International Journal of Scientific & Engineering Research, Volume 7, Issue 10, October-2016
ISSN 2229-5518

Multiple Generators in Onshore Niger Delta

Azuoko George-Best

Abstract—The presence of multiple generators in onshore Niger Delta has been established through detailed velocity analysis using 3D seismic data from an onshore field in the area. This involved extraction of velocity semblance plots from the data and subsequent picking of velocities on a semblance panel. Validity of the picks and geological plausibility was ensured by tying the velocity picking to corresponding locations on seismic. These picked velocities were further used to generate interval velocity-depth models and ultimately, used to migrate the seismic data in the PreStack depth domain. Results from the study demonstrate the presence of higher interval velocities which contrast with the bordering lower velocities. Alternations of high and low interval velocities were also observed on interval velocity model, which was also observed on prestack depth migrated section. Contrasts in strength of reflection events are observed between the bordering sections of the main boundary fault and the area behind (and at the footwall) of the main boundary fault (the shadow zone). These stronger reflection events are adjudged multiple generators, which are responsible for the "curtain of noise" short path multiples in the shadow zone, and the multiples mimicking a section of the overlying stretch of strong reflectors. Thus with this contrast in reflection events as a result of contact between materials with varying density/compaction and velocity of propagation of sonic waves, 3D seismic data from the field of study exhibits adequate acoustic impedance contrast necessary for the generation of multiples in onshore environments.

Index Terms—Multiple Generators, Onshore Niger Delta, Reflection Events, Velocity Analysis,

1 INTRODUCTION

Until recent times, the presence of multiples in 3D seismic data has not been given adequate attention in onshore Niger Delta. This dearth of attention to multiples has been attributed to the fact that the presence of adequate acoustic impedance contrast created by the water bottom and the overlying water body, which is a necessary condition for the generation of multiples in offshore environments, cannot be readily found in onshore environments. However, studies have revealed that a close replication of what we have in the marine environment can also be obtained in onshore 3D seismic data. Yuan et al, [12] asserted that it is possible to observe multiples from any near surface consolidated formation.

Presence of surface-related and internal multiples in a research carried out by Wildt et al, [11] in the Gulf coast region was attributed to a shallow sequence of shale-sandstone between 1.3 and 2.0 sec TWT (two-way travel time). This sequence can contain different lithologies, and the interbedded units of sandstone in this sequence results in acoustic impedance contrasts observed as high amplitude reflections between 2.3 seconds and 4.0 seconds on a time migrated section [11]. Weiglein et al, [10] submitted that strong reflectors at any depth can be identified as sources of internal multiples. They further argued that this is more the case if geologic bodies having different seismic properties are in contact, as can be readily observed in areas where we have alternating sequences of sedimentary rocks and layers of basalt or seams of coal. Kelamis and Verschuur, [7] stated that in land seismic acquisition, although there is no subsurface media like sea surface and sea bottom, multiples can be generated at the surface by a strong reflection from a near surface consolidated formation.

These observations are in consonance with the depositional sequence found in the lower Agbada Formation where shale and sandstone beds are deposited in equal proportions [6], [5]. This creates adequate acoustic impedance variation in the subsurface for the generation of multiples. Being a function of density and velocity, high acoustic impedance is attributable to high velocity and density, and can be readily investigated by detailed velocity analysis.

2 GEOLOGY OF THE STUDY AREA

3D seismic data used for this study was acquired from a field in onshore Niger Delta (Fig.1.0). The basin is an extensional rift in the basin that is located in the Niger Delta. It is characterized by structural and stratigraphic compositions infested with growth faults, roll over anticlines, shale diapirs and steeply dipping boundary faults

