INVERSION FEASIBILITY STUDY FOR RESERVOIR CHARACTERIZATION OF OSI FIELD ONSHORE NIGER DELTA BASIN

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Abstract: Well based feasibility analysis for the sensitivity of rock properties to variation in reservoir properties was carried out to determine the best seismic inversion process to be adopted for the characterization of the undrilled areas of the CHU reservoir in OSI field. Biot Gassmann's Fluid Substitution Modeling and Castagna Equation were used to estimate shear wave velocity in the absence of acquired shear wave log. Cross plot techniques such as V_p/V_s ratio against P-impedance, Mu-rho against Lambda-rho and Lambda-rho/Mu-rho Vs Lambda-rho were adopted to evaluate the responsiveness of their respective attribute to lithology and fluid discrimination. The V_p/V_s ratio and Lambda-rho attributes gave the best indication of lithology types, while the Lambda-rho attribute demonstrated to be an excellent fluid discriminant. Since the Lambda-rho attribute is a P-wave derived attribute and was sufficient for both lithology and fluid discrimination, P-Impedance inversion will be the best technique for characterization of CHU reservoir in the undrilled area of the studied field.

Keywords: Cross-plot, lambda-rho, mu-rho, rock-physics, seismic-inversion, V_p/V_s ratio

Introduction

Seismic inversion is the process of extracting from seismic data, elastic rock properties that conveys information of the underlying geology that gave rise to the seismic (Russell, 2005). Inversion provides information of the underlying geology using the derived impedance from the seismic data, which is an interval property useful for estimating reservoir properties. Impedance as discussed by Veeken (2007) is an important tool as it contains essential data from the logs and seismic data. Unlike seismic data which is an interface property, acoustic impedance is a rock property which shows geologic layer and is also closely related to lithology and reservoir characteristics such as porosity and hydrocarbon saturation. Reservoir characterization is the integration of different data to describe the reservoir properties of interest in inter-well locations (Mehdipour *et al.*, 2013; Ezekwe and Filler, 2005; Hadi *et al.*, 2005). Hence in reservoir characterization, integrating seismic inversion processes with various rock properties and other petrophysical studies can help in efficient planning and further assist effectively in reservoir management.

The knowledge of rock physics is very important and serves as the bridge that links elastic properties to the reservoir properties (Avseth *et al.*, 2005). Rock properties are those physical properties of a rock such as compressional wave (P-wave), shear wave (S-wave), velocity, bulk density, porosity, compressibility and their derived attributes that will affect how seismic waves physically travel through the rock (Dewar, 2001). Simple combination of compressional wave (V_p), shear wave (V_s) and density properties can be used in generation of all rock properties needed for the cross plots (Omudu and Ebeniro, 2005). Cross plotting of rock properties from well logs is a very convenient and efficient way of studying various rock properties or their attributes at the same time (Burianyk, 2000). It shows quite decisively which rock properties or their attributes will be helpful in discriminating both lithology and fluid content in a particular reservoir.

P-impedance inversion and AVO inversion are two common types of inversion possible base on the kind of rock properties extracted from seismic. P-impedance inversion output elastic properties that have strong relationship with compressional wave velocity. Whereas, AVO inversion is a more complex and effective inversion process that extract elastic properties with shear deformation influence as wave energy travels through a rock. The availability of some input data such as shear sonic log influence the applicability of AVO inversion since it is rarely available in most wells due to the high cost of acquiring the log. Hence, where P-impedance inversion is sufficient to characterize a field, AVO inversion is avoidable. The choice of the most suitable inversion process to execute can only be determined by carrying out well base feasibility study.

This research work focuses on carrying out a well based feasibility study in order to ascertain the sensitivity of rock properties to changes in reservoir properties so as to determine the type of seismic inversion method suitable for reservoir characterization the OSI field, onshore Niger Delta Basin.

