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Vibroseis Hardwire Similarity Tests Results Trend and Signal Strengths from Upper Benue Trough to the Chad Basin Areas, Lithologic Significance

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Abstract: ***Hardwire similarity tests are conducted to verify integrity and performance of the vibrators component machines. It will certainly reveal to what extent it performs optimally. Many source parameters were recorded, which included, varying sweep range, dwell, drag length, number of sweeps, sweep lengths, peak force, boost or gain percentages and number of vibrators. Thus vibrator testing requires a significant amount of time in the field. Hard-wire test uses a cable connected from the Instrument recorder to the vibrator. It is an important performance check. The test is usually carried out at the start of the job and any other time the equipment is pulled for maintenance and repair. Besides, it provides for the integrity analysis check necessary to have a field processing system that will allow a geophysicist to make on the spot decision about further testing that may be necessary beyond the initial test lists. The sweeps and frequency bandwidth that characterize the Upper Benue-Chad Basin axis, have confirmatory identical signatures with stack section from the Doba Formation of SW to central South of Chad Republic.***

Keywords: Hardwire tests, distortion, wave generation, signal strengths

1. Introduction

Vibrators' hardwire similarity tests are conducted to verify integrity and performance of the vibrators component machines. It will certainly reveal to what extent it performs optimally. Many source parameters were recorded, which included, varying sweep range, dwell, drag length, number of sweeps, sweep lengths, peak force, boost or gain percentages and number of vibrators. Thus vibrator testing requires a significant amount of time in the field.

Hard-wire test uses a cable connected from the Instrument recorder to the vibrator. It is an important performance check. The test is usually carried out at the start of the job and any other time the equipment is pulled for maintenance and repair. Besides, it provides for the integrity analysis check necessary to have a field processing system that will allow a geophysicist to make on the spot decision about further testing that may be necessary beyond the initial test lists

The sweeps and frequency bandwidth that characterize the Upper Benue-Chad Basin axis, have confirmatory identical signatures with stack section from the Doba Formation of SW to central South of Chad Republic. Down sweeps have been replaced by up-seeps. Usually, up-sweeps start at a low frequency of about 10Hz and sweep to 100Hz. Linear sweeps or rather that an equal amount of time is spent sweeping through the frequency ranges. The frequency bandwidth tends to be influenced by the nature of the top-sediments. As the sandy terrain of the Chad Basin shows initial up-sweep values of 5Hz to 8Hz, while the A higher frequency was achieved by introducing a boost or dwell into the system. Care was taken to avoid achieving too much frequency, as too much of a dwell could introduce noisy record sections (Andreas et al, 2000). Experiments have shown consistent bandwidths in the Chad Rep portion of the trend.

In terms of optimum S/N estimation, the hardwire similarity test measures the integrity communication efficiency from the Recording Instrument to the line equipment through the medium of the top-soils and refractors. Thus, it provides a reliable pointer to the frequency bandwidth, and high resolution level of frequency content of the signals.

In order to achieve appropriate S/N, careful testing and design of dwell was done. Various sweeps can be used to enhance careful frequencies beyond the dwell (Pritchett, 1994). A phase, force, frequency and time interpolations were performed on all vibrators in order to evaluate their performance. This singled out the vibrators with an optimum S/N. Dense wave testing has also been identified in reducing noise (Regone, 1998). These procedures were carried out to ensure good quality signals

The vibrator shots at any given shot point location SP, is repeated severally for the purpose of enhancement and then summed or stacked. This is also called vibrator sweep, as it vibrates repeatedly according to specification of program issue. In the repetition of frequency sweep, amplitude increases are optimized to a specific level within the same duration. The sweep technique which increases the low-frequency content of the signal, extends the signal bandwidth to below 3Hz in order to greatly improve imaging results at depth. The frequency of the sweep may vary linearly or nonlinearly with time. A linear sweep is that which the plot of the instantaneous frequency against time, produces a straight line. Thus sweep may start at a low-frequency and end at a high frequency. A typical vibrator can create signals with a bandwidth from 8Hz to 105Hz. When it is nonlinear maximum displacement sweep, it helps to generate low-frequencies and illuminate deep reflectors.

