Structural Characterization of the Zaria Batholith Using Multichannel Analysis of Surface Wave (MASW) Seismic Method

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Abstract - **Multichannel analysis of surface waves (MASW) is widely used for the measurement of shear wave velocity and for geotechnical characterization of near surface material. It is also used for the evaluation of material properties, and material boundaries to identify different lithological units. Multichannel analysis of surface waves (MASW) was recently carried out in Zaria, with the aim of evaluating the property of material that constitutes the Zaria batholiths. The outcome of this research will be very useful both for future site assessment and infrastructural development. In a bid to achieve this, profiling seismic method was adopted, which make use of the common mid-point (CMP). The study revealed that the shear wave velocity (Vs) models showed a general increase of velocity with depth. The Vs velocities ranges between 200 m/s to 4000 m/s, with the lowest velocity occurring in regions with very thick overburden cover, and the highest velocity values occurring within the vicinity of massive granitic outcrops. The contoured map and 3D shear wave velocity model, confirm that the Southern part of the survey area that is mainly characterize of granitic outcrop has relatively higher Vs velocity values than the Northern part that is characterize with exposed gneisses and thick overburden. These results therefore point to the fact that, frequency dependent properties of surface waves can be effectively utilized for imaging the shallow subsurface structure that is vital for site characterization and infrastructural development.**

Keywords: Characterization, Shear wave, Batholith, MASW, Seismic

I. INTRODUCTION

Facts within less than 60 ms of seismic reflection data are often covered by surface wave. These amplitude and velocity information within this section are required to mark out the very near surface structure and for appropriate static correction of reflection seismic data.

Hence, this research work was carried out using multichannel recording procedure, with the aim of determining the velocity structure of the near surface material of the batholiths, using Multichannel Analysis of Surface Wave (MASW) method. For these reason areas of well known geology were chosen. These are areas with exposed gneisses mark with very thick overburden and obvious granitic outcrops.

Previous work carried out in this area has shown that, although ground roll is considered noise on body wave surveys (i.e., reflection or refraction profiling), its dispersive properties can be utilized to infer near-surface elastic properties (Nazarian et al., 1983; Stokoe et al., 1994; Park et al., 1998).

When ground roll is acquired using a multichannel recording method and displayed in a swept-frequency format, different frequency components of Rayleigh waves can be identified by distinctive and simple coherency. This leads to a seismic surface-wave method that provides a useful noninvasive tool, where information about elastic properties of near-surface materials can be effectively obtained (Park et al., 1999).

Among the instruments used for this survey include, 24 Channel Digital Seismograph, Vertical Geophone, Reels of Cables with Takeout Point, Trigger Cable, Sledge Hammer and Base Plate.

II. LOCATION OF THE STUDY AREA

The study area is Zaria, located within the basement complex of northern Nigeria. The study area (Fig. 1) is bounded by latitude 11° 13′ 52.37″N, longitude 7° 41′ 49.26″E and latitude 11° 06′ 16.72″N, longitude 7° 42′ 11.56″E, with average elevation of 650 m.
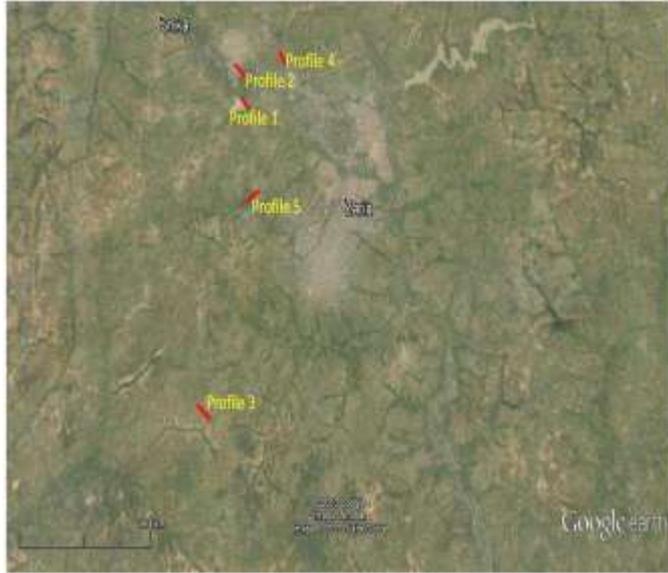
Figure-1: Location Map of the study area, image map adapted from Google earth

