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The use of Geoelectrical Methods for Delineation of Lead-Zinc Mineralization: A Case Study of Eziama Village, Abia State, South- East, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

2D Electrical Resistivity (ER) and Instantaneous Potential (IP) geophysical techniques were used at Eziama village in Abia state of Nigeria to investigate possible Pb-Zn mineralization. The dipole-dipole electrode configuration was employed for data acquisition and Earth Imager software was used for inversion of the acquired data. The analysis of the result of the study showed the presence of the Pb-Zn ore along traverses 1, 2 and 3 while traverses 4 and 5 appear barren. Along traverse 1, the mineralized zone falls within the fractured basement and is characterized by low resistivity (about 316 – 5623 ohm-m) and high chargeability (33.2 – 128 ns) at lateral distance of 73 – 103 m. On traverse two, the ore body was identified at lateral distance of about -18 to 53 m as delineated on the IP structure with resistivity and chargeability of the anomalous zone ranging from 4.6 – 677 ohm-m and 41.8 – 142 ns respectively at depth of about 21.4 m while on traverse three, two ore bodies labeled a, a' and b, b' on the ER and IP cross-sections were delineated at lateral distance of about -130 to -93 m and 78 to 98 m respectively with depth to the top of the suspected ore bodies ranging from about 7.1 m for body 'a' and about 14.3 m for 'a'. Traverses four and five however showed no prospect for Pb-Zn mineralization.

The result of this investigation has once again demonstrated the usefulness of combined electrical resistivity and induced polarization techniques in solid mineral exploration.

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1. INTRODUCTION

Mineral resources are useful earth materials of sufficient quantity and adequate quality to be extracted for human economic benefit. Since time immemorial, minerals resources like Zinc have been exploited and used as raw materials for industrial production and to generate revenue for the national economy, through export to other countries [1]. The solid minerals are subdivided into three subtypes: metallic, non-metallic and energy minerals. The metallic minerals include and base metals (zinc) while the non-metallic minerals (and rocks) can be subdivided into industrial minerals (e.g. barite, salt), industrial rocks (e.g. limestone, granite) and gemstones (e.g. sapphire, diamonds). With a daily production of 2.6 million barrels, Non-metallic energizing the other sectors of the economy. Industrial minerals and rocks such as barite, halite (salt), gemstones, limestone, marble and granite also occur abundantly in many parts of the country, and are being harnessed as raw materials for industrial and infrastructural development, and for import substitution. Metallic ores of Iron, lead-zinc, gold, tin and manganese have been found in substantial quantities in some parts of the country like Abia state [2]. However, Nigeria's solid minerals sector is very much under developed; it is in a situation where minerals that can be easily produced and beneficiated in the country are being imported, while substantial quantities of Zinc and gemstones worth hundreds of millions of dollars extracted by illegal mining are being smuggled out of the country with attendant loss of revenue. Available records indicate that in 2017 alone, Nigeria imported more than $45 million (US dollars) worth of industrial minerals and $3 billion (US dollars) worth of iron and steel products. It is also reported that Nigeria loses up to 10,000 kg of smuggled gold annually, with estimated worth of over $400 million (US dollars). Solid minerals have a major role to play in the growth and diversification of the Nigerian economy. Efforts to transform the solid minerals and mining industry are in progress.

The Zinc mineralization in Nigeria has instigated repeated studies in Abia State using different geological and geophysical techniques, although less has been done with electrical resistivity techniques. The well-established Electrical resistivity method is a rapid, wide coverage and cost effective technique for locating both hidden ores and the structures associated with the mineralization. The proficiency of the electrical resistivity method for high-grading mineralized area in preparation for competent mine development is of significant contribution to an integrated geophysical investigation effort. The readings of electrical resistivity technique, just like E M geophysical prospecting is based on variations in subsurface electrical resistivity which is the inverse of conductivity. This method therefore, provides a quick and powerful tool for the study of 2-D geological structures to a maximum depth of more than 100 m, though variation in the depth is based on changes in subsurface conductivity. Careful study reveals the Zinc mineralization in Abia state is structurally controlled such that both ore and gangue minerals occur in successive and symmetrical layers along vertically and/ or steeply dipping fractures which often have parallel or matched walls, thus indicating its fissure filling mode of occurrence which is so pinpointing to electrical resistivity method of prospecting. This method is very useful and pertinent because of how quickly data can be collected, and large survey area can also be covered quickly with the portable instruments.