Materials and Methods

The adopted techniques involved integrating seismic inversion feasibility studies with both petrophysical interpretation from the well logs and rock physics cross plots. Well log data were used for this study. Hampson Russell suite was the subsurface software used to complete the work. The data were quality check for spurious readings after loading into the software reservoir. The CHU reservoir interval was delineated with the gamma ray log and fluid type were defined with the aid of the resistivity, Density and Neutron logs (Fig. 1). Petrophysical evaluation was done to estimate reservoir properties while elastic rock properties were generated from sonic and density logs (Fig. 2). Biot- Gassmann (1951) fluid substitution and Castagna (1985) equation were used to estimate shear sonic log since the log was not acquired. The cross plot analysis was completed using several crossplot techniques that include V_p/V_s ratio against p-wave impedance, mu-rho against lambda-rho and lambda-rho/mu-rho against lambda-rho.

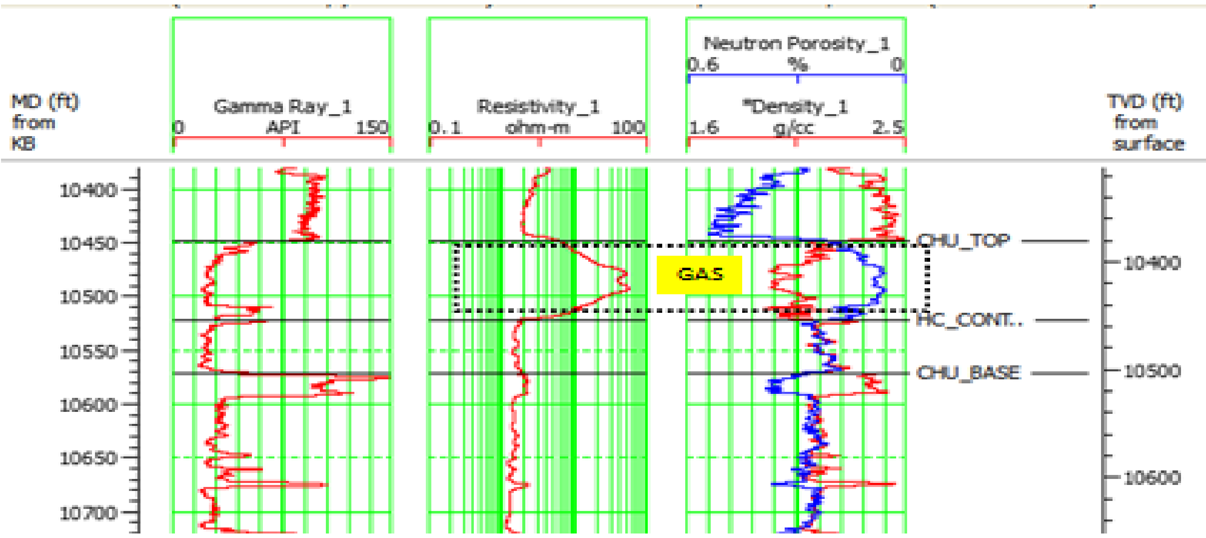

Fig. 1: Lithology and fluid discrimination in the objective CHU reservoir using well logs

