RESERVOIR CHARACTERIZATION OF "UCHE" FIELD ONSHORE NIGER DELTA

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Abstract: *The Niger Delta is one of the major hydrocarbon producing fields in the Gulf of Guinea This field has quite a complex geology which makes routine seismic interpretation a challenging task for understanding the reservoir properties such as lithology and fluid content. Post-stack seismic inversion has proven to be a reliable tool for detailed understanding of the reservoir, especially for lithological identification and fluid properties. In this study, post-stack seismic inversion method was used on acoustic and elastic impedance models to build an inverted impedance model. For this purpose, two reservoir horizons were interpreted to determine geological inputs for the model. Check shot survey was used to build synthetic traces which were then tied to the real seismic data. Crossplot analysis was done to determine the fluid and lithological discrimination within the reservoir. An inverted P-impedance model, using model-based inversion was then built. The result revealed an acoustic impedance contrast caused by lateral changes in lithology and fluid content. The interpretation was constrained by well control which was used to characterize the reservoir.*

Key Words: Reservoir, Niger Delta, Petrophysical.

1. INTRODUCTION:

In characterizing a reservoir, it is relevant to consider all that can be known to better increase knowledge about a reservoir. Its hydrocarbon storing capability, with respect to the porosity and permeability of a formation, when drilled by a well, considering in-situ conditions. Reservoir characterization implies having an understanding of reservoir architecture, its geological and petrophyiscal conditions, mode and distribution of these properties, and understanding how fluid in the subsurface, if any, would flow considering these properties in the reservoir (Michelena, and Chopra, 2011). It then becomes evident that such information helps in decreasing risk and uncertainty, improving production rate, make proper financial plan, in addition, ensuring that management decision making for future development options are controlled.

For Uche field which is the study area, seismic inversion, a quantitative reservoir geophysical procedure was used in order to make an assessment of the attributes within the reservoir. Although well logs are used traditionally to estimate how reservoir properties are evenly distributed in space (geostatistically), integrating seismic data will further help reduce uncertainties in identifying possible exploration targets.

2. AIM AND OBJECTIVES:

For this study, the aim was to show how reservoir rocks identified from well log information can be characterized and fluids in them discriminated, especially for areas not penetrated by wells.

3. LOCATION OF STUDY AREA:

The study area under consideration is situated in the coastal swamp of the Niger Delta. The reservoir under consideration is an oil rim reservoir with sizeable recoverable reserves.

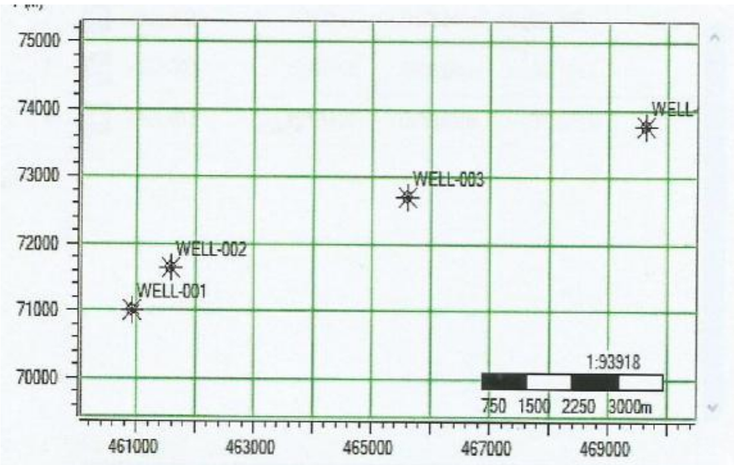

Figure 1; Base map of the study area

4. METHODOLOGY:

The method employed in this inversion process has basically three stages :
- "Well-log editing and modeling",
- "Seismic modeling and horizon interpretation"
- "Attribute generation from seismic data using model-based inversion".

For the model based method, an AT volume is generated from 3D seismic data, the generated volume is then interpreted for the fluid and reservoir rock properties. In order to do this, the inversion was done using "CGG Veritas Hampson-Russell" software 8 modules "Geoview", "eLog", and "STRATA".

