ZIBELINE INTERNATIONAL™ PUBLISHING

E-ISSN: 2990-9295
CODEN: MAGACU

Malaysian Applied Geography (MAGG)

DOI: http://doi.org/10.26480/magg.02.2024.59.64

RESEARCH ARTICLE

THE IMPACT OF SOURCE CHARGE SIZE AND DEPTH OF BURIAL ON ONSHORE SEISMOGRAM DATA QUALITY IN THE NIGER DELTA NIGERIA

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ARTICLE DETAILS

Article History:

Received 23 May 2024
Revised 08 June 2024
Accepted 23 July 2024
Available online 30 July 2024

ABSTRACT

The study aims to investigate the impact of source charge size and burial depth on the quality of onshore seismogram data in the Niger Delta, Nigeria. Dynamite charge sizes of 0.4kg, 0.8kg, 1.2kg and 2kg were used as energy source and detonated in drilled holes at 15m and 40m. Through a thorough analysis of various parameters, the study found that both source charge size and depth of burial significantly affect the quality of seismogram data. The results showed that increasing the source charge size leads to an increase in the amplitude and signal-to-noise ratio, while increasing the depth of burial decreases the amplitude and increases the frequency content of the recorded seismograms. Moreover, a strong correlation was observed between source charge size and depth of burial, indicating that the two parameters cannot be considered independently. These findings have important implications for seismic data acquisition and processing, as they highlight the need for careful selection and optimization of source charge size and depth of burial to achieve high-quality onshore seismogram data in the Niger Delta region. Overall, this study provides valuable insights into the factors that influence the quality of seismogram data and can aid in improving the accuracy and reliability of seismic data interpretation and analysis in the oil and gas industry.

KEYWORDS

energy source, seismogram, source array, dominant frequencies, Niger Delta, Nigeria

1. INTRODUCTION

Seismic data acquisition, processing and interpretation aim at making a geologic image of the subsurface structure. Seismic source is the energy that generates seismic waves that travel through the subsurface from the source to receivers. On land, artificially-generated elastic waves are generated by detonating dynamite either on earth surface or in shallow or deep holes. The reflection or refraction component is of particular interest as it contains valuable information regarding the subsurface. In addition to visibility of primary reflections and accuracy of reflection or refraction times, the recognition and detection of seismic events on a seismogram are based upon five characteristics, namely, coherence, amplitude standout, character (or signature), dip moveout, and normal moveout as demonstrated in Figure 1 (Sheriff and Geldart, 1995; Drijkoningen, 2003). One of these characteristics, *coherence* is the similarity in appearance from trace to trace on a seismogram. When a wave reaches a spread of planted geophones, it tends to produce approximately the same effect on each geophone.

Amplitude standout, another characteristic, refers to an increase in amplitude resulting from the arrival of coherent energy. Coherence and amplitude standout indicate whether or not a strong seismic event is present. *Character* or signature refers to a distinctive appearance of the waveform that identifies a particular event. Moreover, character involves primarily the shape of the envelope, the number of cycles that show amplitude standout, the dominant frequency which is usually within the bandwidth of 10 to 70Hz, and irregularities in the phase resulting from the interference between components of the event (Yilmaz, 1987). Character may help identify reflection events. *Moveout* refers to a orderly difference from trace to trace in the arrival time of an event; it is the most distinctive criterion for identifying the nature of events. Dip moveout is the systematic changes in arrival time because of dip, while normal moveout is the systematic changes in arrival times with source-detector distance. With planar reflectors, dip moveout produces a nearly linear alignment whereas *normal moveout* is characterized by alignment curvature, but reflector curvature or velocity complications can obscure this distinction.

In this work, the effect on the seismogram of charge size and burial depth of charge on coherence, amplitude standout, character or signature, dip moveout, and normal moveout is investigated. A high-resolution data is related to the dominant frequency of the source signal (Yilmaz, 1987). It is of paramount importance to use signal source capable of generating adequate energy for high resolution seismogram to improve signal-to-noise ratio. In this case, seismic resolution can be defined as the minimum distance between two objects which can be identified separately by the seismic wave. Both seismic vertical and lateral resolutions are controlled by frequency and signal-noise ratio of seismic data (Sheriff, 1975).

