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JOINT INVERSION OF MULTICHANNEL ANALYSIS OF SURFACE WAVE (MASW) AND HIGH RESOLUTION SEISMIC REFLECTION TECHNIQUES TO DELINEATE THE NEAR SURFACE STRUCTURE

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ABSTRACT

The aim of this research work is to examine the extent to which joint inversion of Multichannel Analysis of Surface Wave (MASW) and High Resolution Seismic Reflection, could be used to delineate near surface structures and generate the very near surface velocity model, that is crucial for effective processing of reflection seismic data, using the same data set. To achieve this, the data acquisition involves placing the receivers at 1m, with an offset of 10 m for the energy source. It was generally observed that the (MASW) method was able to effectively delineate the near surface structure of less than 10 m, while the high resolution seismic reflection was able to delineate depth to the fresh basement and its topography that could not be access by the (MASW) method, as a result of depth limitation. It is recommended therefore that Multichannel Analysis of Surface Wave (MASW) should be processed along side with High Resolution Seismic Reflection method to delineate the subsurface structure near the surface and at depth using the same seismic data set. This will also help in eliminating the independent velocity shooting carried out to get the near surface velocity information, after acquiring the main seismic data.

Keywords: *Joint Inversion, MASW, High Resolution Seismic Reflection, Near Surface Structure*

I. INTRODUCTION

Information within less than 50 ms are often marred by surface wave, and this amplitude and velocity information are needed for the effective delineation of the very near surface structure and for proper static correction of reflection seismic data. Hence, this research is aim at making use of Multichannel Analysis of Surface Wave (MASW) to recover this information, and apply it to the processing of High Resolution Seismic Reflection to achieve more effective result in delineating near surface structure. The good aspect of these joint inversion techniques is that the same seismic data is used for this analysis, the need to collect two different data may not be necessary. In considering previous work carried out by other researchers, we find out that; in most surface seismic surveys when a compressional wave source is used, more than two-thirds of total seismic energy generated is imparted into Rayleigh waves (Richart et al, 1970). Construction of a shear (S)-wave velocity (Vs) profile through the analysis of plane-wave, fundamental-mode Rayleigh waves is one of the most common ways to use the dispersive properties of surface waves (Bullen, 1963). This type of analysis provides key parameters commonly used to evaluate near-surface stiffness—a critical property for many geotechnical studies (Stokoe et al, 1994). Multichannel Analysis of Surface Wave (MASW) seismic method stands as an effective tool in characterizing the strength of material for engineering and geochemical purpose (Collins, 2014).

It is confirmed that MASW can be used effectively for the soil layer profiling and identification of rock depth and measurement of rock dynamic properties.

High resolution seismic reflection survey can provide result which compares well with direct observation and trenching on land (Zhuping et al, 2001). Analysis of high resolution seismic data to extract parameters like velocities, elastic parameters, the basement topography and densities could serve as a very useful tools for the identification of lithologies within a basement complex, (Collins et al, 2014). The instruments used include: the Terraloc Mark6 digital seismograph, vertical geophone, reels of cables with take-outs and sledge hammer strike on base plates.

II. METHOD & MATERIAL

Location of the study area

The study area (Fig. 1) is bounded by latitude 11o 13′ 52.37″N, longitude 7o 41′ 49.26″E and latitude 11o 06′ 16.72″N, longitude 7o 42′ 11.56″E. with average elevation of 650 m. The seismic reflection profile lines are shown in blue, the direction of the arrows shows the direction of the profile.

