SEISMIC INVERSION AND ATTRIBUTE ANALYSIS OF "UCHE" FIELD ONSHORE, NIGER DELTA

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Abstract: 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). From the results and analysis of the inverted rock attributes considered, they reveal that some of the attributes are good fluid and lithology discriminator

Key Words: Seismic, Niger Delta, Deconvolution.

1. INTRODUCTIONL

As a result of the risky nature of the exploration and production (E&P) industry, it then becomes necessary to not only limit spatial sampling of target reservoirs with well data. Wagner et al (2012) investigated post-stack seismic amplitude inversion, and attribute analysis and established its application in creating a quantitatiative1y, a prediction model of reservoir properties. It is well known now that geophysical technique application for reservoir studies goes beyond ascertaining geometry and determining depth to reservoir, and every reflection carries with it change in amplitude due to different acoustic properties between different reflecting interfaces, the principle aim of seismic inversion then becomes to transform these reflection data into a qualitative rock property, descriptive of the reservoir as is in the works of Barclay et al., (2008). Using zero-phase, true amplitude, and migrated data, a quantitative interpretation of rock and fluid properties can be gotten. A successful interpretation would provide parameters which include travel time, amplitude, event character and pattern and then several other information - lithology, fluid identification, hydrocarbon changes, depositional environments, faults - can be inferred from it (Sheriff, 1992).

Amplitudes are seen on volumes due to character difference of the interface of two layers. These rock properties usually affect the way seismic waves travel through rocks. They include compressional wave velocity (Vp), Shear-wave velocity (Vs), density (p), and their attributes (which is a simple combination of the rock properties), P- / S-impedances (Zp and Zs), Poisson's ratio (v) and incompressibility (p) and shear modulus (jip) (Dewar, 2001)

Amplitudes can indicate layering including spatial distribution of properties. (Brown, 1987). Analysing these amplitude is a reliable technique for reservoir analysis, monitoring and prediction, provides an enhanced insight into the heterogeneity of the subsurface.

2. OBJECTIVES:

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I. Cross plotting rock properties density, resistivity from the well logs and water saturation, Zp, Zs, Vp/Vs ratio, Poisson's (a) ratio, p, and tp obtained from rock property transform of the original well logs using the Castagna' s equation.

II. Determining P-Wav velocity reflectivity (Rp), S-wave velocity reflectivity (Rs), using approximates of Zoeppritz equation.

III. Invert Rp and Rs to produce P- and S- impedances (Ip and Is).

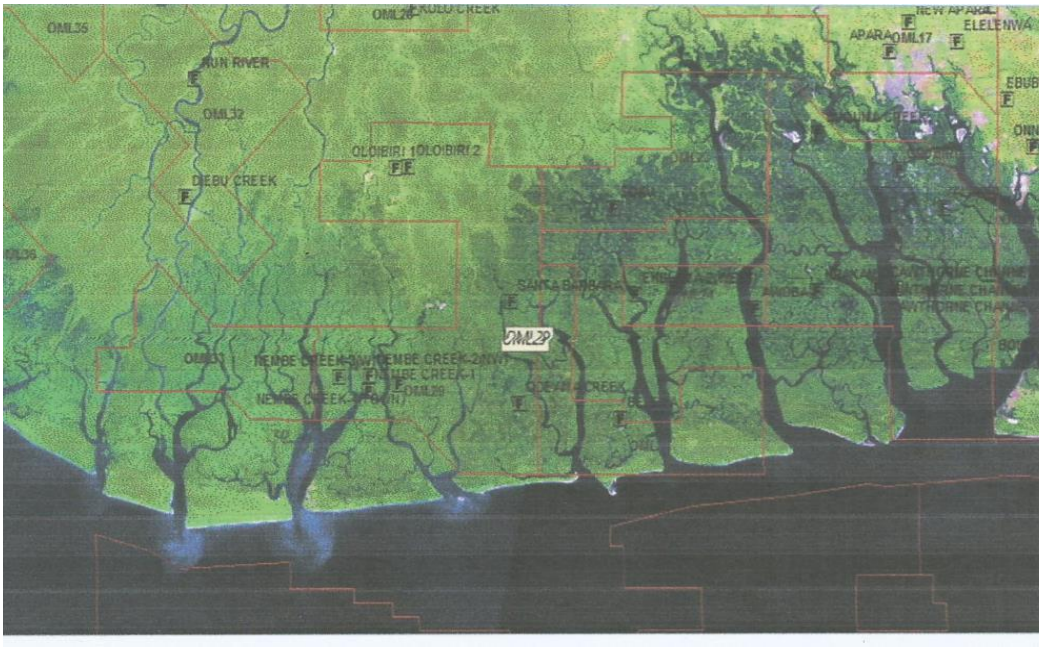
IV. Estimate Lame's incompressibility (Type equation here.) and shear moduli (pp).

