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Assessment of the Response of Seismic Refraction Tomography and Resistivity Imaging to the Same Geologic Environment: A Case Study of Zaria Basement Complex in North Central Nigeria

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Abstract**—**The study area is Zaria, located in the basement complex of northern Nigeria. The rock type forming the major part of the Zaria batholith is granite. This research work was carried out to compare the responses of seismic refraction tomography and resistivity tomography in the same geologic environment and under the same conditions. Hence, the choice of the site that has a visible granitic outcrop that extends across a narrow stream channel and is flanked by unconsolidated overburden, a neutral profile that was covered by plain overburden and a site with thick lateritic cover became necessary. The results of the seismic and resistivity tomography models reveals that seismic velocity and resistivity does not always simultaneously increase with depth, but their responses in any geologic environment are determined by changes in the mechanical and chemical content of the rock types rather than depth.

Keywords**—**Environment, Resistivity, Response, Seismic, Velocity.

I. INTRODUCTION

SEISMIC refraction method is based on the measurement of the travel time of seismic waves refracted at the interfaces between subsurface layers of different velocities. It is mostly employed in the determination of depths and velocities of the overburden and the refractor within the subsurface [3].

Seismic tomography is an imaging technique which generates a cross-sectional picture (a tomogram) of an object by utilizing the object’s response to the non-destructive, probing energy of an external source [6].

Near-surface 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; thus, additional interpretation must occur to generate a geologic model (i.e., determination of what the velocities represent) according to [2]. It is recommended that seismic refraction tomography be employed in an area where there are serious limitations in spread length to probe a particular depth of interest by increasing the energy source [5]. Seismic tomography investigations have been found to provide very useful information about the nature of sub-surface geology in addition to strength characterization of rocks below the surface [1]. The purpose of electrical surveys is to determine the subsurface resistivity distribution by making measurements on the ground surface. From these measurements, the true resistivity of the subsurface can be estimated. The ground resistivity is related to various geological parameters such as the mineral and fluid content, porosity and degree of water saturation in the rock. Electrical resistivity surveys have been used for many decades in hydro-geological, mining and geotechnical investigations. More recently, it has been used for environmental surveys [4]. The instruments employed for this survey include the Terraloc Mark6 24 channels digital seismograph, 25 sets of the vertical geophones, with one acting as the trigger geophone, reels of cable with take out and sledge hammer on base plate as the energy source. The resistivity equipment include SAS (Signal Averaging System) 4000, Terrameter, Electrode Selector, 41 non polarisable electrodes, 41 crocodile clips and reel of cable with takeout at 5 m interval.

The aim of this research is to carry out a joint inversion of seismic and resistivity tomography, in order to assess their different responses under the same geologic environment.

II. LOCATION OF STUDY AREA

Fig. 1, shows the location of the study area, along with the various seismic and resistivity profiles. “A” represents the beginning of the profile, while “A'” represent the end of the profile. The profile lines for both seismic and resistivity profile for Fig. 1 is shown in red, blue and green respectively. The survey area is bounded by 11o 10' 24.56'N, 7o 36' 06.5'E and 11o 09' 46.86'N, 7o 38' 39.28'E.

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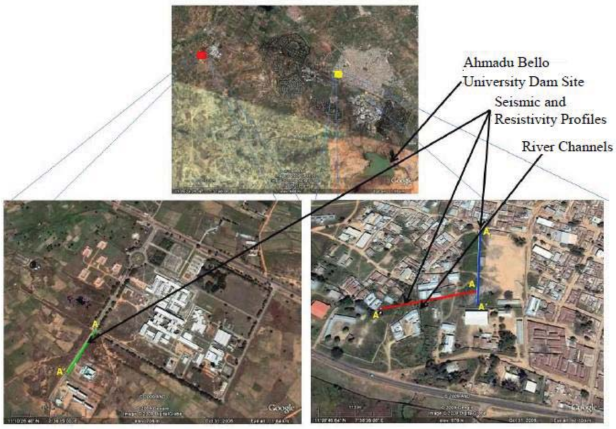

Fig. 1 Map of the survey area showing seismic and resistivity lines, Adapted from Google Earth

III. METHODOLOGY

The geophysical survey for the seismic refraction tomography was carried out by placing the source and receivers in a straight line. The geophones were planted at an interval of 5 m, calculated to be offseted on both side of the river which is about 4.5 m wide to avoid geophone contact with the water. Geophone test was carried out to make sure all the 24 geophones were active and ready to take reading. The first shot was fired at an initial offset distance of 30 m. The shots were fired at 2.5 m interval, before the first receiver, at each receiver point, in between, and at an interval of 2.5 m within an offset distance of 30 m beyond the last receiver. Half of the receivers were moved ahead of the profile, and the shooting process was repeated making use of the same offset distance of 30 m and shot interval. The seismogram that was generated was stored in the seismograph for onward processing.

