Volume 9, Issue 7, July – 2024 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUL341

Evaluation of Subsurface Structures for Mineralization Potential within Kebbi Basement Terrain using Electrical Resistivity Tomography

Y.I. Bawa[1] , A.J. Zainab[1*] , and I.H. Abusufyan[1]
[1]Physics Department, Adamu Augie College of Education Argungu, Kebbi - Nigeria
ORCID ID: 0000-0002-1460-0993

Corresponding Author: A.J. Zainab[1*]

Abstract:- The study area spans from 4°30' E to 5°00' E in longitude and from 11°00' N to 11°30' N in latitude. A total of four profiles 400m long were surveyed using Wenner array configuration with minimal electrode spacing of 3m and repeated with integer multiple of 3 that explored up to 18m during which apparent resistivity values were found. Electrical resistivity tomography has emerged as a powerful geophysical technique for investigating subsurface structures, particularly in mineral exploration. This research explores the application of resistivity tomography in delineating basement structures associated with mineralization. Two-dimensional models were analyzed with the RES2DINV inversion software to achieve precise interpretations. The results revealed a range of geological features and variations at different depths. High resistivity zones indicated the presence of schist and moderately weathered gneiss with quartz veins, which are structurally controlled and oriented North-West and Northeast-Southwest. This technique proved effective in identifying potential mineral deposits, aiming to provide a comprehensive overview of the study area and improve mineral exploration strategies through resistivity tomography.

Keywords:- *Resistivity Tomography, Basement Structure, Mineralization, Mineral Exploration.*

I. INTRODUCTION

Mineral exploration in complex geological terrains often requires detailed subsurface imaging techniques to locate potential mineral deposits buried beneath weathered layers and sediments. Rare minerals can easily be missed, and the process of searching for them is an expensive risk. In many parts of the world, mineralization is controlled by structural elements and is commonly associated with faults, fractures, and shear zones. Minerals are naturally occurring crystalline entities with a specific chemical composition, unique atomic structure, and distinctive physical properties (Olalekan et al., 2016). Resistivity tomography, also known as electrical resistivity tomography (ERT), is a non-invasive geophysical method used to measure the electrical resistivity of subsurface materials. This method has gained popularity due to its ability to map geological structures with high resolution, providing valuable insights into the distribution and nature of mineral deposits within basement structures. Exploring for minerals is a challenge that need to approach with as much information as possible. Understanding the complex subsurface structures of the earth is crucial for various industries, including mineral exploration, environmental assessment, and civil engineering projects (Bawa *et al* 2020: Bawa *et al* 2022). Electrical conductivity, as a physical property, is valuable in mineral exploration for solving various challenges. It can indicate mineralization directly or help map the geological structures related to it. The electrical resistivity method effectively identifies the locations and depth extensions of mineral-bearing veins (Guo et al., 1999; Bawa et al., 2020). Recently, geophysical exploration has become crucial for detecting mineralized structures beneath surface cover (Liu et al., 2006).

Thus, the Electrical Resistivity (ER) method in geophysics can be used to evaluate the properties of gold ore within metamorphic basement rock, provided there is a resistivity difference between the host rock and the ore. ER is a non-invasive and environmentally friendly technique appropriate for subsurface exploration in both urban and rural areas. It is easy to use and cost-effective (Abubakar et al. 2014) compared to the labor-intensive and environmentally destructive trial-and-error exploration methods employed by artisanal and small-scale miners. A two-dimensional (2D) ER survey is particularly useful for mineral exploration because it can estimate the size of the mineral reserve and the depth of the mineralized zones, thereby allowing in-situ assessment before drilling mineral deposits.

Mineralization is often associated with quartz veins, disseminated sulfides, or magnetic minerals, creating a notable contrast in electrical properties between mineralized areas and surrounding rocks. Fracture zones within faults and shear zones, formed during metamorphism, enhance permeability and fluid flow, and frequently contain significant vein contents. These veins are planar hydrothermal deposits filling rock fractures. Thus, identifying zones with high fracture density is a key method for locating potential ore targets (Tripp and Vearncombe 2004).

