Radon de-multiple method is one of the methods of multiple attenuation. It generally consists of three stages: decomposition, modelling and subtraction. This scheme usually decomposes data (i.e. both primaries and multiples) into parabolas as this allows the method to operate in the frequency domain. It models the multiples by muting in the Radon domain, and then subtracts the resulting model from the original data. Both the modelling and subtraction are generally performed with least squares algorithms in the frequency domain. The Radon de-multiple method performs well with the correct primary velocity and adequate move-out differences between the primaries and multiples [28-30].

3. THE STUDY AREA AND GEOLOGICAL SETTING

The area of study is within the offshore portion of the Niger Delta Province. It is delineated by the geology of southern Nigeria and south-western Cameroon (Figure 1) in the Gulf of Guinea. The Gulf of Guinea consists of the coastal and offshore areas of Cote d'lvoire, Ghana, Togo, and Benin, and the western part of the coast of Nigeria, from the Liberian border east to the west edge of the Niger Delta. The province includes the Ivory Coast, Tano, Central, Saltpond, Keta, and Benin basins and the Dahomey Embayment. The Gulf of Guinea formed at the culmination of Late Jurassic to Early Cretaceous tectonism that was characterized by both block and transform faulting superimposed across an extensive Paleozoic basin breakup of the African, North American, and South American paleocontinents [31]. The deep offshore contains Alba, Azurita and Zafiro Canyons [32-34].

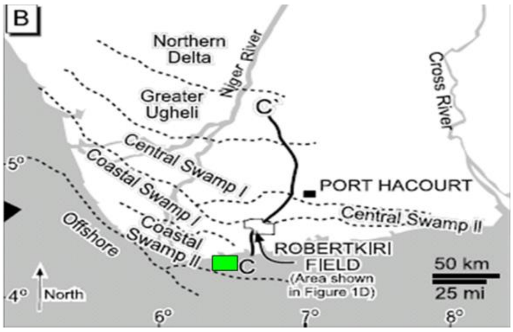

Figure 1: Map of Niger Delta showing the area of study [18, 15].

4. MATERIALS AND METHODOLOGY

4.1 Data Acquisition

In the areas under this study, the data are from Shallow Marine (250m deep) in the Gulf of Guinea, off the Niger Delta. Two traverse lines arbitrarily selected - inline and crossline from sample datasets - are taken from the offshore Niger Delta area of southern Nigeria to demonstrate the impact of multiple removal from a seismic data. The data is with water depth of 250meters (shallow marine). Acquisition parameters for datasets are shown in Table 1. Figure 2 shows the raw Stack for dataset for Inline 1001 masked by noise and multiples.

Table 1: Acquisition Parameters for shallow marine

Parameters	Shallow Marine
streamer	
Recording length	6s
Sample rate	2ms
Bin size	12.5 x 18.75m
Far offset	4500m
Coverage (fold)	45
Channels	360
Cables	8
Cable depth	7m
Cable separation	100m
Group interval Group interval	12.5
Source	
Source power	2120ci 2000psi
Source depth	5m
Shot point interval	25m

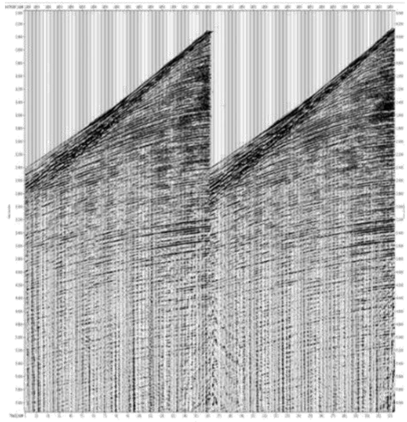

Figure 2: Raw Shots for Dataset for Inline 1001

4.2 Data Processing

The data processing was executed on a 64 bit processing system comprising of a 32-Node pc cluster with 50tb online storage disk. Job submission was done using an RS690 engineering workstation as front end machine. Proprietary software with client-server architecture developed by Information Technology (IT) department of Integrated Data Services Limited was used for the processing. The first multiple attenuation method applied to the data was filtering based on move-out and dip discrimination. This determined the velocities of Multiples energy and separates them from primaries. The common-mid-point (CMP) gathers, semblance and stack response are all placed side by side for quality control purposes. The CMP gathers were NMO-corrected with velocity functions that are between the primary and multiple velocities, such that the overcorrected primaries map into the negative wave numbers plane and the under-corrected multiples map unto the positive wave numbers. By muting the data for the positive wave numbers, multiples were suppressed.

An NMO correction was applied to make the originally hyperbolic events in CMP gathers nearly parabolic in the x-t domain, thereby mapping them into approximately discrete points after the parabolic transform. Yilmaz (1989) improved on Hampson's method by replacing the NMO correction prior to the transform with a stretching of the CMP data. This converts the hyperbolic events to exact parabolas, improving the velocity resolution and hence the primary-multiple discrimination in the transform domain.