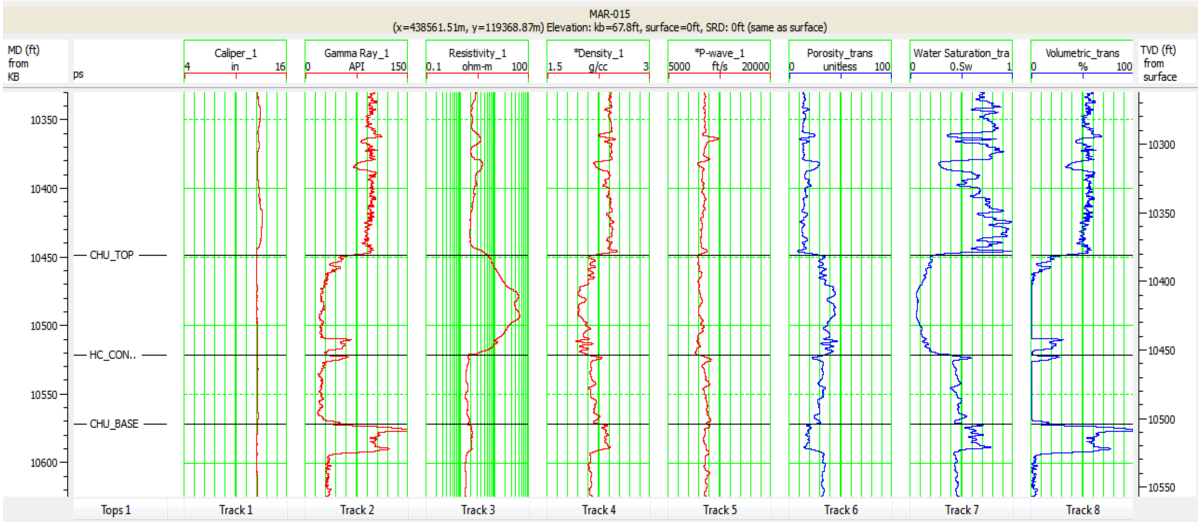

Fig. 2: The raw logs, generated petrophysical logs and the defined CHU reservoir interval

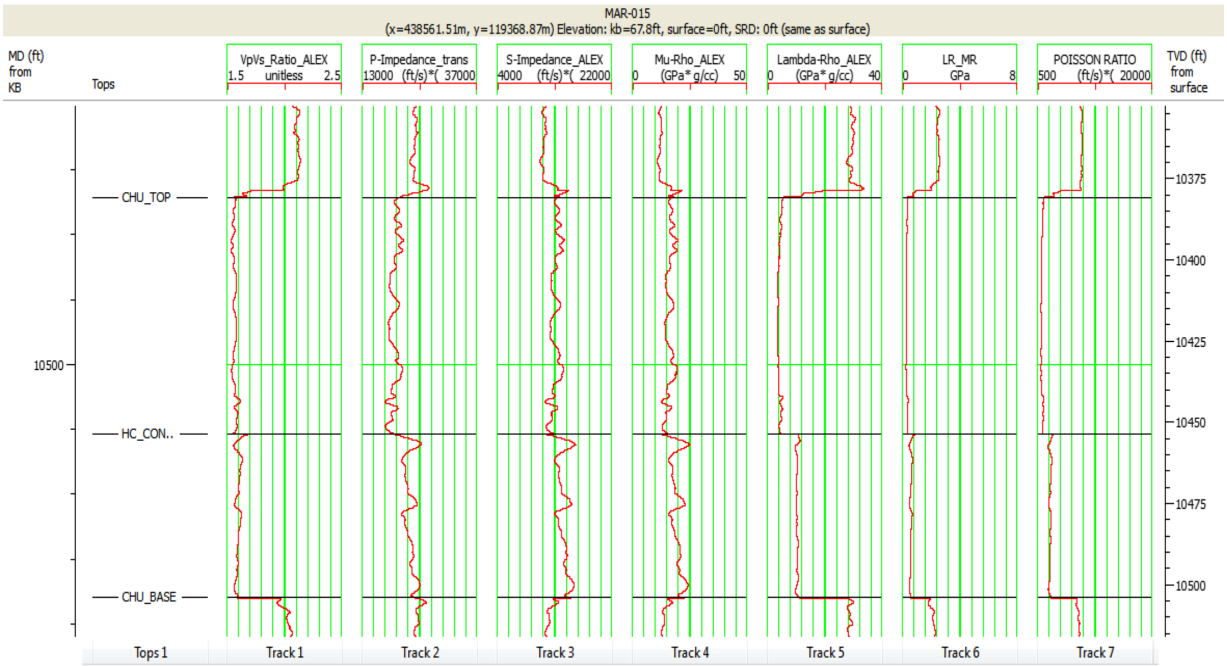

Fig. 3: Derived rock–physics attribute logs and the objective reservoir interval

Results and Discussion

Five acoustic rock properties were selected for this study; V_p/V_s ratio, P-wave impedance, lambda-rho, mu-rho and lambda-rho/mu-rho. P- Impedance and lambda-rho attribute are derivative of P-wave velocity that can be generated from P-impedance inversion while V_p/V_s ratio, mu-rho and lambda-rho/mu-rho are complex derivative that has shear wave and AVO effect that depends on the presence of shear wave and can only be generated from AVO inversion process. These rock properties were evaluated, cross plotted and analysed for their sensitivity to variation of lithology and fluid to present the best attribute, cross plot technique and inversion type that will be suitable for characterization of the undrilled areas in the field.