Numerous studies have been conducted to determine subsurface structural patterns and mapping using electrical resistivity Technique among others (Chifu *et al.*, 2019; Syed et al., 2018; Emujakporue et al., 2017; Olalekan et al., 2016; Osinowo et al., 2013; etc).Information about subsurface mineralization zones and depth at which mineralization may occur is very crucial for accurate discrimination and exploring mineral deposit and associated features (Batista-Rodrıguez *et al*, 2017). Therefore, in this research, we investigate the crustal deformation that could be alteration zone, fractures or faults system of the basement rocks that controls the mineralization of the research study.

II. LOCATION AND GEOLOGICAL SETTING OF THE STUDY AREA

The study area is located in the northwestern part of Nigeria, bounded by 4°30′E and 5°00′E longitudes and 11°00′N and 11°30′N latitudes (Figure 1). The study area is known for its abundant mineral resources and unexplored subsurface geology. The region boasts significant deposits of gold, limestone, gypsum, and granite, making it a prime area for mining and exploration.Geologically, the area is underlain by a complex of rocks in the basement, consisting of undifferentiated schists including granite, rhyolite, biotite granite, conglomerate, quartz-mica schist, migmatite, gneiss, sandstone, ironstone and laterite (Augie et al., 2023). The topographical conditions in the area range from 132 m in the lowlands, especially in the southwestern fringes of the map (Tungan Magaje, Shanga, Dugu Tofo Ganwo and Nasarawa), to 352 m in the highlands according to the analysis of the digital data. Elevation Model (DEM). Study area (Tawaye et al., 2023; (Obaje, 2009)

