Journal of Scientific Research & Reports
3(5): 675-685, 2014; Article no. JSRR.2014.004

SCIENCEDOMAIN *international*
www.sciencedomain.org

SCIENCEDOMAIN

Reducing Ambiguity with Geoelectric Investigations: Implications for Near-Surface Cavities

David O. Anomneze[1*], Ajana G. Onwuemesi[1], Benard I. Odoh[1], Chibuzor V. Ahaneku[1], Churchill C. Okonkwo[1] and Oladotun A. Oluwajana[2]

[1]Department of Geological Sciences, Nnamdi Azikiwe University, Nigeria.
[2]Department of Geology and Applied Geophysics, Adekunle Ajasin University, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author DOA introduced and mapped out strategies of how to carry out the research and was involved in the entire data acquisition and manuscript preparation process. Author AGO, BIO and CVA supervised the project and made significant contributions on the process of data collection and interpretation, Author CCO and OAO were involved in the data collection and report writing. All authors read and approved the final manuscript.

Original Research Article

Received 23rd May 2013
Accepted 31st July 2013
Published 14th January 2014

ABSTRACT

Aims: The purpose of this study include to evaluate the theoretical and practical aspects of the 1D and 2D resistivity data types, especially with respect to precision as they pertain to cavity depth investigation for site characterization in Ogbunike community, Southeastern Nigeria.
Study Design: The results of geoelectrical survey carried out at the Ogbunike community, Southeastern Nigeria where underground cavities exist are presented and discussed.
Place and Duration of Study: The study was carried out at Ogbunike community, Southeastern Nigeria and it lasted for about six months from November 2011 to April 2012.
Methodology: The 1D and 2D electrical resistivity method using schlumberger array and dipole-dipole array respectively were applied in the course of the geophysical

**Corresponding author: E-mail: davanomneze@gmail.com;*

investigation of known and unknown cavities. Anomalous zones of the cavities were distinguishable by the zones with very high resistivity, surrounded by the lower background resistivity zones.

Results: The 1D resistivity method revealed the depth to the subsurface cavities only while the 2D resistivity method gave a more precise definition of the size of the cavities including the width and depth to the target. From the results obtained, the 2D electrical method interprets depth to known cavity to be deeper than the actual depth while the 1D electrical method interprets the depth to known cavity to be less than the actual depth to the cavity. Also, from the results of the geoelectrical survey an unknown cave was detected.

Keywords: Near surface cavity; anomalous zones; electrical resistivity; site investigation.

1. INTRODUCTION

Geophysical methods are effective methods for many site investigations. They are usually applied at the assessment and monitoring stage. The methods continue to be relevant today, as the inspection of subsurface cavities and voids becomes important to both domestic and industrial construction projects. A variety of geophysical techniques can be used to detect the presence of cavities below the surface. All of them are based on the physical contrast between a cave and the surrounding rock. Because the electrical resistivity of the air-filled void is higher than the surrounding substrate, resistivity method is used successfully [1,2,3]. The dipole-dipole array was selected as one of the array because it has low Electromagnetic Coupling between the current and potential circuits [4]. In addition it is very sensitive to horizontal and vertical changes in resistivity, which makes it a good choice for mapping lateral and vertical extent of structures such as faults, dykes, and cavities [4].

The study area is within the Ogbunike community, south-eastern Nigeria (Fig. 1). It is located within the Nanka Formation of the Anambra Basin which was formed as a failed arm of a rift system that took place during the separation of South America from Africa. During the Santonian deformation the upliftment of Abakaliki Anticlinorium led to the depression of this failed arm which later became the site of deposition of sediments. This depression is called Anambra Basin.

The Nanka Formation is made up of a structural framework of sandstone and consists of semi-consolidated sediments of the Nanka sand (Eocene age). Nwajide, 1997 [5] carried out studies on the textural and mineralogical attributes of the Nanka sands which indicated that the Nanka Formation is a sequence of unconsolidated friable poorly converted sandstone and consist of distinct units of sand, shale, siltstone and finely laminated shale.