V. Generate and display attributes (ASp and i'p, amplitude) sections to discriminate fluids and lithology in Uche field. These will further help in future planning, putting risk factor, when making development decisions.

The seismic volume used for the inversion appear to be severely clipped. It did not have any information in some in lines and cross-lines. The nature of the transparent amplitude, especially at the boundary fault where it was particularly noisy and chaotic made it difficult to pick the top sands for the reservoirs of interest. Furthermore, there were no check-shot data for Well-003 and Well004, however, Check-shot-data for Well-002 was used for Well-003 due to their closeness with respect to distance apart. Same was done for Well-004, although the distance apart between wells -002 and -004 appear to be further apart.

3. LOCATION OF STUDY AREA:

The study area under consideration is situated in the coastal swamp of the Niger Delta (SPDC, 2005). The reservoir under consideration is an oil rim reservoir with sizeable recoverable oil reserves.



Figure;1 Location Map of Uche field in the Niger Delta

4. LITERATURE REVIEW:

4.1 The Forward and Inverse Problem

One of the goals of geophysical exploration is to use wave propagation to try and model subsurface through a given set of data; this process is known as "Forward Modelling" (Snieder, 1998; Treitel and Lines, 2001). In exploration seismic for example, the forward model consists of model of the subsurface, source and receiver characteristics, and the laws of physics that describe seismic wave propagation (Tetyukhina, 2010). It refers to the empirical relationship used to generate a synthetic seismic data (Cooke and Cant, 2010). With inverse problem, the reverse is the case, where the aim is to reconstruct the subsurface from a set of measurements; seismic recorded data.

Attempts to get solution to the problem were made more than 25 years ago by Lailly (1983) and Tarantola (1984). Owing to the complication of the wave propagation theory a number of abridging assumptions are made in the present inversion technique. In practice, uncertainties seem unavoidable, "and therefore an inverse problem should be formulated using probability theory". Well known problems in inversion are non-uniqueness, and uncertainty. Moreover, the data, source-receiver characteristics, noise models, forward model, data processing, etc., are imperfect. All maximum likelihood methods use all this information.

Methods that use Bayes' nile, by contrast, employ prior information about the solution to solve the problems mentioned.

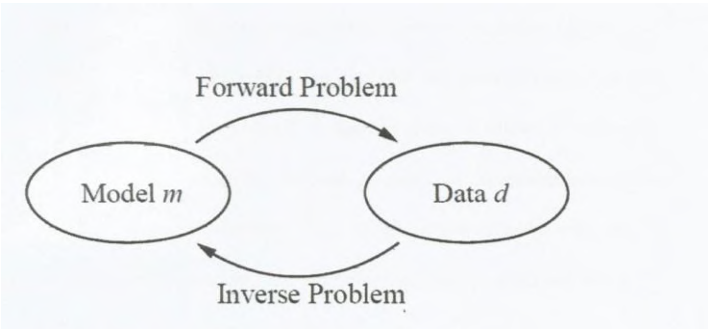


Figure 2 : An illustration showing the conventional division of a problem into a forward and inverse problem, modified from Snieder (1998).

4.2 Statistical and Probabilistic Approach to Inversion

According to Rothman's (1985), when there exists no initial idea of what model parameters may be, residual states estimation, statistical mechanics, and nonlinear inversion may be used. "The non-linear inversion is set as a problem of Bayesian estimation, in which the a-prior probability distribution is the Gibb's distribution of statistical mechanics". The Gibbs Markov model provides guidelines for the reduction of a large nonlinear inverse problem into small, independent and computationally manageable sub-problems that does not depend upon a good initial guess.

