Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2017, 4(4):290-298**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Evaluation of Hydrocarbon Viability and Production in Niger delta basin, Nigeria

Acra E.J.[1], Ogbonna-Orji O.C.[2], Adiela U.P.[3]

[1,2]Centre of Petroleum Geosciences, University of Port Harcourt, Nigeria
[1]Department of Geology, University of Port Harcourt, Nigeria
[3]Department of Petroleum Engineering, Nigerian Agip Oil Company, Port Harcourt, Nigeria

Abstract In recent times, there has been a growing need to understand as well as evaluate fluid movement, pressure and temperature changes as hydrocarbon is produced in any field in the oil and industry. This has made the acquisition of 4D seismic important. In this study, time-lapse Lion of hydrocarbon production using rock properties and attributes obtained from well and 4D seismic data comprising of two 3D seismic volumes acquired at different times, has been successfully applied in an offshore Niger Delta field. Cross-plots of the rock attributes were carried out on reservoir D2000 across three wells, to test their sensitivity to fluid type lithology, and to constrain the interpretation of the time-lapse inversion results. Lambda-rho, density, and P-impedance gave the best response to fluid among the cross-plotted attributes. Therefore, rock properties and attribute analysis can give Geoscientists greater confidence towards understanding fluid movement and better reserviour characterization over time.

Keywords Evaluation, Hydrocarbon Viability, Production, Nigeria

Introduction

Rock properties are the properties of a rock which determines or affect how seismic waves physically travel through the rock. They include but not limited to P-wave velocity, S-wave velocity, and density. Rock attributes, on the other hand, generally refers to the combination of two or more these rock properties. Attributes can be combined to make new attributes. Transformation of attributes are sometimes given physical property names (such as porosity, fluid saturation, Lithology, etc) usually based on local cross plots and local correction with borehole logs or other measurements.

Objective of the Study

The objective of this study is to

- Cross-plot different rock attributes in order to test fluid sensitivity
- Estimate Acoustic Impedance from seismic amplitudes using model-based inversion
- Map our regions of remarkable 4D changes by comparing attributes on base and monitor.

Therefore, the study will focus on qualitative measure of these effects on rock properties and attributes under consideration while attempting to delineate pockets of bypassed hydrocarbon

Location of the Study Area

The data-sets used for the study were acquired from an offshore Niger Delta oilfield, South —South Nigeria. The Niger delta is situated on the continental margin of the Gulf of Guinea in Equatorial West Africa, at the Southern flank of Nigeria bordering the Atlantic Ocean between latitude3°N and 6°N, and longitude 5°E and 8°E.

Stratigraphy of the niger delta

The established Tertiary sequence in the Niger Delta consists, in ascending order, of the Akata, Agbada, and Benin Formation. The strata composed an estimated 8,535 m (28000 ft) of section at the approximate depocenter in the central part of the delta.

Akata Formation

The Akata Formation which is the basal unit of the Cenozoic delta complex is composed mainly of marine shales deposited as the high energy delta advanced into deep water [2]. It is characterized by a uniform shale development and the shale in general is dark grey, while in some places it is silty or sandy and contains especially in the upper part of the formation, some thin sandstone lenses.

The Akata Formation probably underlies the whole Niger Delta south of the Imo Shale outcrop of the Paleocene age from Eocene to Recent (The Akata Formation has been penetrated in most of the onshore fields between 12,000 and 18,000 ft (~3,700 – 5,500 m) and in many of the offshore fields between 5,000 and 10,000 ft (~1,530 – 3050 m); however, the maximum thickness of the Akata Formation is believed to average 20,000 ft (~7,000 m).

For all practical prospecting purposes, the top of the Akata Formation is the economic basement for oil; however, there may be potential for gas dissolved in oil field waters under high pressure in the deeper formation.

Agbada Formation

The Agbada Formation is a paralic succession of alternating sandstones and shales, whose sandstone reservoirs account for the oil and gas production in the Niger Delta [4].

The formation consists of an alternating sequence of sandstones and shales of delta-front, distributary-channel, and deltaic-plain origin. The sandstones are medium to fine-grained, fairly clean and locally calcareous, glauconitic, and shelly. The shales are medium to dark grey, fairly consolidated, and silty with local glauconite.

The sand beds constitute the main hydrocarbon reservoirs while the shale beds present form the cap rock. These shale beds constitute important seals to traps and the shales interbedded with the sandstones at the lower portions of the Agbada Formation are the most effective delta source rocks. Petroleum occurs throughout the Agbada Formation of the Niger Delta.