The area under consideration is characterized by the occurrence of a series of open caves with several unknown cave extension. The present study focuses on electrical resistivity surveys of the subsurface by application of direct current at the surface and was designed to test the effectiveness of using 1D and 2D electrical resistivity in revealing cavities. The purpose of this study is also to describe the results of 1D and 2D electrical resistivity surveys at two sites within the Ogbunike community, Southeastern Nigeria. At one site (Fig. 2), an open cave was noted and the 1D and 2D resistivity was used to run surveys across the cave. At a second site, in a fast developing area in the Ogbunike community where residential buildings exist and construction of new massive structures are ongoing, the geoelectrical methods was also used to run survey to inspect the presence of a cave for geotechnical investigations.

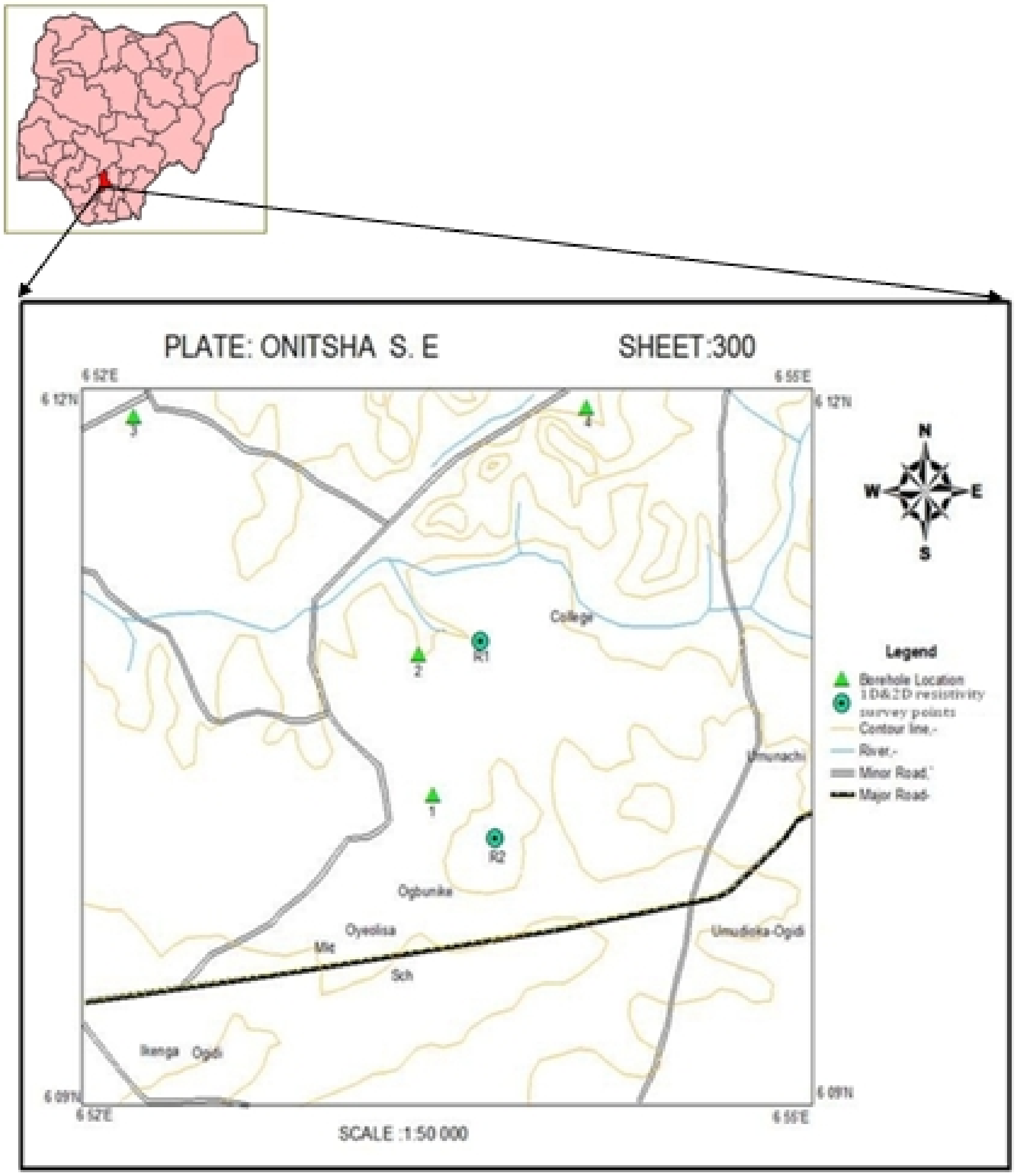

Fig. 1. Location map of the study area and the geophysical measurements in the Ogbunike community, Southeastern Nigeria

