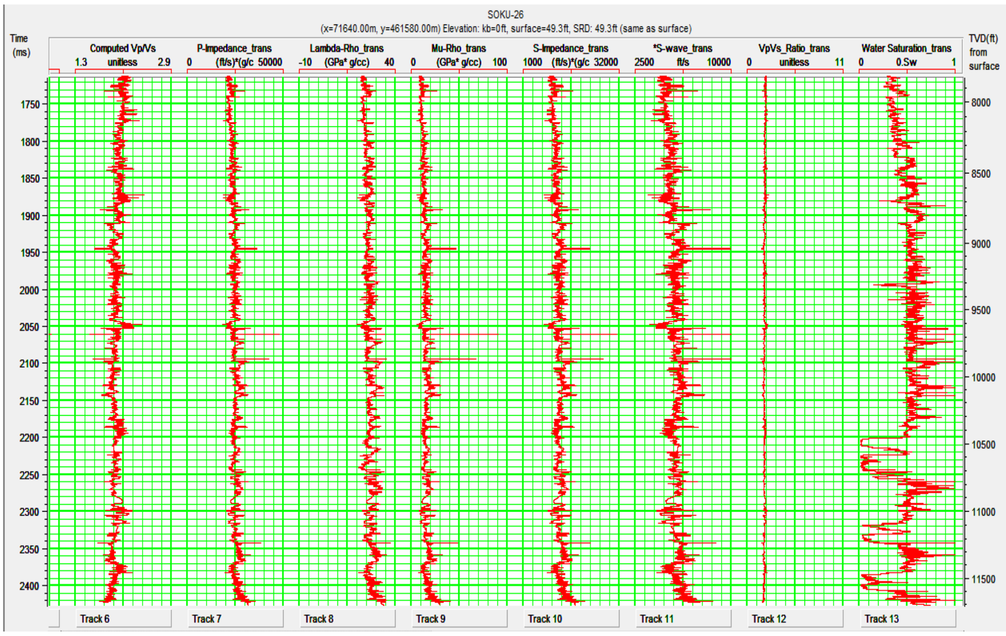

Fig. 3. Suite of logs for X-26 showing computed VP/VS ratio and P-Impedance, λρ, μρ, S-Impedance, S- wave, water saturation logs.