Also "Lambda-rho" (p) and "Mu-rho" (jip) attributes, proposed by (Goodway et a!., 1997) were extracted from the inverted seismic volumes. These attributes provide information about how compressible and rigid the rocks are which, in turn, depend upon the type of fluid occupying pore space and matrix properties of rocks.

Other attributes considered in this work gotten from seismic and well log include Poisson fgg impedance proposed by (Quakenbush et al., 2006), Elastic, P and S impedance. In the end, the results from the three stages are analyzed in other to ascertain fluid presence and differentiate lithology.

Well Log Data

"The suite of log comprises of density, caliper, gamma ray, resistivity and sonic log". The inverse of the interval transit times of the sonic logs were used to produce the compressional velocities for each well. Shear log data are not available. However we generated S-wave data from Castagna's relation. Rock physics analysis through cross plot was used in this study to relate the two groups. The zone of interest is characteristically a paralic sequence of sand and shale. The wells used for the analysis are located at the north - eastern region of the field.

Seismic Data

The seismic volume has cross-line and inline ranges from 4505 to 5560 and 274 to 2064, respectively . The seismic volume, highly clipped, extends to 5200 milliseconds two way travel time (TWT), below which exists no reflection continuity. The seismic volume has a characteristic feature of series of parallel reflections offset and deformed by major normal faults with collapsed crestal faults in the overlying sediments. Major counter regional fault are evident in the cross line section through the volume and collapsed crest normal and roll over faults evident in the inline section through the volume.

The normal faults are traceable. The faults exhibit throws ranging from 90m at (7300 ftss/ 2190 mss) to 240m at (10,SOOftssf 3240mss) with the major boundary fault from 1115 mss (3717 ftss) to 3001 mss (10,003 ftss). The seismic record character changes with depth. The basal part of the seismic record (below 2190ms TWT) is disrupted by several zones with transparent to chaotic highly- discontinuous reflection patterns, which extend higher within the seismic volume under footwalls of major faults, making it a bit difficult to interpret.

Reflections within this region have moderate to good continuity and high amplitude variations. Reflections in the shallowest 2750ms TWT of the seismic volume are parallel, nearly horizontal, and less continuous. Most wells of the field include logs of this interval.

5. DATA ANALYSIS AND RESULT PRESENTATION:

In this section, we present cross plots and horizon maps of rock attributes extracted from 3-D seismic data for LOUIS_l000 and LOUIS_4000 sand tops. The crossplots analysis has shown to be an important technique in differentiating between fluid and lithologies in the reservoir (Omudu and Ebeniro, 2005). The corresponding horizon maps and their difference for each rock attribute were investigated in order to map out regions in the field that would account for presence of hydrocarbon sands or brine sands.

6. WELL LOG ANALYSIS:

Well curves used for the analysis are logs of Well-002 and Well-003. The logs include caliper, gamma ray, resistivity, density, P-wave and acoustic impedance curves generated through rock property transform. The true vertical depth (TVD) of investigation for Well-002 ranges from 8966.45fl (2732.97m) to 9497.94ft (2894.97m), while WeIl-003 ranges from 7233.96ft (2204.91m) to 8674.25ft (2643.91m). "The wells exhibit a dominantly shale/sand/shale sequence typical of the Niger - delta formation". The hydrocarbon-water- contact (HCWC) occurs at depth of 9226.28ft for Well-002 which was estimated visually. The wells were analysed for "fluid type", and "lithology". Shale lithologies were defined by "high gamma ray" value and "high acoustic impedance value", responsible for the deflection to the right of the Al curve and to the left of the resistivity curve due to it being conductive. Also, zones with hydrocarbon where identified with high resistivity to the right and low Lambda- Rho values of less than 2.5 GPa*g/cc. Zones with "low gamma ray", "high resistivity", and "low Al" are mapped as "sand lithologies". "Sand lithologies showing very low Al and high resistivity are regions of hydrocarbon saturation although most zones showed little resistivity peaks". However, the unavailability of neutron log and SP log has restrained further discrimination of the wells in temis of their fluid contacts and fluid type.