Benin Formation

Benin Formation attains a maximum thickness of 1,970m (6,000ft) in the Warri-Degema area, which coincides with the maximum thickness (*i.e.* depocenter) of the Agbada Formation. The first marine foraminifera within shales define the base of the Benin Formation, as the formation is non-marine in origin. Composition, structure, and grain size of the sequence indicate deposition of the formation in a continental, probably upper deltaic environment. The age of the formation varies from Oligocene (or earlier) to Recent [5].

Literature Review

It has been appreciated for some time that saturation and fluid pressure changes in a reservoir can lead to detectable changes in seismic attributes. Petrophysical studies have shown that seismic properties of rocks are influenced by changes of pore fluids, pressure and temperatures, which commonly occur during the production of hydrocarbon reservoirs. Time-lapse seismic surveys have evolved into a very promising, intensely investigated technique which .has been to monitoring the movement of fluid and pressure fronts, and water-oil contact during hydrocarbon production [6].

By analyzing changes of multiple seismic surveys acquired over a producing reservoir, such as travel time, amplitude, velocity, impedance etc, time-lapse seismic data can provide valuable insight on dynamic reservoir properties such as fluid saturation, effective stress and temperature. Four dimensional seismic monitoring is maturing as a technology and it is becoming a tool in reservoir management [7], still the methodology is advancing, and new techniques are under development for pressure and fluid saturation changes over time. Numerous theoretical, laboratory and field researchers have carried out studies aimed ultimately at

characterizing it and clearer imaging of the subsurface. Certain rock properties and attributes have been found to be diagnostic of lithologies and fluids, and thus effective for reservoir characterization and time-lapse analysis.
It was showed that Vp/Vs ratio of gas saturated rocks often increase markedly with increasing effective pressure and decreases slightly with increasing temperature. However, when the rocks are saturated with fluids, Vp/Vs ratio usually decreases as effective pressure increases in low pressure ranges, due to the closures of the thin pores and cracks of the rocks and the ratios are insensitive to temperature changes [8].
It was showed crossplots of well-log derived lambda-mu-rho attributes and their use as discriminant of pore fluids and lithologies, while Hilterman (200l)'s numerous rock property and attribute crossplots for lithology and pore-fluid identification was able to show that elastic impedance (EI) is quite similar to Poisson's ratio using the crossplots of 0. 51n (Al) against 0.5 In (EI) and 0.5In (AI) against Poisson's ratio [9].

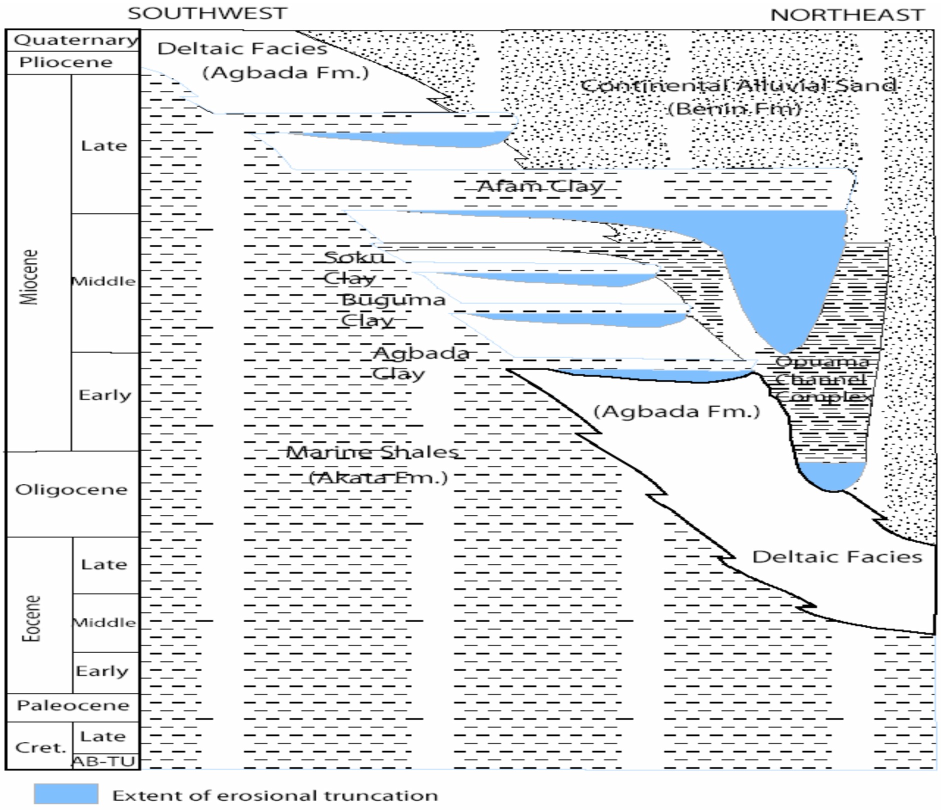

Figure 1: Stratigraphic column showing the three formations of the Niger Delta [4].