In this study, electrical resistivity method of geophysics is used to delineation of zinc deposit in complex geological environments, and has been adopted by several authors such as: Krishnamurthy [3], Nthaba [4]. This is because it find its usefulness in mapping out vertical and the lateral extents of the zinc deposit with estimated overburden thickness. Thus, by combining data on the surface geological features with subsurface information obtained from geo-electrical investigations, one may define the subsurface features and details of the zinc deposit.

1.1 The Study Area

1.1.1 Location of the study area

Eziama village, Umuch-Ileze is located in Abia state, Nigeria. Abia State is located between lat 4˚49.30'N - 6˚02'N and between long 7˚08'E - 8°04'E in the south- eastern part of Nigeria (Fig. 1). It has an area of about 5833.77 km2, which is roughly 9% of Nigeria’s land mass. It is bounded in the north by Enugu state, in the south by River state, in the east by Cross River and Akwa Ibom states and in the west by Imo state.

Abia state has a population of 2,293,978 inhabitants, residing in both the rural and urban areas in the state. This is about 393 inhabitants per square km on the average, which is about 3.5 times the mean population in Nigeria. While some parts like Ngwa is below the average, Umuahia and Aba are each above the mean population density with about 2000 inhabitants per square km respectively. Abia State enjoys an equatorial climate consisting mainly of two major seasons: Rainy season, (Mar- ch-October) and Dry season (November-February) each year. The north east trade wind from Sahara Desert and the southerly humid marine air mass from the Atlantic Ocean cause the seasonal variation in the climate of Abia state. The number of sunshine hours in the state is 3600 hours per year.

1.1.2 Geology

There are two principal geological Formations in the state namely Bende-Ameki and the Coastal Plain Sands otherwise known as Benin Formation. The Bende-Ameki Formation of Eocene to Oligocene age consists of medium–coarse-grained white sand stones, (Fig. 1). The late Tetiary-Early Quaternary Benin Formation is the most predominant [5] and completely overlies the Bende-Ameki Formation with a south west-ward dip. The Formation is about 200m thick [6]. The lithology is unconsolidated fine-medium-coarse-grained cross bedded sands occasionally pebbly with localized clay and shale [7]. The two principal geological Forma-tions have a comparative groundwater regime. They bothhave reliable groundwater that can sustain regional bore- hole production. The Bende-Ameki Formation has less groundwater when compared to the benin Formation. The numerous lenticular sand bodies within the Bende- Ameki Formation are not extensive and constitute minor aquifer with narrow zones of sub-artesian condition. Specific capacities are in the range of 3 - 6 m3 per meter per hour, [9,10]. On the other hand, the high permeability of Benin Formation, the overlying lateritic earth, and the weathered top of this Formation as well as the underlying clay shale member of Bende-Ameki series provide the hydrogeological condition favouring the aquifer forma-tion in the area. Drainage: Abia state is drained by five important riv-ers namely: Imo, Esu, Akpoha, Igu and Aba River. The drainage is however dominated by two main rivers: the Imo River on the west and Cross-River on the east. Rainfall: The rainfall duration in the state can be clas-sified into the wet and the dry seasons. Abia state enjoys a copious rainfall during rainy (monsoon) season. The mean monthly rainfall during this season [5] is 335 mm and falls to 65 mm during the dry season. The annual rainfall is between 2000 mm and 2250 mm south of Abia and between 1250 and 2000 mm north-east of Abia. There are about 240 rain days towards the north of Ovim-Abriba axis and about 255 rain days south of it.

