Asian Journal of Geological Research

3(1): 53-61, 2020; Article no.AJOGER.55818

Integration of Seismic Inversion Attributes in Field Development Planning at Malay Basin-Asia and North Sea Fields

Sofolabo Adekunle[1*] and Justin Obilo[2]

[1]Department of Physics and Geophysics, Geophysics Research Group, University of Port Harcourt, Nigeria.
[2]Reservoir Seismic Services, Schlumberger, Port Harcourt, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Author SA designed the study, wrote the protocol and wrote the first draft of the manuscript, while author JO performed the geophysical analysis of the study, managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

Article Information

Editor(s):
(1) Dr. Adewumi, Adeniyi John Paul, Achievers University, Nigeria.
Reviewers:
(1) George M. Tetteh, University of Mines and Technology, Tarkwa, Ghana.
(2) Jianhui Yang, Henan Polytechnic University, China.
(3) S. Suppiah, Vel Tech Rangarajan Dr. Sagunthala R & D Institute of Science and Technology, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/55818

Original Research Article

Received 01 February 2020
Accepted 06 April 2020
Published 12 April 2020

ABSTRACT

A major and very important stage in exploration and production projects of any given field is the field development planning program. Conventionally most Field Development Planning (FDP's) are performed without the use of high resolution and fidelity data, such as seismic inversion products. This paper demonstrates the need for integration of seismic inversion products into FDP's and its added values in the process. The lithology and fluid volumes were computed using seismic inversion products, acoustic impedance (AI) and Poisson's ratio (PR). The volume obtained shows oil, gas or water probabilities, which are crucial in well placement program and optimal well planning (FDP's common goals). The values of seismic inversion integration added to FDP includes improved volumetrics from high fidelity porosity and permeability volumes, better lithology and fluid discrimination, Proper placement of oil water contact for better history matching for flow simulation. Also the rock property changes were estimated from seismic inversion to determine reservoir behavior over time, the acoustic impedance was observed to decrease with an increase

**Corresponding author: Email: adekunle.sofolabo@uniport.edu.ng, aosofolabo@gmail.com;*

in Poisson ratio, when pore pressure increases and vice versa. But with decrease in pore pressure, both the acoustic impedance (AI) and poisson's ratio (PR) thus increase, thereby causing the lighter fluid (oil) to be replaced by heavier fluid (water). Based on the obtained 4-D inversion result, the oil water contact was shifted downwards in the reservoir model, which subsequently gives a better history matching for flow simulation. The study shows the robustness of using seismic attributes in FDP's.

Keywords: Seismic inversion; attributes; acoustic impedance; Poisson's ratio; field development planning.

1. INTRODUCTION

Hydrocarbon exploitation and exploration, especially in deepwater region requires accurate and precise mapping of possible prospects, reduce possible uncertainty in simulation, location of any possible by passed hydrocarbon sand units so as to optimize well placement programs and reduce cost of operation [1,2]. These are needed by any operating oil and gas companies to secure the future of production. Seismic inversion products are high resolution data, which are used to constrain and build high fidelity models for reservoir simulation [3]. Expects in reservoir studies require accurate knowledge of the reservoir geometry, reservoir properties and parameters (especially its porosity, water saturation and permeability volumes) to build reservoir models and compute volumetrics [4-6]. These parameters are often not known with precision and accuracy (some degree of certainty), because of scaling issues, uncertainty in production test results and spatial sparse patterns of sampling [2]. Thus production history matching often suffers nonuniqueness and poor comparison of the initial simulation results with measured pressure and production data, but seismic inversion provides the necessary accuracy parameters needed such as precise densely sampled attributes which are incorporated in building high fidelity reservoir models for improved volumetrics [1,7,8].

