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REVIEW ARTICLE

GROUND ROLL NOISE ATTENUATION IN 3D LAND SEISMIC DATA IN PARTS OF NIGER DELTA, NIGERIA

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ABSTRACT

Three-dimensional (3D) land seismic datasets were acquired from Central Depobelt in the Niger Delta region, Nigeria, with with the aim of attenuating ground roll noise from the dataset. The Omega (Schlumberger) software 2018 version was used along with frequency offset coherent noise suppression (FXCNS) and Anomalous Amplitude Attenuation (AAA) algorithms for ground roll attenuation. From the results obtained, Frequency Offset Coherent Noise Suppression (FXCNS) attenuates ground roll while AAA algorithm attenuates the residual high amplitude noise from the seismic data. Average frequency of the ground roll in the seismic data is 10.50Hz which falls within the actual range of ground roll frequency which is within the range of 3.00 – 18.00Hz. The average velocity of the ground roll in the seismic data is 477.36ms^{-1} while the velocity of ground roll ranges between 347.44 and 677.37ms^{-1}. The wavelength of ground roll in the seismic data is 50.28m. The amplitude of the ground roll of -6.24dB is maximum at 4.2Hz. Frequency of signal ranges between 10.21 and 25.12Hz with an average of 17.67Hz. Signal amplitude of -8.32dB is maximum at 6.30Hz, while its wavelength is 57.12m. The results of this work can be used in the seismic source-receiver design for application in the area of study. Moreover, with ground roll noise attenuated, a better image of the subsurface geology is obtained hence reducing the risk of obtaining a wild cat drilling.

KEYWORDS

seismic, groundroll, signal, frequency, attenuation, anomalous, amplitude, Niger Delta, Nigeria

1. INTRODUCTION

In seismic data acquisition, both signal and undesired noise are recorded at the same time. Such undesired ground roll noise contaminates the seismic signal causing poor quality images of the subsurface which can lead to misinterpretation of the subsurface geology (Linville and Meek, 1995). Signal here is defined as that which is coherent on nearby traces over a range of frequencies and velocities, while the noise is random. Ground roll has low velocity with low frequency which can overshadow coherent signals (Anstey, 1993; Chukwueke and Ghosh, 2004; Hudson and Knopoff, 1967; Telford et al., 1976; McMechan and Sun, 1991). Due to their dispersive characteristics, ground roll masks shallow reflections at short offsets and at long offsets (Claerbout, 1983; Saatcilar and Canitez, 1988; Henly, 2003; Mooney and Kaasa, 2005; Sengbush, 1983; Futherman, 2001; Chidi, 1988; Fitch, 1976; Short and Stauble, 1967; Uko et al., 1992). This paper aims at removing ground roll noise from land seismic data.

2. THEORETICAL BACKGROUND

2.1 Ground Roll Noise Generation

Seismic Data**, d,** is made of the needed signal, **s**, and the unwanted noise, **n**, represented as:

$$\mathbf{d = s + n} \tag{1}$$

where $\boldsymbol{d}$ = the data; $\boldsymbol{s}$ = noise-free data; and $\boldsymbol{n}$ = the noise (ground roll, multiples & others). Ground roll noise is a random surface wave caused by seismic energy source (Ansley, 1993; Chuckwuete ang Ghosh, 2004; Hudson and Knopoff, 1967; Telford et al., 1976). Its energy travels horizontally along the earth's boundary, dips and spreads triangularly down the seismic data. This is very visible both in the near, mid and far offsets (Figure 1).