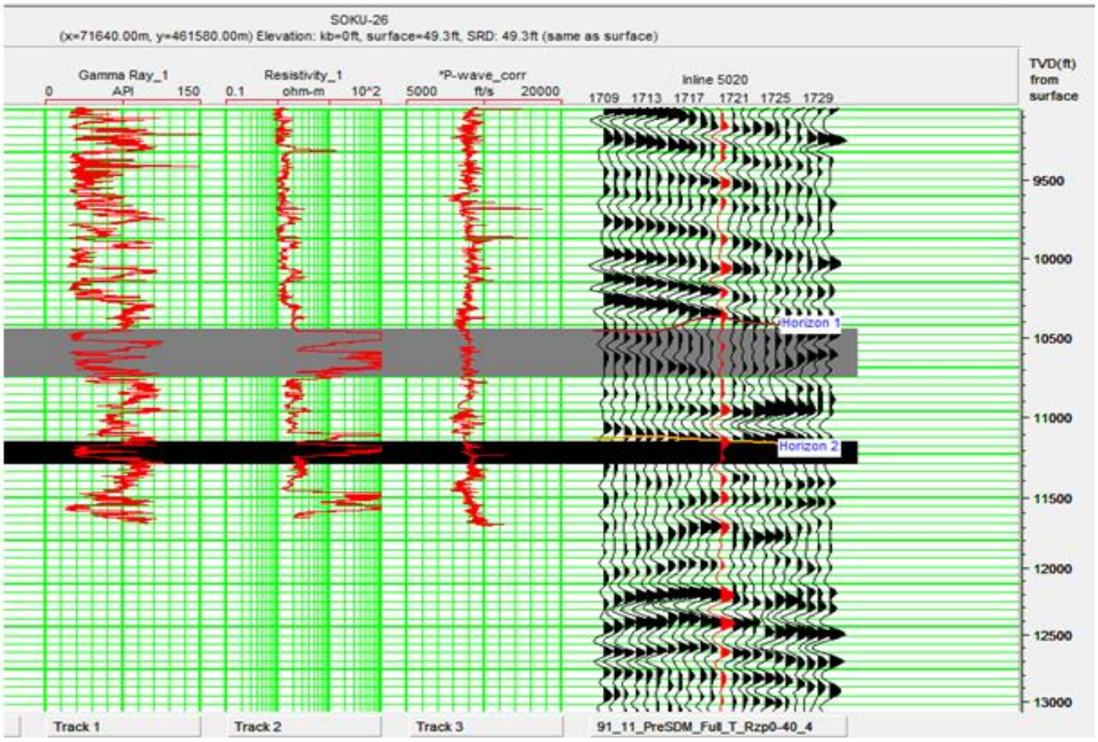

Fig. 4. Horizon-1 was delineated from the gamma ray, resistivity, and sonic logs and tied to seismic.

The first stage of this workflow which involve identifying the zone of interest. In this step, the zone of interest representing the producing interval is mapped out using the resistivity log, gamma ray log, P-wave velocity log and density log curves in the well. We can observe the unavailability of neutron log and SP log that has restrained further discrimination of the wells regarding their fluid contacts and fluid type. The logs then passed through a series of log editing operations. The log editing operations applied in this work include mainly median filtering and checkshot correction using the LOG MATH Function of the Hampson Russell eLOG tool.

The true vertical depth (TVD) of investigation ranges from 10,424 ft (3177.24 m) just at Horizon 1 top to 10 724 ft (3268 m) at the hydrocarbon-water-contact (HWC), as shown in Fig. 4.

4. Result dan Discussion

From the results of the study observed in the site of Watuadegpillow lava, there were many damages which made during the development of the geoheritage site so that become not maintained, thus reducing the value of education and attractiveness, especially in the geological context. Evidence of damage to the geoheritage site of WatuadegPillow Lava is the construction of irrigation by the local government which is the function of irrigation development, namely for surface water channels and the availability of water for agriculture. However, the development of irrigation in the beds of pumice and tuffs of Semilir Formation around it is very influential on the geological history and geological processes that occur and take place in the area, especially as stratigraphic correlation data that are connecting the surrounding rocks.

We can better discriminate our fluids in a cross plot of P-impedance against Vp/Vs ratio, as seen in Fig. 6. The Vp/Vs ratio is a fluid indicator because compressional waves are sensitive to fluid changes, whereas shear waves are not except in the particular case of very viscous oil. Acoustic impedance and Vp/Vs ratio contrast shows the position of gas-sand, brine-sand and shale (Bello and Igwenagu, 2015).

Within relatively high Vp/Vs ratio, we can identify our gas sands in green oval at very low impedances. As impedance increases we move from gas sands to oil sands in yellow oval and finally brine sands consistent with increasing bulk density values possibly caused by changes in fluid type as seen in Fig. 6. Shales were identified in grey oval with varying ranges of Vp/Vs ratio and relatively higher impedances.

Combining Vp and Vs impedances which depend on Lame's parameter, modulus of rigidity and density, and not isolating the density term, we arrive at attributes that characterize the incompressibility (LambdaRho) and the rigidity (MuRho) of the rocks and the fluids in their pore spaces.

Considering from the basic principle that sandstones are more incompressible than shales, and that water filled sandstones would be more incompressible than gas-filled sandstones, also that shales have less rigidity than sandstones and changes in the fluid would not affect rigidity, crossplot of these properties would be more revealing on discriminating lithologies and fluids.

Cluster pattern for different lithologies is separated more easily in the crossplot of the LambdaRho against the MuRho as compared to the crossplot between the Vp and Vs impedances, as observed in Fig. 6 and 7.