Three cross plot techniques were adopted for this study; V_p/V_s ratio Vs P-wave impedance, Mu-rho Vs Lambda-rho and Lambda-rho/Mu-rho Vs Lambda-rho.

Low V_p/V_s ratio value corresponds to a clean sand lithology which could be hydrocarbon saturated while higher values defines shale lithology (Assefa *et al.,* 2003; Ebeniro *et al.,* 2003). P-impedance values are higher for shales due to greater compaction response in shales, but are generally lower for sand and much more lower for hydrocarbon bearing sands. The V_p/V_s ratio Vs P-wave impedance plot of the CHU reservoir interval and the top bounding shale shows three distinct clusters of data points (Fig. 4); each of the cluster zone defined by a particular colour ellipse in the cross plot panel (the right panel) corresponds to the depth interval defined by the same colour in the well log panel (the left panel). In the well log panel, the first two tract houses the cross plotted rock physics attribute while the last two panels are the gamma ray and resistivity log employed to define the reservoir interval and hydrocarbon presence, respectively. The cluster points within the *'Red'* ellipse is defined by a very low value of V_p/V_s ratio and the least value of P-impedance and this corresponds to areas on the resistivity colour coded region with high resistivity value indicative of hydrocarbon presence. The area of the plots clustered within the *'Blue'* ellipse is defined by greater values for V_p/V_s ratio and P-Impedance. The low value of resistivity within the cluster confirms that the region is a brine sand since their exist similarity in V_p/V_s ratio that resulted due to fluid content variation. A horizontal line inserted along the V_p/V_s ratio axis clearly separate the lithology. Hence we can conclude here that the attribute is a good lithology discriminant compared to the P-impedance attribute. For fluid discrimination, both attribute are required.

According to Omudu and Ebeniro (2005), high lambda-rho values indicate greater incompressibility as typically evident in shale and highly compact sandstone Lithologies. Burianyk (2000) argued that water filled sandstones are more incompressible than gas filled sandstones, and that the Mu-rho attribute is insensitive to fluid change in the pore space of rocks. As observed in the lambda-rho Vs Mu-rho plot (Fig. 5), shale lithology has the lowest Mu-rho values than sands and can be used to discriminate shale from sand (Burianyk, 2000). The hydrocarbon bearing zone was excellently separated from the brine filled sand along the lambda-rho axis indicating an excellent sensitivity to fluid change. Also, the attribute was able to conveniently discriminate between the two lithologies. Therefore, Lambda-rho attribute can serve as an excellent fluid and good lithology discriminant for the objective reservoir in the field. Low values of lambda-rho with little variation in Mu-rho are indicative of hydrocarbon sands presence (Burianyk, 2000; Dewar, 2001).

The cross plot of lambda-rho/mu-rho ratio with lambda-rho gave a very good result for both lithology and fluid discrimination. The lambda-rho/mu-rho ratio is a complex average similar to the Vp/Vs ratio. The attribute show a good separation between shale and sand on the vertical axis, and fair fluid separation between brine sand and hydrocarbon sand better than the Vp/Vs ratio in Fig. 4. The lambda-rho attribute in this cross plot again shows its superiority for fluid and lithology discrimination for the study field. A very high values for Lambda-rho/Mu-rho ratio and Lambda-rho defined the shale lithology cluster, low values for both attributes define the brine sand while very low value for both cross plotted attribute define the hydrocarbon sand.

From the rock physics attribute evaluated in the cross plot, Vp/Vs ratio and Lambda-rho were the best lithology indicators while the Lambda-rho attribute gave the best fluid discrimination. Vp/Vs ratio is an AVO attribute that can be generated from AVO inversion that require acquired shear wave log. But the Lambda-rho attribute that has been demonstrated to be the best attribute for lithology and fluid discrimination is a P-wave dependent attribute and can be generated from P-Impedance inversion from seismic. Therefore, for seismic base characterization of CHU reservoir in the undrilled area of the study field, P-impedance inversion is sufficient especially as there are no acquired shear wave logs present in the field.