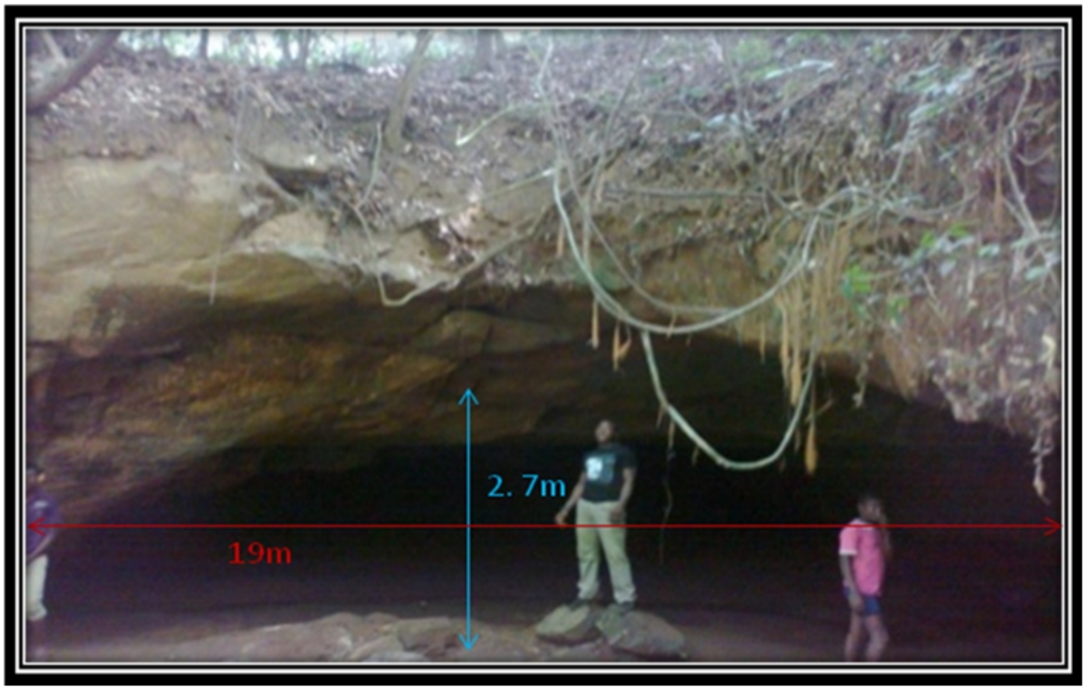

Fig. 2. Open cave exposure at Ogbunike community

2. METHODOLOGY

Surface observation of the study area was carried out which included measuring the depth to the known cave from the top of the survey point and the size of the cave. The 1D electrical resistivity method using the schlumberger array was carried out at the two sites. Also, the 2D electrical resistivity method using the dipole-dipole array was carried out at the two sites with the least electrode spacing of 8m and a significant increase in 'n' value from 1 to 5. The locations of the 1D and 2D electrical resistivity surveys were decided using the Nav 5000 handheld Global Positioning System (GPS). The coordinates of the starting and end points of the soundings and profiles were recorded. The Ohmega terrameter produced by Allied Associate Geophysical Limited was used to carry out the 1D and 2D electrical resistivity survey at the two sites. The Res2Dinv software was used to interpret the 2D electrical resistivity data while Ipi2win software was used to interpret the 1D electrical resistivity data.

The electrical resistivity method as shown in Fig. 3a can measure lateral and vertical changes in the resistivity of the subsurface, while the array type shown in Fig. 3b can measure only vertical changes in the resistivity of the subsurface. However, resistivity differences typically correspond to changes in the lithologic composition of subsurface materials. The electrical resistivity method employs a direct current (I) applied to a pair of electrodes in contact with the ground; the voltage (V) or electrical potential is measured between a second pair of electrodes. The applied current, the resulting voltage potentials, and the electrode geometry are computed to get the apparent resistivity which is inverted with software to get the true resistivity.