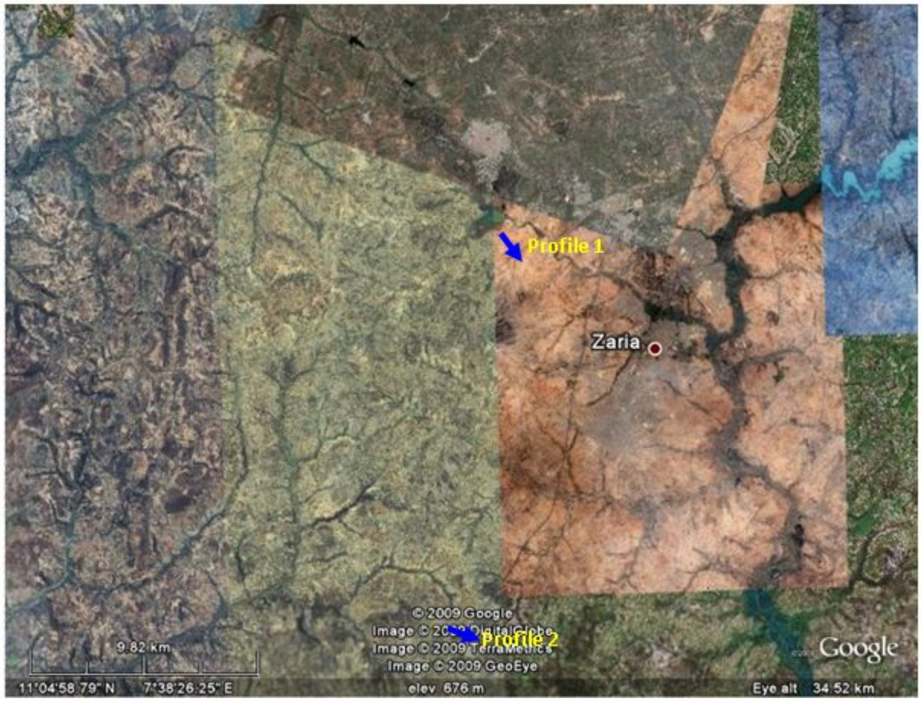

Figure 1: location map of the study area showing profile lines in blue, adapter from Google earth

Geology of the study 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 batholith belong to a suite of syn 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).

Data acquisition

The data acquisition was carried by putting the source and receivers (Geophones) on a straight line. The Common Dept Point (CDP) that resulted in a 12 fold coverage sampling of the underground was achieved making use of a 24 channel Seismograph. An offset distance of 10 m from the first receiver was used for data acquisition. The receivers were placed at an interval of 1 m. After each sets of five stacks of shots, the first receiver closer to the shot was removed and place 1 m ahead of the last receivers. The source was advanced 1 m, and the connections to each of the take-outs were swapped in the direction of increasing profile. When the connections were completed, the shots were repeated, and the resulting seismogram was saved using a 24 channel digital seismograph for onward processing.

Data Processing

The processing flow for Multichannel Analysis of Surface Wave (MASW) 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 number. The values were consequently, saved in the specified header fields of the dataset in the project database. The dispersion image (Fig. 2) which is a plot of phase velocity versus frequency was calculated for the different shot points in the current data sets. The dispersion image was calculated in a range of phase velocities 0 to 500 m/s and in 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. The same data sets that were used for the processing of MASW, were also used in processing of High Resolution Seismic Reflection. The processing flow started with editing of the trace geometry for any possible wrong values mistakenly entered in the field. Static correction times generated from the MASW model was then applied to remove the effect of the weathered layers. F-k filter was applied to get rid of refraction event and ground roll of very low frequency. Semblance analysis was carried out to generate a 2-D model of the seismic velocity, the velocity model was used to carry out dynamic correction and the stacking of the common midpoint traces. The stacked seismic section was migrated in time and depth to produce a time and depth migrated seismic section.