5. METHODOLOGY:

5.1 Datasets

The data used in this work include "well log and a 31 post-stack seismic data from Uche field within the Niger Delta basin provided by SPDC Port Harcourt.

The data consist of suites of well logs from four wells, with no unique well name (Well-00l, Well-002, Wefl-003, and Well-004). These data were analysed using "Geoview" of the "Harnpson-Russell software (HRS)". The well log data was evaluated using "eLog", and the seismic and rock attribute cross-sections were created using "STRATA" and "eLog" from the Hampson-Russell software.

5.2 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 aparalic sequence of sand and shale. The wells used for the analysis are located at the north - eastern region of the field.

Table 1: Table showing the available logs in the four wells used in the study

WELLS	DEPTH REGISTRATION (ft)	AVAILABLE LOGS
WeIl-OO1	10436-13576	CALl, GR, DT, POR, RHOB, Checkshot data, Deviation Survey
Well-002	0-13000.5	CALl, GR, DT, RES, RHOB, Checkshot data
Well-003	0-13000	CALl, GR, DT, RES, RHOB, Sw
WeH-004	0-12200.5	CALL, GR, DT, RES, RHOB,

5.3 Wavelet Extraction

Wavelet analysis involves estimation of "a filter, which best fits well log reflection coefficients to the input seismic at well location". The wavelet extraction method applied is model supported, using seismic and well information. A wavelet is completely defined by its amplitude spectrum (amplitude versus frequency plot) and its phase spectrum (phase-shift versus frequency plot). Accurately extracting a wavelet is essential to the success of the inversion. Two wavelet extraction methods have been applied in this work; they are statistical wavelet extraction and wavelet extraction using the full log.

The former uses seismic traces and available wells near the seismic to extract the wavelet by Wemer-Levmson deconvolution process and should be zero- phased. The latter procedure uses the log to generate the wavelet. The extracted wavelet from the cube — statistical wavelet - was then used in any process requiring a wavelet, such as well-to-seismic correlation,, inversion or wavelet deconvolution.

6. WELL-TO-SEISMIC CORRELATION:

Before creating a model for seismic inversion, an accurate depth-to-time conversion must be performed to make the vertical scale of the well log Al data match the vertical scale of the seismic volume to allow for spatial correlation.

This conversion is carried out using the sonic log and the initial two-way travel time for the first sample that provides the highest correlation coefficient between synthetic and the observed trace. This is commonly known as well- seismic tie (White and Hu, 1998). This process manually stretches or squeezes the log - to improve the time relationship between the target log and the seismic attributes.

Once any needed bulk shift and stretch are applied, the well log depth-to-time map will match the measured P-wave seismic times. This process simultaneously creates a composite trace from the seismic and a synthetic seismogram from the log. The Al log (the product of P-wave log and density log) is then used to compute the reflectivity series for the synthetic seismogram.

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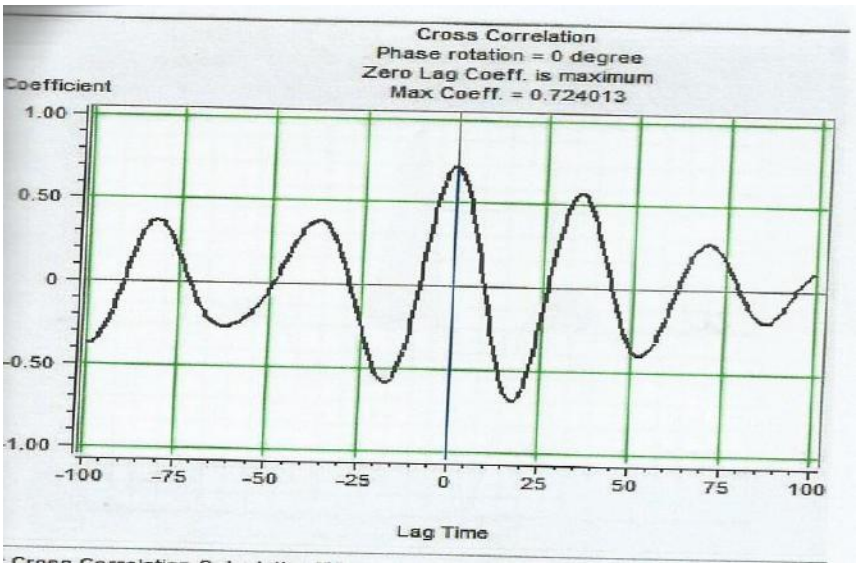


