Vibroseis or Vibrators - Effective Seismic Energy Source in Northern Nigeria and Niger Republic Petroleum Exploration

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Abstract: ***Vibroseis or vibrators are seismic trucks used in the generation of force that transmits seismic wave to the earth. The transmitted seismic waves are described as sweeps, that are recorded data from either up-sweep or down-sweep (increasing or decreasing frequency respectively) are added together and compared with the source input signals to produce a nominal seismic section. Vibroseis operation is used increasingly in land surveys of pro-desert vegetation/terrain, instead of explosive energy sources in recent years due to open door to vibroseis machines or vibrators. The output of 5 vibrators were effective energy source that vibrated into the earth, and returned signals on encountering impedance; the signals were summed together for each vibe point, and stacked together to produce the record representing a vibe point. The records were viewed to identify noisy channels for field checks and corrections. Data processing was carried out to produce the brute stack section after survey coordinates were merged into the seismic data. The resulting brute stack sections showed strong reflections interpreted as structures of layers and faults.***

Keywords: Vibroseis, vibraators, sweeps, sediments

1. Introduction

Vibroseis or vibrators are seismic trucks used in the generation of force that transmits seismic wave to the earth. The transmitted seismic waves are described as sweeps, that are recorded data from either up-sweep or down-sweep (increasing or decreasing frequency respectively) are added together and compared with the source input signals to produce a nominal seismic section. Vibroseis operation is used increasingly in land surveys of pro-desert vegetation/terrain, instead of explosive energy sources in recent years due to open door to vibroseis machines or vibrators. An added factor is the Joint Venture (JV) collaboration of Nigeria National Petroleum Corporation via its Seismic subsidiary, Integrated Data Services Limited (NNPC/IDSL) with China National Petroleum Corporation (CNPC), which imported fleet of vibrators NORMAD-65 series for petroleum exploration in the Chad Basin and/or upper Benue Trough of Nigeria. Similarly, these categories of vibrators were found in use in the desert terrain of Niger Republic, Ethiopia, and Pakistan, to mention but a few.

Seismic vibrators are truck-mounted or buggy-mounted devices that are capable of injecting low-frequency vibrations into the subsurface. It is one of seismic energy sources used in reflection seismology. The vibroseis exploration technique (performed with vibrators) which was developed in the 1950s has become increasingly acceptable in the industry within the last three decades. Today, seismic vibrators are used to perform nearly half of all seismic surveys on dry land to desert terrain. The largest seismic vibration truck in the world, known as “Nomad 90”, weighs 41.5T and has a 90,000ibf force, but common to Nigerian seismic operation is NOMAD-65. The ground surface is generally covered with sandstone and sandy sediments.

2. Methodology

A seismic vibrator transforms the energy provided by a diesel engine into a vibration. It is performed by a shaker, a movable element that generates the vibration tanks to a piston-reaction mass device driven by an electrohydraulic servo-valve. The shaker is applied to the ground for each vibration, then raised up so that the seismic vibrator can move to another vibrating point. Vibrator capacity is defined by the maximum force it is capable to generate called High Peak Force and measured in pound-force. To transmit a maximum force to the ground and prevent the shaker from bumping, part of the weight of the vibrator is applied to the shaker.

On the other hand, dynamite is a chemical with the composition that burns extremely fast when detonating. It generates high amount of energy, temperature and pressure. It is made up of combination of explosive glyceroltrinitrate and glycoldinitrate as major constituents (2003n).

Vibroseis/vibrators are trucks that exert a surface source of energy and emits seismic energy through the vibration of a plate which the vibrator machine from its centre of gravity, places in contact with the earth surface. It works on the principle of the hydraulic system, and electrodynamics. An attached metal supplies the system with the push on the baseplate which is kept on the earth. This sends wave through the earth.

Nomad 90 is a vibrator owned by Sercel (R). It is a seismic truck used in the generation of force that transmits seismic wave to the earth.

The design and functionality of NOMAD 90 is an improvement of other nomads. It has long mass strokes, a heavy mass, and a high hydraulic pressure. Normad 90 is specifically suited for for generating high quality, low frequency sweeps, 90,000lbf hydraulic peak force and an ultra stiff base plate to improve high quality signal assurance.