1.1 Theoretical Background

Real earth rock layers have an inherent acoustic impedance (layer based property), but contrast in their acoustic impedance (AI) between the layers gives rise to a reflection coefficient (RC).When this is convolved with the wavelet, it produces the seismic data of the area Fig. 1. Inversion process either "reverses" or "inverts" the whole process i.e. Removal (extraction) of the wavelet then derives the AI from the Reflection Coefficients together with a background (low frequency) model [3,7]. Using the AI (sometimes together with other properties e.g. Shear Impedance, Poisson's Ratio) to infers or describes the rock properties of the field [3].

Seismic inversion attributes are normally derived from post-stack inversion and pre-stack inversion methods. The post stack inversion techniques are used basically to obtain information about the acoustic impedance, which is commonly used in porosity modeling and lithology delineation while pre-stack inversion techniques gives information about the acoustic and shear impedances, and the density, which are commonly used for fluid discrimination [3,4,5]. Spatial distribution of petrophysical properties within any given heterogeneous reservoir formation are performed using only well data and statistical techniques, which are often affected by uncertainty factors. However, the spatial modeling of the reservoir properties can be constrained using seismic data especially away from the well location because of its high resolution [3,6]. Seismic attributes can be used to reduce the risk and uncertainty common in integrated reservoir characterization, which are generally used to map sand bodies, build static reservoir modeling, understand the changes in reservoir properties and for stimulation of production history. As opposed to "elastic" inversion (where each angle stack is inverted separately to produce elastic impedance) the Simultaneous inversion combines the information from all the angle stacks and inverts them at the same time (hence simultaneous) [3,9,10]. Performing the inversion simultaneously allows the direct generation of the three rock properties; AI, PR (Poisson's Ratio) and Density. These are all physical rock properties leading to the quantitative domain [11]. These properties can then be used to determine quantitative reservoir properties such as lithology, fluid, porosity, saturation which can lead on to net pay and volumetrics [12].

2. MATERIALS AND METHODS

A typical seismic data inversion workflow includes the following steps:

- Editing of the wash outs, cycle skipping, shales alteration, modeling the Vp and density of the reservoir formation [1,2].
- Petrophysical and geophysical well log analysis, in which mud filtrate invasion is corrected and the lithology of the reservoir formation delineated using Vshale and Vclay. The total and effective porosities are also determined as well as the pore fluids. Rock physics modeling is performed to determine the permeability, fluid substitution and shear wave modeling [4].
- Preconditioning of the seismic data, which involves zero phasing of the seismic data, enhancement of the seismic signal bandwidth, removing of residual normal movement applying non-rigid matching techniques and spectral balancing between angles stacks [3,11].
- Building of low frequency modeling, which includes horizon and fault guided interpolation of well log impedance and density across the entire survey area [13].
- The modelled low frequency is extracted and used to invert the acoustic impedance to generate the absolute impedances of the reservoirs [7].
- Performing neural network for the seismic inversion or perform seismic inversion motor, in which the inverted seismic attributes is used as the inputs [9,10].
- Lithology delineation, fluid discrimination and rock property are finally performed [7,11-15].

Two different scenarios are performed to show the use and advantages of integrating Seismic Inversion Attributes in Field Development Planning (FDP's) program.

2.1 Lithology and Fluid Discrimination – Case 1

Lithology and Fluid discrimination using Simultaneous AVO inversion: Case study of a field from Malay Basin in Asia. This study was used to confirm the prospects in the eastern part of the field survey. The data used consist mainly of a large volume (~ 1150 sq km) of 3-D seismic and the two wells located around the western part of the field survey. The prospects to be confirmed are as far as 30 km away from the nearest well control, this poses great challenges during the seismic inversion process especially in the presence of strong lateral lithology variation. The seismic data and two wells located in the western part of the field survey were used to generate acoustic impedance and Poisson ratio volumes through amplitude versus offset simultaneous inversion.