2. Objective of Study

The objective of the study is to investigate for possible trend of vibrators hardwire similarity tests results in changing terrains from desert dry land underlain with sandstone to mixed sediments of the Chad Basin environment. The mixture of dry and wet lands in the adjoining Chad Republic area can be compared for possible high distortions signatures at dry lands and the lithology in place.

3. Methodology

In the area of known geology, underlying rocks was mapped of the Upper Benue Trough, seismic profiles were run using the vibroseis method of geophysical investigation. The hardwire tests were conducted and results compared for the profiles of changing lithology. The force and distortion plots were re-run for regional profiles along changing lithology and comparative plots reviewed.

4. Geologic Setting of the Upper Benue Trough

Nigeria is underlain by seven major sedimentary basins, viz: (from the oldest), the Calabar Flank, the Benue Trough, the Chad Basin, Nupe Basin, SE Lullemmendan (Sokoto) Basin, the Dahomey Basin, and the Niger Delta Basin. The sedimentary successions in these basins are middle Mesozoic to Recent age. Older sedimentary deposits were not preserved, probably because during the Paleozoic to early Mesozoic, the current Nigeria location was a broad regional Basement upliftment with no major basin subsidence for sediment accumulation.

The sedimentary successions in the Nigerian basins can broadly be subdivided into the following:
1) Basal continental sandstones, siltstones, and mudstones;
2) Middle marine shales and limestones, interbedded with sandstones and siltstones;
3) Upper sandstone sequences that is continental or paralic.

Regionally, the Benue Trough is part of the Early Cretaceous rift complex known as the West African. A widespread, shallow, marine transgression occurred during lower Turonian times. The marine conditions persisted until the Maestrichtian and were accompanied in the south by localized volcanic activity. Over the northern central areas, marine conditions gradually gave way to deltaic and estuarine environments in which the Gombe sandstone was deposited. There are some evidences that the Gombe Sandstone was unconformable with the Older Cretaceous rocks. In the south, marine sedimentation persisted for a longer period but culminated in swampy conditions which favoured the accumulation of a thin sequence of coal measures.

Sedimentation recommenced in the Paleocene, and a younger sequence of continental deposits, the Kerri Kerri Formation, was laid down. These are now restricted to the northern and western parts of the region and their original extent to the south and east is not known. The continental sedimentation was followed by a period during which the extensive laterite sheet overlying the Kerri Kerri Formation was formed.

During the late Tertiary and Quaternary, lacustrine deposits of the Chad Formation were laid down in the northern part of the area widespread volcanic activity occurred in the southern and central areas.

The structural pattern of the region is dominated by a series of large folds with axes trending NE-SW. The folds are remarkable for their simplicity, narrowness and great length; the Lamurde anticline, one of the major structural units, is over 60miles long. From south to north the more important fold are the Benue, Dadiya, Reme, and Bobbini synclines which are separated by the Lamurde, Bwonian, Talasse and Guyuk anticlines. The lowest member of the Cretaceous sequence, the resistant grits and sandstone of the Bima Sandstone form the core of the anticlines, while the overlying less resistant marine sediments are preserved in the synclinal troughs.

Differential Basin Origin and Configuration

Benkhelil (1989) and Genik (1992, 1993) have demonstrated that Upper Benue Trough is linked with Late Pan-African structural weakness which was reactivated as sinistral strike-slip faults during the early to Mid–Cretaceous time. The reactivation was responsible for the formation of geologic structures in the entire Benue Trough, including Upper Benue Trough. The structures include the alternation of uplifted basement rocks, blocks and pull-apart basins. The Upper Benue Trough was later significantly restructured by a later Cretaceous deformation by causing uplift and upward arching of the basin especially along its axis. The origin of the Chad Basin and its tectonic activities seem to be a response to the general uplift of the Upper Benue Trough due to the late Cretaceous folding (Benkhelil, 1989). The processes leading to the origin of which is summarized by the hypothesis of Burke (1976a) into at least four phases as follows:

Phase 1: This is the first stage which began when the African plate was still (no movement) with respect to the mantle below it. (Burke and Wilson, 1972)

Phase 2: The stage marked the thermal irregularities of the basin as a result of being above hotter parts of the mantle. As a result the area became elevated relative to other parts of the plate.