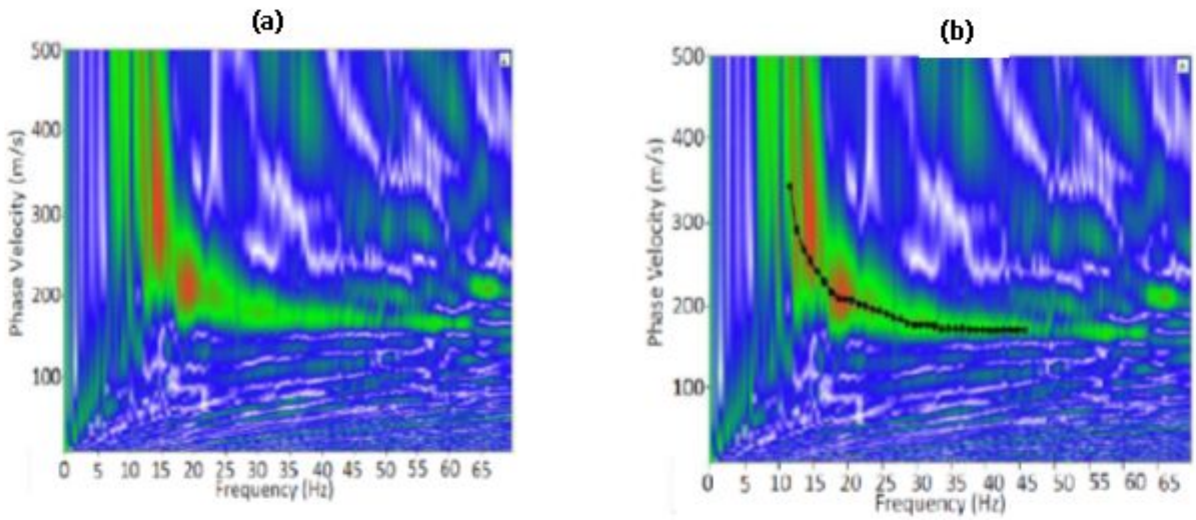

Figure 2 (a) The generated dispersion image of a shot point (b) Extracted Dispersion curve

III. RESULT & DISCUSSION

The 2D shear wave velocity models generated from the Multichannel Analysis of Surface Wave (MASW) are shown in figure 4 and 6. The models are displayed in shade of colours. The interpretation of the models should not be base on the colour displayed, but base on the velocity values attached to the colour scale bar by the side of the model. The two models figure 4 and 6 have revealed a general increase of velocity with depth, down to a depth of 12 m. The 2D velocity model of figure 4 has a shear wave velocity range of 300 m/s to 800 m/s. The 2D velocity model was able to delineate the layers within the near surface structure. The model was able to delineate the highly weathered layer with a shear wave velocity range of 300 m/s to 600 m/s, which is from the surface down to a depth of 9 m. The model was also able to delineate the layering structure of the weathered basement, with velocity range of 700 m/s to 800 m/s at a depth of 10 m.

The high resolution seismic reflection section, displayed with variable area wiggle trace is shown in figure 5. The high resolution seismic reflection section, probe down to a depth of 40 m.

The high resolution seismic section (Fig. 5), like the Multichannel Analysis of Surface Wave (MASW), was able to delineate the thickness of the overburden with an average depth of 9 m, and the depth to the weathered basement at a depth of 10 m, marked with Blue line, where the first seismic event occurred (Fig. 5). The seismic reflection section was able to probe down up to the fresh basement at about 30 m depth, marked with red line (Fig. 5). Considering figure 4 and 5, it was obvious that both method (Multichannel Analysis of Surface Wave (MASW) and High Resolution Seismic Reflection Techniques) were able determine the thickness of the overburden (highly weathered layer) and depth to the weathered basement. With both thickness and depths in both sections correlating well.