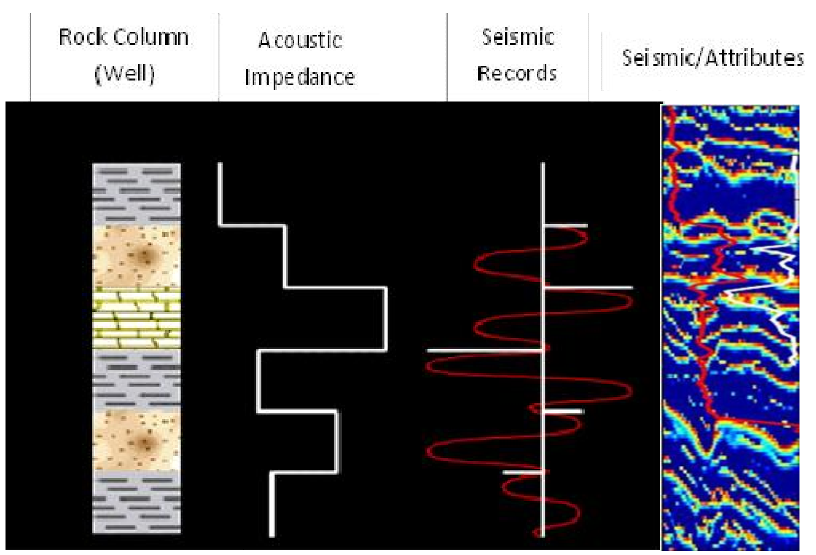

Fig. 1. Schematics of rock properties and production of seismicity and its attributes
**The Reflection coefficient (RC) convolves with the wavelet resulting in the recorded seismogram and attributes*

2.2 Fluid Monitoring Using Time Lapse Inversion – Case 2

4-Dimensional/Time Lapse inversion for Fluid Monitoring (4-D simultaneous Inversion) from Gulfaks and Nelson Field, North Sea. The study shows how lithology probability prediction varies over time during a 10 years production period of the field (from 1990 to 2000).

The seismic data of the field was processed through some of the steps stated above and inverted into acoustic and shear impedances. The inverted attributes was used to generate the lithology probability as shown in Figs. 5 and 6 shows the pre-production startup, showing clearly thick accumulation in the reservoir, but when the reservoir was depleted over a period of seven years (7 years: 1990 – 1997) as shown in Fig. 7, the probability section shows the effect on the reservoir sand and its effect after further three years depletion (1997-2000), a total of 10 years after start up Fig. 8.

3. RESULTS AND DISCUSSION

3.1 Case 1

The first step was to invert to Acoustic Impedance "AI". The acoustic impedance map generated clearly highlights and identifies the channels in the central meander belts beautifully shown in Fig. 2. However the solid bright, high reflectivity zones to the north and south of the meander belt are seen as sheet-like coals, which totally mask any other prospective areas and they have a similar acoustic impedance signature like hydrocarbon.

The next step was to perform a Simultaneous ISIS inversion in producing the Poisson's Ratio, because Poisson's Ratio is derived from Shear Impedance it acts as an extra fluid & lithology discriminator and allows us to separate out the coals Fig. 3. The acoustic impedance (AI) and Poisson ratio (PR) volumes obtained were then used (using the ISIS lithology cubes) to generate probability volumes for each lithology Fig. 4.

The map shows a horizon slice through the hydrocarbon lithology cube. Red and light green colors indicate high probability sands and these can be seen around the two proposed well locations. These lithology cubes were used as one of the main tools to choose the well locations with increased confidence prior to drilling. Fig. 5a is the pre-drill predictions of the sand units compared to the actual well results in Fig. 5b; the plot shows a cross section through each well location.

The red layers in the water saturation log are the hydrocarbon sand units as predicted before drilling, based on the ISIS Simultaneous inversion at seismic resolution, while the white log is the water saturation log (S_w) after drilling, which shows a very close match with the predicted hydrocarbon zones. The inversion prediction shows a very close match to the actual drilling results even in the presence of strong lateral lithology variation, bearing in mind that the nearest well control is located at about 30km from the prospect. Based on this work the client commissioned a series of further inversion projects leading eventually to 7 commercial successes out of 7 wells drilled over approximately a 2 year period.