Figure 3; Maximum correlation coefficient of extracted zero- phased wavelength used

6.1 Well-log rock attributes estimation

For this study, empirical relations in the HAMPSON RUSSELL eLOG tool was used create rock attributes. These attributes include Castagna's shear wave velocity equation , Vp/Vs ratio, and acoustic impedance. Castagna et al, (1985) have given empirical relations from estimating Vs from Vp in multimineral, brine-saturated rocks based on empirical, polynomial Vp-Vs relations in pure monornineralic lithology (Castagna et at., 1993). This rock physics algorithm was used to generate the missing log and other rock attributes, the operation considered in the eLOG tool include Castagna model, LMR operation to generate Iamda-rho and murho rock attributes, "P- and S impedance attributes", "Vp ratio Vs", 'poisson ratio", and "water saturation".

7. RESULT AND DISCUSSION: MODEL-BASED INVERSION

A model-based deconvolution was used to invert the post-stacked seismic sections to pseudo-velocity sections. The model-based inversion develops an impedance profile that best fits the synthetic trace and the seismic trace in a least squares sense using an initial guess impedance. "It uses a forward model to produce a synthetic seismic data as part of the inverse algorithm". The wavelet is then scaled to compensate for the difference.

This iterative process for updating the estimated reflectivity requires input parameter. The input parameter were obtained from the "sonic and density logs" of Well-002, Well-003 and Well-004, which are used to produce a property model that forms the input to a forward model and output of a seismic inversion, During this process, each well was stretched to get a match of the impedance contrast with the formation tops associated with the horizon of interest. A flowchart of the model-based inversion approach and the error analysis showing a small enough error trace.