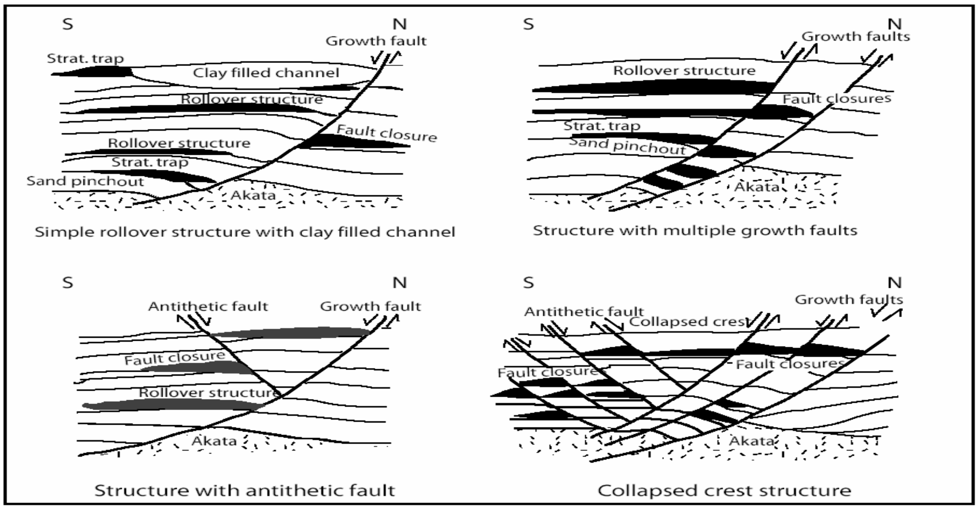

Figure 2: Principal types of oil-field structures in the Niger Delta with schematic indications of common trapping configurations [4]

Methodology and Research Design

The suite of well logs and seismic data (3D-Base and 3D-Monitor) includes Directional surveys, Check shot, Well (reservoir) markers of the three wells, and Horizons

Hamson-Russell Suite (HRS) [10] is a geophysical tool that has been providing innovative seismic solutions since 1987. Designed by Dan Hampson and Brian Russell, under the CGG Veritas Company, the tool encompasses all aspects of seismic exploration and reservoir characterization, from AVO analysis and inversion to 4D and multi-component interpretation. This suite (HRS) also provides accurate data through the integration of geological and geophysical parameters and algorithms, thereby interpreters with unique information needed to qualify, quantify and as well as increase reserves and prospects. Thus using this tool, the E-log, Strata and Emerge programs were utilized for well-log editing, Gassman's fluid substitution and inversion processes. Therefore, the choice of this tool was based on its built in models which aids in the generation of other rock property and attribute models as well as its user friendliness.