In general, the greater the distance between electrodes, the greater the depth of current penetration. A fixed electrode spacing along a survey line typically is used to examine lateral variations in earth resistivity. Given the same number of electrodes, a larger electrode spacing in an array gains more depth of penetration, and a smaller electrode spacing gains more resolution. In this study, surveys are denoted by the electrode spacing and array type. Two types of arrays- dipole-dipole, and schlumberger were employed for this study.

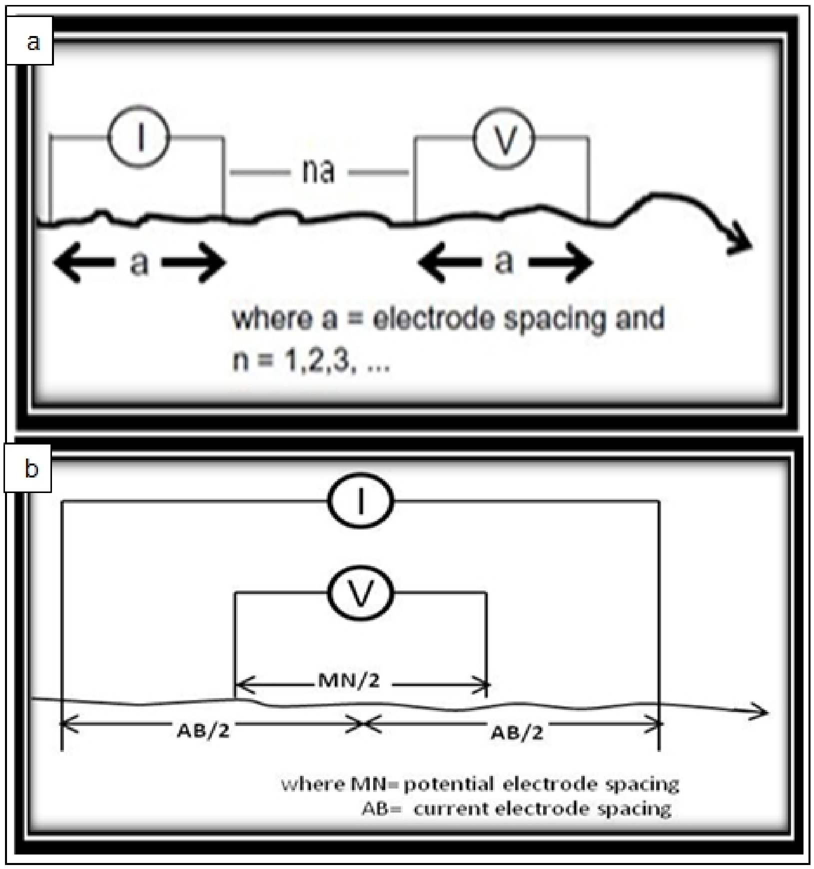

Fig. 3. A typical diagram of (a) Axial Dipole-Dipole and, (b) Schlumberger configuration

3. DATA ANALYSIS AND INTERPRETATION

Results were plotted in the field to verify proper collection of data. Pseudosections were used to plot the dipole-dipole data; in pseudosections, values of apparent resistivity are plotted against electrode geometry. Because pseudosections are difficult to interpret, an inversion of the data was done to determine the electrical properties that give rise to the measured (apparent) electrical resistivity. Inversion of an apparent resistivity data set results in a model of the resistivity characteristics of the subsurface. The inversion process theoretically, allows researchers to obtain reasonable models for the geological structures being studied [6]. Over the last few years, several inversion techniques have been developed to invert 2D pseudosections to produce a 2D image of the subsurface conditions.

These recent developments in 2D inversion tools have led to increasing applications of 2D resistivity imaging as a rapid tool for environmental, engineering and groundwater investigations [7,8,9]. For inversion of the dipole-dipole pseudosections, the inversion program Res2Dinv, version 3.4 [10] was used to construct an image of the true subsurface resistivity distribution. The inversion procedures used in this program are based on the smoothness-constrained least-squares algorithm.