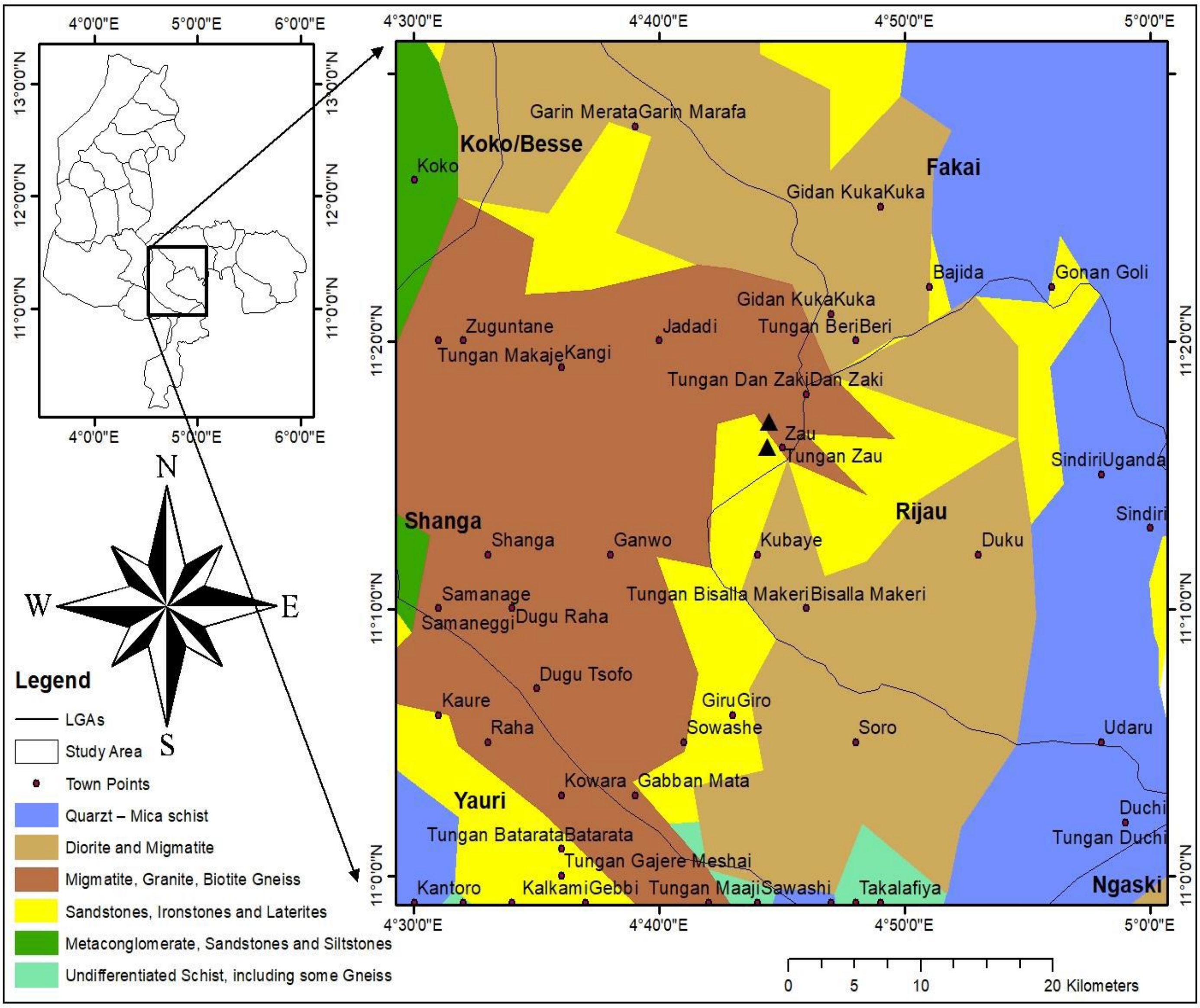

Fig 1 Geology Map of the Study Area (Bawa et al, 2020)

III. BASIC THEORY OF ELECTRICAL RESISTIVITY

The Electrical resistivity method is based on the flow of d.c current underground. The flow current injected is governed by equation (i) as shown in Figure 1. The fundamental physical principle employed in resistivity surveys is Ohm's Law, which dictates the flow of current through the ground. The distribution of current flow lines is influenced by the properties of the medium being investigated, with a higher concentration in conductive volumes. For a simple body, resistivity (r) (Ωm) is defined as follows:

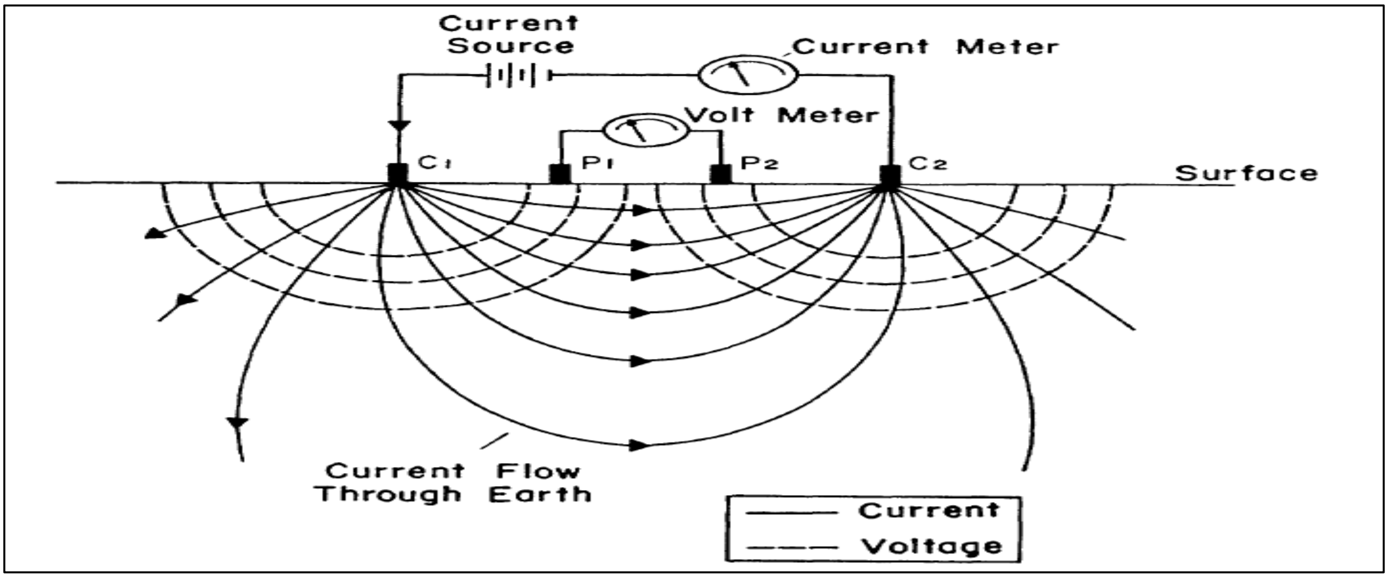

Fig 2 Current Flow Distribution in a Homogeneous Soil. (Bernard, 2006)