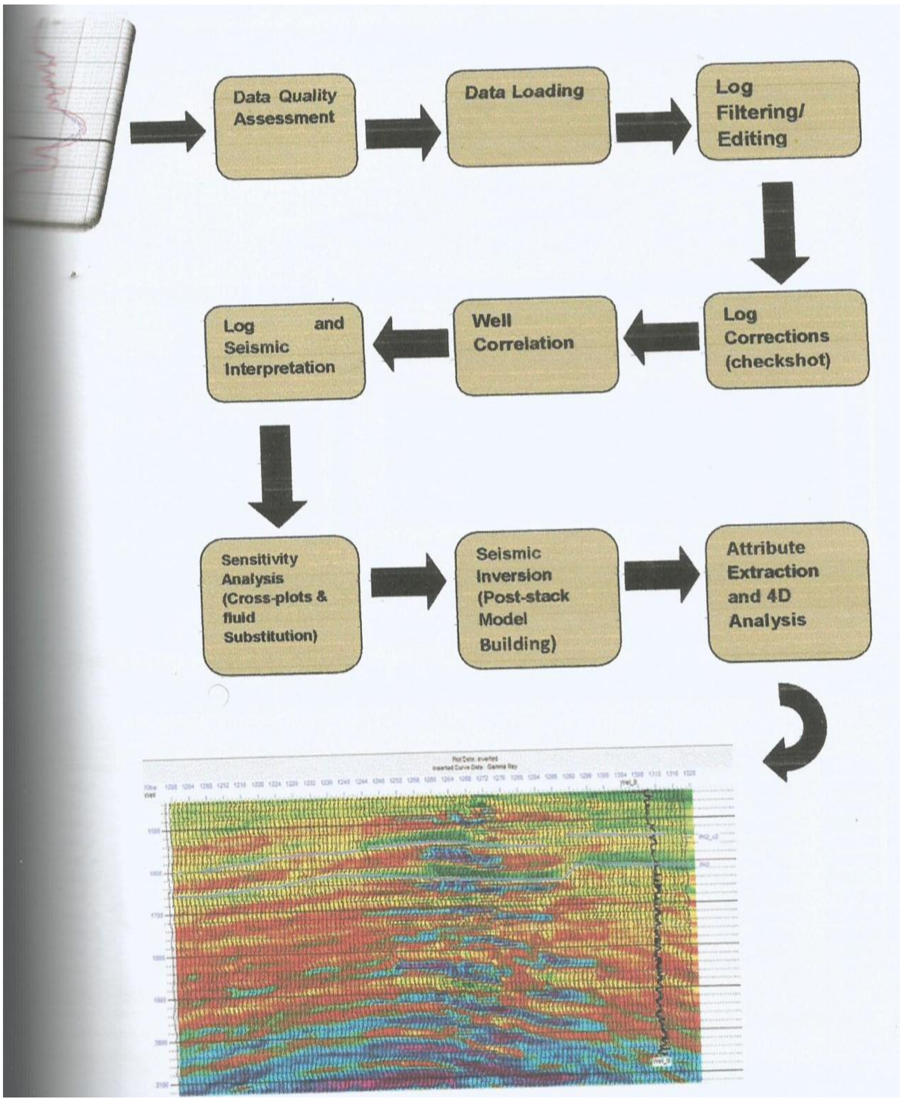

Figure 3: Work flow approach to the research work

Data quality assessment

The well logs were first checked for quality in order to preempt any challenges. It was discovered that none of the wells has neutron log and so it became difficult to accurately and correctly define hydrocarbon type across the wells.

Data loading

All data sets used in this research were imported into the software through the Geoview platform of the tool [10]. With the data sets in LAS format, it became possible to load these data sets by calling up the "import data" option as illustrated below. Notice imported Wells A, B & C with their X and Y coordinates.

Petropiiysical Formation Evaluation

Petrophysical formation evaluation was performed on the well logs to identify probable hydrocarbon bearing zones as well as lithology types. Within the wells investigated, analysis on gamma ray, resistivity, density and porosity logs revealed some reservoirs marked at various. These reservoirs were characterized with low gamma reading, high resistivity, low bulk density and high porosity signatures designating them eligible for further investigation. Prediction of reservoir properties away from the wellbore as covered by the seismic in the field us be possible using these reservoirs. The delineated reservoirs are the D1000, D2000, and D5000 as it cuts across the three wells. However, emphasis was laid on the D2000 reservoir its thickness ranging from 583 lft-5940ft in well A and about 5830ft-5966ft in well B.

Seismic Horizon Picking

A horizon is a surface separating two different rock layers. A horizon map on the other hand, a surface associated with a reflection that can be carried over a large area thereby generating a map based on the reflection event. These horizons are used to guide the interpolation between the wells and the seismic data. The depth of these sand tops is then converted to time using the check-shot data, wherein the nearest, brightest and most continuous reflection mapped on the cross-lines and in-lines respectively. In this research, the horizons picked along the troughs of the seismic section and upon correlation; these horizons were found to mark the top and bottom reservoir sections of D2000 reservoir within the field, using time equivalent of the top of the D2000 reservoir located on the well path. Two seismic horizons, PH2_version2 and PH2 were however imported into the seismic data which was used for well-to-seismic tie.

Table 1: Reservoir D2000 Information across wells

WELL NAME	MARKER	TOP (ft)	BASE (ft)	OIL DOWN (ft)	HCWC (ft)	AVE POROSITY (%)	WATER SATURATION (%)
Well A	D2000	5831	5940	-	-	28	13
Well B	D2000	5830	5966	-	-	28	9
Well C	D2000	5983	-	5983	5983	32	15

Rock Property and Attributes Crossplot Analysis

Understanding key accurate seismic interpretation parameters remains paramount for any reserviour characterization [11-12]. Cross-plotting has evolved to be a widely used technique in attribute analysis as it enables the simultaneous and meaningful evaluation of two attributes with ease [13]. One attribute alone may not explain anomalies related to oil and gas bearing units. By cross-plotting multiple seismic and well log attributes, interpreters can easily visualize the hidden relationships between the attributes and thus identify hydrocarbon indicators in the reserviour. Generally, common lithology units and fluid types tend to form separate clusters, thereby helping in making a straight forward interpretation.