III. GEOLOGY OF THE AREA

The older granite outcrops in the vicinity of Zaria are exposures of a syntectonics to late-tectonic granite batholiths which intruded a crystalline gneissic basement during the Pan-African Orogeny. This batholith is a north-south oriented body, about 90 x 22 km, extending from Zaria southward to the vicinity of Kaduna. The Zaria granite batholiths belong to a suite of syntectonics and late tectonic granites and granodiorites that marked the intrusive phase of the late Precambrian to early Palaeozoic Pan-African Orogeny in Nigeria (McCurry, 1973).

IV. DATA ACQUISITION

The data acquisition made use of Common Depth Point (CDP) profiling method, with the receivers set at 1 m interval. A maximum offset distance of 10 m from the first receiver, with a stack of 5 shots was employed during the data acquisition. After a complete shot, the generated seismogram was recorded, and the source was advance by 1 m. The first receiver was taken ahead of other receivers, and placed 1 m beyond the last receiver. The connections to each of the receivers were swapped in the forward direction, and the shot were repeated after the connections were complete. The whole process was repeated until the end of the profile where reached. The recording parameters are show in table 1. Figure 2 show part of the raw seismic data.

TABLE-I
Acquisition recording parameter

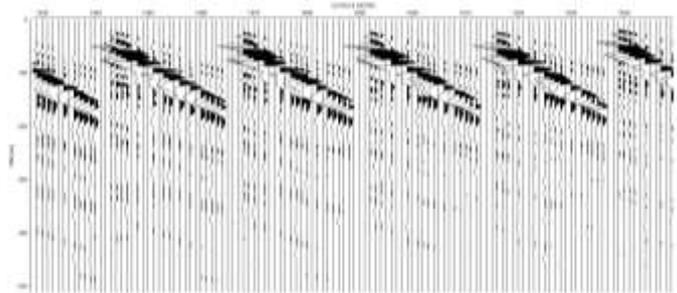| Recording Parameter	
Source	Sledge Hammer
Receiver Type	Planted Vertical Geophone
Receiver Interval	1 m
Source Interval	1 m
Source Offset	1 to 10 m
Receiver spread length	23 m
Record Length	1 s
Sample Interval	0.25 ms

Figure-2: Raw seismic data showing the amplitude of the recorded surface wave

V. DATA PROCESSING

The processing flow started with importing of the raw seismic data recorded in SEG2 format into the geophysical software used for the data processing. Geometry assignment to the seismic data was carried out, so that each trace is given a unique number of values which were consequently, saved in the specified header fields of the dataset in the project database. The dispersion image (Fig. 3) which is a plot of phase velocity versus frequency was calculated for the respective shot points in the current data sets. The range of phase velocity that was used to calculate the dispersion image was within the range of 0 to 500 m/s and with a frequency range of 0 to 70 Hz. The fundamental mode was identified in the vicinity of the higher mode and the body waves. The dispersion curve was extracted by clicking on the maximum and the minimum point on the fundamental mode. The dispersion curves were saved for onward processing. The Vs profiles were calculated using an iterative inversion process that involved initial input of poison's ratio and density. At the end of the inversion process 2D