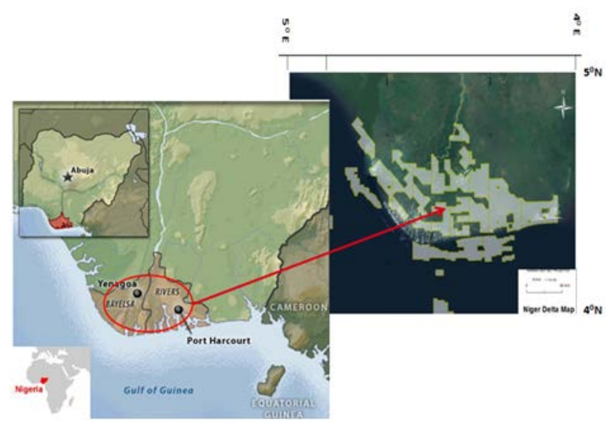

Fig.1. Map of the study location

The area of study is underlain by three main formations - the Akata, the Agbada and the Benin Formations as shown in Fig.

ISSN 2229-5518

2.0. The entire delta is underlain by the Akata Formation which is of marine origin. Thick shale sequences, turbidite sand, minor amounts of clay and silt and a typically over pressured nature are the attributes of this Formation [3]. The Akata formation is estimated to be up to 7,000 meters thick [5].The Agbada Formation consists of paralic silicic clastics over 3,700 meters thick and overlies the Akata Formation. Being the actual deltaic portion of the sequence the portion has a lower section comprising of shale and sandstone beds deposited in equal proportions and an upper portion which is mostly sandy, having only minor shale intercalations.

The entire Agbada Formation bears petroleum in the Niger Delta [6], [5]. The Benin Formation overlies the Agbada Formation and consists of alluvial and upper coastal plain sands deposits about 2,000m thick [2]. The main objectives of oil exploration in the Niger Delta are rollover anticlines in front of growth faults, with hydrocarbons found in sandstone reservoirs of the Agbada Formation [9].

These depositional sequences readily create an environment that permits proximity of consolidated deposits and their unconsolidated counterparts, thus creating adequate acoustic impedance contrast necessary for the generation of multiples in onshore seismic data.

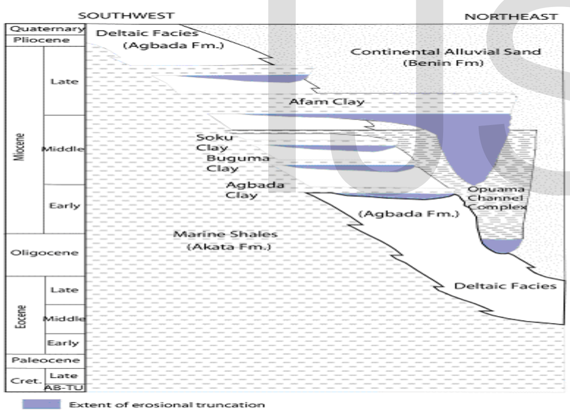

Fig.2. Stratigraphic Succession map of the area(Niger Delta)

3 MATERIALS AND METHOD

The data used in this study was acquired recently using novel acquisition parameters which include 6km offset, and single deep hole. These enhanced ability to image at depth, get a better handle on velocities, and enhanced the Signal to Noise Ratio of the data. This novelty of the data acquisition and enhancement is seen in the ability of different views of the 3D Seismic section from the study area (Fig. 3a and 3b) to clearly show a replication of the marine (offshore) seismic data in data from an onshore environment.