5. RESULTS AND DISCUSSION

5.1 Velocity Discrimination

A preliminary 2km by 2km velocity analysis was performed on 8 CMP locations. Inline stack was displayed to validate the result of the velocities. CMP velocity function for dataset and the raw data without velocity applied are shown in Figures 3 - 5. Figure 5 clearly shows the effect of velocity application on dataset. It is clear from results that stack velocity has resolved some of the structures in the dataset. Improvement in the dataset is very pronounced because of the gentle subsurface structures.

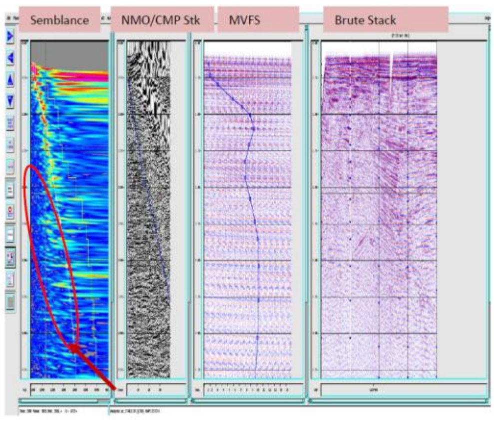

Figure 3: Velocity analysis for dataset for Inline 1001.

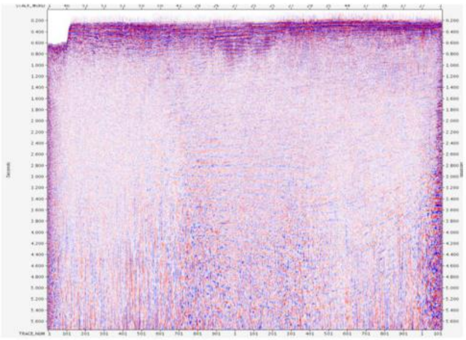

Figure 4: Inline 1001 stack from dataset after velocity without velocity application

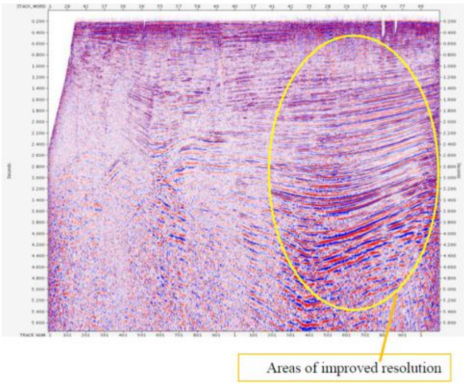

Figure 5: Inline 1001 from dataset stack Application

5.2 Amplitude Analysis of Primaries and Multiples

Spectral analysis was applied on the dataset to see the difference between the primaries and multiples amplitude values. Amplitude response trend indicates that the processing preserved true amplitudes as there was no change in the spectrum (Figure 6). Spectral analysis for the dataset showed that the multiple energies were of higher amplitude than the primaries. This was a major characteristic which was used for its discrimination and attenuation. The amplitudes of primaries and multiples are significantly different as shown in Figures 7 and 8.

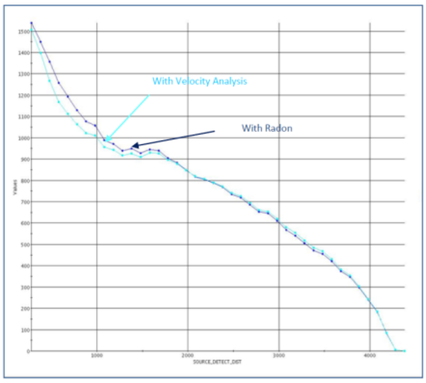

Figure 6: Amplitude Response for dataset from inline 1001

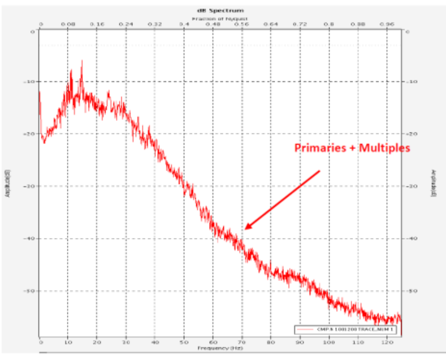

Figure 7: Pre-demultiple amplitude for dataset

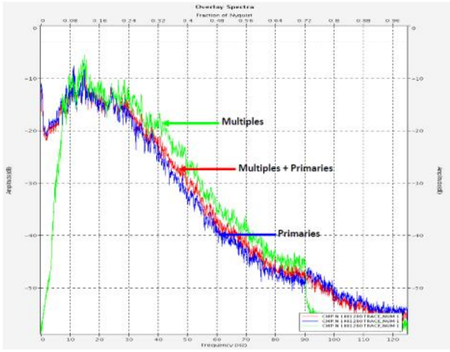

Figure 8: Overlay of amplitude spectrum for primaries and multiples post demultiplex for dataset from inlin 1001

5.3 Predictive Deconvolution

Predictive deconvolution was performed on the dataset. Various values of deconvolution operator, operator length, and deconvolution window and frequency range were applied. Figures 9 and 10 show the dataset without and with deconvolution operations.