Vs velocity model was generated displayed in station number distance along the surface and depth within the subsurface.
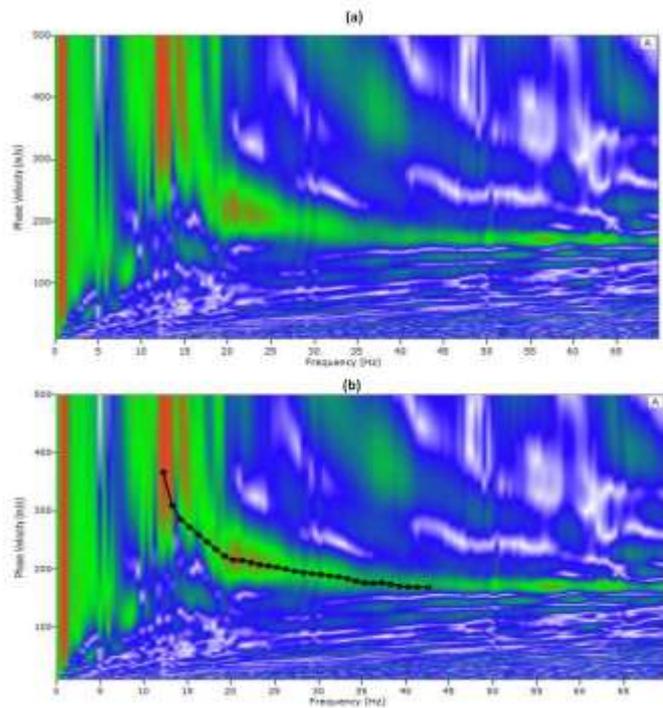

Figure -3: (a) The generated dispersion image of a shot point (b) Extracted Dispersion curve

VI. RESULTS

The Vs models of the five profiles are shown in figure 4 to 8, which represent the distribution shear wave velocities within the subsurface at the various profiles. The velocities values for the various models were obtained from the coloured scaled bar attached to the right side of the models. The Vs models showed a general increase of velocities with depth. Each of the Vs models appears heterogeneous since there were only probing a shallow layer of less than 14 m within the basement complex, except for profile 3, figure 6 that appear to have relatively flat continuous layer. The models Vs velocities range between 200 m/s to 4000 m/s. The lowest Vs values occurred in profile 1, figure 4, which data acquisition is on a Dam Embankment and profile 2, figure 5, which was acquired in area with very thick overburden. The highest Vs value occurred in profile 5, figure 8, which was acquired very close to a massive granitic outcrop that has the highest elevation in the survey area as a result of its hardness and resistant to weathering activity. The velocities values were extracted from each profile, at the beginning, midpoint and at the end of each profile at a depth of 7.5 m as shown in table 2. The extracted velocity values were contoured into a contour map and a 3D surface as shown in figure 9 and 10, using the profiles Global

Positioning System (GPS) co-ordinates, for ease of visualization of velocities distribution in the survey area. The contour map and the 3D surface revealed area of low velocity and areas of high velocity within the survey area. It also showed that the Southern part of the survey area that is characterize majorly of granitic outcrop has relatively higher velocity values than the Northern part that is majorly characterize with exposure of gneiss and thick overburden cover. This is also in agreement with the geology and activities on ground were quarry activities are predominant in the South Western part of the survey with many granitic outcrops. Hence this has revealed that, the Multichannel Analysis of Surface Wave (MASW) seismic method can be effectively used to determine the velocity distribution in a given region by taking advantage of the potential utility of ground roll inversion to obtain the near surface velocity structures, that would greatly enhance exploration and processing purpose.