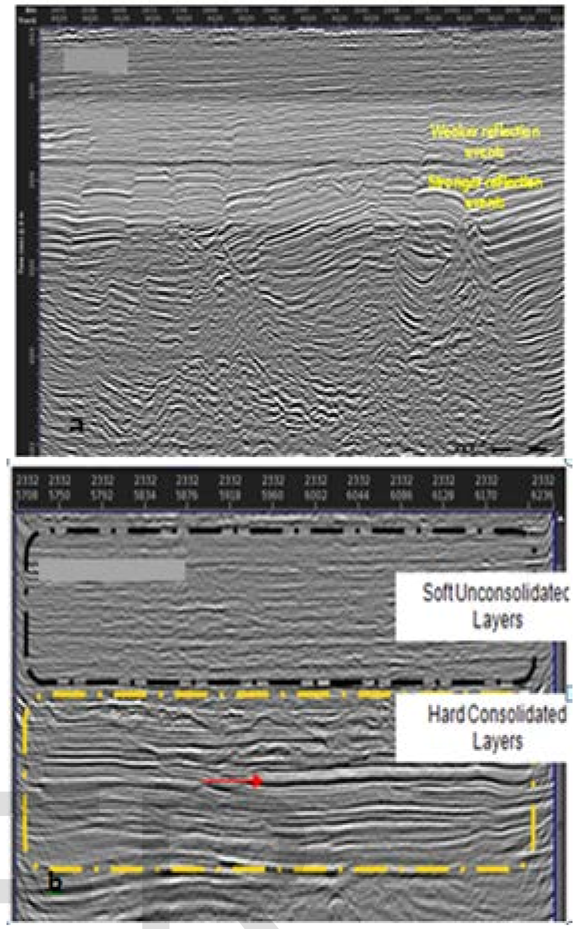

Fig.3(a&b).Typical 3D Seismic sections from the study location illustrating the replication of offshore seismic data.

The data was prepared and enhanced by implementing refraction statics correction, noise attenuation, deconvolution, Common Mid-Point sorting (CMP), processes which helped to further improve the signal to noise ration of the data. Using Common Image point gathers as input data, velocity semblance plots were generated by carrying out hyperbolic scans on the gathers. Based on the principle that hyperbolic move out energy for primary reflections correspond to highest energy clusters on the semblance plots [4], Root-Mean-Square (effective) velocities were picked on semblance panel. The suitability of the semblance velocity analysis tool is based on its sensitivity to the variation of velocity with depth. As the maximum offset increases, the semblance power decreases, since the best-fit hyperbolic moveout does not simulate the actual non hyperbolic moveout [1]. Offset gathers were used to QC the velocity picking. Plots of the variation of the effective velocity with two way time both on the semblance analysis panel and a single function velocity plot are further analyzed and compared to observations on seismic reflection events on corresponding 3D seismic section for variations in the strength of the reflection events as seen on seismic. The picked velocities are further used in the generation of a velocity depth model that gives a representation of the velocities that were picked. The interval velocity depth model is finally used for prestack depth migration (PSDM) to validate the occurrence of the variations in strength of reflection events as a result of the observed velocity variations. The result of the PSDM is further analyzed to establish the existence stronger reflection events bordering weaker reflection events, a condition necessary for the creation of adequate acoustic impedance variation in 3D seismic data from onshore Niger Delta.

4 PRESENTATION OF RESULTS

The results from the detailed velocity analysis revealed the presence of anomalous higher effective velocities and corresponding interval velocities than the surrounding effective velocities (Fig.4.0) in the field of study. These correspond to the stronger seismic reflection events observed on seismic with corresponding coordinates and contrast very well with the surrounding weak seismic reflection events. A single function velocity plot (Fig.5.0) from the same location corroborates these observations. This single function velocity plot which is also a plot of the variation of effective velocity with two way time also shows the prevalence of higher effective velocities in the study area.

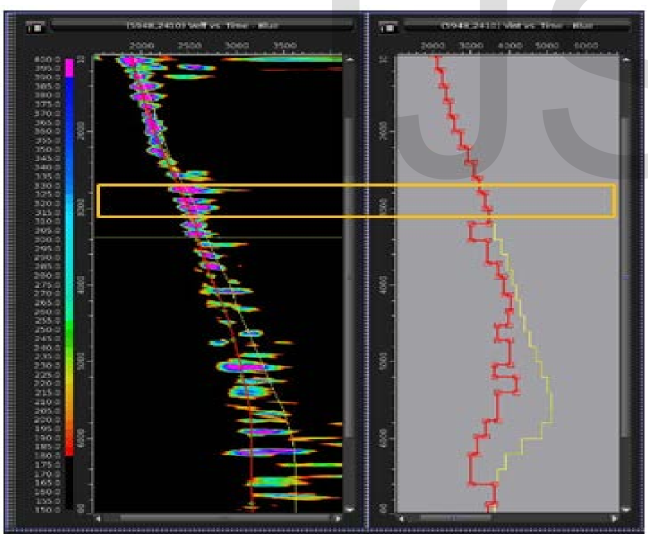

Fig.4. Picking of effective (Root-mean-square) velocity; Observe the anomalously higher effective and interval velocities within the yellow rectangle