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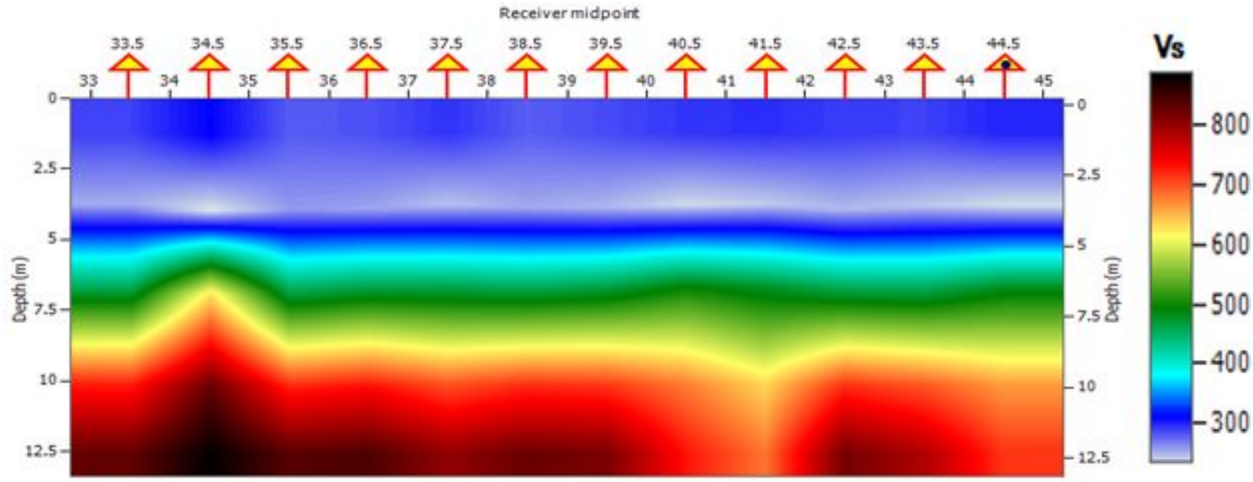

Figure 4: 2D shear wave velocity model, depicting the distribution of shear wave within the subsurface acquired at profile 1

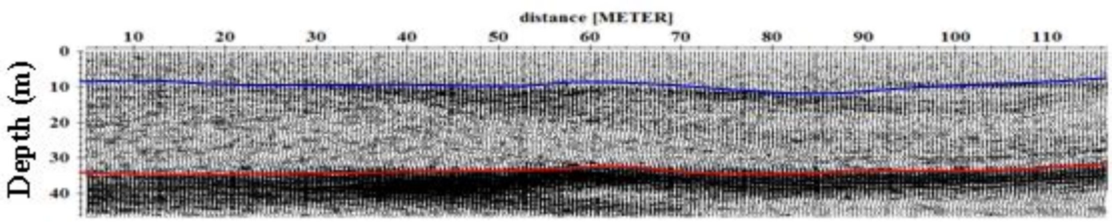

Figure 5: High resolution seismic reflection section generated with the same seismic data set acquired in profile 1.

The 2D shear wave velocity model is displayed in figure 6, revealing a general increase of shear wave velocity with depth. This sction was able to delineate the overburden with a shear wave velocity range of 200 m/s to 600 m/s, and an average thickness of 10 m. The shear wave 2D model was able to delineate the layering structure of the weathered basement, which has a range of velocity of 700 m/s to 900 m/s, at an average depth of 11 m.

The high resolution seismi reflection section of figure 7, was also displayed with variable area wiggle trace. The seismic reflection section probe down to a depth of 40. The section was like the Multichannel Analysis of Surface Wave (MASW) section was able to delineate the thickness of the highly weathered layer (Overburden), which has an average thickness of 10 m. The high resolution seismic reflection section was able to map the depth to the weathered basement, which stand at an average depth of 11m.This was marked with blue outline, where the first seismic event occurred in the section. The second seismic event on figure 7 marks the depth to the fresh basement which occurred at an average depth of 25 m. the topography of the weathered basement is marked with red line. Once again both methods (Multichannel Analysis of Surface Wave (MASW) and High Resolution Seismic Reflection Techniques) were able to determine the same thickness of the overburden and depth to the weathered basement using the same seismic data set for analysis.