Using the available logs from the three wells, other attribute logs were generated using the Transform equation program in the [10] geophysical suite. Shear logs were not available in the wells and so Vs was generated from P-wave velocity logs using [10] equation, which is valid for brine filled elastic rocks only. For hydrocarbon filled zones, the P-wave modulus equation of Gassman was used to correct the P-wave velocities before utilizing it for S-wave velocity generation. Attributes derived includes P and S-Impedance, Mu- rho, Lambda-rho, Poisson Ratio and Vp/Vs ratio. The cross-plots performed were to examine the fluid discrimination capability of the rock properties and attributes as well as its lithology response. The colour codes give a 3-dimensional picture of the attributes responses while the pattern of clusters gives a qualitative measure of the discrimination. Lambda-rho, Mu-rho, S impedance, P-impedance, Poisson's ratio and Vp/Vs ratio were cross-plotted while using Gamma ray, Density, Resistivity and Water saturation as colour codes. Note that the depth analyzed ranges from 5830ft-5966ft which encloses the D2000 reservoir sand in well B. In each cross-plot, three zones, namely hydrocarbon sands (red ellipse), brine sands (blue ellipse) and shale (green ellipse) were identified and marked.

Results and Interpretation

The Hampson-Russell [10] suite provided a platform on which volumes of rock properties and attributes identified to be sensitive to fluid and lithology discrimination were extracted using the inverted acoustic impedance volumes and well logs data by implementing a probabilistic neural network algorithm. The results obtained from the cross-plot and fluid substitution analysis formed the basis on which the attributes were extracted. Slices for different properties and attributes are shown below.

The attributes extraction was performed along the PH2_v2 and P112 seismic horizons serving as reference point for taking the slices, with a window of l0ms which implies 5ms above and below the picked horizons. Rock properties and attributes such as Bulk Density, Porosity, Water Saturation, Acoustic Impedance, Lambda-rho, Mu-rho and Poisson's ratio slices were extracted from the Base and Monitor volumes and analyzed. On analysis, we find segments with attribute signatures that correspond to those expected of hydrocarbon charged sands as established by cross-plot analysis. Changes in the rock properties and attributes were evaluated by comparing the baseline seismic and monitor slice with the 4-D difference slices generated from acoustic impedances. From the analysis, production induced effects due to fluid and pressure changes were mapped and sections of potentially un-drained/by-passed hydrocarbons detected.

Analysis of Lameda-Rho Slices

A cross-section of Lambda-rho is used for pore fluid discrimination, as it distinguishes between hydrocarbon charged sands and brine charged sands. In other words, this attribute describes the compressibility or incompressibility of a rock unit. When compression (hydrostatic stress) is applied to a rock, the compression squeezes the grains causing a decrease in the pore space. If fluids such as oil or water are introduced into the pore space, the will reduce the compression by increasing the pressure against the grains and produce a more incompressible rock. The introduction of gas will however give a low incompressibility [8]. This is because gas cannot resist the compression as effectively as oil or water. Thus, very low values of this attribute indicates gas charged sands, low values indicates oil sands while brine filled sands are marked with high values. Lambda-rho values from the slice ranges from 59 to as high as 26.6 (ft/s*g/cc)2.

The Base slices of PH2_v2 and PH2 horizons taken around the producing well locations showed relatively low values of the lambda-rho attribute as compared to the Monitor. This is as expected since they are hydrocarbon charged sands. The high values of lambda-rho on PH2 horizon as observed on the monitor especially around wells A and C from 22.3 (ft/s*glcc)2 to 25.0 (ftls*g/cc)2 must have resulted from hydrocarbon production and subsequent replacement/influx with brine (figure 4). Other zones (HC1 and HC2) on PH2 and PH2_v2 horizons with consistent low values of lambda-rho are probable bypassed/hydrocarbon charged sands.

Analysis of Poisson's Ratio Slices

Poisson Impedance (PT) attribute is the difference between P-Impedance and scaled S Impedance arising from the difference of two squares of the lambda-rho (?p) attribute where the scalar (c) can be determined from the slope of the regression line between Ip and Is. Using well data, if the PT curve is correlated with the gamma ray curve, porosity curve or water saturation curve for different values of (c), it is possible to determine the maximum correlation coefficient in each case. It is more sensitive to gas effect than oil, and also with relative sensitivity to oil effect when compared to the pi.tp ratio attribute [11-12]. Low Poisson Impedance value ranges from 2.7-3.0 x 103(ft/s*g/cc)2 while values above 3.1 x 1o3(ft/s*g/cc)2 are considered high.

Poisson's ratio slices are shown in figure 5. A close observation of these slices, revealed a slight change in the volumes. On both PH2_v2 and PH2 horizons, the value of Poisson's ratio was low on the Base volume indicating hydrocarbon sands. This agrees with theoretical explanations as hydrocarbon charged sands are associated with low values of Poisson's ratio. On the other hand, as hydrocarbon is produced and replaced with brine in a well location, higher values of Poisson's ratio is expected as observed from the Monitor on both horizons within the well location. Zones HC1 and HC2 on both horizons, which exhibits consistent low Poisson's ratio value indicates hydrocarbon charged sand.