3. Technical Specifications (As Stated by Manufacturer)

Shaker

With a Mass/Baseplate weight ratio of 3.2, the NOMAD 90 actuator can achieve higher acceleration than ever before. This has been designed to produce better high frequency performance with a high power vibrator. To improve the low frequency generation, NOMAD 90 benefits from a large usable stroke.

Power Pack

The power pack of the NOMAD 90 has the same design as the NOMAD 65 driven by a more powerful engine; the 520 HP AFTERCOOLED 1242VE VOLVO PENTA or C15 Caterpillar.

Hydraulic Circuits

Based on the same kinematic chain as the NOMAD 65, the NOMAD 90 drive hydraulic system uses a higher capacity variable displacement pump and motors. This ensures, as with the NOMAD 65, continuous variable speed under constant power. The actuator hydraulics benefits from 2 high flow and fast response pumps designed to deliver the highest quality low frequency performance. Ancillary functions and the charge pump are managed by a triple stage vane pump, using a small number of hoses for better efficiency and reliability

Carrier

The frame and the manufacturing process for the NOMAD 90 have been completely redesigned in order to produce a vibrator which can sustain peak force vibrations at these levels. The cabin and its equipment have been derived from the NOMAD 65 design after significant field exposure.

Vibroseis and dynamites are seismic sources used over a long time in the exploration for hydrocarbon all over the world. The increasing inaccessibility of oil and gas prospect areas necessitated more strategic and more cost effective ways of exploration. To this end, comparisons are drawn, indicating the usefulness of vibroseis and dynamite at various environments at different conditions.

Emission of signals.

In vibroseis, the signals emitted are of clear and of distinct quality comparable to that of dynamite. The emitted signals contain an amount of energy that is far of better quality for processing and general output. These signals bring into use all the ways of depicting the formation as it is in the subsurface and also for interpretation in petroleum exploration.

Effects on Environment

The environment is less adversely affected in the use of Vibroseiss than the dynamite survey. As a result of high energy output at the point of explosion, sever harm can be done to the environment. The harm can affect the animal and the people living within the vicinity. The adverse nature of the dynamite source prohibits its use in urban or densely populate areas.

Position of Shot Points

In dynamite survey, a hole has to be drilled at every shot point in which the dynamite explosion is expected. The hole is important in order to direct the waves generated vertically below the shot point to the subsurface. This means a lot of work on the use of dynamite.

In vibroseis survey, a vibrator mounted to the machine is used. This vibrator directs waves into the earth to pass through the layered or non-layered media until it is reflected back upon encountering an impedance, and picked by the geophone or hydrophone. The vibrator sends signal to the earth. It provides a direct means of measurement and the control of out-going wavelets. Hughes (1995) concluded that the heavier Vibrators can increase the top end frequencies by 10-15 Hz in a comparison with less impact Vibrators.

Number and Spacing of Sources

As a result of an expanded impulse, the energy density of the source wavelength is much less than the energy density of the dynamite wavelets. As a result, destructive effects are much less. Vibroseis provides means of controlling and measuring outgoing wavelets. However, one vibrator does not deliver a significant amount of energy required for seismic exploration. A series of vibrations have to be used simultaneously, often 4 to 5 sweeps and subsequently summed into composite stacks.

Rayleigh waves from Vibrators

Vibrators present a cumulative band of surface waves. As a result, Rayleigh waves are produced. Rayleigh waves high a very high amplitude and are not useful in the seismic exploration for oil and gas. Data processing trials associated with a 2002 field study (Mosaic, 2002) confirm that the spectral content of seismic data is affected by the near surface sub-weathering interface, which is typical of the area. Suppressing the Rayleigh wave would have been a good choice. However, it is not easily achieved. It is more achievable in dynamite survey by placing the charge for explosion below the bottom of a weathered layer.

Accessibility

Accessibility is very important in seismic exploration. The vibroseis method is mainly applied in areas of good accessibility so as to move the vibrator to area of survey. Flooded zones or areas that have muddy soils are not good for this method. The earth has to be strong enough to carry the weight of the truck.