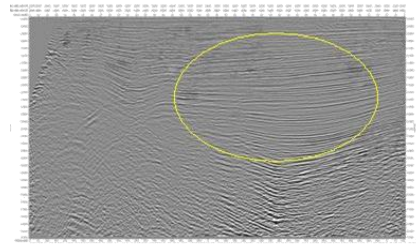

Figure 9: Inline 1001 stack from dataset (Grey Scale) with events with collapsed diffractions.

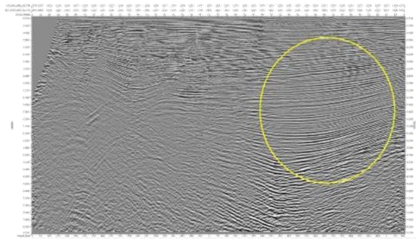

Figure 10: Inline 1001 from dataset (Grey Scale) without deconvolution masked by ringing and deconvolution applied: Sharper events with diffractions.

5.4 Radon Transformation

The objective of the Radon transformation process was to establish parameters for the removal of multiples that may be discriminated from primaries through differences in velocity or, more generally, in moveout. A high-resolution Radon transform was applied to the dataset in order to model or remove events based on moveout criteria. Radon parameters for minimum and maximum moveout in t-x (ms) were 2200ms, 3000ms respectively. Figures 11 and 12 are stacks with and without Radon demultiple. Figure 13 is the difference plot, after the removal of the multiple energy from dataset. Radon had a lot of significant improvements on the data.

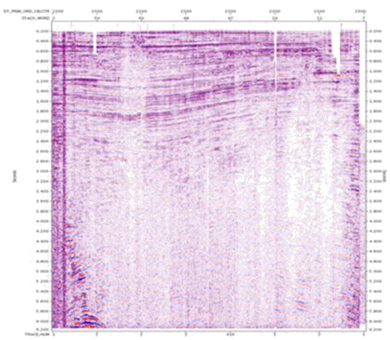

Figure 11: Before Radon Demultiple

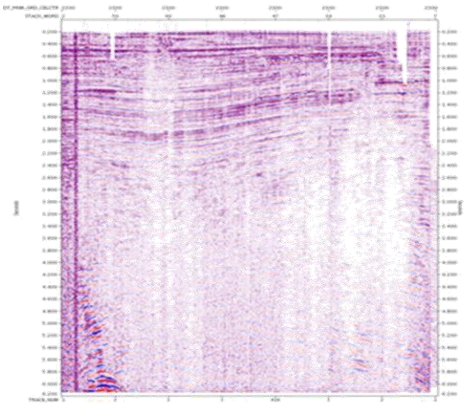

Figure 12: After Radon Demultiple

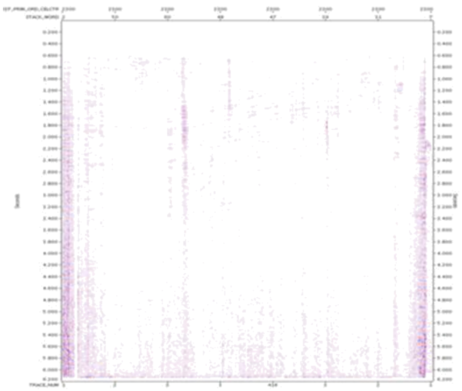

Figure 13: Difference after Radon Demultiple

5.5 Dominant Characteristics of Multiples

Owing to the dominant characteristics (velocity, frequency wavelength, etc.) of the multiples as compared to those of primaries, Velocity Discrimination and Radon transformation was used to eliminate multiples in shallow marine data. Multiples were observed to be of predominantly short-periods with some water bottom reverberation, and high frequency and high amplitude resulting from short travel time. With the short-period and high-frequency content, multiples were quite close to the primaries and therefore required a lot of care in the attenuation process.

5.6 Velocity Responses of Primaries and Multiples

From the velocity spectrum and semblance stack, it is clear that the velocities of multiples are much lower than those of primary events. This is the reason the multiple energy was significantly attenuated when the dataset was stacked with higher velocities.

6. CONCLUSION

The shallow marine dataset at depth of 250m had predominantly interbed multiples. The major differences that were exploited for the multiples removal were multiple-attributes of velocity, frequency, wavelength, periodicity, and predictability using predictive deconvolution and Radon techniques. The dominant frequency of the primary events varies between 3 and 120Hz having dominant amplitude ranging between -12dB and -45dB. The dominant frequency of the multiples ranges between 8 and 90Hz, while dominant amplitude ranges between -5dB and -45dB. This work is relevant because when multiples are attenuated from a seismic section, a better image of the subsurface geology is obtained, thereby reducing the risk of drilling dry oil wells.

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