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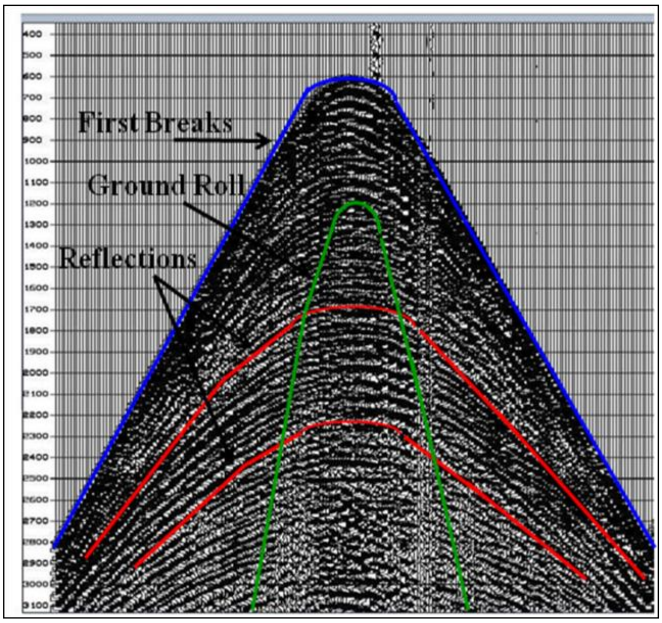

Figure 1: An example of a seismogram at SP 4461 (charge size = 0.4kg at 15m depth) showing first breaks, reflections, ground rolls, coherence, amplitude standout, character (or signature), moveout on the seismogram.

2. AREA OF STUDY, ITS GEOLOGY AND MORPHOLOGY

The area of study of the investigation was in the north-western Niger Delta area (Figure 2), is located at latitudes 10^{o}00’N and 14^{o}00’N and longitudes 39^{o}00’E and 42^{o}50’E. The low-lying wetland Niger Delta area is characterized by swamps, marshes and bogs (Akpokoje, 1989; Onyebuolise and Akpokoje, 2008). The soil vertically and laterally heterogeneous in form and anisotropy (Alaminiokuma and emudianughe, 2014; Nwankwoala and Warmate, 2014; Uko and Udochu, 2016; Avwenagha et al., 2014).

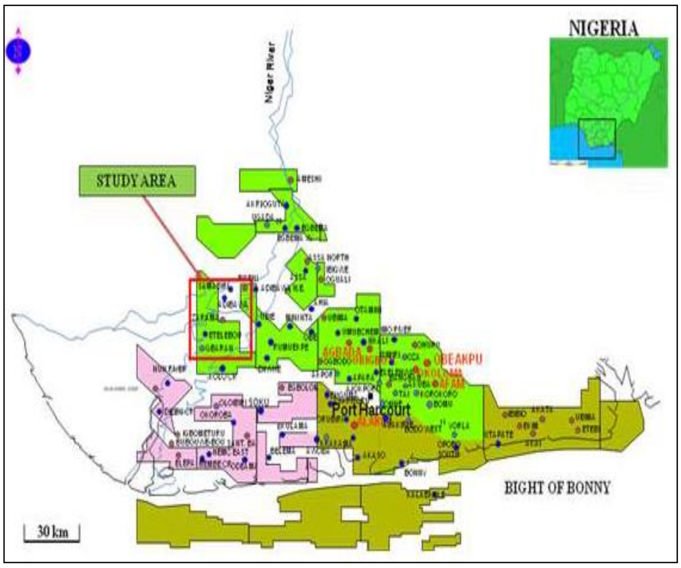

Figure 2: Oil Concessions Map of Niger Delta showing the Study Location

The general geology has been summarized by many authors as consisting of Akata, Agbada and Benin Formations and the Deltaic Coastal Plains [Figure 3] (Short and Stauble, 1967; Evamy et al., 1978; Kogbe, 1976). Akata Formation occupies the lowermost part of the basin. It consists of prodelta marine shales, often dark grey in colour, and clays with lenses of turbidite sand bodies. The formation is under-compacted and hence over pressured. It has much diapiric structures. Agbada Formation lies immediately on top of the Akata Formation. It comprises a paralic sequence of interbedded sands, shales and siltstones with a coarsening sequence. The thickness is variable, ranging from 4,000m at the centre of the delta and thins seaward and towards the delta margin. Benin Formation is the topmost formation. The Benin Formation consists of continental, fluviatile sands and gravels (Whiteman, 1982). The Benin Formation is 2,000m thick at the centre of the Basin and thins out towards the delta margins (Short and Stauble, 1967).

