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# Seismo-lithological Characterisation of the Kubanni Basin of Zaria, North Central Nigeria

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***Abstract:*** *Seismic refraction tomography was carried out to for purpose of determining lithological characterization in part of Kubanni basin, Northern Nigeria. The major instrument used for this survey were Terraloc Mark6* Digital Seismograph, *set of vertical geophones. The layout geometry was such that both the receivers and source were on a straight line. The receivers (geophones) are placed at interval of 5m, and shots fired at the beginning of the profile offset at some distance and at each geophone position. These shots send seismic waves which are detected at the surface by small receivers. The data were processed and interpreted from seismic tomography models generated. Inferences from the seismic tomography model shows that most of the profiles had 3-4 layer cases, with different lithological units* comprising topsoil, which were made of mainly sand and sandy clay, weathered basement with saturated water and fresh basement. *Also, models obtained from the study area indicate* that *that at depth greater than 30m it would not be possible to delineate the lithological unit, because the study was done using a shallow seismic method.*
***Keywords:*** *Seismic, Tomography, Geophone, Lithology, Models*

## I. Introduction

Seismic refraction method is based on the measurement of the travel time of seismic waves refracted at interfaces between subsurface layers of different velocities. These seismic energies are recorded at the surface by multiple receivers from many sources to generate a model of the distribution of seismic velocities in the subsurface [1]. From these measurements, the velocities of the subsurface can be estimated.

The refraction method is mainly used for mapping of the fresh basement, weathered layer, for determining depth to water table, for engineering purposes, and for applying correction to reflection data [2].When the refractor is suspected to have a dip, the velocities of the beds and the dip of the interface can be obtained by shooting a second complementary profile in the opposite direction [3]. Seismic refraction tomography is a geophysical inversion technique designed for subsurface investigations where seismic propagation velocity increases with depth. The output of refraction tomography analysis is a model of the distribution of seismic velocities in the subsurface, in additional interpretation must occur to generate a geologic model (i.e., determination of what the velocities represent) [4].

The seismic reflection method is also important, this method involves how the arrival time events are attributed to seismic waves that have been reflected from interface where changes in acoustic impedance had occurred, and of wave shape changes. The method has mainly been used for deep investigations (>30 m). In recent years however, shallow reflection investigation has become common for engineering and environmental purposes. It has acted as an important complement to refraction investigation, and has sometimes replaced refraction [1].

The aim of the present work includes to determine the lithologies associated with the study area, estimate depth to the weathered basement and determine depth to the aquifer (water saturated zones).

The instruments employed for this work include the Terraloc Mark 6, 24 channel digital seismograph, sets of vertical geophones and reel of wires.

## II. Location and Geology of Study Area

The study area is located west of Ahmadu Bello University (A.B.U, Main Campus). It represents the north-western part of the Kubanni Basin as shown in Fig. 1. It is approximately bounded by latitudes $11^0\ 4^1\ 25^{11}$

N and $11^0$ $10^1$ 46 $^{11}$ N and longitude $7^0$ $36^1$ $55^{11}$ E and $7^0$ $44^1$ $12^{11}$ E. The basin averages about 15 km and 7 km in length and width respectively with an approximate area of about 105 km$^2$ [5].

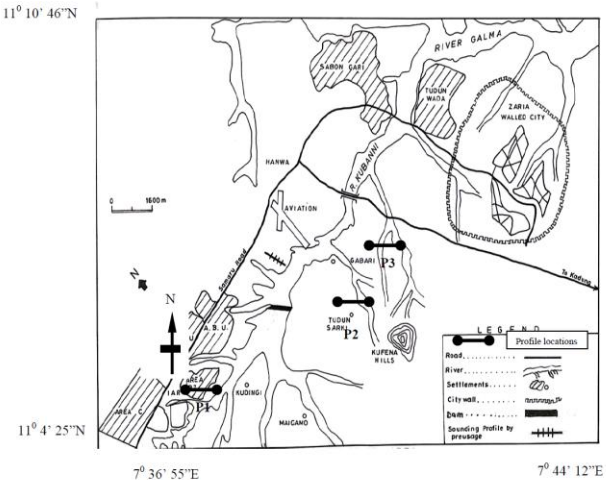


**Figure 1:** Map of study area showing profile locations

The basin is underlain by basement rocks of Precambrian age. The rocks are mainly granites, gneisses, and schists (Fig. 2). The Zaria crystalline rocks are part of the Nigerian Basement Complex. Oyawoye (1965) showed that there is structural relationship between this Basement Complex and the rest of the West African basement [6]. This is partly due to the fact that the whole region was involved in a single set of orogenic episode, the Pan African orogeny, which left an imprint of structural similarity upon the rock units.