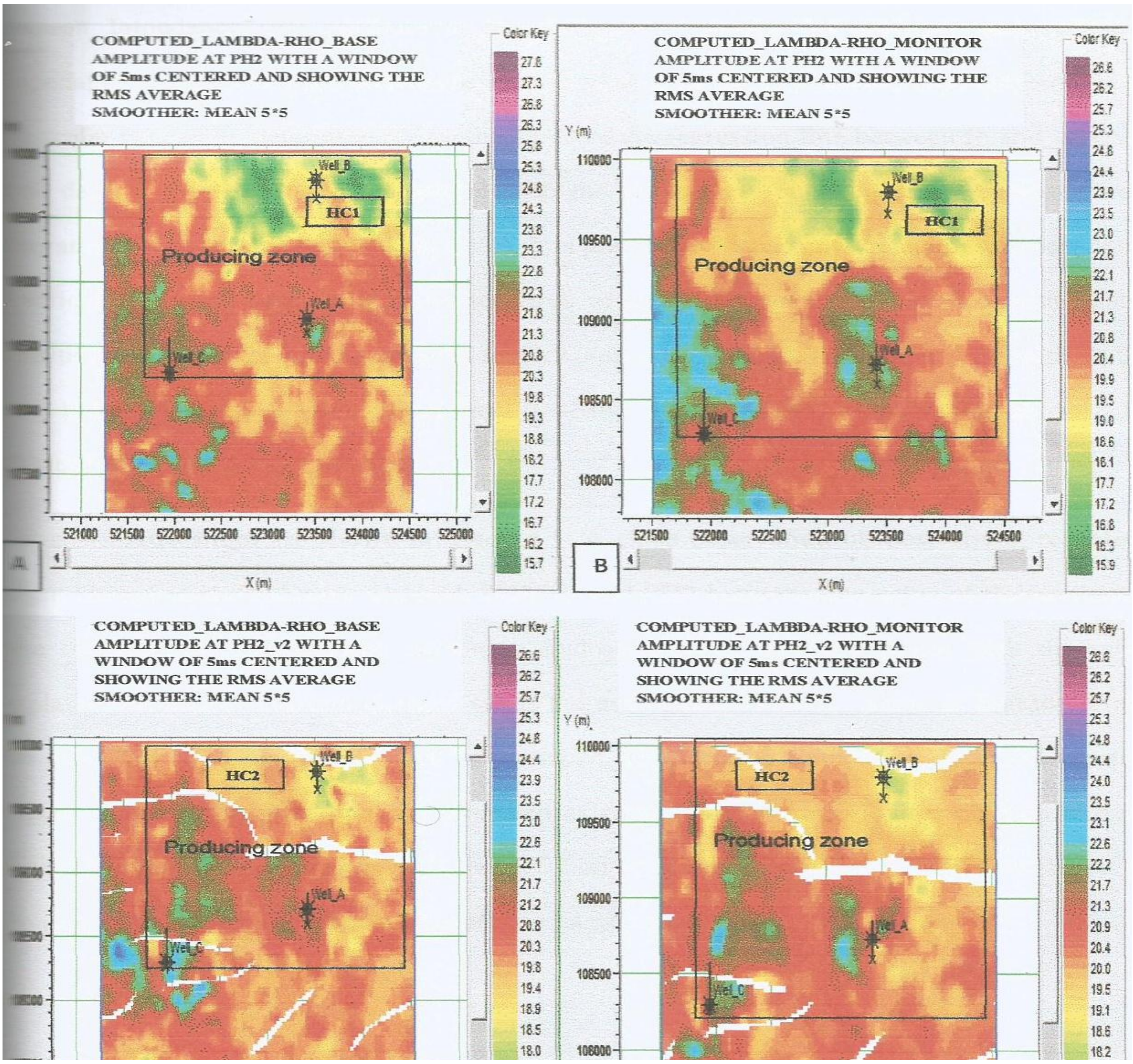

Figure 4: Lamdode-Rho Impedance of PH2 and PH2-v2 horizons on (a) Base and (b) Monitor

Discussion of Results

Time-Lapse Evaluation of hydrocarbon production has been investigated using rock properties and attributes in a Niger Delta field [11]. The well log data were edited and moderately de-spiked using a median filter operator while hydrocarbon reservoirs were chosen using the gamma ray, resistivity, density and porosity logs. The reservoirs delineated were D1000, D2000 and 15000. However, the D2000 reservoirs was further analyzed for-hydrocarbon presence as validated by the logs.