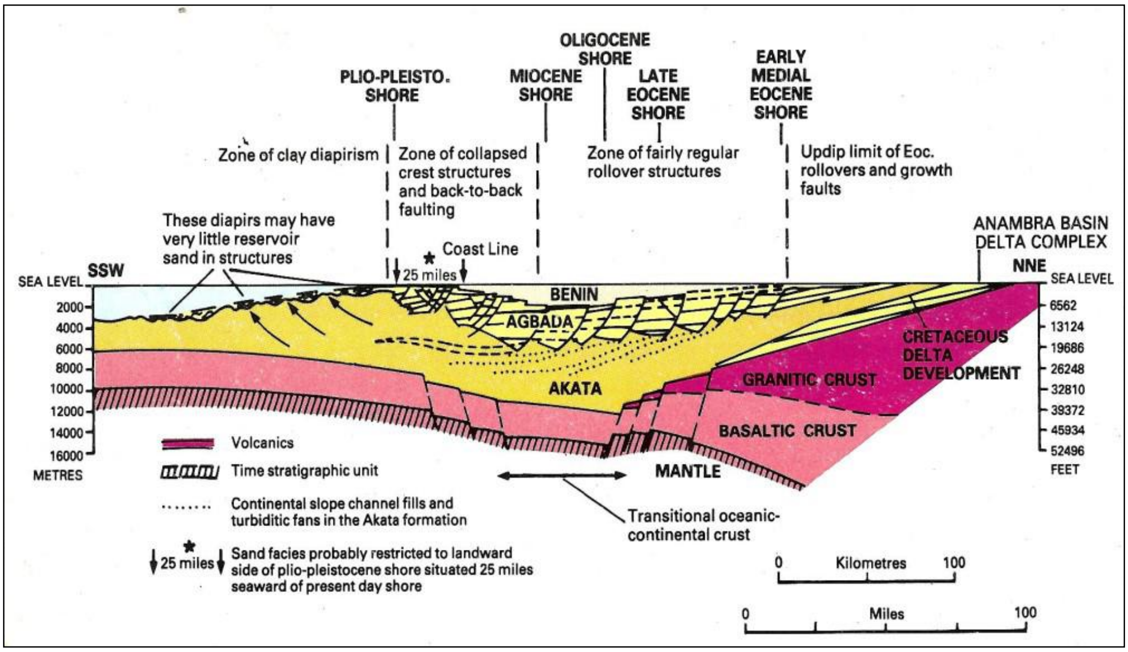

Figure 3: Stratigraphic Section of the Niger Delta showing Benin, Agbada and Akata Formations (Doust and Omatsola, 1990)

3. THEORETICAL BACKGROUND

3.1 Dynamite Explosion Model

When an explosive is detonated in a borehole, the generated energy compresses, reduces the rock's volume, and crushes the rock around the explosive (Figure 4). The breaking of the rock is a result of tension through the tensile component of the shock wave (Gutowski and Dym, 1976; Dong-soo and Jin-sun, 1998; Masson et al., 2006). The radiation pattern emitted from a dynamite explosion is assumed to be a spherical source of radius *a,* as shown in Figure 4 (Sharpe, 1942a,b; Sharpe, 1944; Blake; 1952; O'Brien, 1957, 1969; Peat, 1960). The theory also assumes the source to be planted in a homogeneous isotropic medium. The interior part of the sphere is the anelastic region and the exterior corresponds to the linear elastic zone into which a spherical wave propagates (Figure 4). The response of the earth to this high amplitude pressure impulse is nonlinear, but the nonlinear effects are confined to a region very close to the source. The medium around the source can be partitioned into inner nonlinear zone in which the elastic limit of the material is exceeded, and outer linear zone in which it is assumed that Hooke’s law is obeyed.

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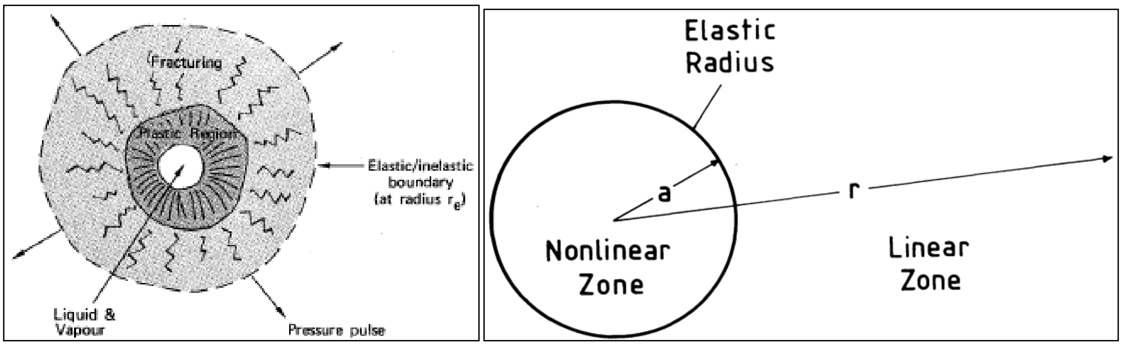

Figure 4: A Sketch of Buried Dynamite Explosion Model showing Rock Fracturing

Close to the charge, the temperatures and pressures generated by the explosion are extremely high and the material is deformed anelastically (Ziolkowski and Bokhorst, 1993). After the explosion, the amplitude of the wave radiating from the source decreases in this anelastic zone by three processes: by permanent deformation of the material, by conversion of work into heat, and by geometrical spreading. At some distance from the explosion the amplitude of the wave decreases to elastic limit of the material after when, the propagation is elastic. Most of researchers state that the signal from a dynamite charge varies both with the mass of the charge and with the medium in which it is detonated (Sharpe, 1942b; Sharpe, 1944; O'Brien, 1969; Ziolkowski and Lerwill, 1979; Sixta, 1982).