In general, the laterite is underlain by basal conglomerate with clay and alluvial gravel materials [7].

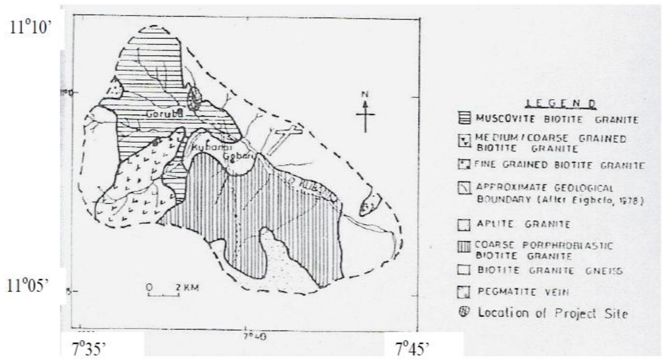


**Figure 2:** Basement Geology of Kubanni Basin (after Eigbefo 1978)

## III. Methodology

The seismic refraction method was used for this survey, and 3 profiles were taken at different locations within the area of study. The survey was such that geophones were planted at regular intervals of 5 m along the profile. An initial offset distance of 10m was used, and shots were fired at a regular interval distance of 5m before the first geophone and also at each geophone point. The generated seismic refracted wave and the resultant seismogram produced were recorded by the seismograph (SAS 4000 Terrameter) where it was stored for further processing.

### 3.2. Data Processing

Spectrum analysis was carried out on the raw seismic data to determine the dominant frequency which constitutes the important seismic signal. The data collected were subjected to different stages of processing to enhance the signal-to-noise ratio. The data were processed by the application of the band-pass filter using an upper cut off frequency of 200 Hz and a lower cut off frequency of 5 Hz, in order to eliminate the seismic noise which could have marred the real seismic signals. The application of this filtering process helped in improving the quality of the real signal, after the noise has been filtered out. This was followed by picking of the first arrivals, which was later used to plot the forward and reversed travel time curve to determine the velocity and the thickness of the overburden, and to also ascertain if there are dipping layers. Thereafter, the first arrival times picked were used for inversion to generate a tomographic model, using the waveform inversion method.

### 3.2. Data Interpretation

This stage involves the interpretation of travel time curves for the profiles .These curves were plotted for the direct and refracted waves to determine the velocities of the various layers. It was observed from the travel time curves that most layers were dipping based on differences observed in the intercept time and the slope of the refractor. This preliminary interpretation was carried out to determine the thickness of the overburden, and depth to basement, this preliminary interpretation will act as a guide to the seismic tomography models. In order to carry out preliminary interpretation and estimate various parameters of interest for this work, three profiles (Profiles 1, 2, and 3) were used. The forward and reverse travel time curves plotted for the profiles indicate that almost all the layers were dipping, and this travel time plots are shown in the figures 3, 5 and 7.

The calculated value arising from the T-x plot shows that Profile 1 (figure 3), the overburden velocity was estimated to be 912 m/s, with refractor velocity estimated as 2439 m/s and thickness of the overburden was estimated as 11.9m. For profile 2, (figure 5), the overburden velocity is about 779 m/s, and refractor velocity is about 3288 m/s, thickness of the overburden from the shot point to the refractor on the up dip and down dip side were 9.4m and 6.8m respectively

Profile 3 (figure 7), has an estimated overburden velocity of 1000 m/s, with refractor velocity of about 3220 m/s. The up dip depth is about 12.6m and down dip depth is about 11.6m. This result would be correlated with the tomography model and from this preliminary interpretation; the profiles are generally dipping in the NW-SE direction.