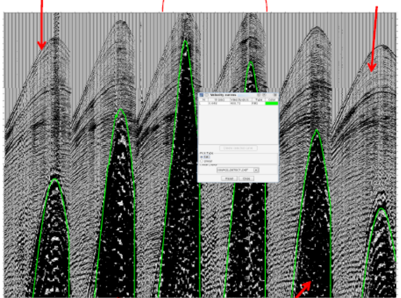

Figure 1: Raw Seismic Data with Visible Ground Roll

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2.2 Ground Roll Noise Detection and Attenuation with Offset Coherent Noise Suppression (FXCNS)

Frequency Offset Coherent Noise Suppression (FXCNS) is a noise attenuation process for handling irregular spatial sampling and noise variability. FXCNS uses a trace's nearest neighbours within an azimuth bin to estimate the attributes of coherent noise for a specified range of apparent velocities. Noise, which is either anomalously high or anomalously low, can be eliminated from pre-stack seismic data by Anomalous Amplitude Attenuation (AAA) filter. Frequency bands that deviate from the median amplitude by a specialized threshold are either scaled (multiplied by a specified scale factor) or replaced with an interpolated band using neighbouring traces.

3. Study Area and its Geology

The area of study is located in the Central Depobelt in the Niger Delta basin surrounded by the geographical grids between latitudes 5°36° to 6°00°N and longitudes 5°30° to 6°43°E (Figure 2). The Niger delta is underlain by three formations, the first is Benin Formation, the middle Agbada Formation and the third is Akata Formation. The Benin Formation is mainly made up of continental sand deposits with intercalation of shale and is covered with topmost low velocity layer. Immediately below the Benin Formation is the reservoir sand of the Agbada Formation which is believed to accommodate the oil and gas resource of the Niger delta. The Akata Formation is also considered to be the source rock for the petroleum resource (White and Sengbush, 1956).

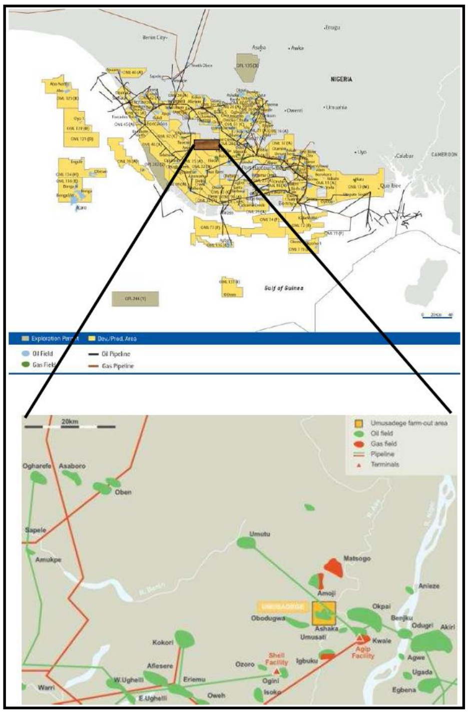


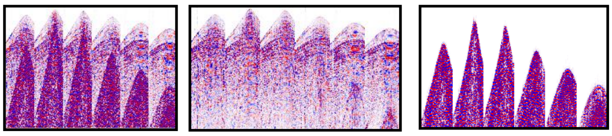
Figure 2: Map of the Niger Delta showing the Study Area

4. Materials and Methods

The procedures aiming at attenuating ground roll are based on the practicability of segregating noise from signal with respect to their velocity, wavelength, frequency, and amplitude content (Yilmaz, 2001; Umoetok and Uko, 2015; Yilmaz, 1989). Signal & Ground Roll Characteristics were modelled at Near Offset, Mid Offset, and Far Offset (Figure 1). The FXCNS algorithm was used to attenuate the ground roll noise from the data using the Omega (Schlumberger) software, 2018 version. After applying the best high stop/high pass velocities (1200/1000 ms^{-1}) and also the best start time (450s) computation velocities, the signal obtained have very minimal high residual amplitude noise. In order to be sure that there is no residual anomalous amplitude ground roll noise that aliases with seismic signal, Anomalous Amplitude Attenuation (AAA) algorithm is employed.

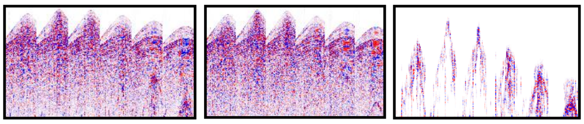
5. Results and Discussion

The results of the work are presented in Figures 3 - 7. Figure 3 shows attenuation with FXCNS. Figure 4 shows attenuation with AAA.