The velocity depth model (Fig. 6) showed variations in velocity, corresponding to the observations in the semblance plot panel and the single velocity function plot. The low and high interval velocity regions indicated in the model are interpreted using the variation of the interval velocity on the color scale, ranging from blue (which is the lowest and corresponds to 1500m/s) to purple (which is the highest and corresponds to 4500m/s).

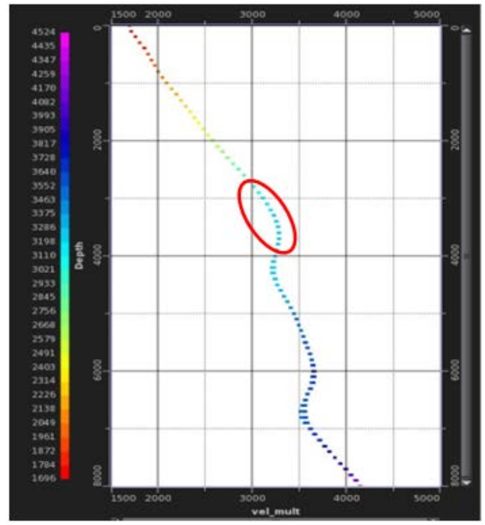

Fig.5. Single velocity; Observe higher effective velocities within the red band

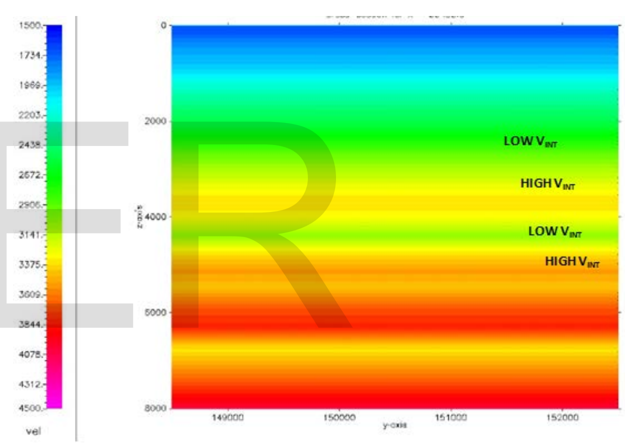

Fig.6. Velocity depth model built from the picked velocities; observe variations in interval velocities (V_{INT})

Migrating in the prestack-depth domain using the interval velocity depth model gives us the seismic sections in Figures 7 and 8. Stronger seismic reflection events bordering weak reflection events are observed in the shallower region of the section.

In the deeper section, northward and in the downthrown block of the fault plane, these stronger reflections are predominant, starting out at the northernmost area, and fading out as we progress southward into the footwall of the fault. These weaker reflection events in the footwall also contrast with the strong reflection events in the up thrown block of the fault.

ISSN 2229-5518

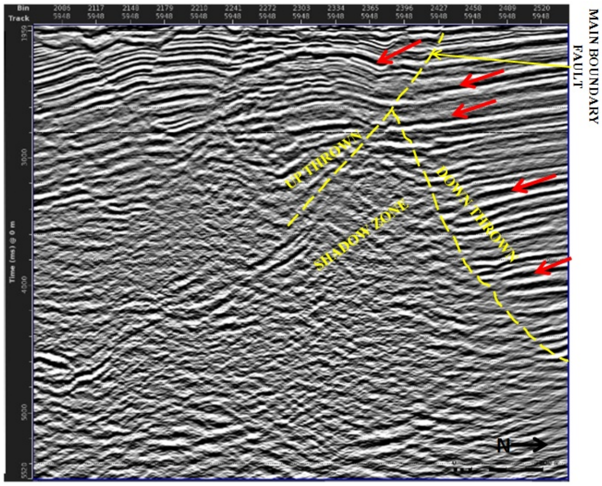

Fig.7.0: Prestack Depth Migrated seismic section; observe the stronger reflection events (indicated by the red arrows) and the contrasting weak reflection events