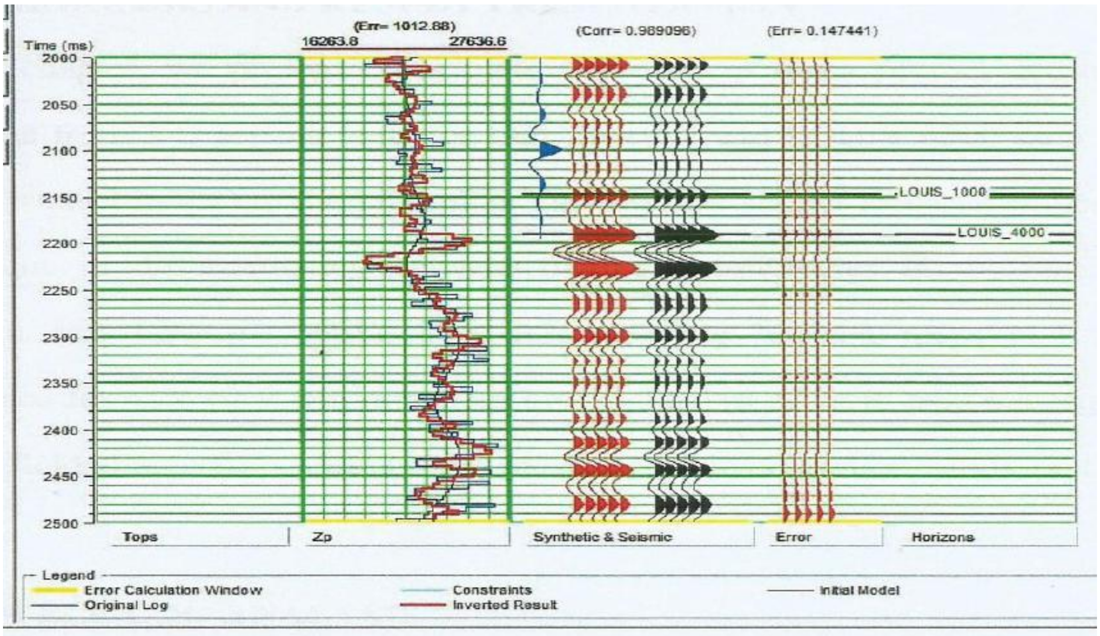


Figure 4; Result obtained after applying the model-based inversion at Well 002

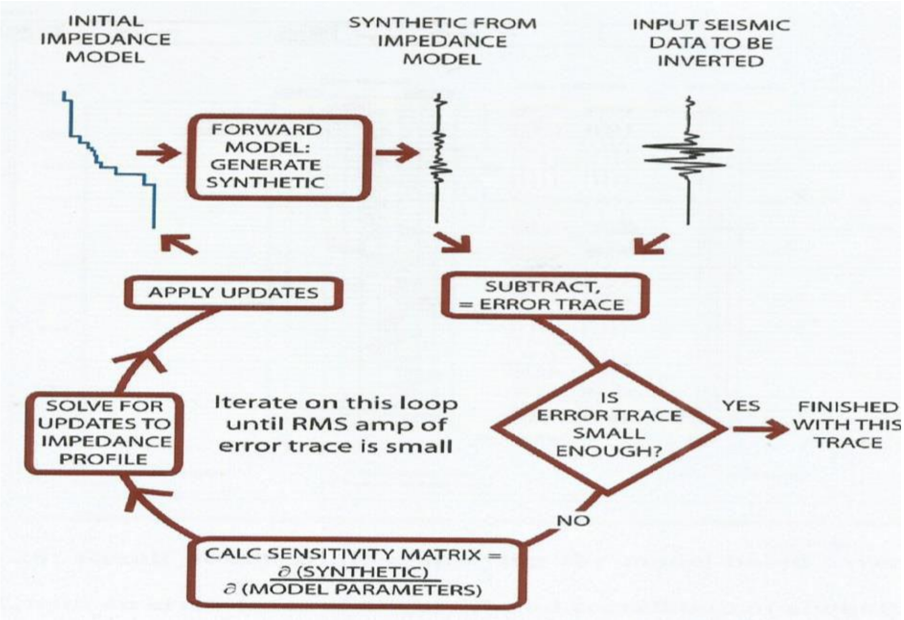
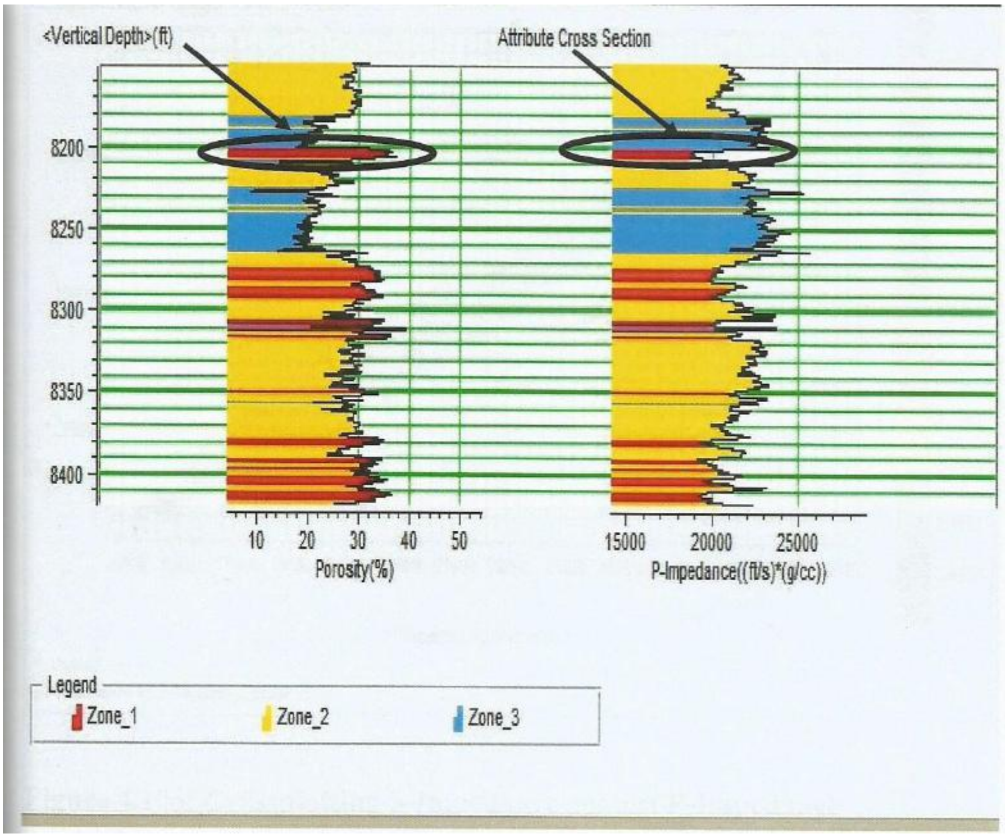