For inversion of the 1D electrical resistivity survey data, the inversion program Ipi2win by [11] was used for an automatic interpretation of resistivity sounding data. The Ipi2win works in an iterative mode by calculating at the end of each step:

(a) An updated model of layer thicknesses and resistivities.
(b) The misfit function between observed and calculated data [12]

3.1 At Site R1 (Known Cave)

3.1.1 1D Resistivity Survey Result

The anomalous zone of highest resistivity value of 10186Ωm identified the presence of the cave at a depth of 6.05m which is a bit less than the actual depth of 7m. The result of the 1D resistivity showed the thickness of the cave as being higher than the actual thickness.

3.1.2 2D Resistivity Survey Result

Here, the anomalous zone of the highest resistivity values identified the presence of the cave on the left flank of the profile at a depth of 7.5m which is a bit deeper than the actual depth of 7m as seen in Fig. 4. The resistivity values of the cave were between 29552 and 56660Ωm. Also, the 2D resistivity profile described the width of the cave to be about 24m which is about 5m larger than that of the physical measurement of the cave.

3.2 At Site R2 (Dwelling Place)

3.2.1 1D Resistivity Survey Result

The anomalous zone of the highest resistivity value indicated the presence of an unknown cave at a depth of 7.28m which is lesser than the result of the 2D resistivity result as shown in Fig. 6 a & b.

3.2.2 2D Resistivity Survey Result

A zone of very high resistivity values indicated the presence of an unknown cave at a depth of 11.9m which is quite larger than the result of the 1D resistivity survey gotten from schlumberger configuration.

However from the results obtained, an extension of the detected cave was inferred which is 2.2km from the known cave. Also, the depth of the cave is predicted to have increased from 6.05m as detected by the 1D resistivity survey across the known cave to 7.28m while the 2D resistivity survey reflected an increase in depth also from 7.5m to 11.9m. The shallow nature and the weak unconsolidated sandstone framework of the cave make it prone to future collapse.