$$R = \frac{V}{I} \tag{1}$$

According to Reynolds, 1997, four electrodes system as commonly used in subsurface direct current resistivity, the relationship between the injected current (I), the measured potential difference (ΔV) and the generalized surface electrode distribution is given by

$$\rho = \frac{\Delta V}{I} 2\pi \left[\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}\right]^{-1} \tag{2}$$

In compact form

$$\rho = KR \tag{3}$$

$$K = 2\pi \left[\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}\right]^{-1} \tag{4}$$

K is the geometric factor, r with subscripts stand for electrodes spacings (Figure 2) and R stands for resistance of the medium that is given by the ratio of ΔV to I.

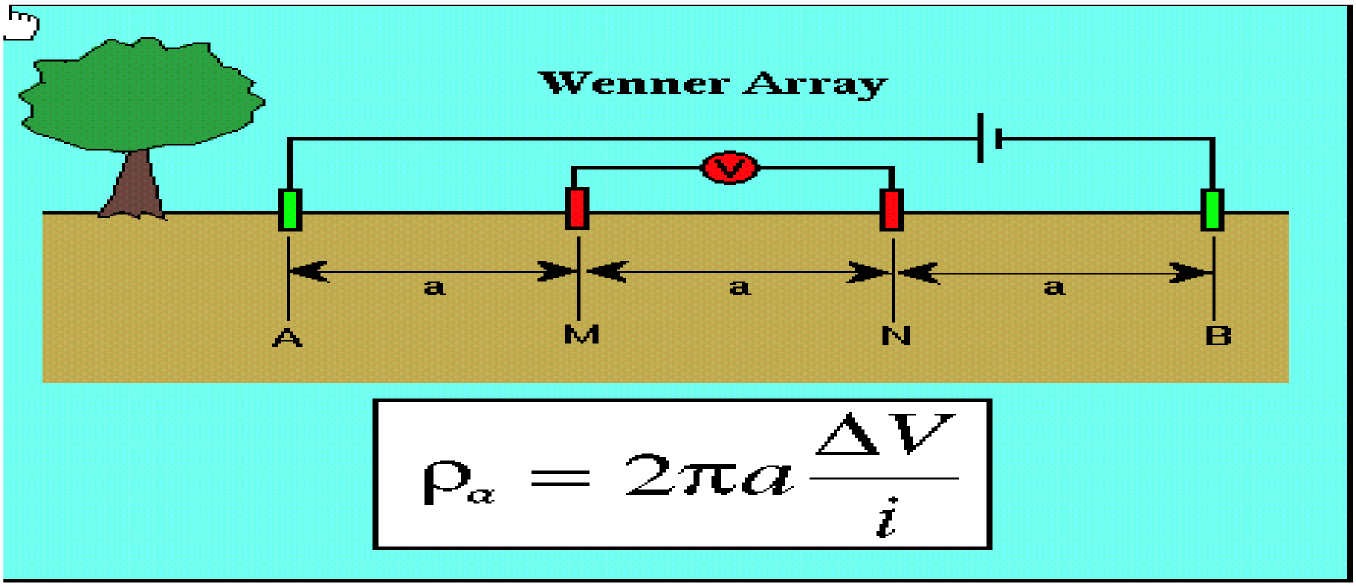

Fig 3 Generalized Four Electrode System

Measuring electrical resistivity typically requires four electrodes: two electrodes, designated as A and B, are used to inject the current ("current electrodes"), and two other electrodes, designated as M and N, are used to measure the resulting potential difference ("potential electrodes"). The potential difference ΔV measured between the electrodes M and N is given by the equation:

Thus, apparent resistivity for Wenner array is given by

$$\rho_a = 2\pi a.R \qquad (5)$$

IV. METHODOLOGY

➢ *Data Acquisition*

Electrical resistivity survey were conducted to detect major faults and fracture zones. The success of resistivity tomography depends on careful planning of electrode configurations and data acquisition parameters. In the present study, four Profiles (Figure 3) using Wenner electrode arrays configurations was employed during this field surveys. Readings were taken with the guide of Supersting Terrameter because of its prime quality knowledge acquisition capability as well as its field value. The profiles were kept at 400m length, at first four electrode were placed at 3m spacing along transect symmetrically regarding x-position. Measurements were made by increasing electrode spacing’s in multiple number of three (3) up to 6 data level.

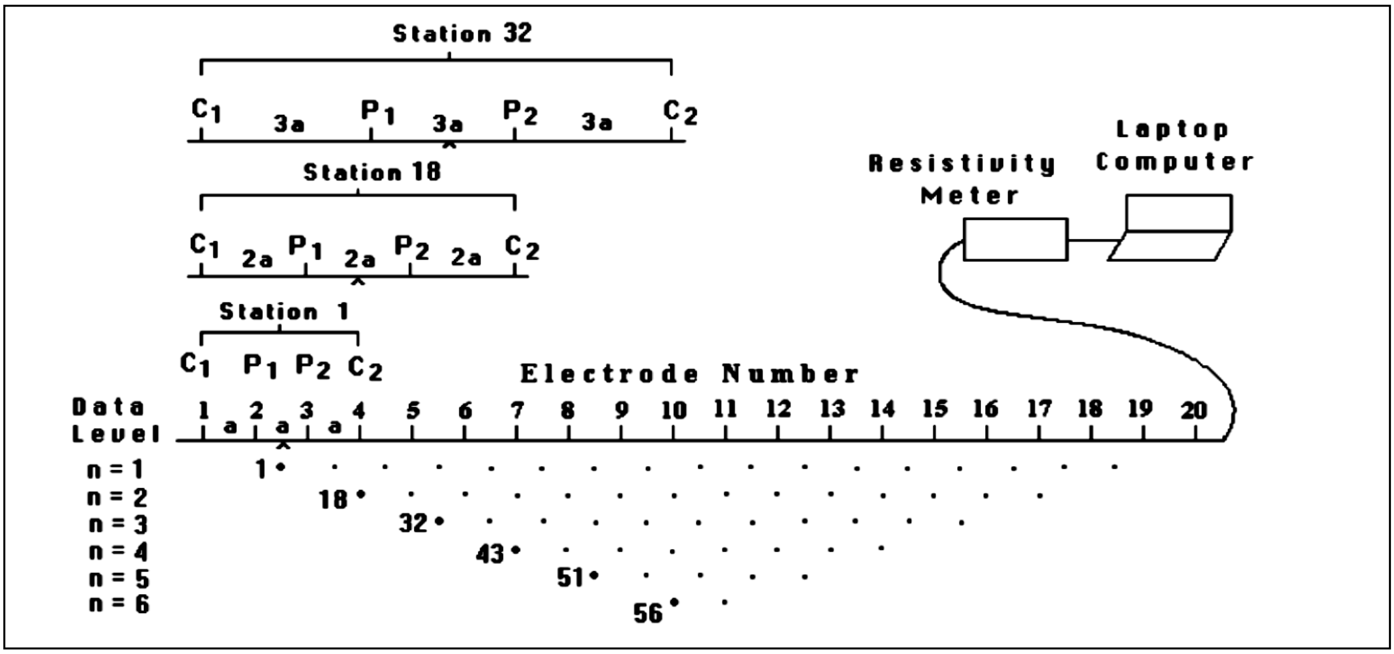

Fig 4 Sequence of Measurement Build Up

Plate 1 Data Acquisition

V. RESULTS AND DISCUSSION

Sections of the 2D resistivity inversion model (Figures 4.1 - 4.4) are shown that analyze resistivity variations and correlate them with known geological features. An advanced software package (Res2dinVx) was used to create an accurate subsurface model. The results show a resistivity model that varies in shape with depth due to the heterogeneous nature of the mineralization within the study area. Essentially, the 2D resistivity model represents the rather heterogeneous geology of the area, consisting of quartz veins or quartzite. These anomalies occurred in zones of increased resistivity. These zones may represent mineral-rich areas with identifiable fault structures, hydrothermal alteration zones, and ore bodies buried under caprock. This is confirmed by the abundance of quartz veins (locals call them Jirgi) in the area from various artisanal holes and trenches in the study area. The heterogeneous pattern and trend defined by the anomalous zones indicate that the mineralization is structurally controlled and trends from the northeast to the east, northeast to southeast. Traces of quartz veins are identified by high resistivity anomalies (>600 ohm-m) at both shallow and deeper depths, while the shallow anomalies do not show any specific trend and are partly related to the influence of weathered soils caused by weathering and attention to sulphite-containing quartz vein.