TABLE-II
Acquisition recording parameter

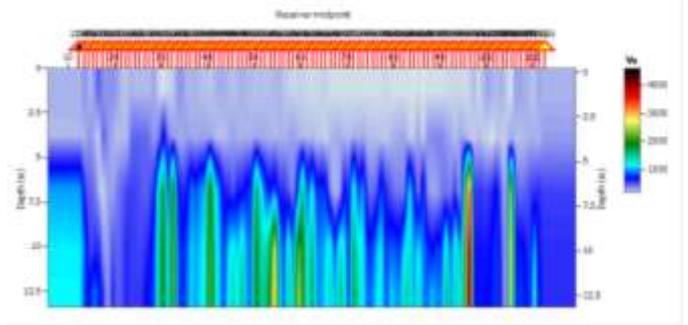| Profile	Longitude (Degrees)	Latitude (Degrees)
Profile 1	7.657517	11.13402
Profile 2	7.660417	11.15310
Profile 3	7.646033	10.97565
Profile 4	7.675083	11.17390
Profile 5	7.652367	11.08430
Station Positions where velocity was extracted (m)		
Beginning	**Mid Point**	**End**
20	70	120
12.5	15	17.5
34	39	44
55	60	65
10	60	110
Vs (m/s) Values at each Station Positions		
Beginning	**Mid Point**	**End**
350	150	330
280	350	392
602	551	510
550	610	570
1000	1200	850
Profile	**Longitude (Degrees)**	**Average Vs (m/s)**
Profile 1	7.657517	277
Profile 2	7.660417	341
Profile 3	7.646033	554
Profile 4	7.675083	577
Profile 5	7.652367	1017
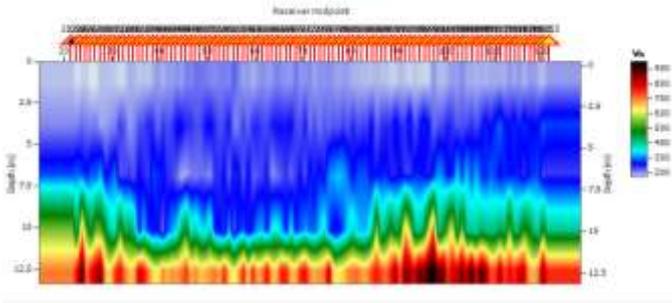
Figure -4: Vs model of profile 1, showing the distribution of shear wave velocity
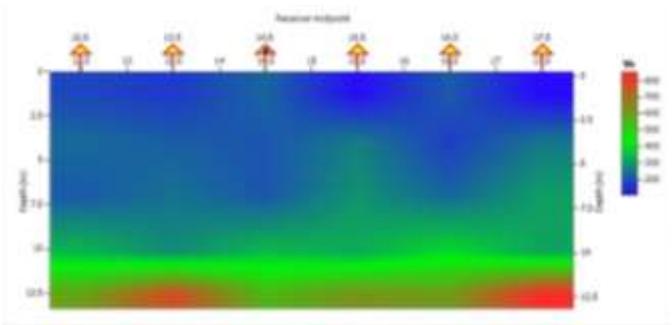

Figure -5: Vs model of profile 2, showing the distribution of shear wave velocity
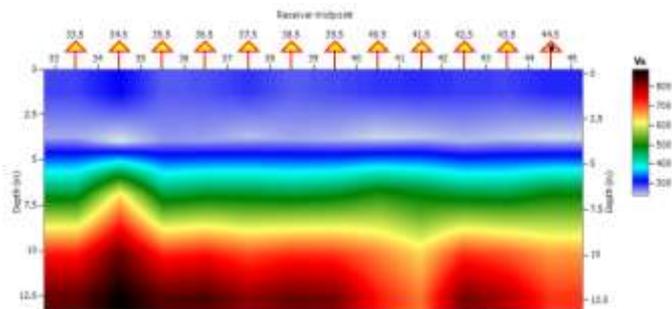

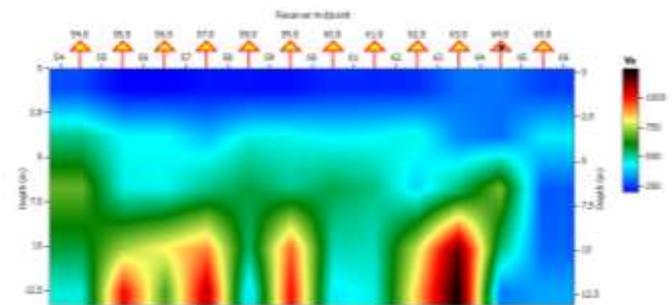**Figure -6: Vs model of profile 3, showing the distribution of shear wave velocity**

Figure -7: Vs model of profile 4, showing the distribution of shear wave velocity