Phase 3: This is marked by a volcanic eruption on the elevated areas. This was followed by erosion and eventually an increased deposition rates and to accelerated progradation of the Niger Delta area (Burke 1972). Kerri-Kerri Formation, the first deposition of Chad Basin was formed at this phase.

Phase 4. Volcanism continued on elevated areas overlying the hot upper mantle. Erosion from the watershed into the basin, and uplift with volcanicity led to the deposition of the underlying Chad Formation. The Southwestern part of the Chad basin sits on the northern extreme of the Benue rift system. This is indicated by the gravity study of Cratchley and Jones (1965) exposing the outcropping in the nearby Gongola area and Southwards extents under the Chad Basin.

Differential Physiography

The Upper Benue Trough is characterized by ragged granitic hills namely: Jos Craton, the Adamawa Craton and the Mandara Craton. Many volcanic plugs punctuate the area. Also, sedimentary rocks form topographic identity as they stand elevated. Example: to the west, the Paleocene Keri-Kerri Formation forms a plateau whose eastern edge oversteps the Cretaceous terrain. The same applies to the Chad Formation to the north. Lankoveri–Bajama Hills(to the south) and Bima Sandstone Cuesta form hills of the Lamurde anticline(to the north) flank the wide alluvial valley of the Benue River. The most impressive feature of the entire area are seen to be Biu and Lunguda basalt Plateaux. They all rise up to 90m above the surrounding sedimentary terrain. The Benue River, however flows on its own alluvium in a 12-22km wide swampy valley.

The Benue River is essentially the major drainage channel of the area with its major tributary, the Gongola River. Drainage is dendritic defined by the tree-like pattern and making rivers to flow towards the Lake Chad. The Chad Basin is a basin of internal drainage since no surface drainage flows out of the basin. The present Lake Chad is about 280m above the sea level. The Bodele depression within the Chad is lower. Lake Chad is the receiving centre of centripetal drainage pattern featuring four drainage lines from the South-Komadugu, Yobe and Ngadda system from Nigeria and Logone/Chari system from Cameroon.

Lake Chad is shallow. The shallowness is attributed to the fact that rivers supplying the lakes are shallow and flow sluggishly. The higher sediments in the northern part lead to precipitation of various salts especially calcite. The surface deposit of Chad Basin consisits of aeolian sands, river alluvium, deltaic deposits and clay plains (Pullan, 1964). Esu et al (1999) noted that the soil in the Chad Basin are sandy, poorly aggregated, highly erodible, very deep, and contains moderate levels of phosphorus which is capable of enhancing moderate soil moisture retaining capacity.

Differential Basin Fill

The lithofacies and structures of the Upper Benue Trough were contained in the sheet of geological maps accompanying Geological Survey of Nigeria Bulletin 30 as compiled by Carter et al (1963). It shows that Zambuk ridge separates the Upper Benue Trough into two: the area adjourning the Chad basin and the area to the south. Avbovbo et al (1986) in an interpretation of north eastern to southwestern seismic reflection lines in the north eastern part of Nigeria, identified an intrusive igneous horizon and several stratigraphic units, the top two of which are Tertiary Chad Basin facies. The lower facies were assigned to the Benue Trough.

Seismic Sequence 1. The basal unit rests directly on the basement and marked by a baselap.

Seismic Sequence 2. This unit suggests a fluvial deposition. It is correlatable with the Upper part of Bima Formation as described by Carter et al (1963)

Seismic Sequence 3. This unit shows a continuous low-amplitude seismic reflection pattern suggesting monolithic identity and correlatable to Gongola Formamtion

Seismic Sequence 4. This unit is a discontinuous low amplitude seismic facie correlatable to the marine Fika Formation.

Seismic Sequence 5. This marks the top of the Cretaceous succession with an Angular Uncomformity. It is cortrelatable to the Gombe Sandstone which is marked as Fluvio-lithoral deposit with interbedded shales, sands and coal (Carter et al 1963). From the same seismic interpretation, it is realized that the Chad basin is associated with seismic sequences 6 and 7. This is illustrated as follows:

Seismic Sequence 6. This is a parallel but continous high-amplitide reflection. This is about 350m thick and dips at a low angle. It is unaffected by faulting and folding. It shows an anuular uncomformity with the underlying sequence 5 classified under the Upper Benue Trough. It is suggested to be the lower part of Chad Formation. It maybe correlated with the Kerri Kerri formation since it is not faulted .