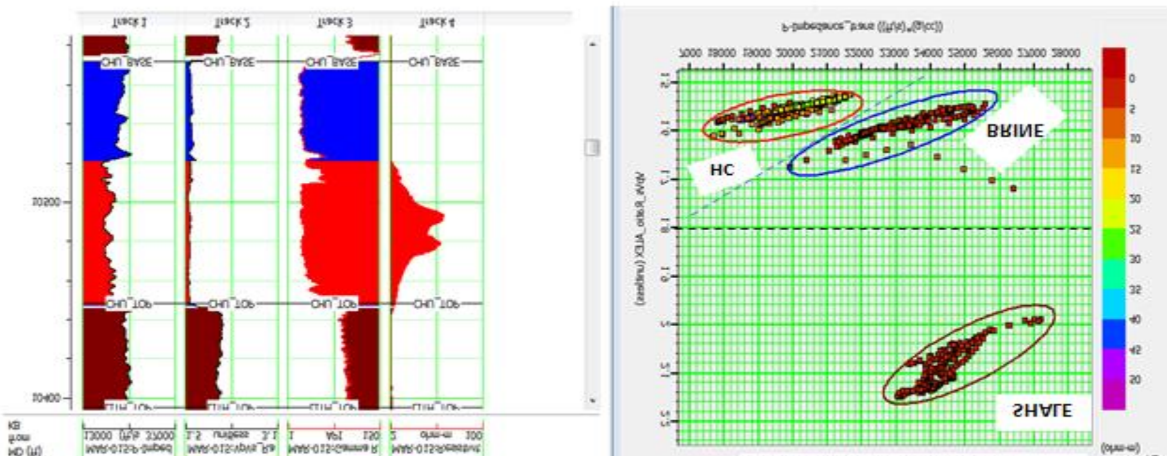

Fig. 4: Cross section and cross plot of V_p/V_s ratio (Y-axis) against P-wave impedance (X-axis) colour coded with Resistivity

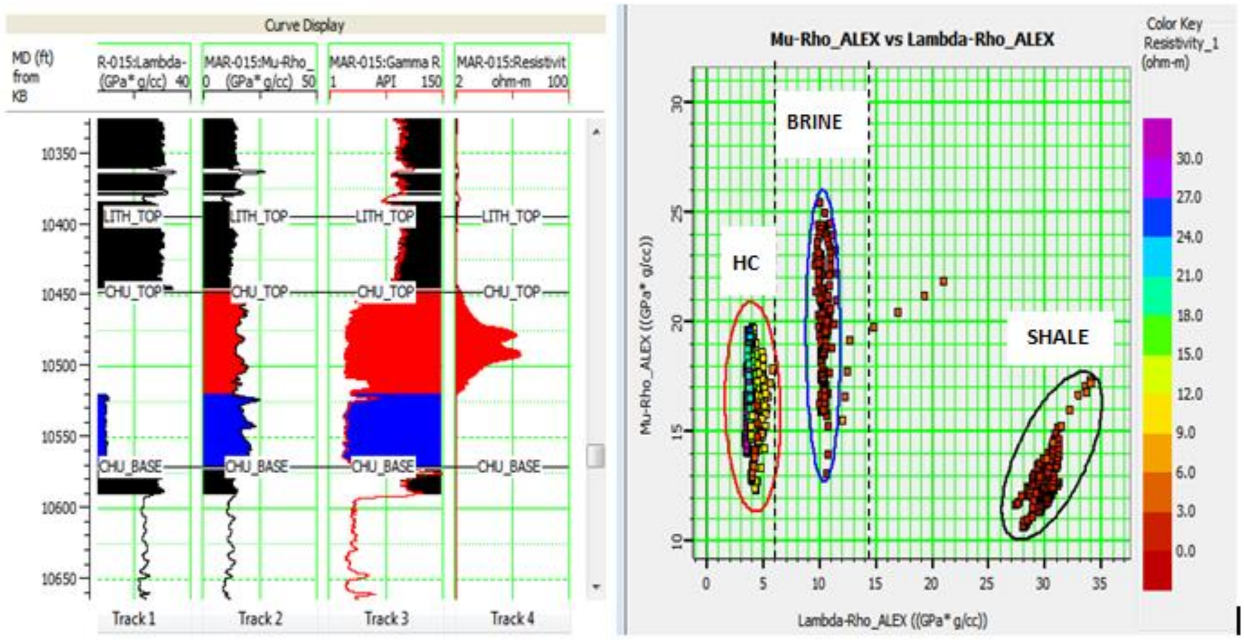

Fig. 5: Cross section and cross plot of Mu-rho (Y-axis) against Lambda-rho (X-axis) colour coded with Resistivity