2. METHODOLOGY

The electrical resistivity tomography (ERT) allows for the mapping of the subsurface electrical resistivity distribution. It is based on the injection of electric current (I) and measurement of the resulting electric potential difference (V). Several geological factors such as mineral and fluid content, porosity and degree of water saturation present in rock affects ground electrical resistivity. To investigate the subsurface for mineral exploration, it is best to employ both the electrical resistivity and induced polarization (IP) method.

The common electrode array used in resistivity and IP survey includes: Wenner array, dipole-dipole array, schlumberger array, pole-pole array and gradient array. For this study, five (5) traverses were established in orthogonal directions as shown in Fig. 2.

The dipole-dipole configuration was adopted and the AGI Earth Imager software was used for joint inversion of the resistivity and IP data to generate the 2D resistivity and IP image of the subsurface. The images were then interpreted qualitatively and semi-quantitatively to map out the possible mineralized zones within the area.

3. RESULTS AND DISCUSSION

The 2D Electrical Resistivity (ER) and Induced Polarization (IP) models generated from the inversion of the acquired resistivity and IP data are shown below.

The ER and IP inverted structure along traverse one is as displayed in Fig. 3. The electrical resistivity values along traverse one ranges from 1.0 - 10000 ohm-m while the IP values ranges from -156 - 222 ns. The total depth of penetration is 28.5 m. It is expected that the mineralized zone will have low resistivity and high chargeability. The 2D resistivity structure shows that the subsurface along the traverse is