7. WELL LOG ATTRIBUTE-CROSSPLOT ANALYSIS:

Bello et al., (2015) showed in their study the importance of cross-plotting rock properties for accurate delineation of reservoir parameters. WelI-003 was analyzed for the rock and fluid properties / attributes using cross piot, this was used to better discriminate the reservoir (Omudu and Ebeniro, 2005).

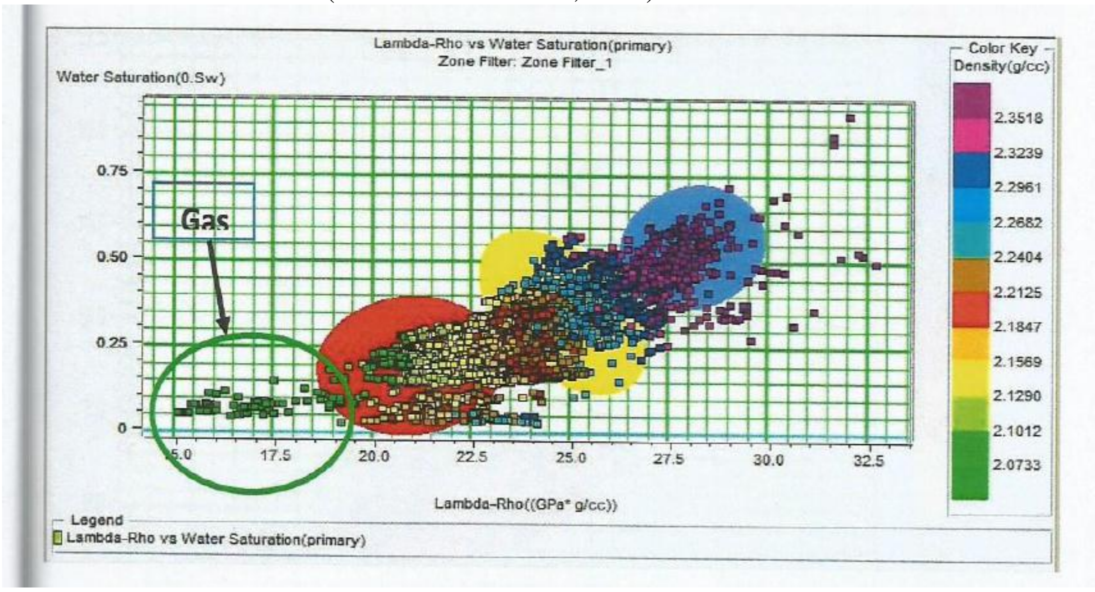

Figure 2 ; Cross plot of water saturation indicative of hydrocarbon

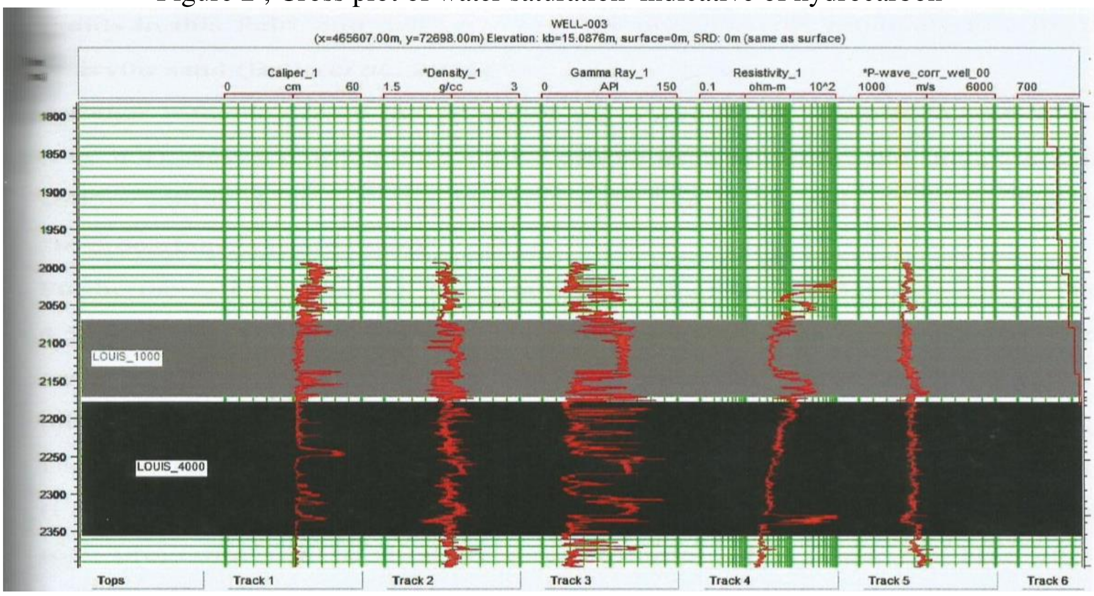

Figure 3 ; Reservoir of interest for Well-003; LOIUS_ 1000 and LOIUS _4000

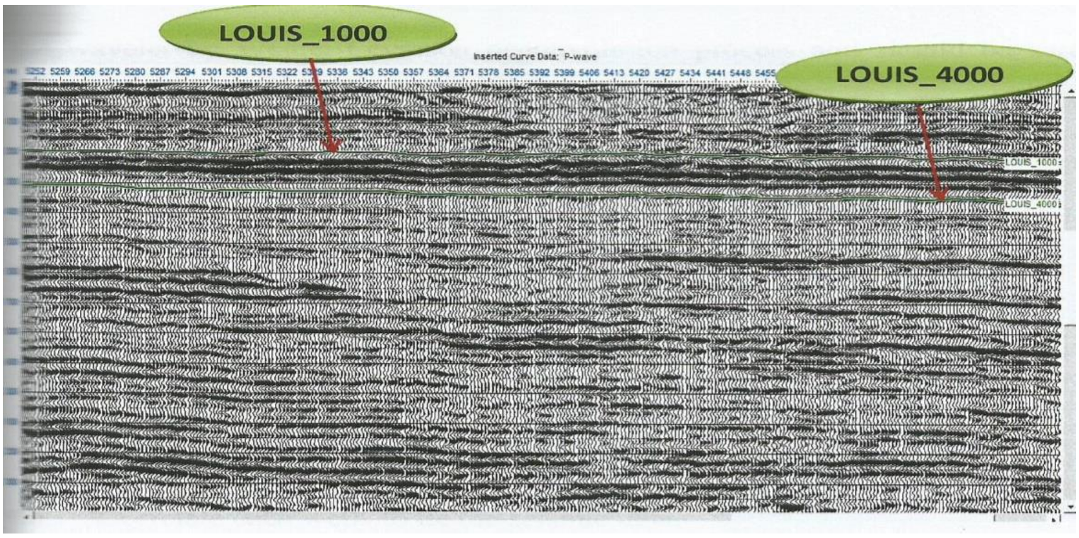

Figure 4 ; Seismic section showing horizon tops of LOUIS_1000 and LOIUS 4000

"The cross plot of Mu-rhO (rip) against Lamhda-rho (p) distinguishes the LOUIS_4000 reservoir into three zones namely; hydrocarbon sands (red ellipse), brine sands (yellow elipse) and shaly sands (blue eipsei . Low values of "Lambda-rho", corresponding to "low values of Mu-rho" indicate the presence of hydrocarbons within sand reservoirs . "The plot indicates p is more robust than in the discrimination of fluids in this field, and that dip values are unexpectedly relatively low for the reservoir sand (Bello et al., 2015)".

Another inference from the cross plot of "Vp ratio Vs" against "Lambda-rho" , shows that the blue ellipse can be used to outline the shale zone, the yellow ellipse indicates the "brine sand", and "red ellipse" maps out the "hydrocarbon saturated sand".

Furthermore, cross plot of water saturation (Sw) against Lambda-rho in shows low values of water saturation as represented by the green ellipse is used to indicate gas sand, moderate water saturation value is indicative of oil sand (red ellipse).

Using resistivity as the colour key, a cross plot Of "Mu-rhO" against "density" shows that the red ellipse which corresponds to low values of both rock properties can be used to describe hydrocarbon sand; the blue ellipse indicates brine sand. The resistivity color code delineates the clusters into high and low resistivity zones showing clean hydrocarbon bearing sand and reservoir sand having inversions of shale. Cross plotting Mu rho against density with density as color key, with density being a fluid discriminator and the density of gas being the lowest however, a neutron log will be required to make certain of this of it being a gas zone. The Vp/Vs against P-impedance will also give a clearer view, with gas sands having low Vp/Vs values.