Well derived rock properties and attributes were generated using basic rock physics transforms from the E-.log program of the Hampson-Russell geophysical suite after well to seismic correlation has been performed.

Rock properties and attributes derived includes P and Simpedance, Mu-rho, Lambda-rho, Poisson Ratio and Vp/Vs ratio logs having generated the S. wave log using Castagna's equation. Cross-plots of these attributes within the D2000 reservoir revealed interesting features. From the cross-plot analysis, P-impedance, density, lambda-rho, mu-rho and Poisson's ratio were more robust in terms of fluid and lithology discrimination having high sensitivity to fluids within the reservoir. Three probable zones; hydrocarbon, brine and an intercalation shale layer were delineated.

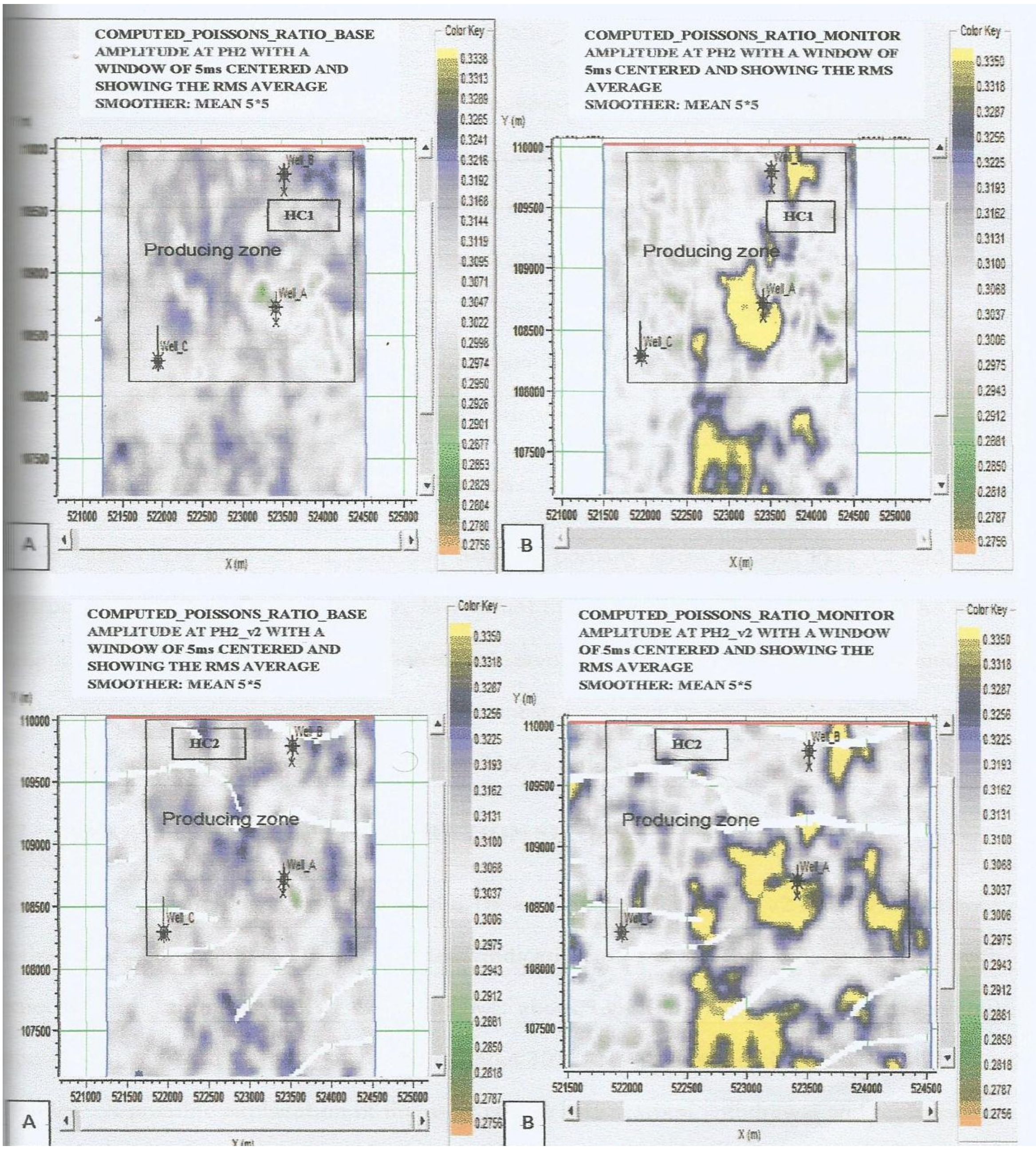

Figure 5: Poisson's Ratio Impedance Slices of PH12 and PH12_v2 (a) Base and (b) Monitor

Owing to interesting results from the cross-plots, a further investigation of the 1)2000 reserviour using the Gassmann's fluid substitution was performed. Again, from the modeling, density, lambda-rho and P-impedance were most robust in terms of fluid sensitivity to oil and gas saturations. Thus, validating results gotten earlier from cross-plot analysis. These results thereby provided the platform for initiating inversion processes on which acoustic impedance volumes were generated from the Base and Monitor seismic sections. Analysis of the effects of hydrocarbon production on rock properties and attributes was then carried out using the inverted slices.