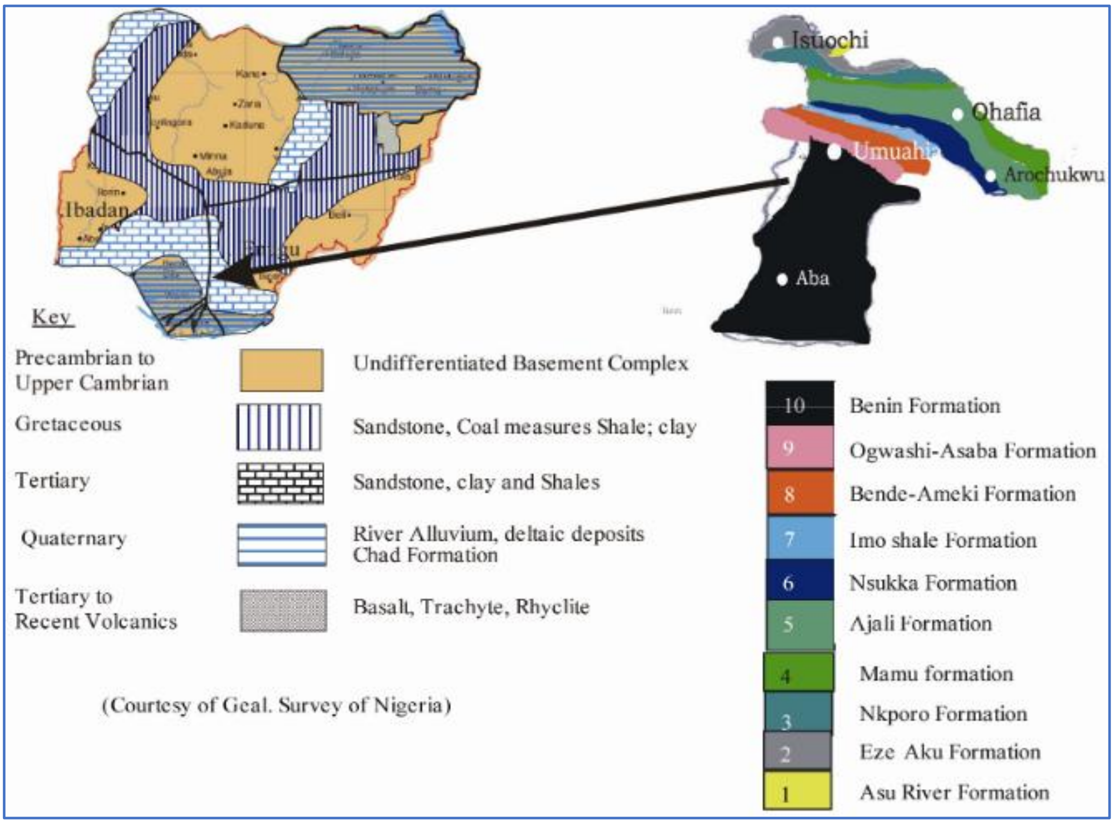

Fig. 1. Geographic location and geological map of Abia State [8]