The resistivity method involved placing the 41 electrodes in a straight line at 5 m interval. Each electrode was connected to the different take-out on the cable, via a crocodile clip. The cable was connected to a multichannel ES 464 electrode selector that was connected to the SAS 4000 through a multicore cable. Sufficient current was injected into the ground after excellent electrode contact with the ground was verified and confirmed through the electrode test that was carried out before the commencement of the measurements. The measured apparent resistivity values were automatically stored in the Terrameter and later downloaded to the processing system with the compatible software.

IV. DATA PROCESSING

The data processing of the seismic refraction tomography started with the editing of the wrong refraction geometry. Bandpass filter of low cutoff (High pass) of 50 Hz and high cutoff of 200 Hz was applied to the raw data, after spectrum analysis, to ascertain were the refraction event lies. Gain filter was then applied to enhance the refraction event. The first arrival times was picked, and assigned into layers. The picked travel times was jointly inverted to produce an initial model, which was iteratively inverted with the travel time to produce a tomographic model.

V. RESULTS

Three pairs of independent seismic and resistivity profiles were carried out for the purpose of this research. The first seismic and resistivity profiles was carried out in the vicinity of an outcrop across a stream channel, the second profiles were carried out in an environment with thick lateritic cover, while the third profiles where carried out in an area covered with thick sediments about 100 m away from the first profile.

The first seismic tomography model, Fig. 2 (a), was conveniently able to map out the granitic outcrop that occurred between of 115 to 135 m along the profile. It was also able to map out area along the profile that was covered by overburden. These two lithologies could be identified base on their difference in seismic velocities, which are about 1874 m/s for the outcrop, that has weathered slightly and about 903 m/s for the overburden. The first resistivity tomography model, Fig. 2 (b), taken along the same profile was also able to map out the granitic outcrop along the same profile, also recognised base on its high resistivity value which is about 1000 Ωm. The accuracy with which the two methods were able to map out the granitic outcrop and the overburden cover shows the extent of reliability of the two methods and the data. Across the stream channel which is located between 120 m to 125 m flowing across the granitic outcrop, the seismic tomography model maintained a high velocity value, while resistivity tomography registered a low resistivity value down to a depth of about 10 m. Hence, the high velocity was due to the granitic rock on which the stream was flowing across. The low resistivity value could have resulted from the percolation of water into the slightly weathered granitic outcrop underlying the stream channel which may have saturated the pores down to a depth of about 10 m, thereby lowering the resistivity.

The second profile (Figs. 3 (a) and (b)) that has a thick lateritic cover that is known for its high resistivity, showed evidence of high resistivity above 1500 Ωm down to depth of 12 m. This was interrupted by low resistivity that may have resulted from underground water within the weathered basement down to depth of 30 m. However, seismic tomography model taken on the same profile showed relative increase of velocity with depth. It revealed the depth to the basement rock, which could not be accessed by the resistivity model, at 35 m, base on the high velocity values. This is another geologic environment where seismic velocity and resistivity did not increase correspondingly with depth.

The Third seismic and resistivity profiles (Figs. 4 (a) and (b)), that were taken very close to the first profile, showed strikingly very good correlation between the seismic tomography and resistivity tomography model. The two models (Figs. 4 (a) and (b)) were able to map out the subsurface valley that exists along the profile down to a depth of 30 m. Both the seismic and resistivity values had a corresponding increase with depth without any contradiction.