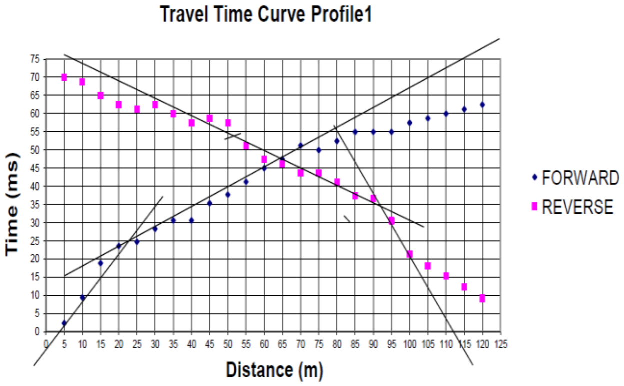


**Figure 3:** Forward and Reverse Profile Plot, Profile 1

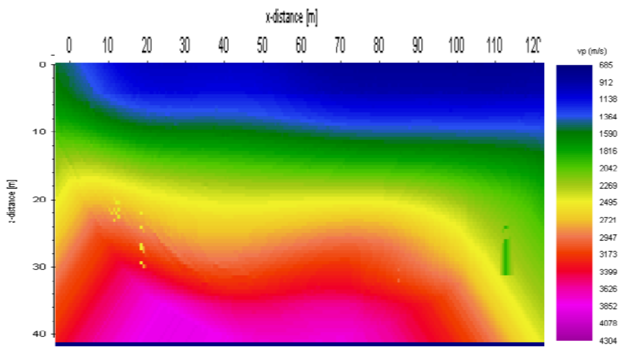


**Figure 4:** Tomography Model for Profile 1

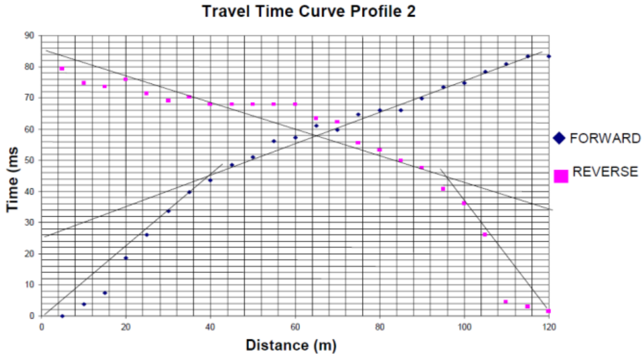


**Figure 5:** Forward and Reverse Profile Plot, Profile 2

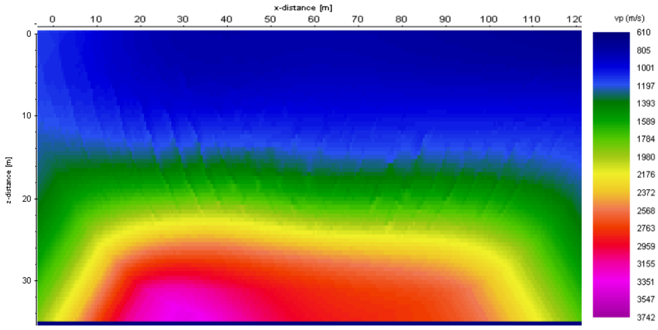


**Figure 6:** Tomography Model for Profile 2

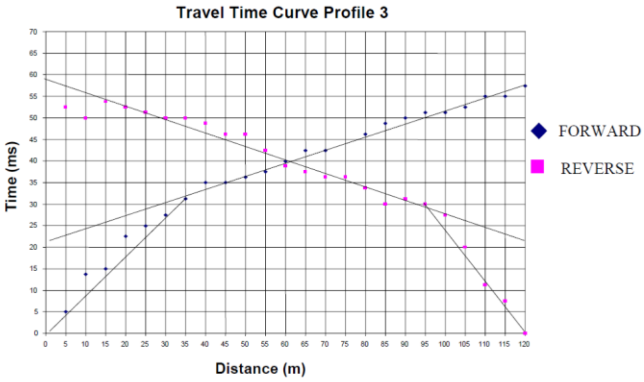


**Figure 7:** Forward and reverse profile plot, profile 3

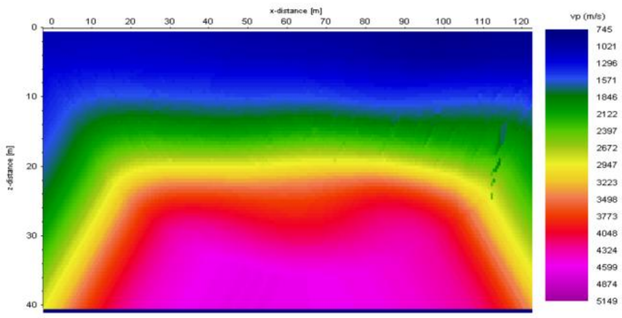


**Figure 8:** Tomography Model for Profile 3

## IV. Results and Discussion

The inverse model for seismic tomography data along Profiles 1-3 are shown in figures 4, 6 and 8. These models have spread length of 120 m and taken along the same profile, were able to probe up to a depth of 40 m, with very high resolution. The range of velocity indicated in the velocity color bar for the model and the velocity values of the seismic tomography above 3000 m/s is a clear indication that the seismic energy probed to the basement. The overburden velocity estimated from the model shows that there was a correlated with the preliminary interpretation calculated from the T-x plot above.

Lithological inferences from interpreted profiles and models show that most of the profiles had 3-4 layer cases, with different lithological units mainly sand, sandy clay, water saturated sand and crystalline rocks occurring at the bottom. Some had dipping layers, while others were relatively flat with thin layers. Standard velocities of rock types when compared with seismic velocities from the field indicates that the layers had shown some lithological characterization in the area under investigation. The different velocities for each model form the seismic sections in the study area, but no geologic section was available at the time of this study, however based on result obtained, a geologic section can be inferred for the study area by comparing borehole log obtained in other areas around the study area with the layers obtained in the study area, since most area around the basin showed similar lithologic. Also, models obtained from the study area indicate that there is no distinct