Figure -8: Vs model of profile 5, showing the distribution of shear wave velocity
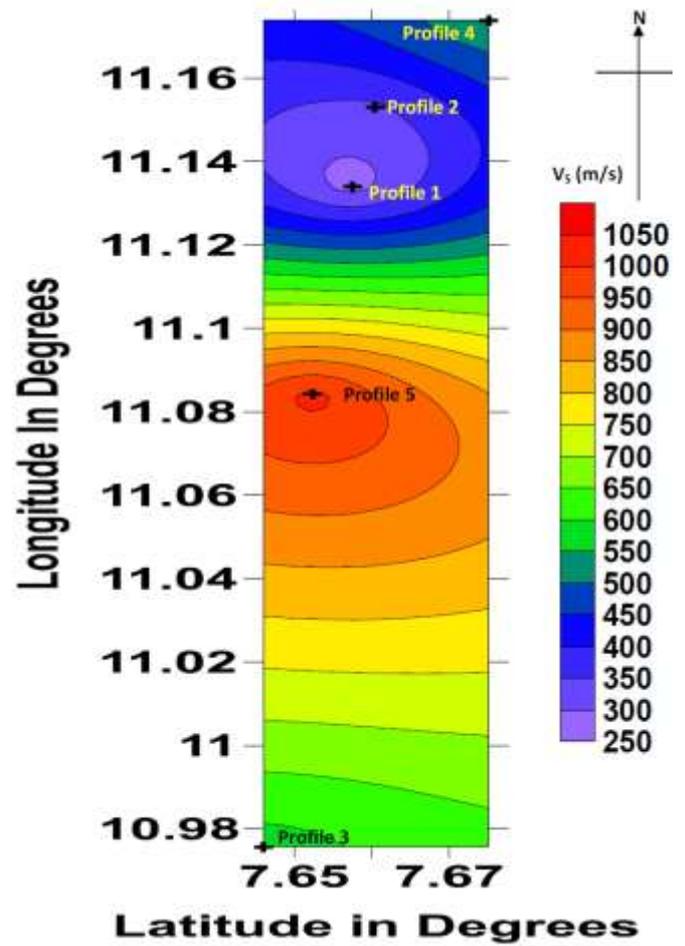

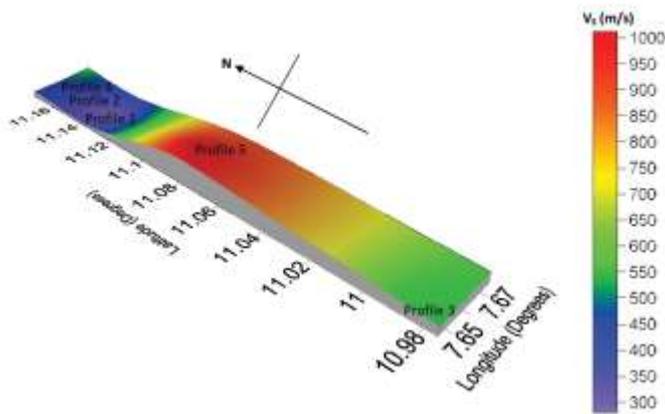**Figure -9: Contour map of s waves distribution in the survey area**

Figure -10: Corresponding 3D surface distribution of s waves in the survey area

VI. CONCLUSION

The survey carried out in the region under investigation was able to identify two different velocity structures emplaced, the high shear wave seismic velocity in southern part, and the low velocity region in the northern part of the batholiths that is characterize by thick overburden cover and exposure of gneisses. This research has also revealed that the northern part of the batholiths has experienced more weathering than the southern part that is characterized with hard material that is more resistant to weathering. In terms of putting up structures within the Batholiths it showed that the northern part of the batholiths will require more engineering remediation than the southern part the is characterized with high shear wave velocity. When Multichannel Analysis of Surface Wave (MASW) method is well implemented it can serve as an. accurate means of determining the velocity structure of the near surface at very low cost. The results obtained so far has pointed to the fact that, frequency dependent properties of surface waves can be effectively utilized for imaging and characterizing the shallow surface that is vital for site assessment and infrastructural development.

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