4. MATERIALS AND METHODS

The shot holes were drilled with motorised pump. The drilled holes depths are 15m and 40m. The geometry of the experiment is shown in Figure 5. The seismograms were recorded with a sampling interval of 2ms, were from charges of 0.4, 0.8, 1.2 and 2kg sizes, each at 15m and 40m depths at the same vicinity along the seismic line. Prior to charge-loading, all the holes were depth checked to ensure charges are at the required depths. The holes were well-tamped to minimize energy loss through hole-blowout.

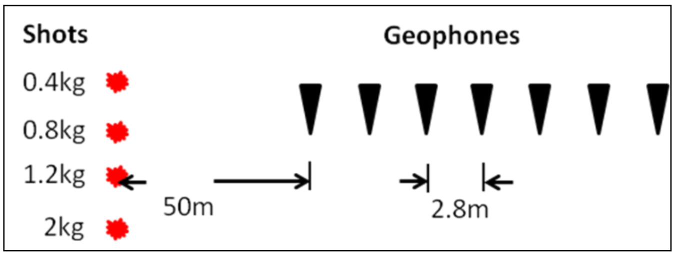

Figure 5: Geometry of the data acquisition with three different charge sizes

The data was obtained during routine seismic data acquisition. For effective noise cancellation and enhanced high signal to noise ratio of data quality, two geophone strings of nine geophones in series were laid out linearly at 2.8m spacing about the peg position along the receiver line. Receiver station interval was 50m. All the experimental shots were acquired with full receiver spread (1200 stations). The recorded raw monitors were subjected to visual physical examination and on-site processing using SeisSpace ProMax Seismic Processing software.

5. RESULTS AND DISCUSSION

5.1 Results

Without applying automatic gain control (AGC), the seismograms, amplitude and frequency from the dynamite detonation are presented in Figures 6 - 9.