(a) (b) (c)

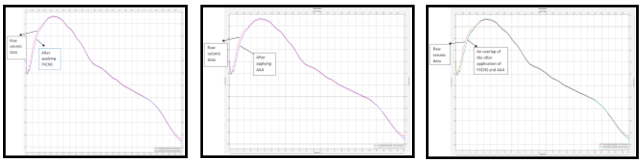
Figure 3: a: Raw Seismic Data with Visible Ground Roll before Attenuation, modelled to get the velocity values; Figure 3b: Signal After applying FXCNS Algorithm; Figure 3c: Ground Roll attenuated from the dataset.



(a) (b) (c)

Figure 4: a: Raw Data (Signal + Ground Roll) before applying Anomalous Amplitude Attenuation (AAA) algorithm; Figure 4b: Signal After applying Anomalous Amplitude Attenuation (AAA) algorithm; Figure 4c: Ground Roll after applying Anomalous Amplitude Attenuation (AAA) algorithm.

Figure 5 is the spectral analysis using FXCNS for attenuation, while Figure 6 the spectral analysis illustrates attenuation with AAA algorithm. There is a reduction in the low frequency and high amplitude region which indicates that ground roll noise has been separated from the raw seismic data. The similarity in the trend of spectrum indicates that there is no loss of primary energy. There is usually frequency overlap between ground roll and primary signal. Spectral analysis showed that the ground roll noise was of higher amplitude than the primaries. This was a major characteristic which was used for the ground roll discrimination and attenuation.



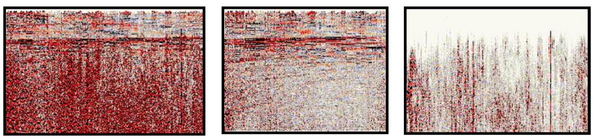
(a) (b) (c)

Figure 5: a: Spectral analysis for raw data and after applying FXCNS algorithm; Figure 5b: Spectral Analysis for raw seismic data before and after applying Anomalous Amplitude Attenuation (AAA) algorithm; Figure 5c: Spectral Analysis before after applying both FXCNS and Anomalous Amplitude Attenuation (AAA).

The stacked raw data are presented in Figures 6 and 7, illustrating the successful elimination of the ground roll from the data.

(a) (b) (c)

Figure 6: a: Stack of the raw seismic data (Signal + Ground roll); Figure 6b: Stack response of dataset (Signal + Residual high amplitude noise) after FXCNS algorithm; Figure c: Ground Roll noise attenuated after applying FXCNS algorithm.



(a) (b) (c)

Figure 7: a: Stack response of the Raw Seismic Data (Signal + Ground roll); Figure 7b: Stack response of Signal (without any visible ground roll noise) after applying Anomalous Amplitude Attenuation (AAA) algorithm; Figure 7c: Stack response of Ground Roll noise after applying FXCNS and AAA algorithm.

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5. Conclusion

From the results obtained, the following conclusions are reached:

(1) Ground Roll has the following characteristics:

(a) Velocity, V = 477.36ms^{-1};

(b) Frequency, F = 3.00Hz - 18.00Hz; Average F = 10.50 Hz;
(c) Wavelength, λ = 50.28m.
(d) Amplitude, A = - 6.24dB maximum @ 4.2Hz.

(2) Signal has the following characteristics:

(i) Velocity = 494.22ms^{-1};
(ii) Frequency = 10.21 – 25.12 Hz; Average F = 17.67Hz;
(iii) Wavelength = 57.12m;
(iv) Amplitude = -8.32dB maximum @ 6.30dB.

In the past, frequency offset coherent noise suppression (FXCNS) was the practice to attenuate ground roll noise from any land seismic data. Now, the introduction of the anomalous amplitude attenuation (AAA) filter in the attenuation of ground roll illustrates that the signals are more clearly and better enhanced.

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