Seismic sequence 7. This is the topmost sequence with a concordant boundary and parallel seismic reflection with a very low ($1\text{-}2^0$) dip. This indicates a uniform rate deposition in a basinal setting suggestive of a low energy basin . it is correlated with a partly-exposed Quaternary age of Chad Formation

Stratigraphic Differences

The Upper Benue Trough is made up of Cretaceous sediments and starts from the extensive continental Bima formation which directly overlies the Basement Complex. A subdivision was into three formations corresponding to what has been regarded as Members. Overlying Bima formation is largely marine Yolde Formation which is heterolithic. The continental deposition is terminated by basin fill. The continental deposition is associated with the withdrawal of the sea at the end of the Cretaceous; at which folding translated the depo axis westward to form the Kerri-Kerri sub Basin.

The Bima Sandstone overlies the basement Complex in the Chad Basin Area. It outcrops both in the Chad Basin and the Benue Basin although thickness varies from place to place.

5. Analysis of Geophysical Data

Details of geophysical signatures in figures 1 to 3, are displayed reflecting the algorithm of measurement of the efficiency of vibrators on various lithologic environment and the shot records and the composited seismic stacks figures 4a to 5b, revealed suitability of tracking/monitoring and confining of any problem or fault in the Recording Instrument to peculiar locations. Generally on all the regional profiles, the average distortion deflections were prominent at the lithologic boundaries which were delineated by ground geologic mapping.

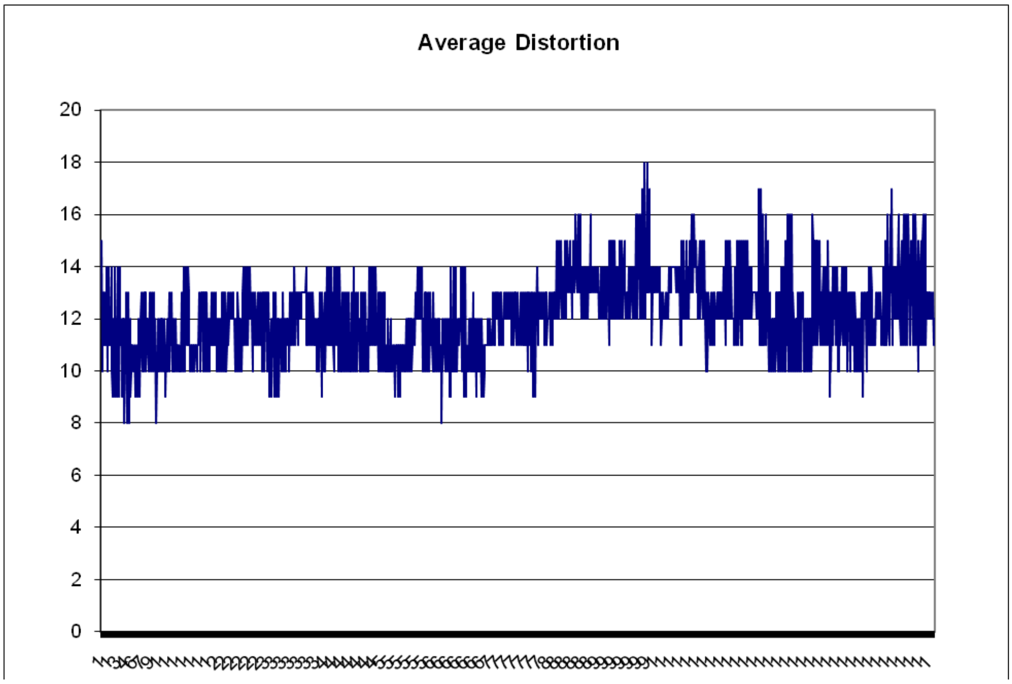

Figure 1: Vibroseis Hardwire Similarity Test showing Average Distortion along Seismic line