The cross plot of Lambda-rho against Poisson's ratio shows the red sand which shows the lowest Lambda-rho values. The yellow ellipse shows brine. Poisson ratio has a higher value for shale (blue ellipse) than for brine sand and hydrocarbon sands. In the cross plot of acoustic impedance against porosity, the blue ellipse is a pointer to presence of shale, relating to high PT impedance and low porosity. The highest value of porosity is seen in the red ellipse and corresponds to hydrocarbon sands.

Also in the P-impedance and S-impedance cross plot , hydrocarbon is indicated by the red ellipse, which relates to low values of both rock properties, the yellow ellipse describes brine sand, and the blue ellipse shows the shale bearing zone of the formation.

Finally, the "VP ratio Vs" cross plot against "acoustic impedance" shows hydrocarbon indicated by the red ellipse, yellow eclipse shows brine sand, while blue defines shaly zone in the reservoir. This cross plot shows good "fluid and lithology" discrimination. Vp/Vs can also serve as a good discriminator against gas zones for fluid discrimination, due to gas having low value of Vp/Vs compared to oil and brine, and the corresponding impedance value also low for oil and gas.

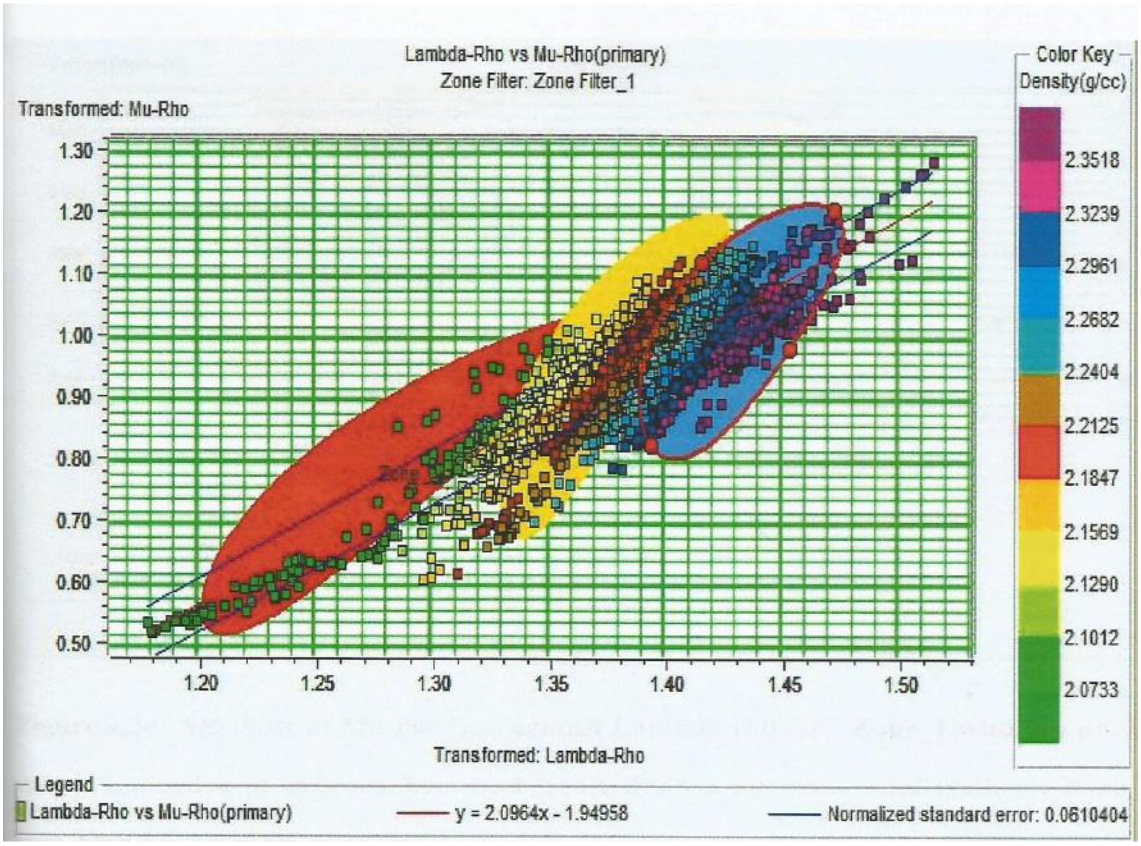

Figure 5; cross plot indicative of three zones ; hydrocarbon sands (red), brine sands (yellow) , shaly sands (blue)

8. ROCK PROPERTIES ATTRIBUTE ANALYSIS:

Inverted rock properties gotten from model-based inversion, acoustic impedance and shear impedance were used to generate rock attributes (simple combination of rock properties), using approach of Goodway et al., (1997) and the newest attribute Poisson impedance method of Quakenbush et al., (2006).

The purpose of this analysis is to discriminate between lithology and fluids within the selected LOUIS_1000 and LOUIS_4000 reservoir sands. The model shows low impedance values around and away from well control. Moving further from well control, there exhibits a reversal in amplitude which is indicative of a possible gas sand. This is further illustrate in the inverted P-impedance section. The reservoirs on both sections indicate a low acoustic impedance value from 18, 000 - 21, 500 (ft/s x glce). LMR inversion also shows low values around and away from the reservoirs, indicative of spatial distribution of fluid in the reservoir. However, clue to the effect of compaction and pressure with depth, values tend to increase, as also witnessed in the inverted P-impedance volume.

Horizon Slice

The inverted acoustic impedance slices for LOUIS_1000 reservoir clearly shows the wells situated around zones of low acoustic impedance indicated by the color key ranging from red to yellow to green in the volume.

The red colored zones indicate brine sand, which is seen around the well locations, corroborating with the history of the field being an oil rim reservoir with predominately brine and gas. The green color is indicative of zones with low acoustic impedance and could be attributed to gas zones with gas having expanded to occupy the space previously occupied by oil.