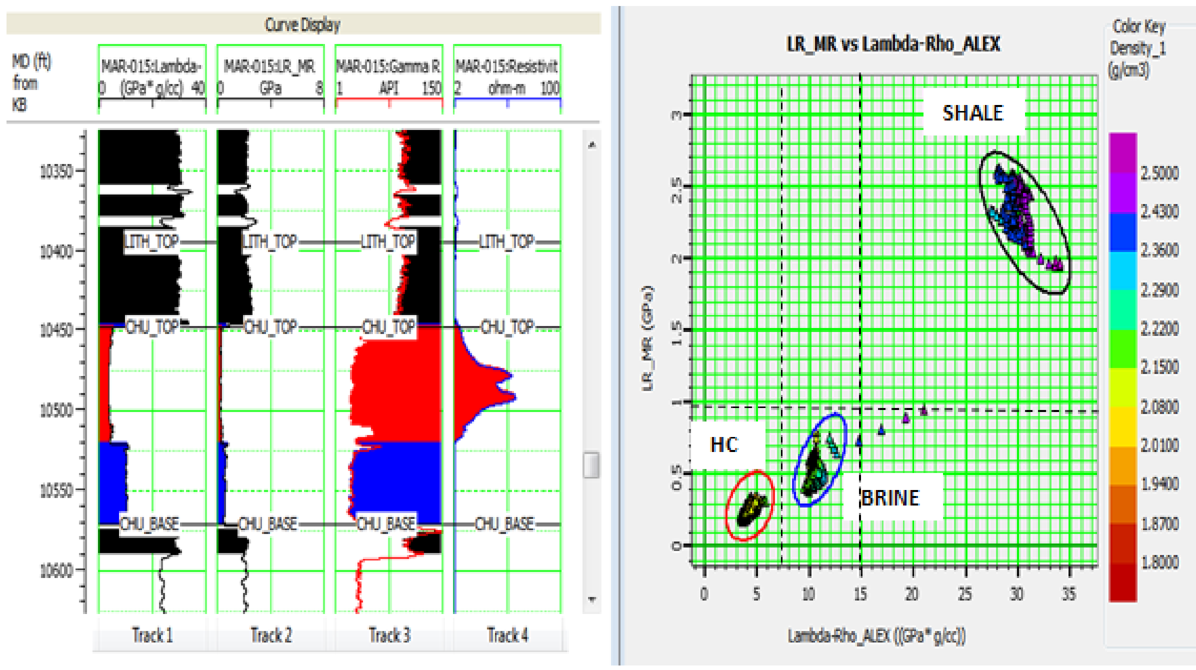

Fig. 6: Cross section and cross plot of Lambda-rho/Mu-rho (Y-axis) against Lambda-rho (X-axis) colour coded with Density

Conclusion

The inversion feasibility study on the CHU reservoir examined both AVO rock attributes and P-wave dependent rock attributes using three cross plot techniques; Vp/Vs ratio against P-wave impedance , Lambda-rho/Mu-rho against Lambda-rho and Mu-rho against Lambda-rho. Vp/Vs ratio and lambda-rho attribute gave the best lithology discrimination while the lambda-rho proved to be an excellent discriminator for fluid as it was extremely sensitive to fluid change. Lambda-rho attribute is a P-wave derived attribute from simple P-Impedance inversion result, and has been demonstrated to be the best combined lithology and fluid discriminator. Hence, the P-Impedance inversion result has proved to be sufficient for CHU reservoir characterization in the undrilled areas of the field.

Conflict of Interest

Authors declare that there are no conflicts of interest.

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