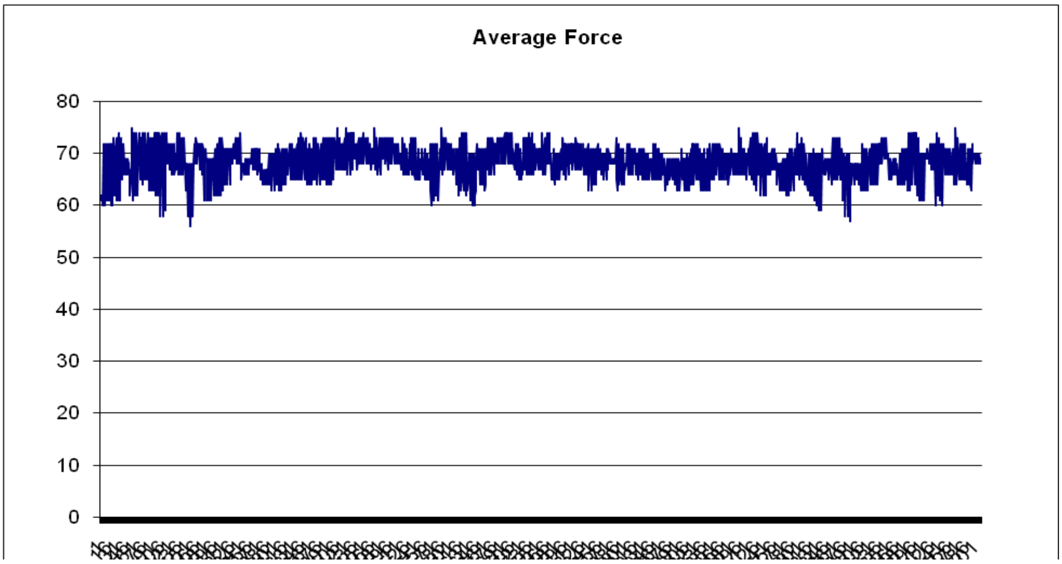

Figure 2: Vibroseis Hardwire Similarity Test showing Average Force applied on plate to impact on ground along Seismic line

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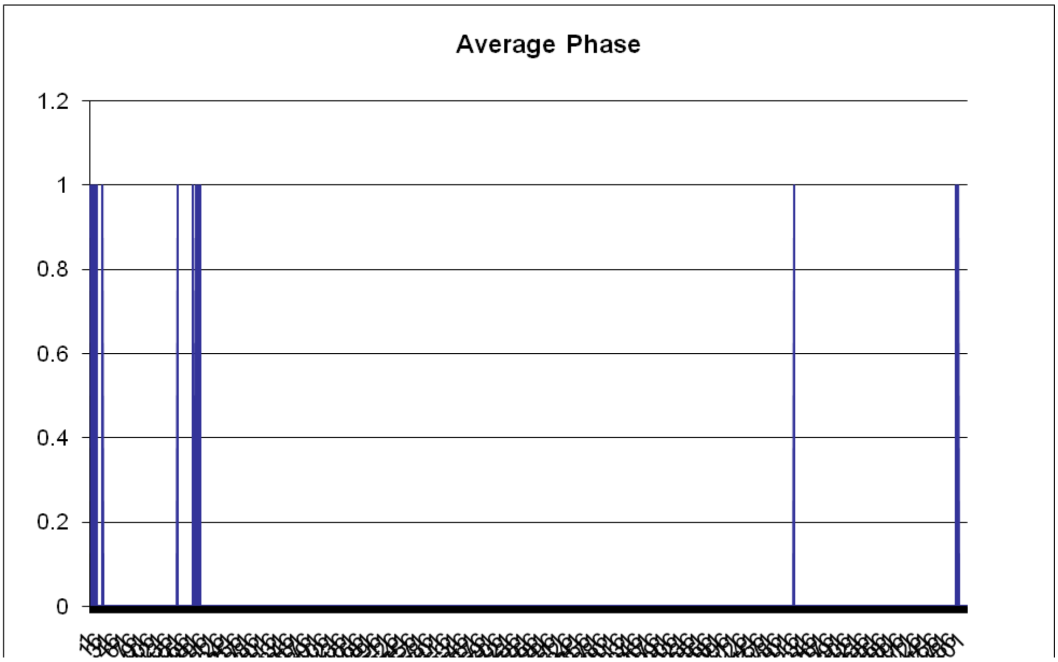