- *Profile One*

The 2D resistivity model is run in a curvilinear direction. The NW-NE trend is characterized by a distribution of high and medium resistivity, with the highest resistivity values being >1000.0 ohm-m (Figure 5). The high resistivity zone indicates the presence of solidified material. Solidified material generally has high conductive resistivity due to its crystallinity and lack of interconnected pore space. The hydrothermal zone has very low resistivity (3.84-18.5 ohm-m) and is about 12m thick. This very low resistivity zone starts at 340 m along the W-E profile and has a lateral extent of about 400 m towards fracture zone B. They are clearly visible on the surface of the study area very close to fracture zone B. The drag profile increases from the surface towards the bottom of the profile. Fracture zone A has relatively moderate resistivity (40-48 ohms) and extends to a depth of about 17 m. This often indicates a fractured rock layer containing clay minerals that affect its electrical conductivity.

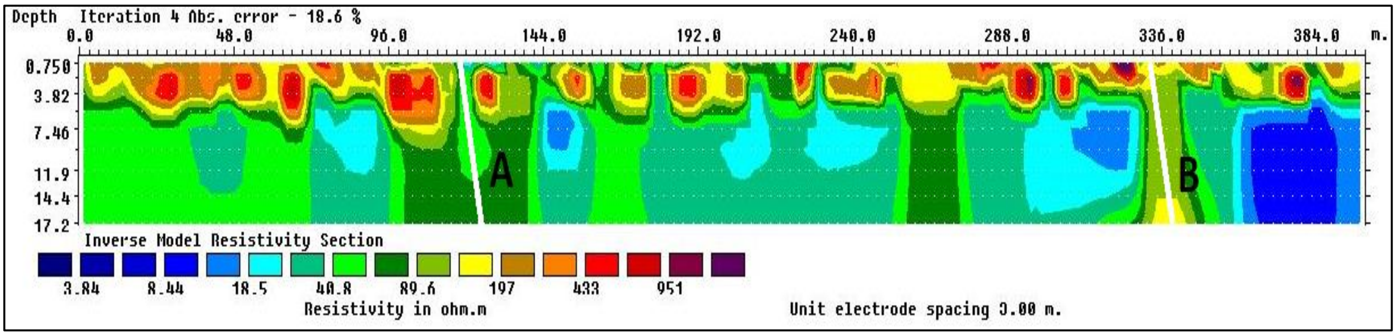

Fig 5 Inverse Resistivity Section of Profile One

- *Profile Two*

The result of the inverted model (Figure 6) show that the stratigraphic sequence in the study area is composed of four layers. The locations marked C and D indicate faults at depths of 10 m and 11 to 14.2 m which are characterized by relatively high resistivity (665 – 2000 ohm-m) that is consistent with the linear orientation (North-South) of rock outcrops in the study area . The resistive structures covered by sediments are fractured to some degree in the basement. The main low resistivity anomalies are associated with veins and faults.

- *Profile Three*

The 2D inverted electrical resistivity profiles and geologic interpretations (Figure 6) reveal three geoelectrical layers. The result show linear funnel shaped feature with low. This funnel shaped feature which extends to surface is bounded on both sides by high resistivity structures. The low resistivity is characteristic of a typical fluid circulates within fracture. The geo-electric structure shows the subsurface faults which can be classified as normal fault from the west to east which lateral extent of about 118 m to 122m at depths of about 14m.