It is evident that the Vibroseiss is the most preferred seismic source. It is the standard method in seismic exploration for oil and gas. The operational advantage and cost are better than the use of dynamite which of course is dangerous to the environment. Bellow is the summary of the advantages

4. Geologic and Tectonic Setting of the Upper Benue Trough

The Chad Basin with an area of about 2335000km^2 is the largest area of inland drainage in Africa and it extends into Nigeria, Cameroon, Central African Republic, Chad, Sudan, Niger Republic, Libya and Algeria (Okosun, 1992). The Benue Trough itself is geographically subdivided into lower, middle and upper portions. It is a rift basin that trends SSW-NNE for about 800km in length and 150km in width. The southern limit is the northern boundary of the Niger Delta while the northern limit is the southern boundary of the Chad Basin. The trough contains up to 6000m of Cretaceous-Tertiary sediments of which those predating the mid-Santonian were compressionally folded, faulted and uplifted in several places (Obaje, 1994; Abubakar, M.B and Obaje, N.G., 2001).

The Upper Benue Trough is made up of two arms, the Gongola Arm and the Yola Arm (although some authors have sub-divided the Upper Benue Trough to include a third central Lau-Gombe sub-baisn, eg. Akande et al., 1998). In both arms of the basin, the Albian Bima Sandstone lies unconformably on the Precambian Basement. This formation was deposited under continental conditions (fluvial, deltaic, lacustrine) and is made up of coarse to medium grained sandstones, intercalated with carbonaceous clays, shales, and mudstones. The Bima Sandstone was subdivided by Carter et al. (1963) into a Lower, Middle and Upper Bima. The Middle Bima is reported to be shaley in most parts with some limestone intercalations and was assumed to be deposited under a more aqueous anoxic condition (lacustrine, brief marine).

The Yolde Formation lies conformably on the Bima Sandstone. This formation of Cenomanian age represents the beginning of marine incursion into this part of the Benue Trough. The Yolde Formation was deposited under a transitional/coastal marine environment and is made up of sandstones, limestones, shales, clays and claystones.

In the Gongola Arm, the laterally equivalents Gongila and Pindiga Formations and the possibly younger Fika Shale lie conformably on the Yolde Formation. These formations represent full marine incursion into the Upper Benue during the Turonian – Santonian times. Lithologically, these formations are characterized by the dark/black carbonaceous shales and limestones, intercalating with pale colored limestones, shales and minor sandstones. The Fika Shale is lithologically made up of bluish-greenish carbonaceous, sometime pale gypsiferous, highly fissile shales and occasional limestones in places.

In the Yola Arm, the Dukul, Jessu and Sekuliye Formations, theNumanha Shale, and the Lamja Sandstone are the Turonian – Santonian equivalents of the Gongila and Pindiga Formations. The Turonian – Santonian deposits in the Yola Arm are lithologically and palaeoenvironmentally similar to those in the Gongola Arm, except the Lamja Sandstone which has a dominating marine sandstone lithology. The recovery of diverse assemblages of arenaceous alongside planktonic foraminifera from samples obtained from the Dukul, Jessu and Sekuliye formations indicate deposition in shallow marine – neritic – shelfal environments (Obaje, 2009).

The Santonian was a period of folding and deformation in the whole of the Benue Trough. Post-folding sediments are represented by the continental Gombe Sandstone of Maastrichtian age and the Keri–Keri Formation of Tertiary age. The Gombe Sandstone is lithologically similar to the Bima Sandstone, attesting to the establishment of the Albian palaeoenvironmental condition. The Gombe Sandstone Formation, however, contains coal, lignite, and coally shale intercalations which in places are very thick. The Keri–Keri Formation is made up of whitish grey sandstones, siltstones, and claystones with the claystones dominating the lithology in most places (Obaje, 2009)

Table 2: Stratigraphical succession for the Chad Basin in Nigeria

Formation	*Lithology*	*Age*	*Environment*
Chad	Clay, sand	Pleistocene unconformity	Continental unconformity
Kerri Kerri	Clay, sandstone, grit	Paleocene unconformity	Continental unconformity
Gombe sandstone	Shale, sandstone, siltstone	Maastrichtian	Deltaic, estuarine
Fika shale	Blue black shale	Turonian-Santonian	Marine
Gongila FM	Sandstone, shale	Turonian	Marine estuarine
Bima sandstone	sandstone	Cenomanian unconformity	Continental unconformity
Basement			

5. Results and Analysis

Field Layout of Vibrators along Seismic Line:
The vibrators are positioned on the traverse at designated or surveyed points pegged as shot points, while the telemetry cables are laid on the other ((Right-hand-side) of the seismic line and connected into the boxes, in a pattern array for the seismic data acquisition as shown in the figure below.