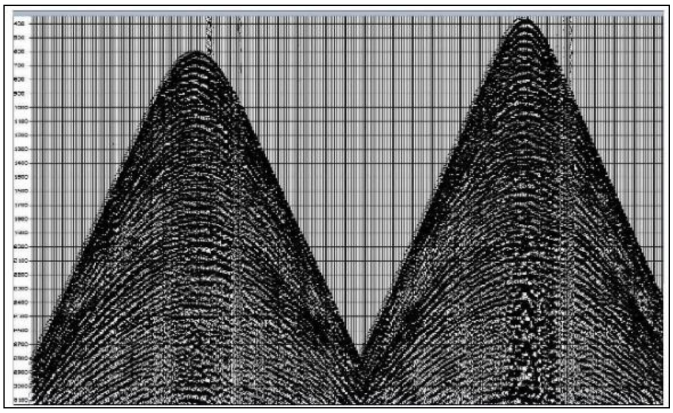

Figure 6a: Seismogram of 0.4kg charge at 40m depth

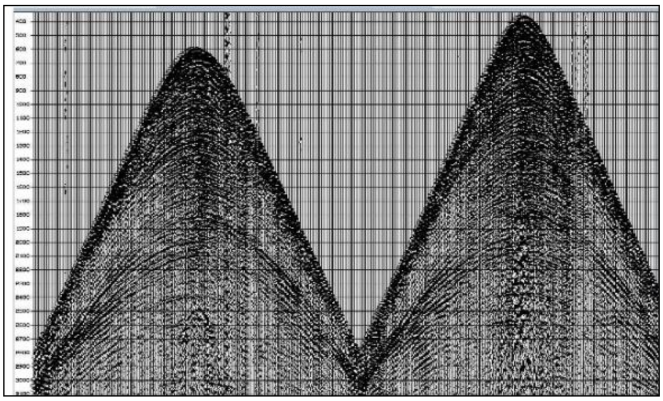

Figure 6b: Seismogram of 0.4kg charge at 15m depth

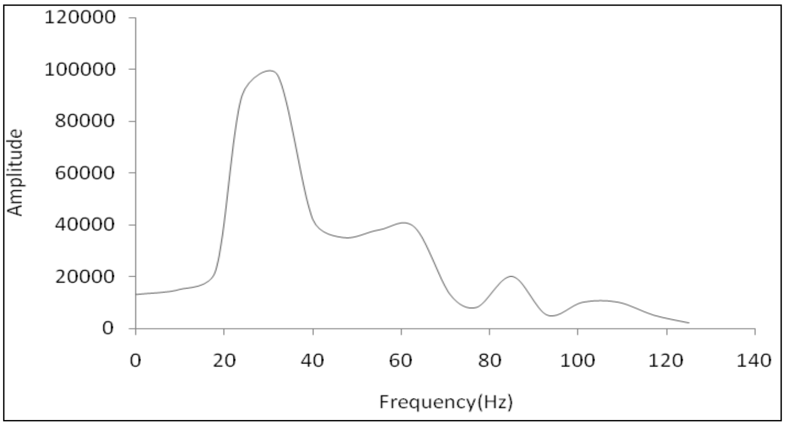

Figure 6d: Amplitude-frequency spectrum of 0.4kg at 15m depth

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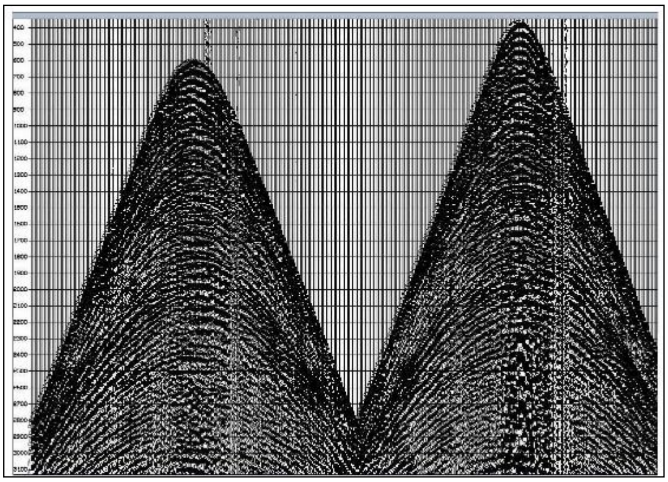