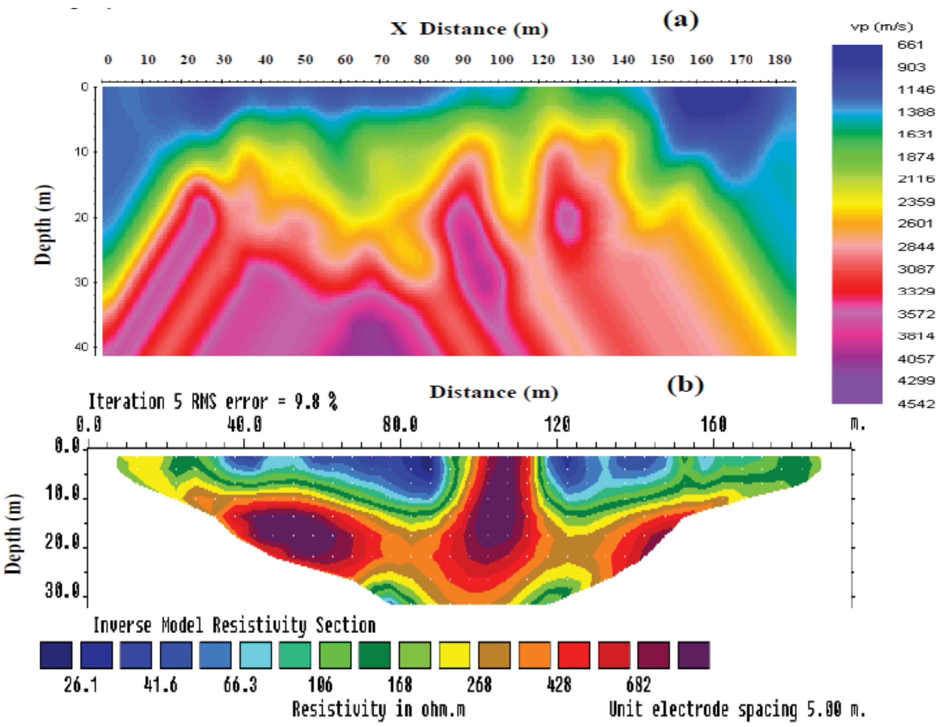

Fig. 2 (a) Seismic refraction tomography model taken in the vicinity of an outcrop across stream channel, (b) First resistivity tomography model taken in the vicinity of an outcrop across stream channel

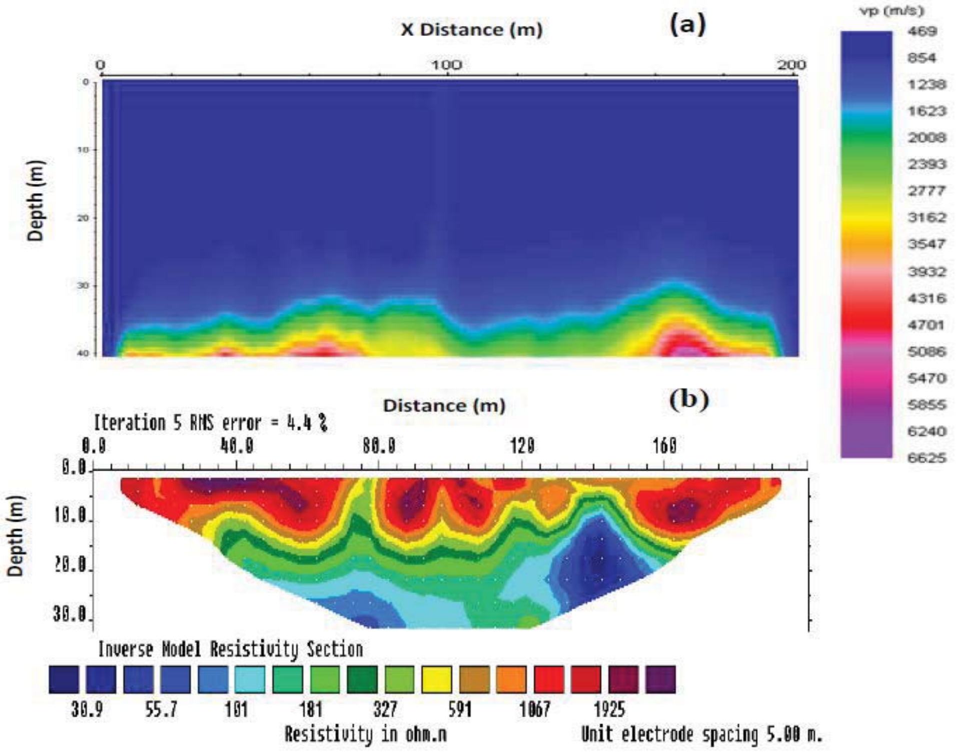

Fig. 3 (a) Second refraction tomography model (b) Second resistivity tomography model carried out in an area with thick lateritic cover