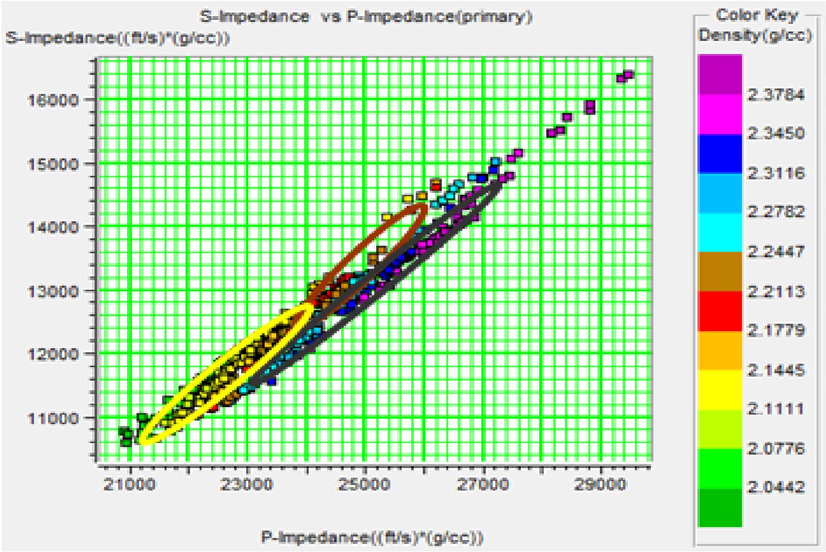

Fig 5. Cross plot of P-Impedance against S-Impedance.