Figure 7a: Seismogram of 0.8kg charge at 40m depth

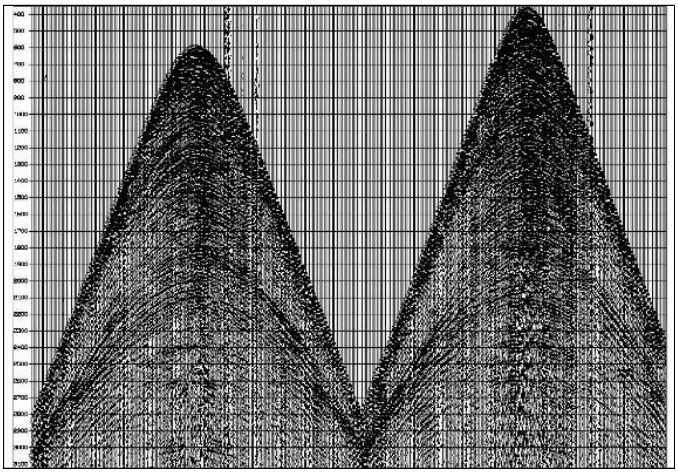

Figure 7b: Seismogram of 0.8kg charge at 15m depth

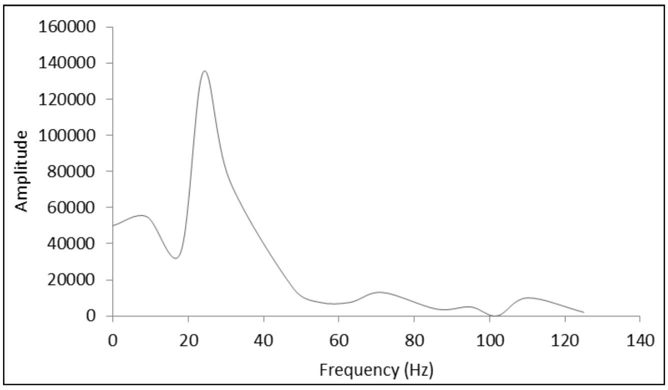

Figure 7c: Amplitude-frequency spectrum of 0.8kg at 40m depth

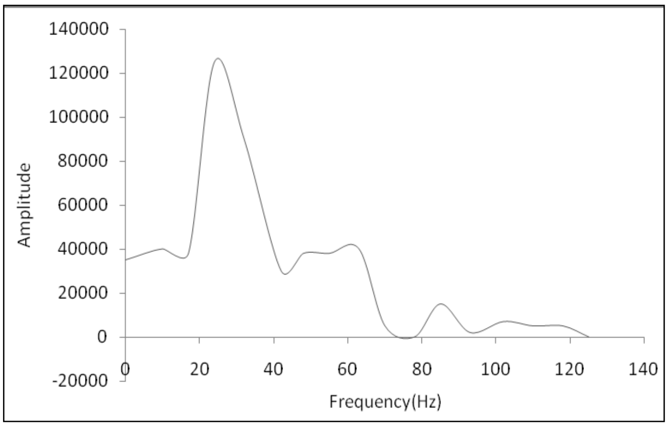

Figure 7d: Amplitude-frequency spectrum of 0.8kg at 15m depth

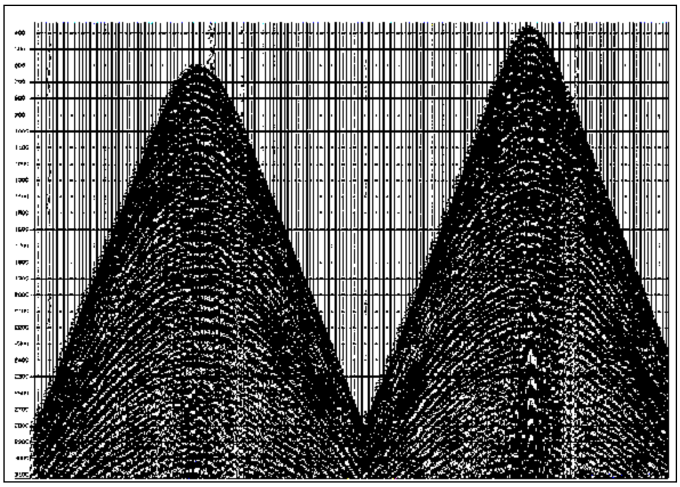

Figure 8a: Seismogram of 1.2.kg charge at at 40m depth

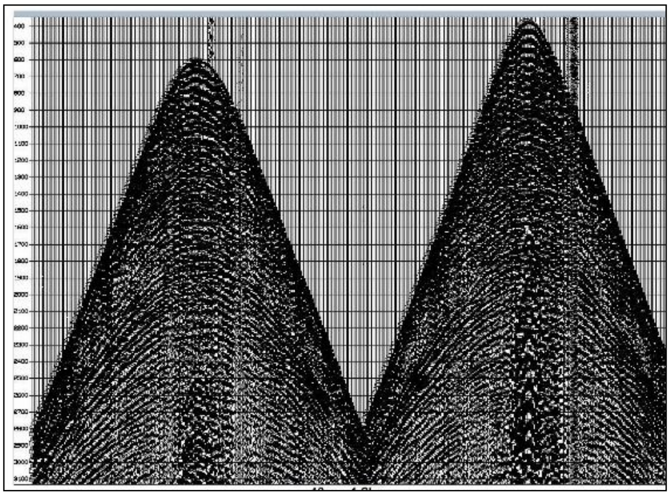

Figure 8b: Seismogram of 1.2kg charge 15m depth

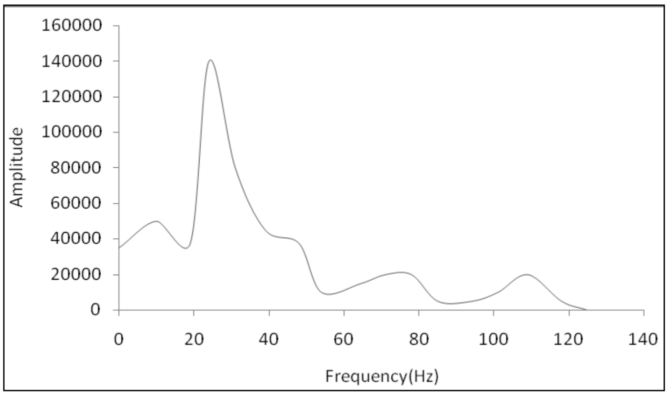

Figure 8c: Amplitude-frequency spectrum of 1.2kg at 40m depth

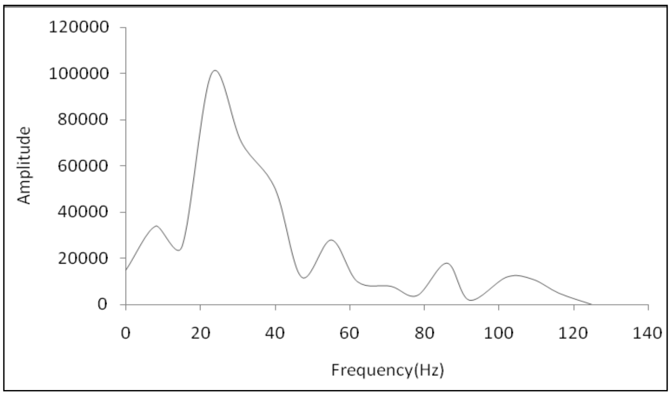

Figure 8d: Amplitude-frequency spectrum of 1.2kg at 15m depth

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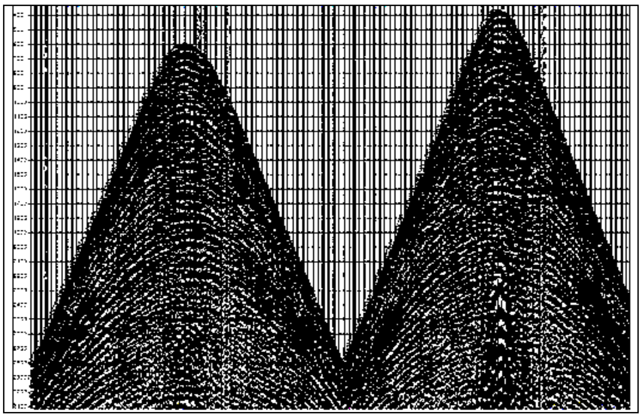