3.2 Case 2

The study shows how lithology probability prediction varies over time during a 10 years production period of the field (from 1990 to 2000).

This is a good example of how the lithology probability prediction varies over time during a 10years production period in the Nelson field, North Sea. Here in 1990 (pre-production startup) there is a fairly thick accumulation in the reservoir as shown in Fig. 6. We also notice also the detailed variability of probability in the prediction (color bar variation).

Seven years later, the reservoir has been substantially depleted Fig. 7.

Ten years later, the reservoir has been substantially depleted Fig. 8.

The result of the study shows how the 4D inversion was used to search for any bypassed oil. The top section of the section shows the oil sand probability from the 1990 seismic survey indicating a continuous thick oil reservoir. The lower section shows where there has been an increase in the impedance of the field over time (far offset data from 1990 to 2000). This is usually associated with oil production which involves the replacement of the lighter hydrocarbons with the heavier brine. Before the study, it was predicted that by year 2000, most of the oil would have been produced, however the results indicates that only the lower part of the reservoir had been depleted. Based on the study, the oil water contact (OWC) was shifted downwards in the reservoir model which gives a better history match for flow stimulation. The 3D Plot Fig. 9 shows how the 4D inversion results can be color coded to visualize the areas of produced vs remaining oil (based on the increase in far offset impedance over time from the previous slide). Thus the operator of the project has proposed drilling more several wells into the areas of "remaining oil" to increase production on the field (FDP's goals).

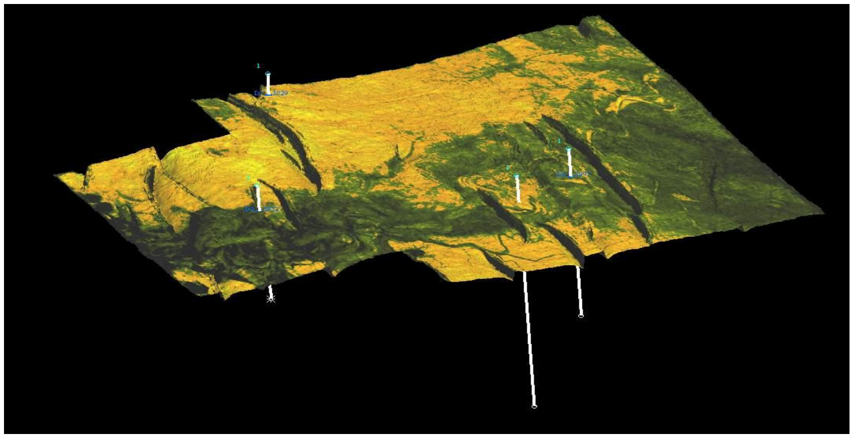

Fig. 2. Acoustic impedance maps of the basin showing the presence of channel meander belts

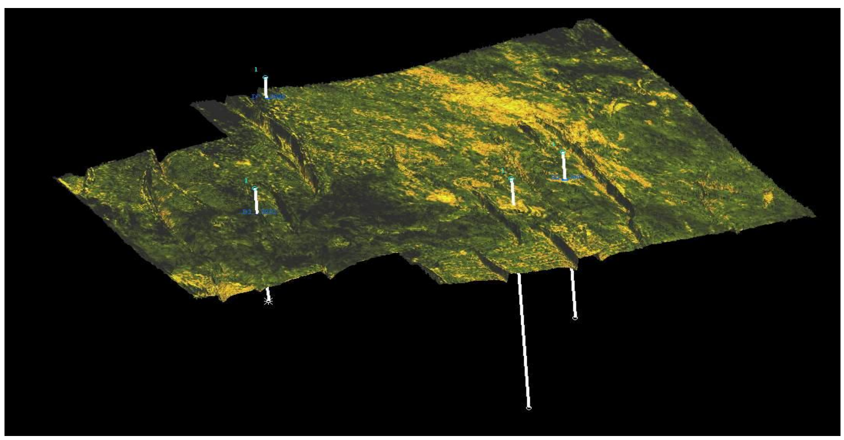

Fig. 3. Poisson ratio map of the basin, clearly discriminating the fluid and lithology, thus identifying and separating out the coals in the basin