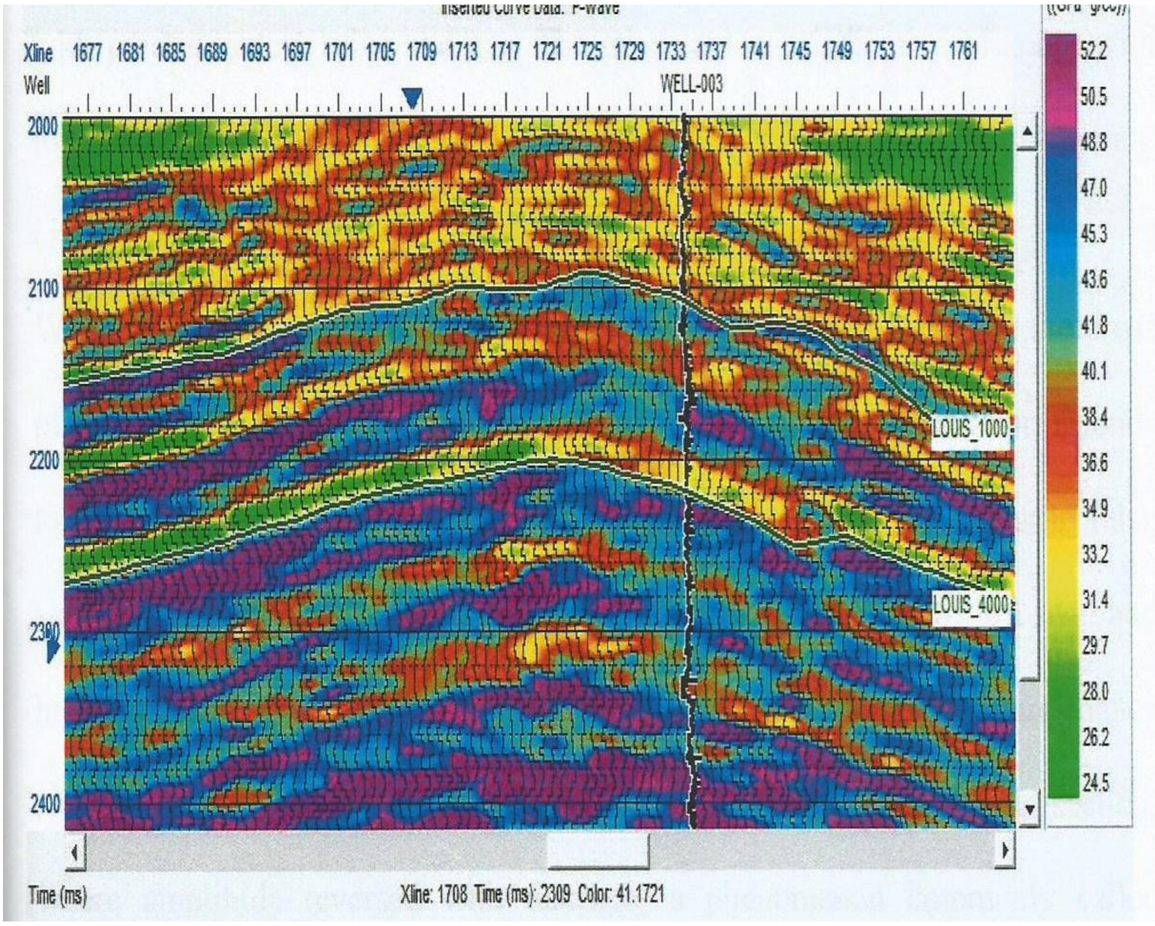

Figure 6; inverted LMR cross section with Well-003 superimposed on it showing low values indicative of hydrocarbon .

When the aboved diagram is compared to the behavior of acoustic impedance observed in the cross plot of P impedance versus S impedance, the above interpretation corresponds to the expected behavior of P Impedance which is very low for gas sand (also seen in the Mu rho against density cross-plot, moderately low for oil sand and high for brine sand.

Although this is was not seen in the Vp/Vs P-impedance cross-plot, it however was seen in the inverted P-impedance cross section where amplitude reversed with distance, a phenomenon commonly called “Amplitude Variation with Offset (AVO)”.

In the Lambda-Rho slice, at the zones having the wells are values ranging from low to very low, an indicator for the presence of hydrocarbon in the field.

9.CONCLUSION:

Determination of hydrocarbon bearing sands is a desirable goal for most chat characterization projects especially when the objective is to increase the level of confidence, putting into cognizance the associated risks in drilling and exploration activities. The present study has resulted in an inversion model calibrated with well log data through cross-plot analysis giving us an insight into the subsurface.

With the same result gotten on the cross-plot being repeated on the inverted horizon with well control, this goes to show that spatial distribution of rock properties not enclosed by well data could be trusted, and as such, a good tool for quality control (QC).