Figure 3: Vibroseis Hardwire Similarity Test showing Average Phase of signal waves impacted to the ground along Seismic line

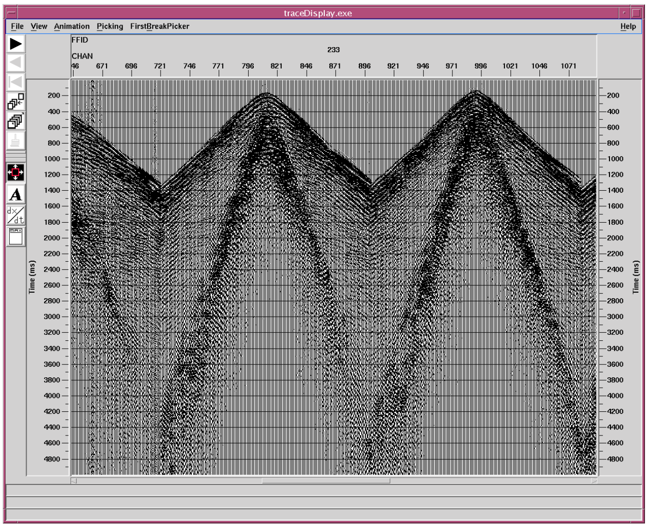

Figure 4a: Vibe Shot Record after Hardwire Similarity Test confirmation of good Instrument-line connection

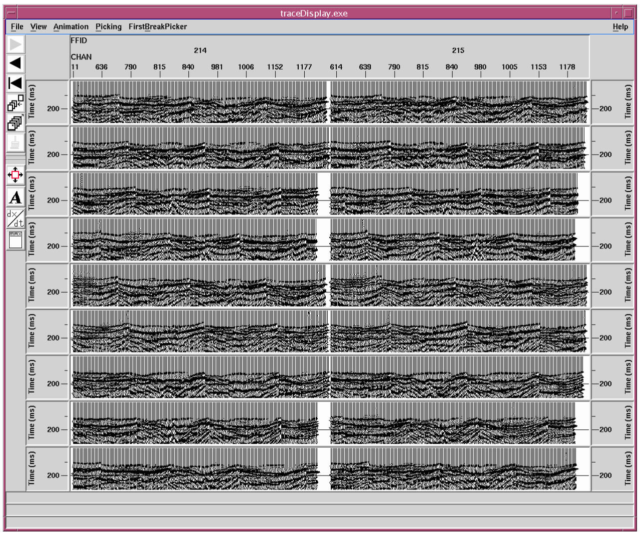

Figure 4b: Monitor of Vibrator records and the associated Geometry Quality Control, Linear Move Out (LMO) QC tool.

The surface within the prospect area was varied ranging from sand to clay and rocky outcrops with Longone River which traversed area.