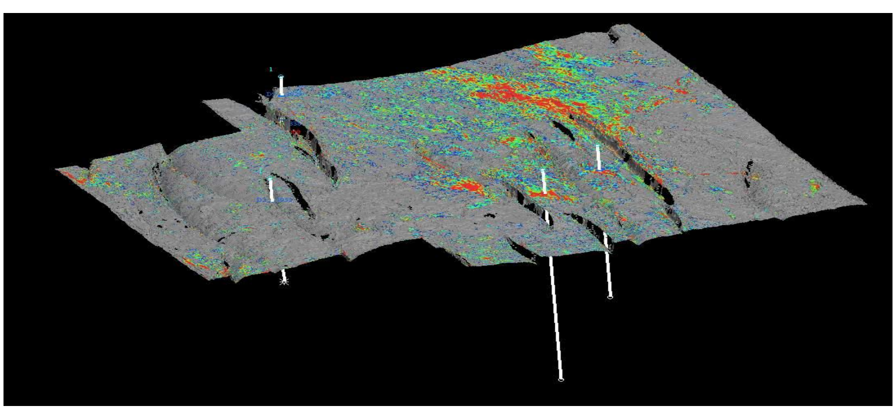

Fig. 4. Map of the horizon slice through the hydrocarbon lithology cube

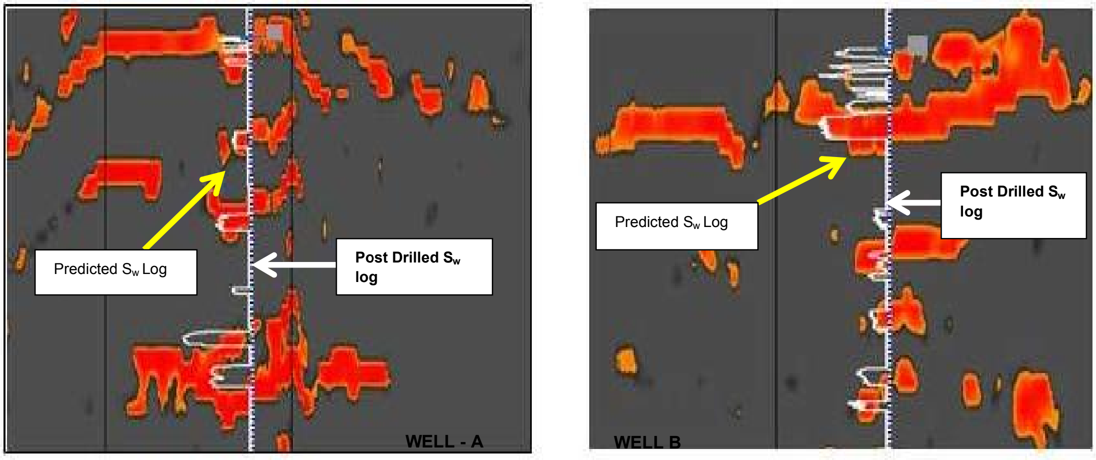

Fig. 5. Pre-drilling prediction sand units and post drill water saturation log of the well