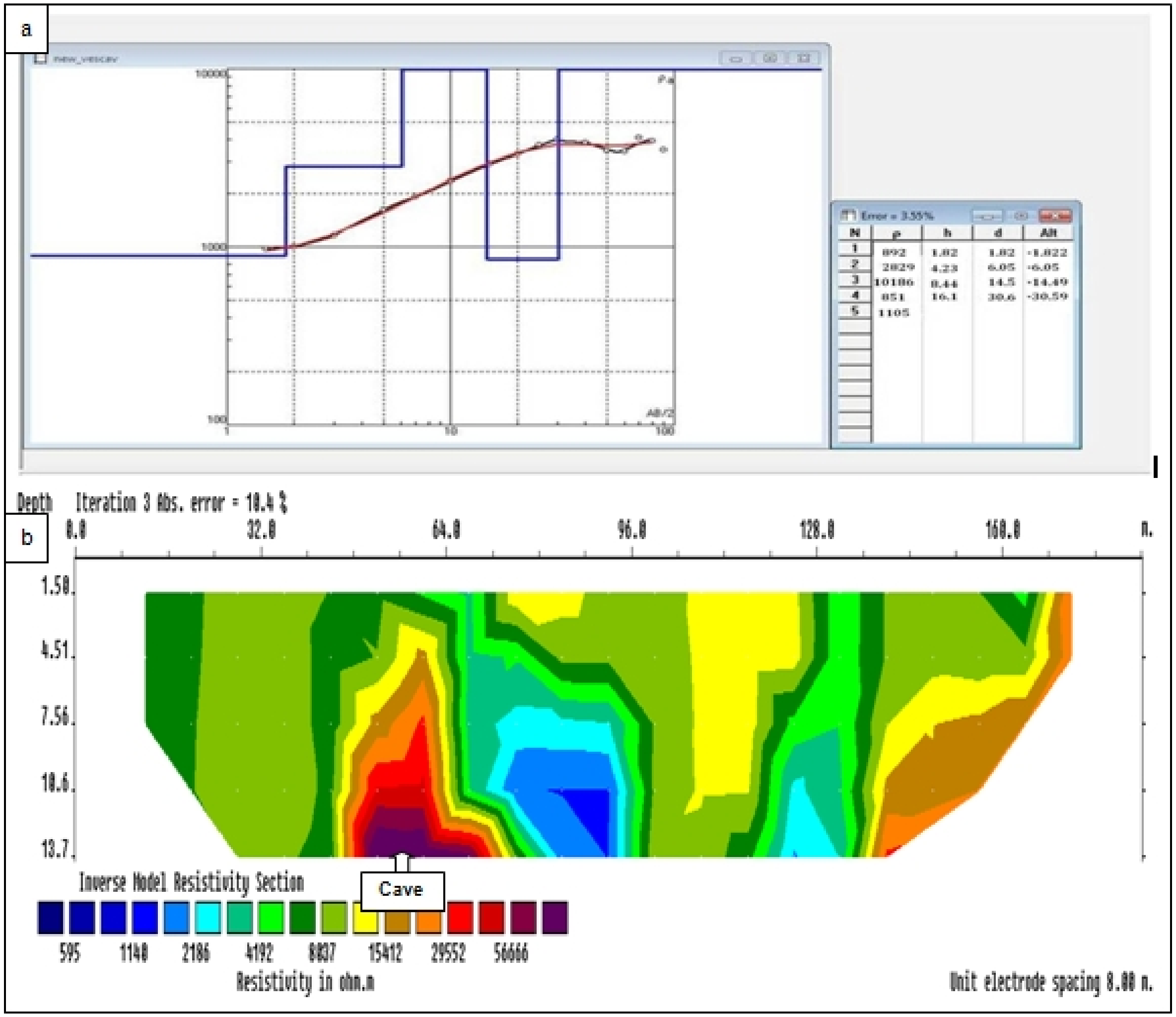

Fig. 4. Inverted results at site R1 from (a) 1D electrical resistivity method (b) 2D electrical resistivity method

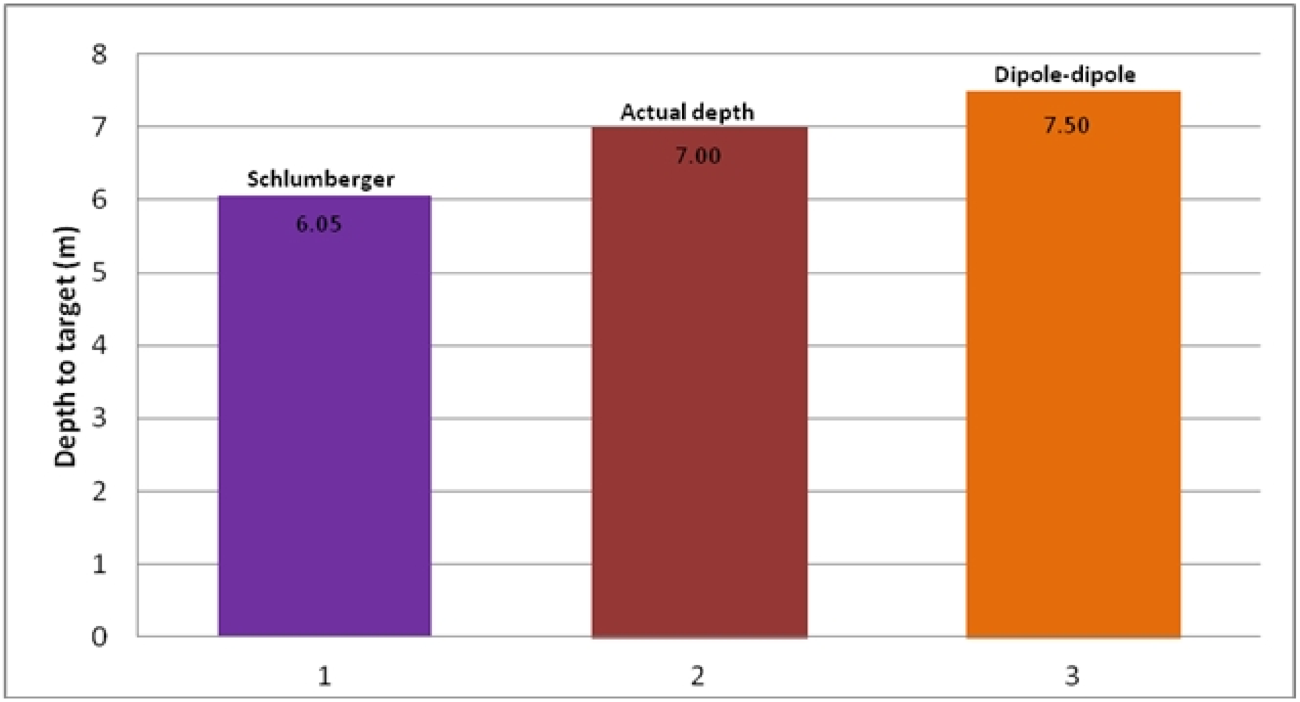

Fig. 5. Plot of depth to target using the actual depth, schlumberger, and dipole-dipole configuration