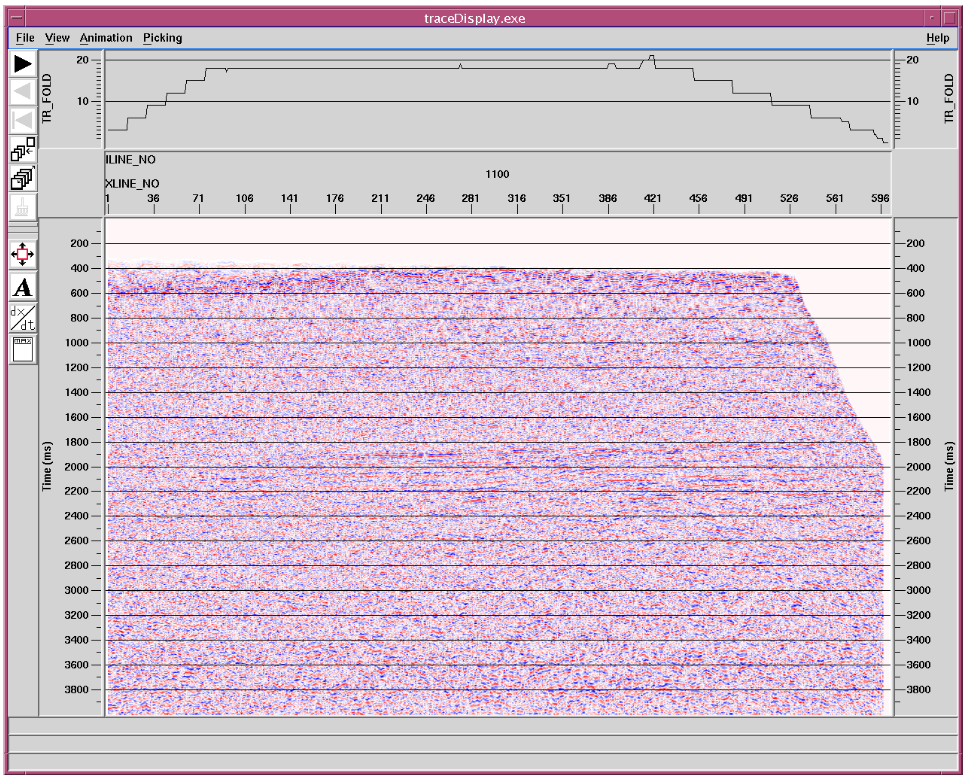

Figure 5a: Brute stack of Seismic line 1100, Inline from Doba Basin, Chad Basin NE-axis.

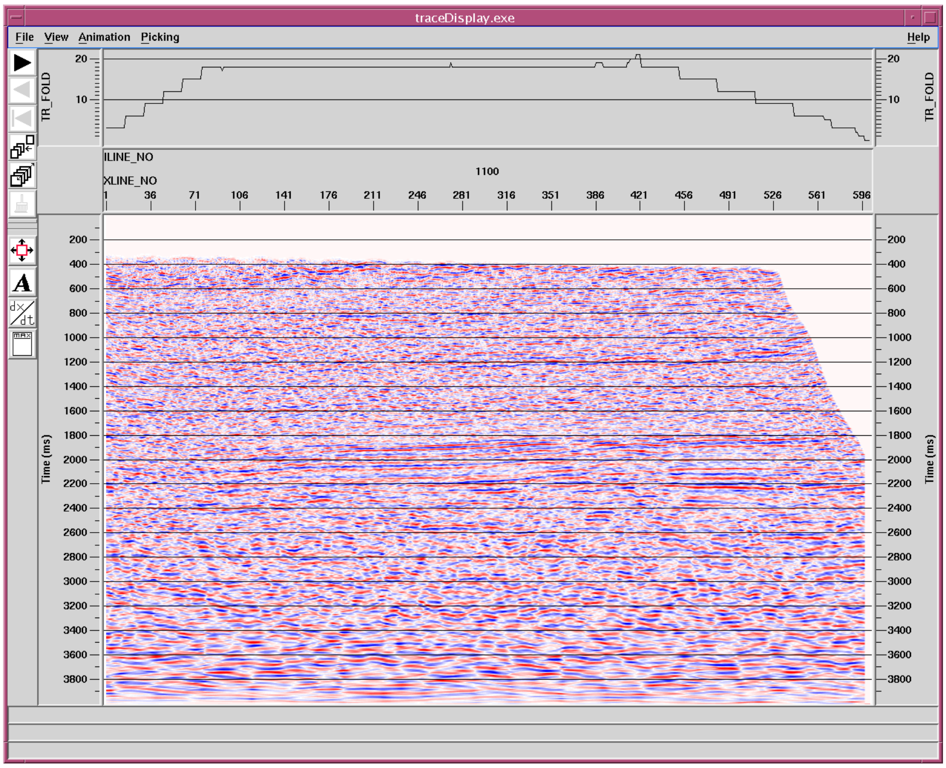

Figure 5b: Migrated stack Section Inline 1100 produced in field using Stolt or Phase shift 3D Migration

6. Conclusion

In some parts of the Chad Basin, the hardwire similarity tests recordings show slight degree of damping of signal amplitudes and slightly on signal strength by the underlain silt sediment of that part of the plain. But in higher elevation areas of consolidated vadose zone of sandy sediments, are characterized with good amplitudes and strong reflections.

In the Northeastern axis at the Doba Basin in the Chad Republic area, the wet areas were omitted by the vibrator profile, but the brute stack of the dry areas showed good reflections evidence of strong propagation of waves in a consolidated earth medium, marked by consistent and coherent LMO signatures, and strong reflectors traceable on the brute stacks.

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