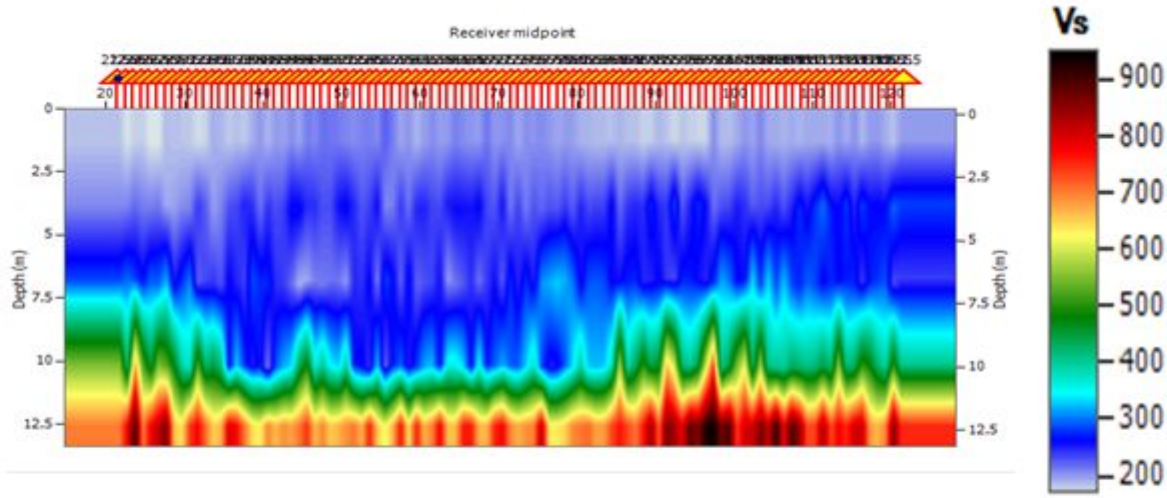

Figure 6: 2D shear wave velocity model, depicting the distribution of shear wave within the subsurface acquired at profile 2

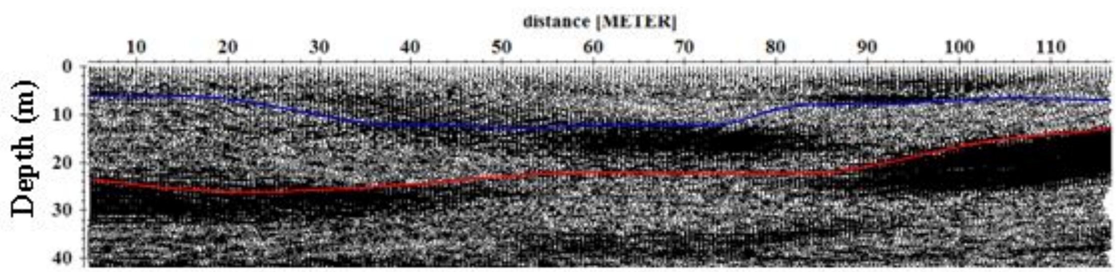

Figure 7: High resolution seismi reflection section generated with the same seismic data set aquired in profile 2

IV. CONCLUSION

Joint inversion of Multichannel Analysis of Surface Wave (MASW) and High Resolution Seismic Reflection Techniques has been successfully used to delineate the near surface structures. Both methods were able to delineate the overburden thickness, depth to the weathered basement and depth to the fresh basement, with very good depth correlation. The very near surface less than 10 m of the subsurface was adequately imaged by (MASW) method, which was naturally quiet on the high resolution seismic section. While the deeper layers of the fresh basement was delineated by high resolution seismic section, which have greater depth penetration. It can be recommended therefore that Multichannel Analysis of Surface Wave (MASW) processing should be carried out along side with High Resolution Seismic Reflection to delineate the subsurface structure near the surface and at depth using the same seismic data set. This method work for both "split spread" and the "end on" method of data acquisition and rule out the possibility of independent velocity shooting done after acquiring the main seismic data acquisition.
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