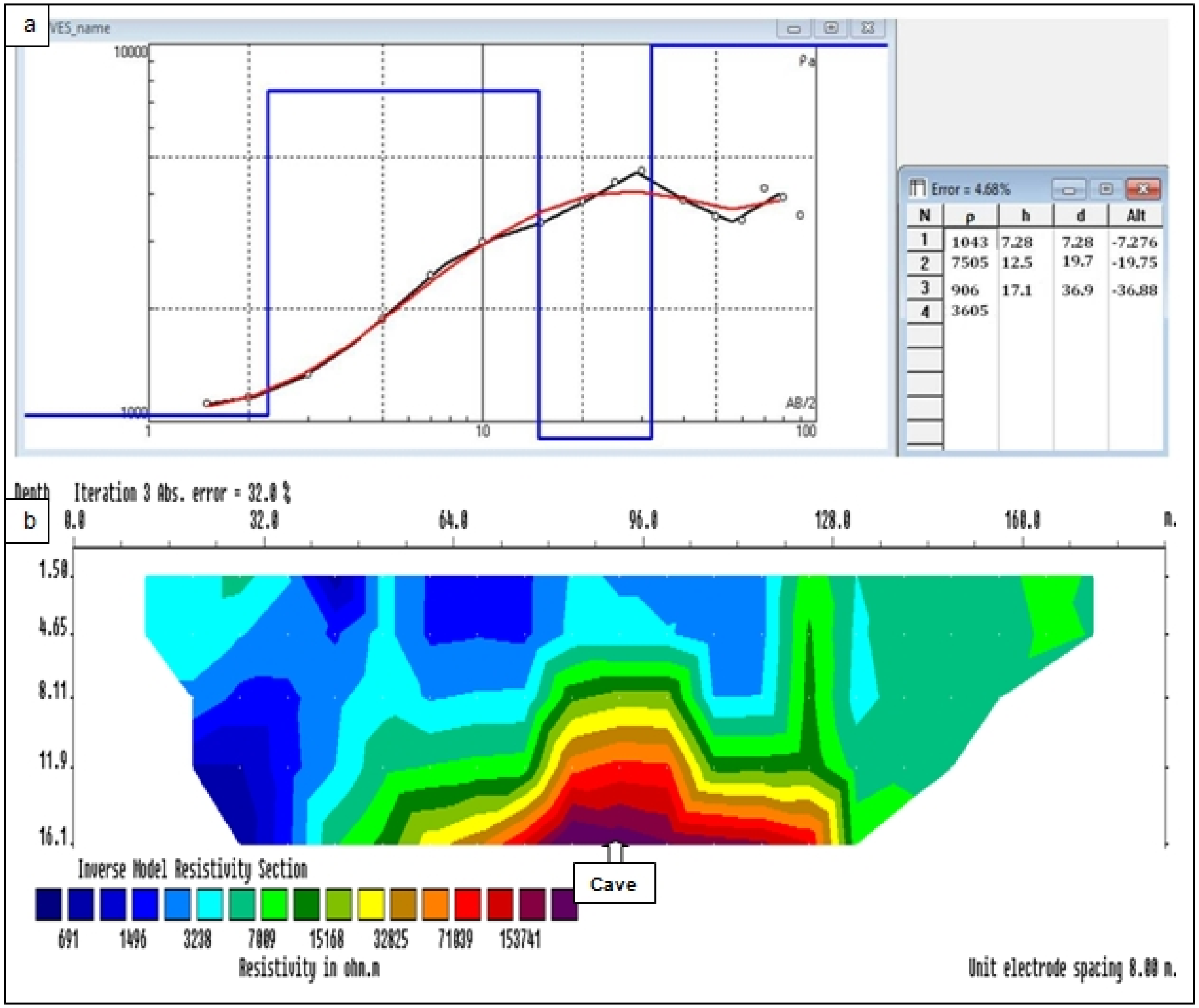

Fig. 6. Inverted results at site R2 from (a) 1D electrical resistivity method (b) 2D electrical resistivity method

4. CONCLUSION

This study demonstrates the effectiveness of combining all the available information (surface observation, geologic studies, and geophysical studies) to develop a geo-picture of the extent of near surface cavity. The resistivity results clearly show that higher resistivity zones are the areas that locate the cavities, which is in agreement with [13,2] and [3].