Figure 8.0 on the other hand, does not only show contrasting reflection events in the shallow section (the green ellipse), but also illustrates two deeper clusters of reflection events (red ellipses) located at specific depth intervals. The cluster in the shallow section has other bordering events and is thus continuous, while the clusters of replicating events seem to terminate abruptly and are not as continuous as the former.

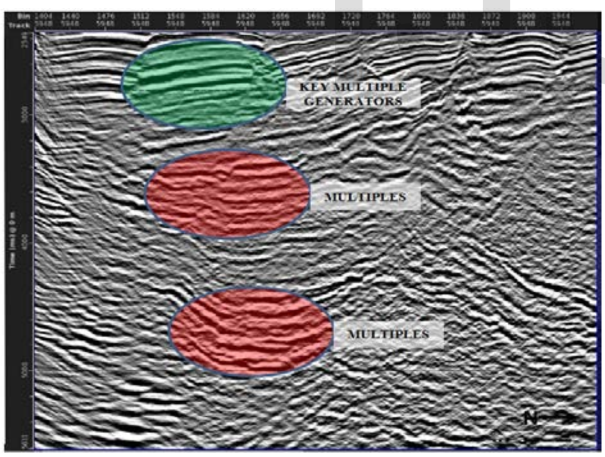

Fig.8.0: Prestack Depth Migrated seismic section; the green ellipse captures a section of the stretch of strong reflection events, the two red ellipses both indicate reflection events mimicking the events in the green ellipse.

5 DISCUSSION OF RESULTS

The presence of stronger reflection events on seismic data from onshore Niger Delta has been investigated and tied to the higher effective and interval velocities observed during velocity analysis. The velocity analysis was carried out through detailed velocity picking. Observations from the results show corresponding values of higher effective (Root mean square velocities) and interval velocities. These are seen between 2.5s and 3.2s. Within this depth range, these velocities are readily tied to stronger reflection events on corresponding offset gathers and on seismic sections. These higher velocities are also seen contrasting with the preceding and following lower velocities on the single velocity function extracted from corresponding locations.

Also in this study location, the presence of strong near surface subsurface reflectors between 2.0 and 2.5 seconds (in conformity with the work by Kelamis and Verschuur , [7]) as well as the presence of contacts between geologic bodies of different seismic properties observed around the footwall of main boundary faults are probable causes of internal multiples in onshore Niger delta.

Interval velocity depth model built using the output from the detailed velocity picking also showed alternating intervals of high and low interval velocities, contrary to the conventional continuous increase in velocity with depth. Being a function of density (ϱ) and velocity (V), the corresponding acoustic impedances (Z) as a result of these alternating velocities also vary, creating adequate acoustic impedance contrast necessary for the generation of multiples in onshore seismic data. These contrasts in acoustic Impedance result from the variation in compaction between the higher velocity (and of course higher density) layers and the proximal lower velocity media.

On prestack depth migrated seismic section, stronger seismic reflection events are obvious and clearly contrast with the surrounding weaker reflection events. In the shallow region of the sections, a continuous stretch of stronger reflection events are observed contrasting with the underlying weaker reflection events. Contrast in acoustic impedance can also be attributed to the difference in strength of reflection events observed in the Northern region of the section. The up thrown and downthrown blocks of the fault plane have relatively stronger reflection events than the area behind the main boundary fault which corresponds to the phenomenal fault shadow zone.