Figure 9a: Seismogram of 2.kg charge at 40m depth

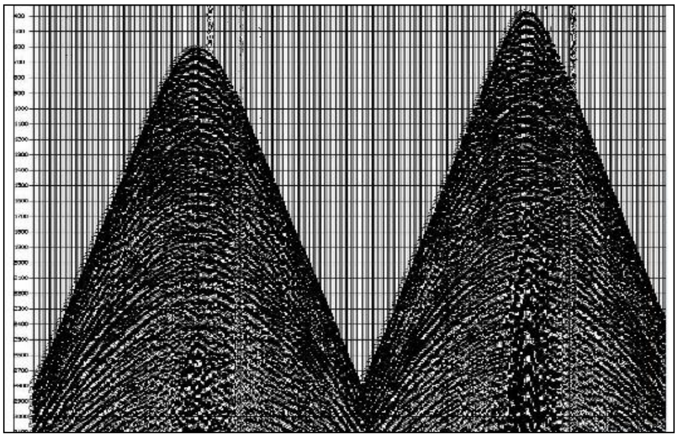

Figure 9b: Seismogram of 2kg charge at 15m depth

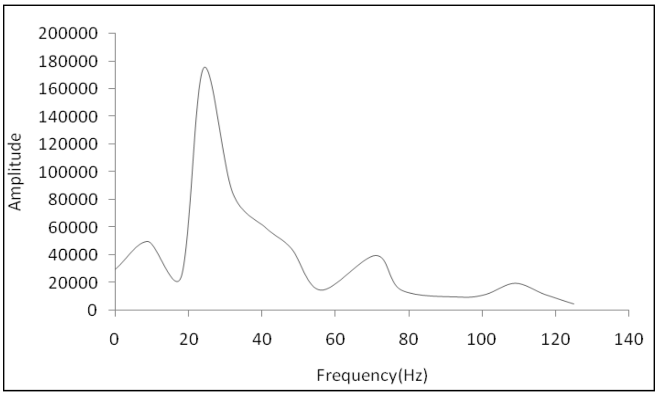

Figure 9c: Amplitude-frequency spectrum of 2kg at 40m depth

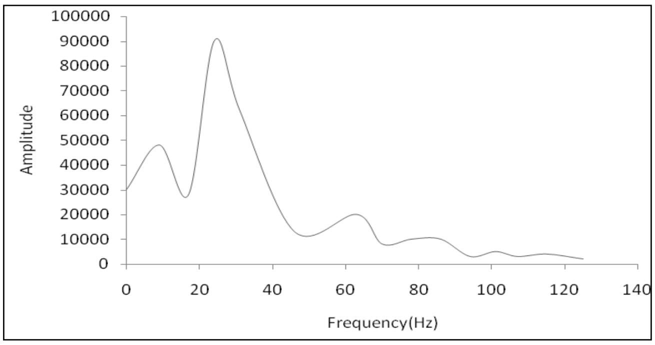

Figure 9d: Amplitude-frequency spectrum of 2kg at 15m depth

5.2 Discussion

5.2.1 *Charge size*

From the data in Figures 6a, 6b, 7a, 7b, 8a, 8b, 9a and 9b, it can be deduced that the zone of anelastic deformation around the first detonator must be small it has no noticeable effect on the record from the second detonator, with behaviour identical with the first. It follows that the anelastic zone around the second detonator must also be small. The third record has lower frequency reflections, less resolution, and a noticeable increase in the low-frequency surface wave, or ground-roll, energy. On the first two records there is a resonance at about 22Hz on the geophones nearest the shot which is barely discernible on the third record. This is the spurious resonance of the geophone and is a horizontal vibration exhibited by all vertical moving coil geophones (Ziolkowski and Bokhorst, 1993). This is clear evidence and observable within the seismic bandwidth that the radiated elastic energy shifts toward the low frequencies and away from the high frequencies, when the charge size is increased (Ziolkowski and Bokhorst, 1993).

5.2.2 *Energy and frequency Contents*

The analysis of energy and frequency level (Figures 10 and 11, Tables 1 and 2) observed within the shallow, mid and deep reflections for the different shot configurations. Sixta[28] has demonstrated in Pierre Shale that the radiated elastic energy is proportional to the mass of the charge. It follows that the energy absorbed by the medium is also proportional to the mass of the charge. Following Rodean, the absorbed energy is distributed throughout the nonlinear zone and centred at the location of the explosive (Rodean, 1971). When the explosive is detonated it is converted to a hot gas in a few microseconds, the pressure rising very rapidly to many thousands of bars.