The comparison of the inverted 1D and 2D resistivity results with the known cave size and depth to target increased the amount of confidence in applying the electrical resistivity technique for inspecting cavities.

The survey results show that the 1D resistivity technique interpreted the known cave to be at a depth of 6.05m which is less than the actual 7m depth from surface observation using a measuring tape while the 2D resistivity technique interpreted the known cave to be at a depth of 7.5m which is deeper than the actual 7m depth as seen in Fig. 5.

Thus, from the resultant electrical resistivity survey, an extension of the detected cave was indicated. Therefore, it is necessary to evaluate the hazard of cave-in and to plan the reclamation of cavities by filling or piling. Also, it is recommended that cautionary measures be carried out before commencement of any massive construction project in the study area.

ACKNOWLEDGEMENTS

Sincere appreciation goes to Emmanuel Ezeama and Solomon Edet - all Nnamdi Azikiwe University geological science graduate students for their field assistance during the survey.

COMPETING INTERESTS

Authors have declared that no competing interests exist

REFERENCES

1. Noel M, Xu B. Cave detection using electrical resistivity tomography. Cave Science. 1992;19:91-94.
2. Satarugsa P, Manjai D, Yangme W. Evaluation of 2-D resistivity imaging technique for mapping and monitoring of subsurface cavity collapsed into sinkhole: In proceedings of Society of Exploration Geophysics Conference and Exhibition, Sydney. 2004;78-81.
3. Elawadi E, El-Qady G, Salem A, Ushijima K. Detection of cavities using pole-dipole resistivity technique: Memoirs of the Faculty of Engineering, Kyushu University. 2001;61:101-112.
4. Loke MH. RES2DINV, Rapid 2D resistivity and IP inversion using least-squares methods, User Manual: Austin. Texas, Advanced Geosciences Inc. 1998;66-68.
5. Nwajide CS. A lithostratigraphic analysis of the Nanka Formation, Southeastern Nigeria: Nigerian Journal of Mining Geologists, 1997;16:103-108.
6. Galas JDF, Taioli F, Filho WM. Induced polarization, resistivity, and self potential: a case history of contamination evaluation due to landfill leakage. Environmental Earth Science Journal. 2011;63:251-261.
7. Dahlin T. 2D resistivity surveying for environmental and engineering applications: First Break. 1996;275–283.

8. Barker RD. Principles of electrical imaging Birmingham University, UK; 2001. Accessed: 01 January 2012.
Available:http//www.bham.ac.uk/earthsciences/research/hydro/envgeo/.
9. Chambers JE, Ogilvy RD, Kuras O, Cripps JC, Meldrum PI. 3D electrical imaging of known targets at a controlled environmental test site. Environmental Geology. 2002;41:690-704.
10. GEOTOMO SOFTWARE, 2002a, RES2DINV- Manual: Accessed 02 January 2012. Available: http://www.geoelectrical.com/.
11. Bobachev C. Ipi2win: A windows software for an automatic interpretation of resistivity sounding data. PhD Dissertation, Moscow State University, Russia; 2002.
Available: http://www.geophys.geol.msu.ru/ipi2win.htm/.
12. Soupios PM, Kouli MM, Vallianatos F, Vafidis A, Stavroulakis G. Estimation of aquifer hydraulic parameters from surficial geophysical methods: a case study of Keritis Basin in Chania (Crete-Greece). Journal of Hydrology. 2007;338:122-131.
13. El-Qady G, Hafez M, Abdalla MA, Ushijima K. Imaging subsurface cavities using geoelectric tomography and ground-penetrating radar. Journal of Cave and Karst Studies. 2005;67(3):174-181.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=398&id=22&aid=3335