Attribute slices were obtained from the P112 v2 and P112 seismic horizons. These attribute analysis on PH2_v2 showed low acoustic impedance, lambda-rho, bulk density, Poisson's ratio, water saturation and mu-rho on the Base seismic slices particularly within the producing well locations due to the presence of hydrocarbon. On the other hand, there was observable remarkable increase in these attributes as indicated on the Monitor seismic section. The change in the values of these attributes is as a result of hydrocarbon withdrawal from the reserviour between the time of acquisition of the Base and Monitor alongside subsequent replacement with brine.
The attribute slices analyzed on PH2 seismic horizon also showed low acoustic impedance, lambda-rho, bulk density, Poisson's ratio, water saturation and mu-rho on the Base seismic slices within the producing well locations which also infer hydrocarbon charged sands. Analysis on the Monitor volume of this same horizon revealed relative increase of these attributes which is in line with theory, as brine replaces hydrocarbon on withdrawal of the later. However, it should be noted that there was no observable change in the value of porosity between the Base and Monitor on both PH2_v2 and P112 seismic horizoii Therefore, hydrocarbon withdrawal and subsequent replacement with brine has no observable effect on the porosity of the formation. The mu-rho attribute exhibited unexpectedly low values around the producing well locations especially on P112 horizon and has thus been attributed to unconsolidated sand hydrocarbon saturated reservoirs. There were also observable zones (HC1 and HC2) which consistently maintained relatively low acoustic impedance, lambda-rho, density and Poisson's ratio which should be investigated further for probable by-passed hydrocarbon saturated sand in the field.

References

[1]. Ajiduah, S. W., (2011): Locating By-passed Oil in an Offshore Niger Delta field using Petrophysical Parameters and Rock Attributes Derived from 4D Seismic, M.Sc thesis, University of Port Harcourt.

[2]. Etu-Efeotor, J.O., (1997): Fundamentals of Petroleum Geology, Paragraphies, Port-Harcourt pp 84-87.

[3]. Short K.C. and Stauble A.J. (1967). Outline of the geology of Niger Delta, American Association of Petroleum Geologists Bulletin, 51 p. 761-779.

[4]. Doust H. and Omatsola E. (1990). Niger Delta, in Divergent/passive Margin Basins, Edwards J.D. and Santogrossi P.A. eds., AAPG Memoir 48 : Tulsa, American Association of Petroleum Geologists, p. 239-248.

[5]. Carr, M., Cooper, IL, Smith M., Turhaam, T., and Taylor, G., (2001): Generation of Rock and fluid Properties Volume via the Integration of Multiple Seismic Attributes and Log data, EAGE. First Break, vol. 19, pp 567-574.

[6]. Dobrin, M.B., (1981): Introduction to Geophysical Prospecting (Third Edition), McGraw-Hill Book Company, Japan. pp 18 1-189.

[7]. Goodway, B., Chen, T., and Downton, J., (1997): Tmproved AVO fluid detection and lithology discrimination using Lame Petrophysical Parameters;)p, j.ip & Ap4ip fluid stack, from P- and S-inversions, Presented at the 67th Annual International Meeting, Society of Exploration Geophysicist, Expanded Abstracts, pp 183-186,

[8]. Dewar, J., (2001): Rock Physics for the Rest of Us- An Informai Discussion, The Canadian Society of Exploration Geophysicists Recorder, vol. 5, pp 43-49.

[9]. Hampson-Russell; Fluid properties discrimination; A Biot-Gassmann perspective; Geophysiscs,68,29-39

[10]. Ebeniro, J. 0., Dike, R.S..U., Udochu, L.0., and Ezebio, A.A.A., (2003): Cross-plotting and hydrocarbon indication in the Niger Delta, NAPE International Conference and Exhibitions, Abuja, Nigeria.119

[11]. Gregory, AR, (1976): Fluid Saturation Effects on Dynamic Elastic Properties of Sedimentary Rocks. Geophysics, vol. 41, pp 895-921.

[12]. Al-Sadi, H.N., (1980): Seismic Exploration. Birkhausler Verlag, Basel. pp 19-30