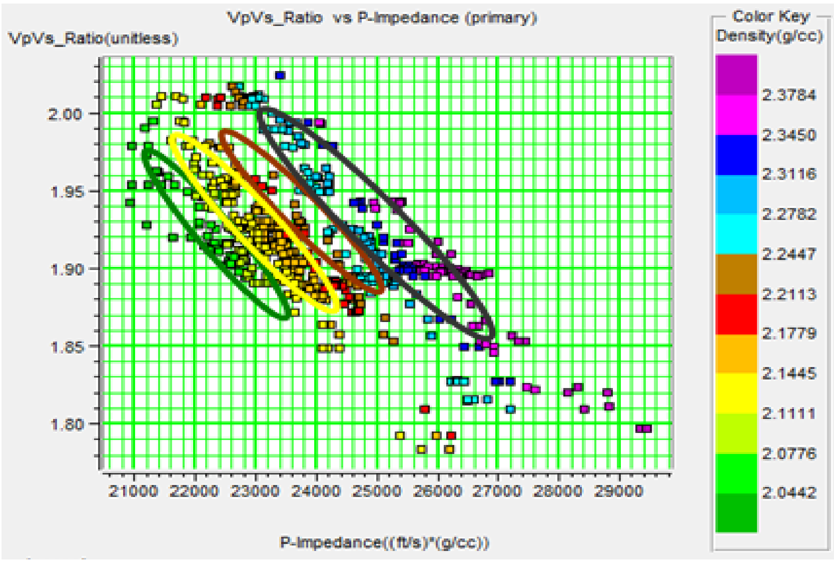

Fig. 6. Cross plot of VP/VS ratio against P-Impedance

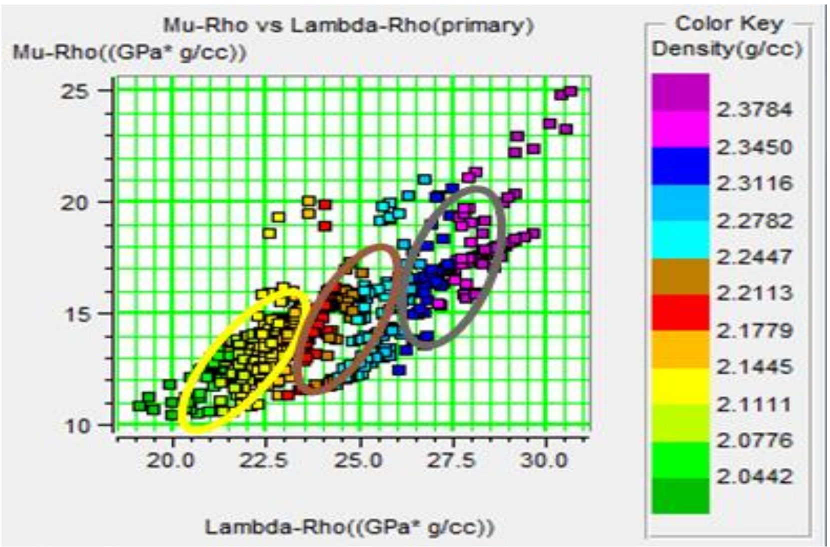

Fig 7. Cross plot of MuRho (μρ) against LambdaRho

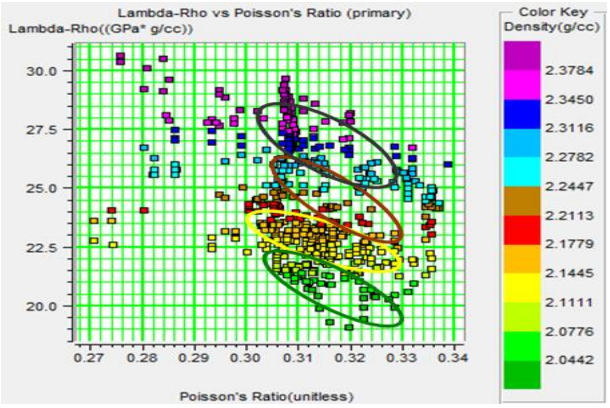

Fig. 8. Cross plot of LambdaRho (λρ) against Poisson ratio

From Fig. 7, a crossplot of LambdaRho versus MuRho, low values of Lambda-rho, corresponding to low values of Mu-rho indicate the presence of hydrocarbons within sand reservoirs. The plot indicates that λρ is more robust than μρ in the discrimination of fluids in this field and that μρ values are unexpectedly relatively low for the reservoir sand.

A better tool for fluid discrimination would be the crossplot between the LambdaRho and Poisson ratio. This is because relatively low values of LambdaRho corresponding to low values of Poisson ratio would help identify our gas sands as we can see in the green oval, in Fig. 8.

Finally, a quick look at lithology interpretation tool will be the crossplot of MuRho against density constraining with resistivity. Considering Fig. 9 below, the shales identified in the dark grey oval and the hydrocarbon sands in the green oval.

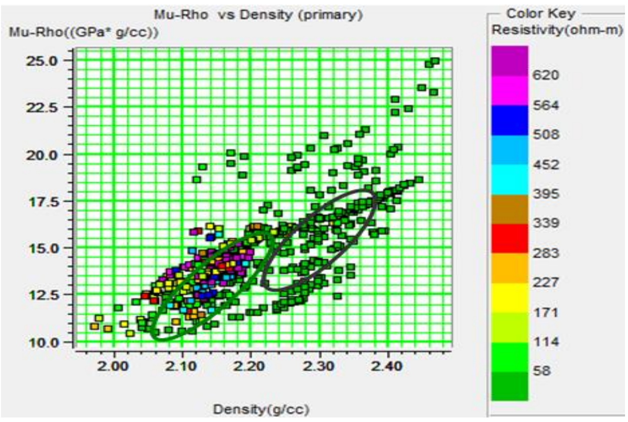

Fig. 9. Cross plot of MuRho against Density

5. Conclusion

Achieving Successful exploration and production of hydrocarbons, it is important to characterize the hydrocarbon reservoir accurately concerning its fluid properties and lithology. Hence, good knowledge of petrophysical parameters must be known to understand the lithology and fluid content. Acoustic impedance, Lambda-rho, Mu-rho, and Poisson impedance attributes were found to be most robust in lithology and fluid discrimination within the reservoir in the crossplot.

From the discussion above, data points taken for Horizon 1 in X-field were consistent with Rock Physics models for lithology and fluid discrimination. The data implies the possibility of further using the crossplot technique on data points of inverted section of various AVO attributes in areas not penetrated by wells within the area covered by the seismic.

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