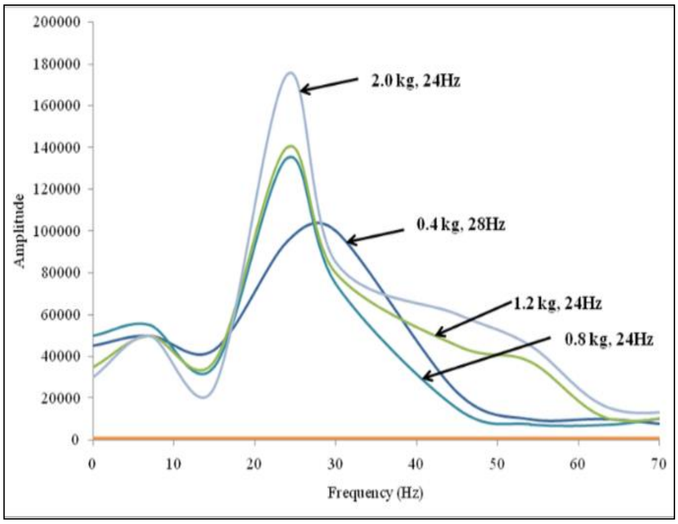

Figure 10: Frequency spectra for varying charge sizes at 40m depth

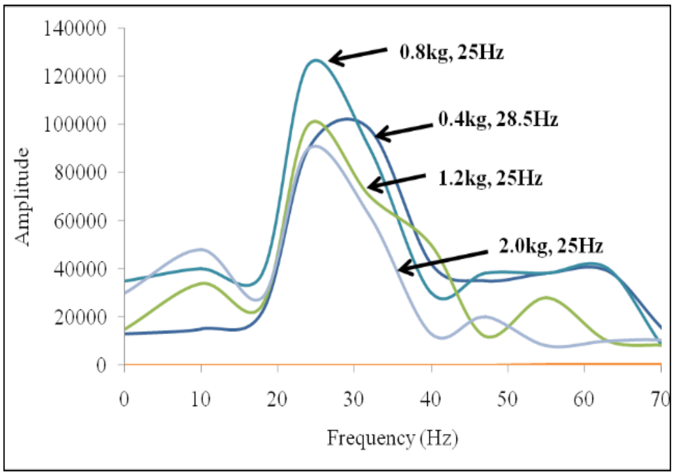

Figure 11: Frequency spectra for varying charge sizes at 15m depth

Table 1: Spectral Analysis of 0.4kg, 0.8kg 1.2kg and 2.0kg at 15m-hole depth

Charge size	Main Peak frequency	Frequency bandwidth
0.4kg	28 HZ	wide
0.8kg	24 HZ	narrow
1.2kg	24 HZ	narrow
2.0kg	24 HZ	narrow

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Table 2: Spectral Analysis of 0.4kg, 0.8kg 1.2kg and 2.0kg at 40m-hole depth

Charge size	Main Peak frequency	Frequency bandwidth
0.4kg	30 HZ	wide
0.8kg	25 HZ	narrow
1.2kg	24 HZ	narrow
2.0kg	24 HZ	narrow

6. CONCLUSIONS

(i) Increase in the size of the charge increases the reflection amplitudes.

(ii) The dominant frequency of the dynamite explosion decreases with increase charge size.

(iii) A charge size of 2.0kg provides a good seismogram quality capable of meeting geophysical objective.

(iv) At the same depth when the charge size is increased from 0.4kg to 1.2kg the energy is strong while the frequency is reduced.

(v) Increase in charge size at same depth does not convert to increment in frequencies.

(vi) Increase in depth results in widening of the frequency bandwidth.

(vii) Charge sizes of 0.4kg and 0.8kg loaded at either 15m or 40m would not provide good seismogram quality needed to achieve the geophysical objective.

(viii) Guided by the energy components, distinctive frequency, better signal-to-noise (S/N) either 1.2kg or 2kg shot records are comparable for charges loaded at 15m or 40m. Both charge size and depth are favourable for geophysical objective.

(ix) There is a decrease in dominant frequency with increased charge size.

ACKNOWLEDGMENTS

The authors are grateful to the Exploration Department of The Shell Petroleum Development Company (SPDC) of Nigeria Limited and the Department of Petroleum Resources (DPR) for the provision of data. We are grateful to Chinese National Petroleum Corporation (CNPC)/Bureau of Geophysical Prospecting (BGP), Nigeria Limited for the software used for this study. We also thank Professor C. Israel-Cookey of the Department of Physics, Rivers State University, Port Harcourt, Nigeria, for assistance mathematical modelling of the Second Order Polynomial Equations used in this work.

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