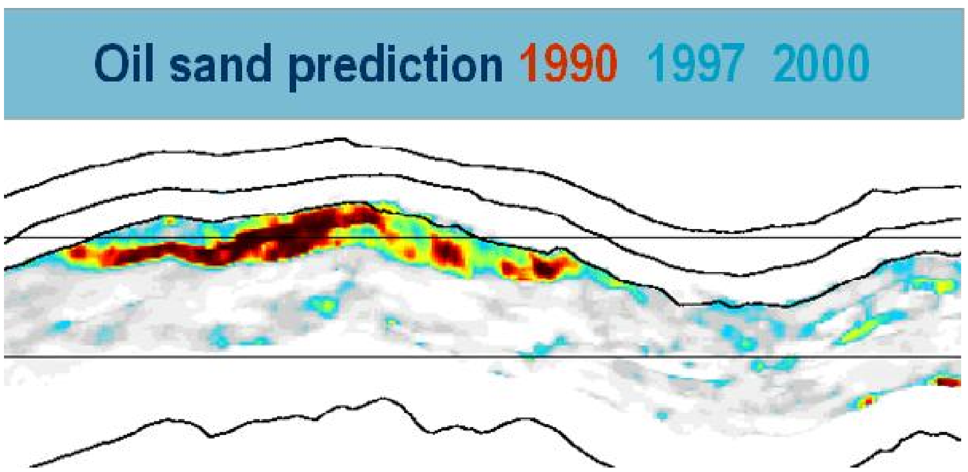

Fig. 6. Pre-production lithology probability profile of reservoir

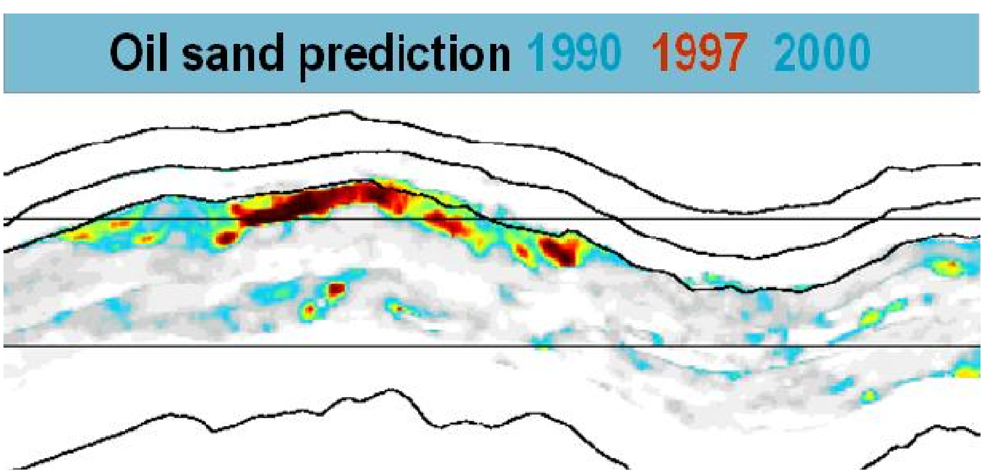

Fig. 7. Lithology probability profile of reservoir after 7 years of depletion

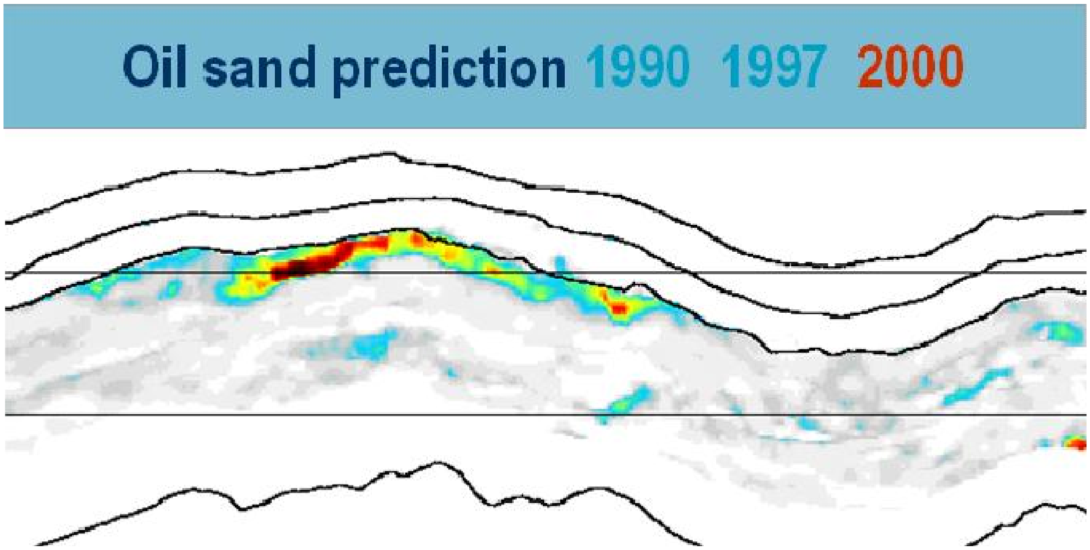

Fig. 8. Lithology probability of reservoir after 10 years depletion period

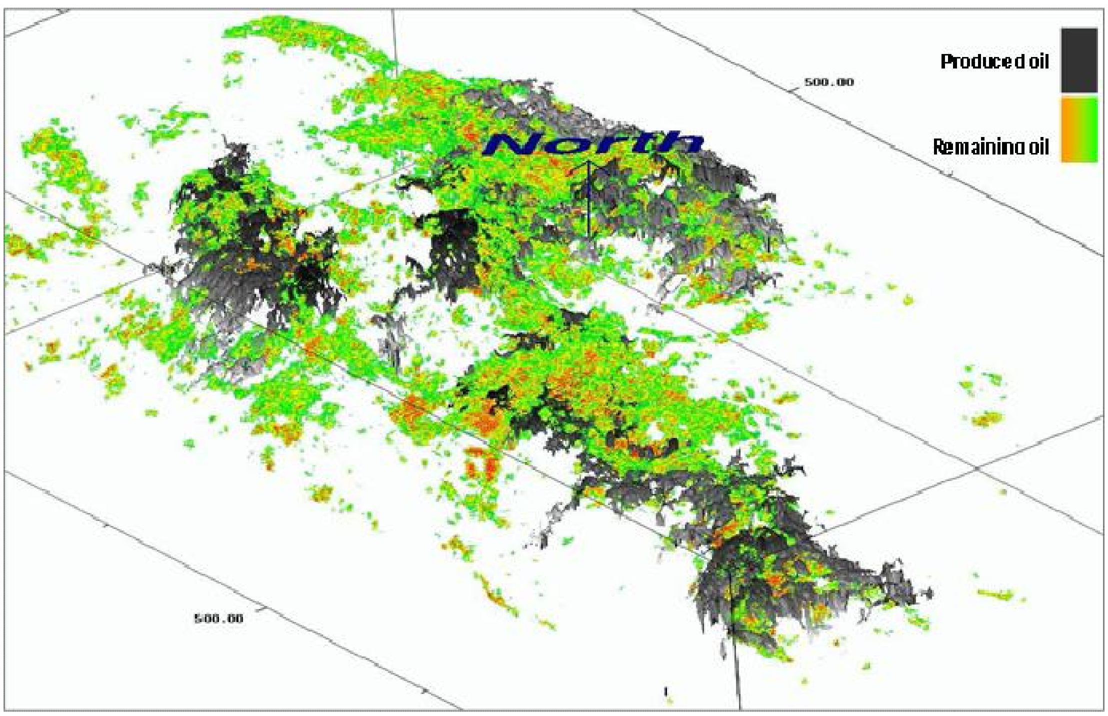

Fig. 9. 3D plot of the effect of time lapse (4D) inversion on the reservoir, showing produced and non-produced areas contrarily to initial simulation forecast

4. CONCLUSION

The Field development planning for the study area has exploits the high resolution information offered by seismic inversion attributes. Some of the benefits added through the study cases include:

- Constraining and building high fidelity models for reservoir simulation.
- Computing the reserve volumes showing oil, gas or water sand probabilities.
- Better understanding of rock property and pressure changes over time caused by hydrocarbon production.