The “Vp/Vs - P-impedance” cross plot shows to be a good technique for identifying gas/light hydrocarbon especially shallow zones of unconsolidated sands. Likewise, the -i-p showed how effective it can be in discriminating fluid type within the reservoirs. The “Acoustic impedance” (Zp), “Lamda-rho” (p), and “Mu-rho” (pp) attributes when used for fluid discrimination and lithology, were accepted to be most robust within the reservoir in the cross plot analysis. Making this technique also impressive as an anomaly tool for understanding how the reservoir would behave in the presence of “fluids” and “artefacts”.

From the results and analysis of the inverted rock attributes considered, they reveal that some of the attributes are good fluid and lithology discriminator (Omudu et aL, 2007). Some are however affected by the influence of compaction, while some are not. Rock attributes that show less compaction effect from the analysis reveals that they are more diagnostic of fluid (oil and gas) at shallower or deeper sections, while the Acoustic impedance is diagnostic of fluid at shallow section the Lambda-Rho would diagnose fluid presence and type at deeper sections. This study has been able to identify spatial distribution of rock and fluid properties, which can come in handy when making developmental decisions. However, in the course of the research, anomalous zones without well control were discovered. Also, the seismic volume had a lot of chaotic amplitude which can undermine the stratigraphic and horizon interpretation proper.

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