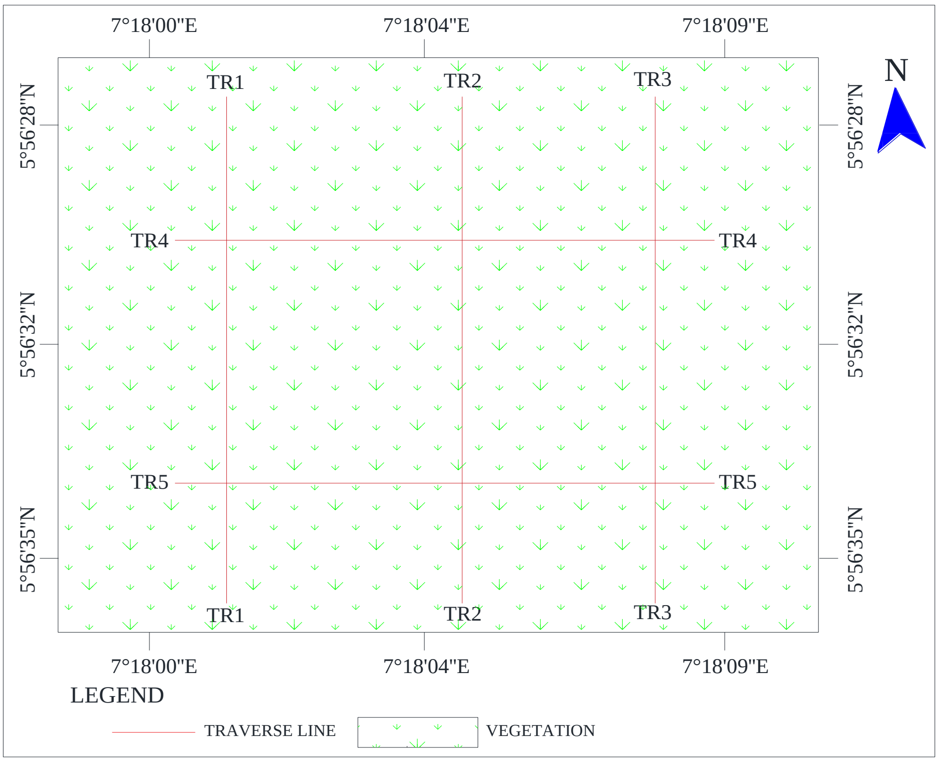

Fig. 2. Basemap of the Study Area Showing the Traverse Lines

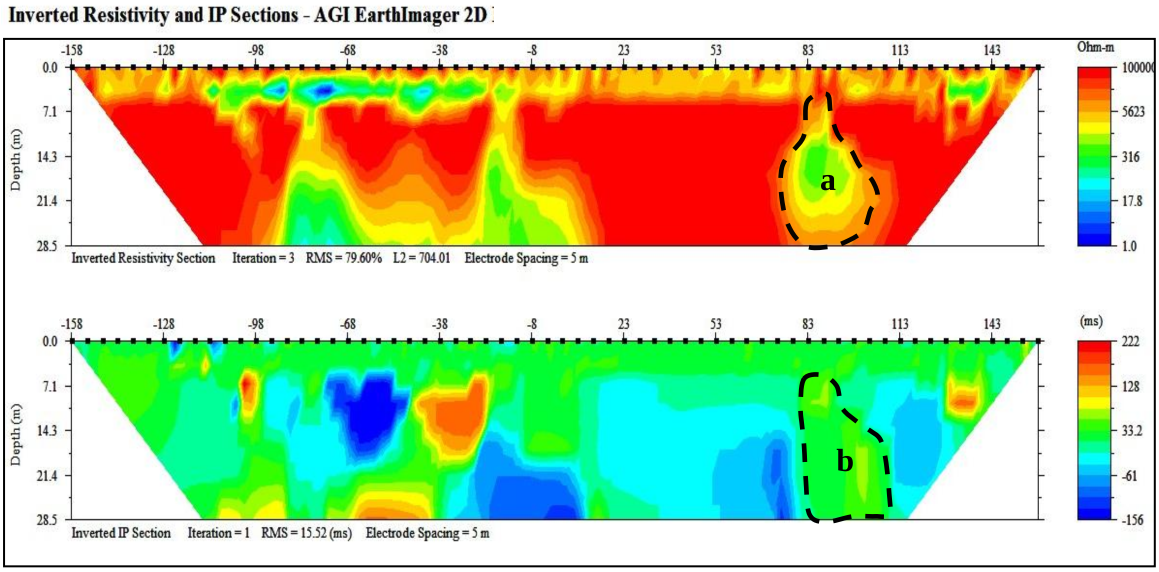

Fig. 3. 2D resistivity and chargeability section along traverse one

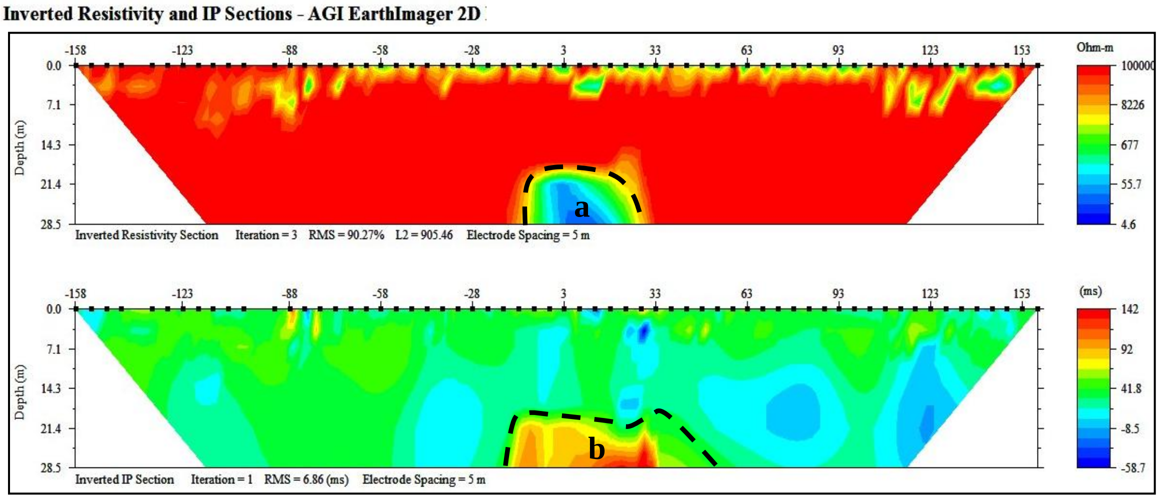

Fig. 4. 2D resistivity and chargeability section along traverse two

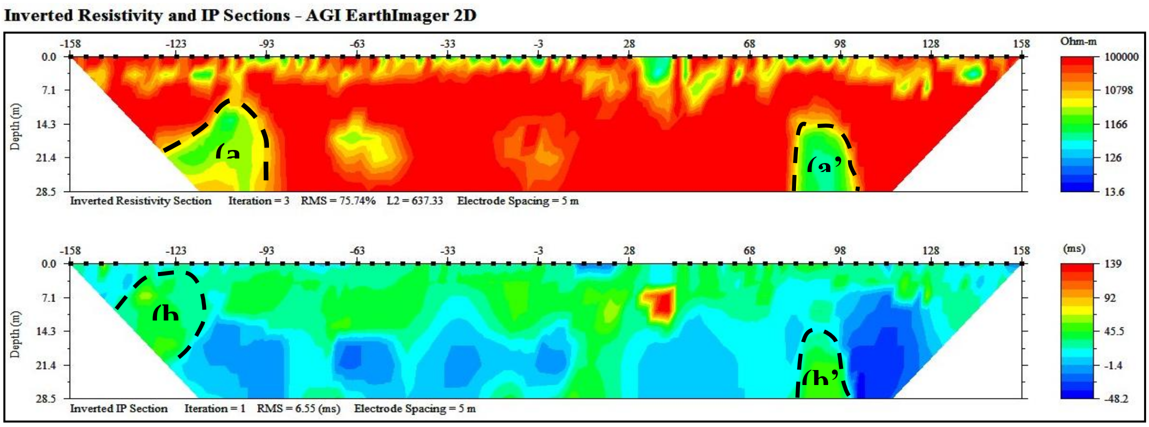

Fig. 5. 2D resistivity and chargeability section along traverse three

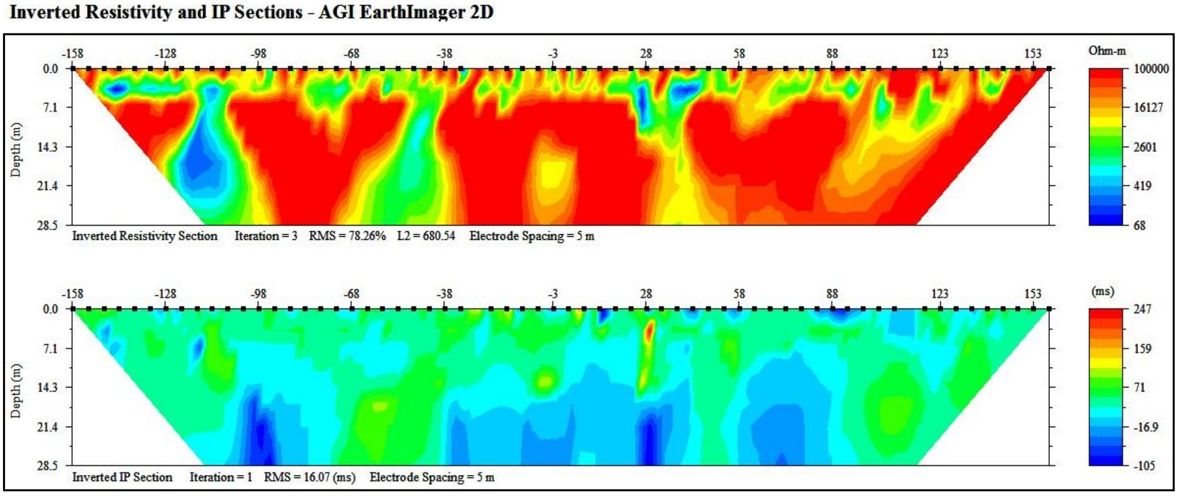

Fig. 6. 2D resistivity and chargeability section along four

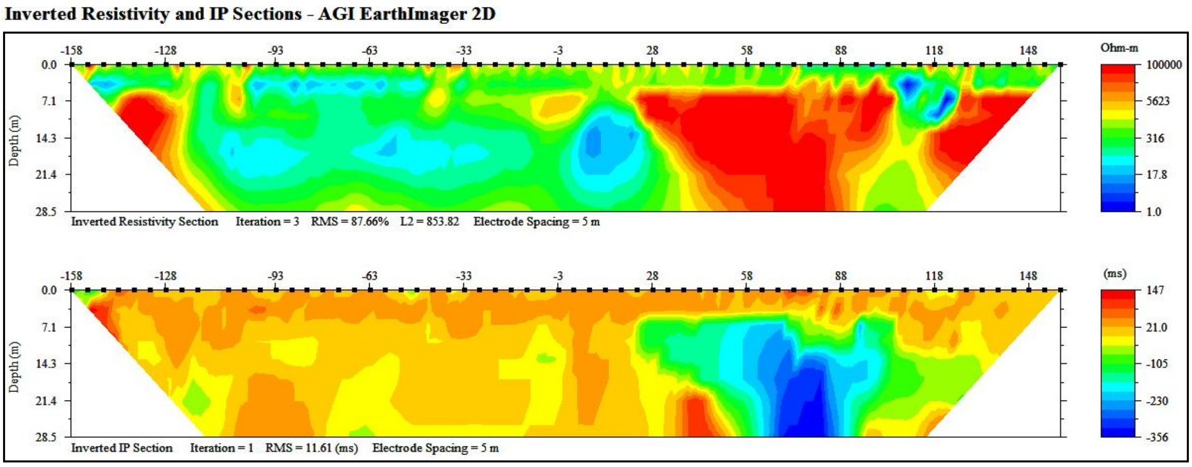

Fig. 7. 2D resistivity and chargeability section along traverse five

majorly made of three layers including the topsoil, the weathered layer (yellow – green colour) and the fractured basement (red – purple colour). The mineralized zone (marked a and b on ER and IP sections respectively) is within the fractured basement. The zone is characterized by low resistivity (about 316 – 5623 ohm-m) and high chargeability (33.2 – 128 ns) at lateral distance of 73 – 103 m.