- An improved volumetrics from high fidelity porosity and permeability volumes.
- Better fluid and lithology discrimination and
- Better understanding of reservoir behavior with time.

Integrating seismic inversion in Field Development Programs has also improves the Lithology mapping and fluid discrimination process, as well as enhance the building of high resolution static and dynamic reservoir models. The Seismic information is fully utilized in reducing the uncertainty and improves interpretation and prospect ranking of the reservoir. Many field development programs have benefitted from this integrated workflow which resulted in drilling successful development wells and effective reservoir management.

DISCLAIMER

The products used for this research are commonly and predominantly used products in the area of research in the country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

ACKNOWLEDGEMENTS

The research team wishes to thanks Schlumberger, Pemex, Shell, Statoil and NAPE for permission to use the information and images for this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Pelemo B, Otubanjo M, Anyadike E, Olusoji M, Sanyaolu A, Ukaonu C, Ovuru M, Akewusola T, Matemilola S, Emmanuel E, Kaar Sijpesteijin C. Integrated Field Development planning for reservoir performance optimization, Shallow water, Offshore Nigeria. 2018;27(2):90-95.
2. D'Souza R, Basu S. Field development planning and platform concept selection for global Deep water development. Offshore Technology Conference. 2011;2(5):1-7.
3. Russell HB. Introduction to seismic inversion methods. A Society of Exploration Geophysics (SEG) Continuous Education Course Notes Series ed. 2006; 2:1-235.
4. A-zdemir H, Hansen JW, Robinson E. Seismic estimation of rock parameters A case study. European Association of Geoscientists and Engineers (EAGE). Stavanger, Norway. Extended Abstract D40; 2003.
5. White RE. Partial coherence matching of synthetic seismograms with seismic traces. Geophysical Prospecting. 1980;28:333-358.
6. Obilo J, Sofolabo A. Use of seismic inversion attributes in field development planning, IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG).2018;6(2): 86-92.
   [e-ISSN: 2321–0990]
   [ISSN: 2321–0982]
7. Olowokere MT, Ojo JS. Fluid detections and lithology discrimination using lame petrophysical parameters from simultaneous inversion – using Northern North Sea, Norway. National Association of Petroleum Explorationists (NAPE) International Bulletin. 2010;22(1):36-42.
8. Johnson DH. Practical application of time lapse seismic data. Distinguished Instructor Series. 2013;16:45-72.
9. A-zdemie H, Ronen S, Olofsson B, Goodway W, Young P. Simultaneous multicomponent AVO inversion. SEG Annual Meeting Extended Abstract, San Antonio, Extended Abstract Session. 2001;4.
10. Larsen J, Margrave G, Lu H. AVO analysis by simultaneous PP, PS weighted stacking applied to 3-C-3D seismic data. SEG Annual Meeting Abstract. 1999;721-724.
11. Aki K, Richards PG. Quantitative Seismology: W.H Freeman and Company; 1980.
12. Goodway W, Chen T, Downton J. Improved AVO fluid detection and lithology discrimination using Lame petrophysical parameters: 67th Annual International Meeting, SEG Expanded Abstracts. 1997; 183-186.
13. Pedersen SI, Randen T, Sonneland L, A Steen. Automatic 3D fault interpretation by artificial ants. European Association of Geoscientists and Engineers (EAGE).

Florence, Italy. Extended Abstract. 2002; 27-30.
14. Oluwasusi A, Adegbasa G, Ude A, Odebeatu C, Sze E. Integrated approach to opportunity using 4D seismic and production Data: C Channel complex set of EN Field. National Association of Petroleum Explorationists (NAPE) International Bulletin. 2018;27(1): 6-11.
15. Adeoti AO, Ayolabi EA, Akinmosin A, Oladele S, Oyediran T, Ayuk MA. Reservoir fluid determination in Jay Field, onshore Niger Delta, Nigeria. 2018;22: 453-458.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/55818