These observations which are slightly localized to the Northward part of the section are also predominant around the fault plane of a main boundary fault, and are thus rightly adjudged to be responsible for the generation of the "curtain of noise" observed within the fault shadow zone. This curtain of noise, as described by Retailleau et al, [8] is often stronger than primary reflection events and has been associated with the presence of short period multiples.

Furthermore, the replication at depth of the seismic reflection events in the shallow section of prestack depth migrated seismic section from the study area is in conformity with the discovery by Wildt et al, [11] in the Gulf coast region, that the presence of a shallow stretch of shale and sandstone between 1.0s and 2.0s two way time resulted in multiples at deeper sections of the section, mimicking the shape of the overlying stretch. In this study, these replications are rightly adjudged multiples, generated by the stronger reflectors in the shallow section.

6 Conclusion

The presence of multiple generators has been identified as higher seismic velocities during velocity analysis of 3D seismic data from onshore Niger Delta. These generators were further identified as stronger seismic reflection events on 3D prestack depth migrated seismic data from the same location. These create adequate acoustic impedance resulting in short period multiples within the footwall of the main boundary fault. This adequate acoustic impedance contrast also resulted in reflection events at depth which just like multiple reflections, try to replicate the overlying reflection events in the shallow section which are responsible for their generation.

Acknowledgment

The author acknowledges SPDC Port Harcourt for the provision of the research internship opportunity, dataset, compute and the permission to publish this work.

References

[1] Alkhalifah, t., 1997 "Velocity Analysis Using Nonhyperbolic Moveout in Transversely Isotropic Media": *Geophysics*, vol. 62, no. 6 (November-December 1997); p. 1839–1854.

[2] Avbovbo, A., A., 1978, Tertiary Lithostratigraphy of Niger Delta: *American Association of* Petroleum *Geologists Bulletin*, v62, p. 295 – 300.

[3] Burke, K., 1972, "Longshore Drift, Submarine Canyons, and Submarine Fans in Development of Niger Delta": *American Association of Petroleum Geologists*," v. 56, p. 1975-1983.

[4] Dutta, N. C., 2002, "Geopressure prediction using seismic data: Current status and the road ahead": Y2K Review Article, *Geophysics*, VOL. 67, No.6 p.2012-2041.

[5] Doust, H., and Omatsola, E., 1990, "Niger Delta": *AAPG Memoir 48:* Tulsa, American Association of Petroleum Geologists, p. 239 -248.

[6] Ejedawe, J.E 1981, "Patterns of Incidence of Oil Reserves in Niger Delta Basin": *American Association of* Petroleum *Geologists, v.65, p.1574 – 1585.*

[7] Kelamis, P. G., and Verschuur D. J., 2000, "Surface-related Multiple Elimination on Land Seismic Data—Strategies via Case Studies": Geophysics, 63,719–734.

[8] Retailleau, M.G., Benjamin, N., Pica, A., Bendjaballah, M., Plasterie, P., Leroy, S., Delmas, L., Hugonnet, P., Khalil, A., Gulunay, N., Smith, R., and Shorter, J., 2012, "Advanced 3D Land Internal Multiple Modeling and Subtraction, A WAZ Oman Case Study" : 74th EAGE Conference & Exhibition incorporating SPE EUROPEC 2012 Copenhagen, Denmark.

[9] Short K.C. and Stauble A.J.,1967, "Outline of Geology of Niger Delta":*AAPG* Bulletin, volume 51.

[10] Weiglein, A.B., Hsu, S.Y., Terenghi, P., Li, X., Stolt, R. H., 2011, "Multiple Attenuation: Recent Advances and the Road Ahead": *The Leading Edge, August*, 2011.

[11] Wildt, J. D, Oldfield, R. K., and Silva, R., 2009 "Practical Application of an Eigen Image Filter":Spectrum; www.spectrrumgeo.com/geological-resources/technical-paper-library

[12] Yuan, Y., Han, D., Zhang, R., 2009, "Multiple Suppression on Land Seismic Data": *Society of Exploration Geophysicists*, 2009.