Figure 5; Flowchart of the iterative loop used in model-based inversion approach (After cooke and cast, 2010)

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 elipse 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; 6 Attribute cross section; showing high porosity (red) hydrocarbon sands

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

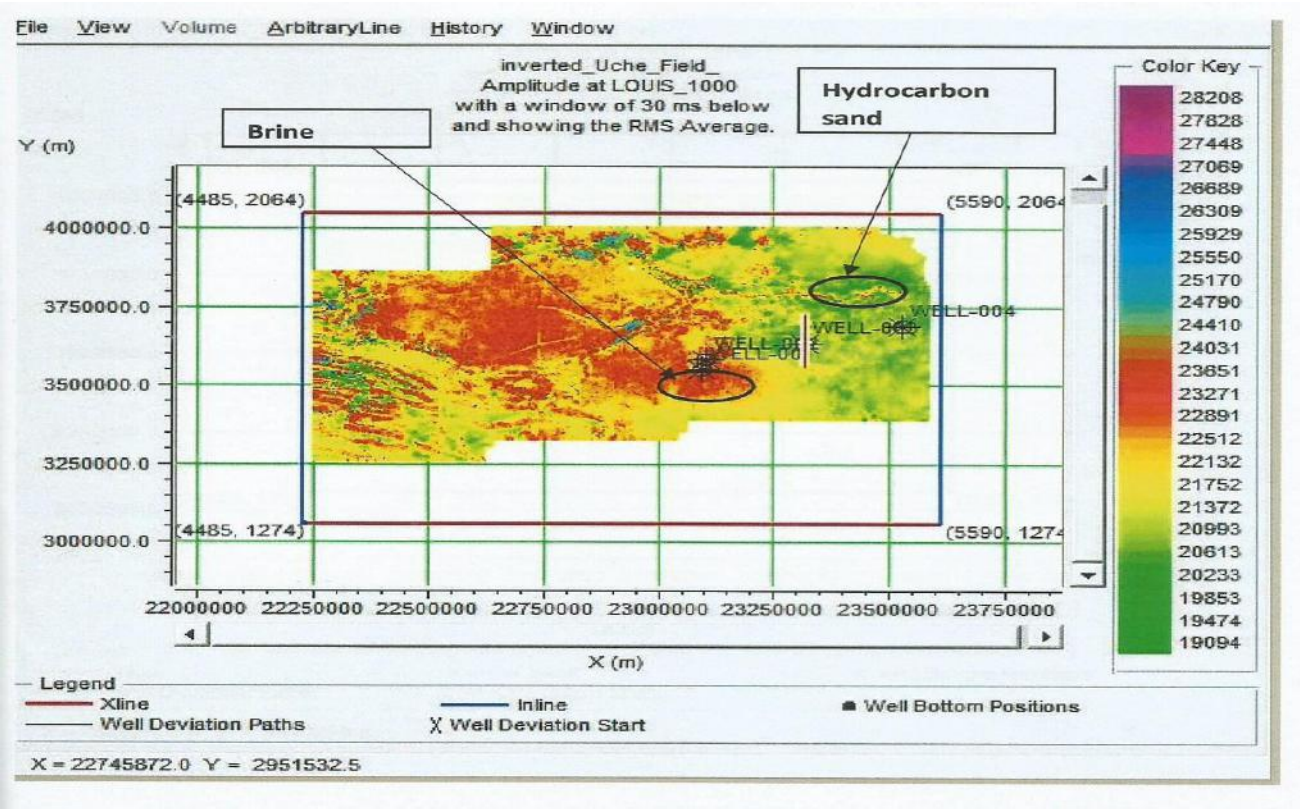


Figure 7; inverted acoustic impedance slice for LOIUS_1000brine conventional region as well as amplitude gas sands

When 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.

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