Figure 1: Vibroseis survey in operation, 5 vibrators in source array along the Seismic line

Figure 2: Vibrators in Source Array, with the Base-plate dropped to impact vibration waves into the ground.

Figure 3: Showing the Geophones (Receivers) laid along the Seismic line 5m away from the Vibrator Array Line or Axis.

Geophones and Station units/boxes/LAUX units are buried in sand for good geophone coupling upon vertical planting or pinning into the earth.

Figure 4: Inside the Recording Truck, Seismic data as the sweeps were into record, showing signal frequencies 30Hz to 60Hz with good amplitudes.

Figure 5: Showing Field Recording Engineer and Supervisor in Recording/Instrument Truck.

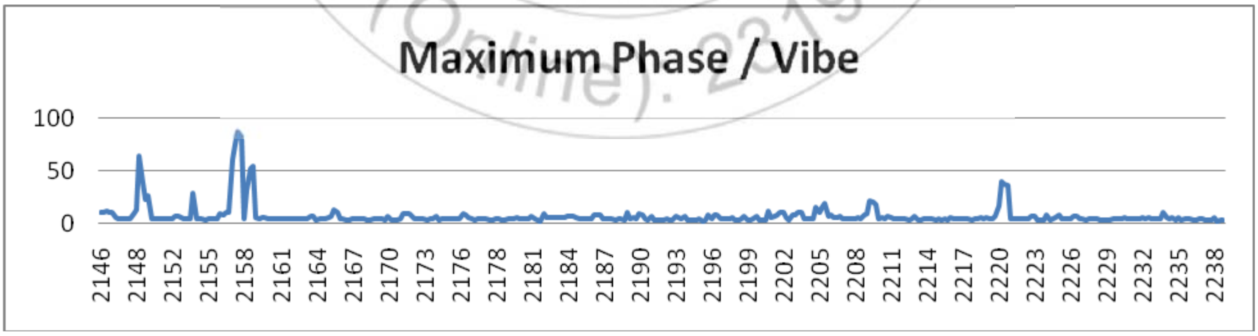

Figure 6: Vibrator 5 Phase characteristics along the Seismic line or profile.

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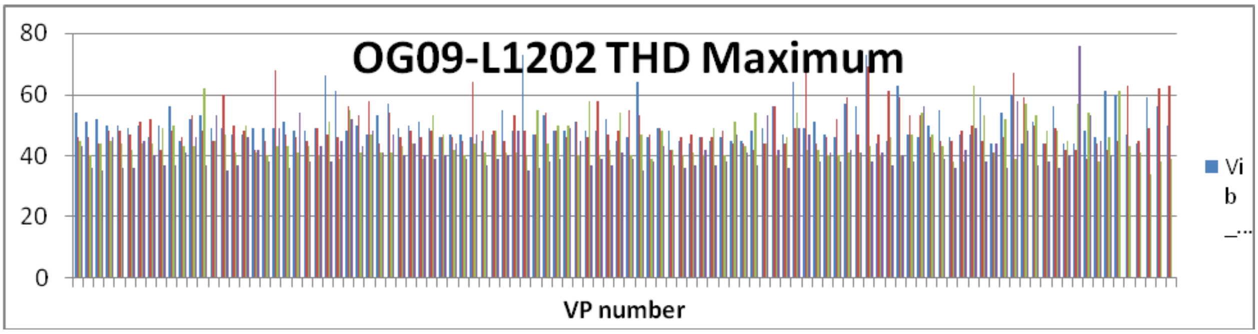

Figure 7: Force characteristic of the 5 vibrators in the Source Array along the Seismic Line

6. Conclusion

The output of 5 vibrators were effective energy source that vibrated into the earth, and returned signals on encountering impedance; the signals were summed together for each vibe point, and stacked together to produce the record representing a vibe point. The records were viewed to identify noisy channels for field checks and corrections. Data processing was carried out to produce the brute stack section after survey coordinates were merged into the seismic data. The resulting brute stack sections showed strong reflections interpreted as structures of layers and faults.

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