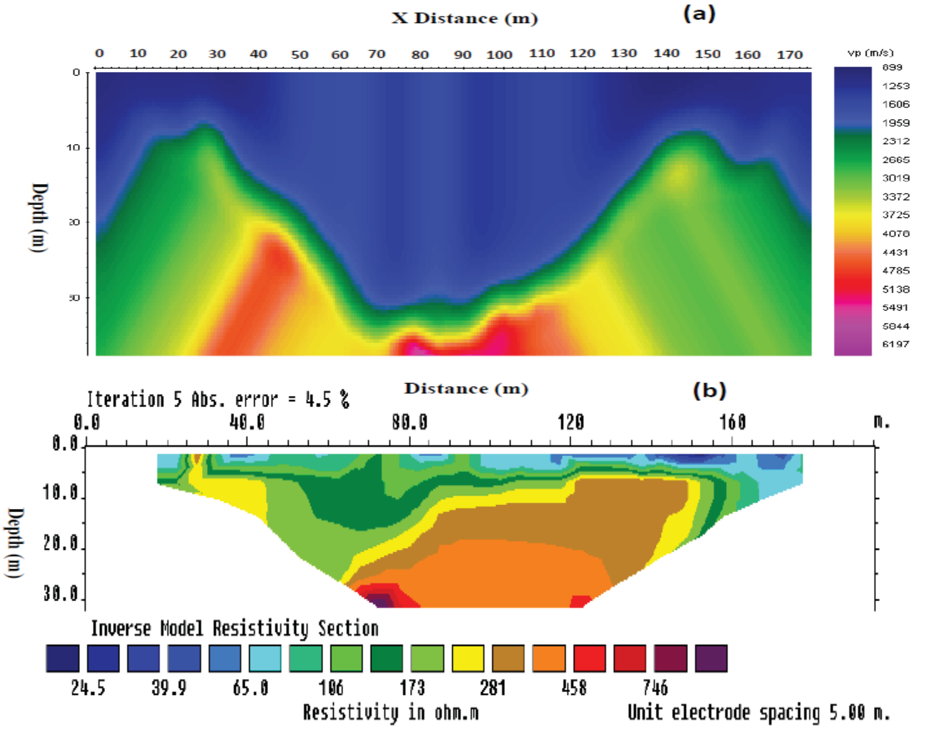

Fig. 4 (a) Third seismic refraction tomography model taken 100 m away from the first profile, (b) Third resistivity tomography model taken 100m away from the first profile

VI. CONCLUSION

The result obtained from this research work has shown that seismic velocities and resistivity does not always increases with depth under the same geologic environment, rather their different responses is determined by changes in the mechanical (elastic constants) and chemical content of the rock types rather than depth. Therefore, in correlating seismic refraction tomography with resistivity tomography sections it should be noted that a region of high seismic velocity does not always denote high resistivity, and vice versa, especially in the vicinity of water table, that most often indicates sharp increase of seismic velocity, with a corresponding drop in resistivity, as a result of the presence of water in the pores of the slightly weathered rock.

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REFERENCES

[1] N. P. Dutta, 1984. Seismic refraction method to study the foundation rock of a dam. Geophysical Prospecting, Vol. 32, pp. 1103-1110.

[2] S. B. Gregory, 2002. Near-surface seismic refraction tomography tutorial. UB Geophysics Report 2002-S0.

[3] P. Kearey, M. Brooks, and I. Hill. 2002. An introduction to geophysical exploration (Third Edition). Blackwell Publishing, Malden, U.S.A. pp. 66-67.

[4] M. H. Loke, 2000. Electrical imaging surveys for environmental and engineering studies, a practical guide to 2-D and 3-D surveys.

[5] I. B Osazuwa, C. C. Chiemeke, N. K. Abdullahi, and C. C. Akaolisa. 2008. Improved depth of penetration of geoelectric imaging in a confined area using refraction tomography. Journal of Environmental Hydrology, Vol.16, Paper 38.

[6] L. Tien-When, and L. Philips. 2002. Fundamentals of seismic tomography. Geophysical Monograph Series; no. 6, Society of Exploration Geophysicists Tulsa.