boundary between the top of the weathered basement and the bottom of the overburden as seen from the seismic sections. Nevertheless, there exist a fusion between these boundaries, which could be attributed to the presence of water. Thus, the fusion could be regarded as the saturated zone. Also observed form the seismic section and the model, is the fresh basement. The fresh basement has been affected by weathering processes, these processes are common with crystalline rocks.

## V. Conclusion

Shallow seismic refraction investigation was carried out to determine subsurface lithologies. The geophysical survey employed the seismic refraction survey, a total of 3 profiles were taken, data were processes and interpreted. The results show between 3-4 layers within the study area. These include the top soil, overburden, weathered basement and fresh basement. These layers gave several indications of high velocities in the area and showed that it was able to probe down to the basement. Seismic refraction tomography was able to delineate the basement topography beyond a depth of 25 m. Also, the result of the geophysical investigation show that the average thickness of layer in the study area is about 20m, while the average velocity within the study area is about 2570m/s. A single geophysical method is not appropriate for geophysical study of the subsurface therefore other geophysical method should be employed for more detailed geophysical work.

**Table 1.** Statistics of the overburden and weathered basement under the three proofiles

| Rock type | Range of thickness from the models (m) | | | Range of Velocity from the models (m/s) | | | Lithological units |
|---|---|---|---|---|---|---|---|
| - | Profile 1 | Profile 2 | Profile 3 | Profile 1 | Profile 2 | Profile 3 | - |
| Sand | 0-3 | 0-3 | 0-10 | 685-912 | 878-1001 | 848-1525 | Top surface soil |
| Sandy clay | 3-10 | 3-12 | - | 912-1364 | 1197-1529 | - | Overburden |
| Sand(Water saturated | 10-17 | 12-25 | 10-17 | 1364-2024 | 1529-2178 | 1525-2142 | Weathered basement |
| Fresh basement | 17-40 | 25m above | 17m above | 2024-4304 | 2178-3742 | 2142-4991 | Fresh basement |

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