The ER/IP along traverse two (shown in Fig. 4) identified one Pb-Zn ore body at lateral distance of about -18 to 53 m as delineated on the IP structure. The ore body is marked a and b on the ER/IP structure. The resistivity and chargeability of the anomalous zone ranges from 4.6 – 677 ohm-m and 41.8 – 142 ns respectively. The depth to the top of the ore body falls at about 21.4 m.

On profile 3 (Fig. 5), two ore bodies labeled a, a' and b, b' on the ER and IP cross-sections are delineated at lateral distance of about -130 to -93 m and 78 to 98 m respectively. These ore bodies are located within the fractured basement. The depth to the top of the suspected ore bodies ranges from about 7.1 m for body (a) and about 14.3 m for (a'). Traverses four (Fig. 6) and five (Fig. 7) however showed no prospect for Pb-Zn mineralization.

4. CONCLUSION

2D ER and IP techniques has been used to investigate possible Pb-Zn mineralization at Eziama village in Abia state of Nigeria. The dipole-dipole electrode array was employed for data acquisition and Earth Imager software was used for inversion of the acquired data. The analysis of the result of the study showed the presence of the Pb-Zn ore along traverses 1, 2 and 3 while traverses 4 and 5 appear barren. Along traverse 1, the mineralized zone falls within the fractured basement and is characterized by low resistivity (about 316 – 5623 ohm-m) and high chargeability (33.2 – 128 ns) at lateral distance of 73 – 103 m. On traverse two, the ore body was identified at lateral distance of about -18 to 53 m as delineated on the IP structure with resistivity and chargeability of the anomalous zone ranging from 4.6 – 677 ohm-m and 41.8 – 142 ns respectively at depth of about 21.4 m while on traverse three, two ore bodies labeled a, a' and b, b' on the ER and IP cross-sections are delineated at lateral distance of about -130 to -93 m and 78 to 98 m respectively with depth to the top of the suspected ore bodies ranging from about 7.1 m for body (a) and about 14.3 m for (a'). Traverses four and five however showed no prospect for Pb-Zn mineralization.

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DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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