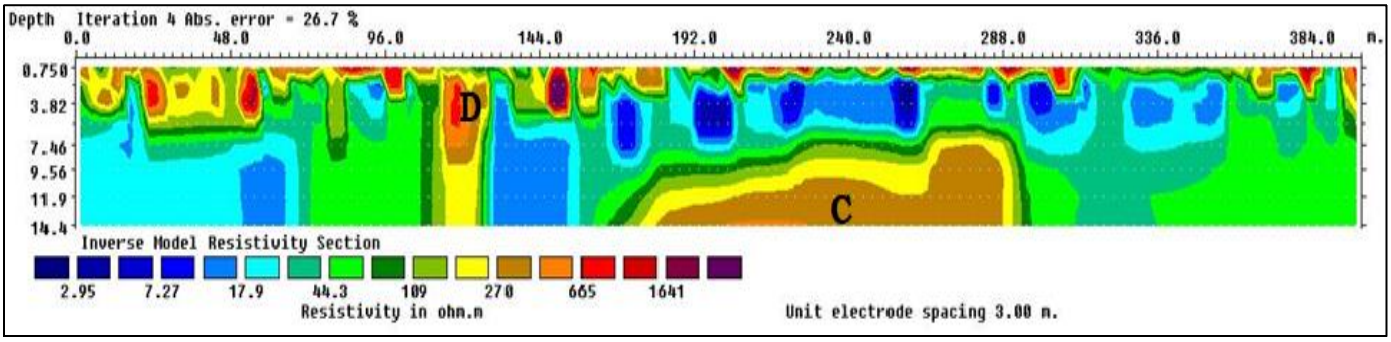

Fig 6 Inverted 2D Resistivity Section for Profile Two

- ➢ *Profile Three*

Inverted 2D resistivity model of profile 3 shows approximately funnel shaped feature with low resistivity (Figure 7). This funnel shaped feature which extends to surface is bounded on both sides by high resistivity structures. The low resistivity is characteristic of a typical fluid circulates within fracture. The geo-electric structure shows the subsurface faults which can be classified as normal fault with splays both to the west and east. The upward inclination of the fluids both to the west and east within the resistive body shows probably that the fluid path follows the direction of the conduits (faults) to the surface.

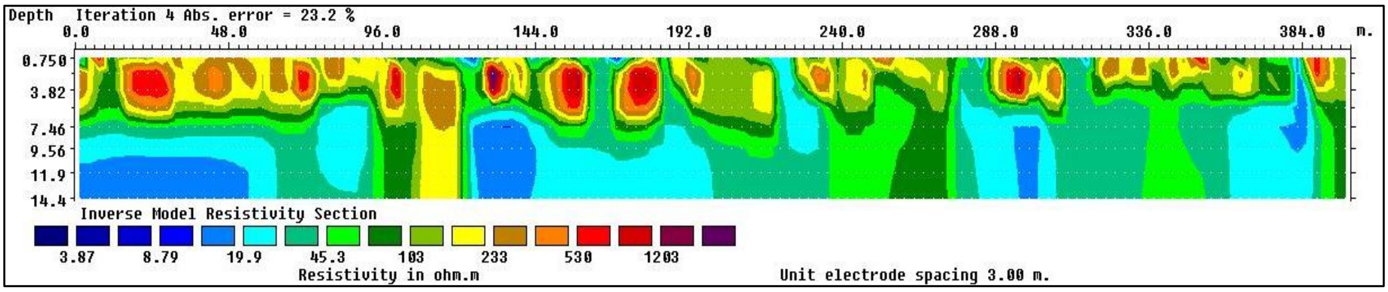

Fig 7 Inverted 2D Resistivity Section for Profile Three

- ➢ *Profile Four*

Figure 8 shows the 2D resistivity model which reveals significant resistivity anomalies with a general trend indicating the high resistivity in the near surface can be attributed to the volcanic rock outcropping from the field observations. The fault zone exists below the high resistivity rock bodies.

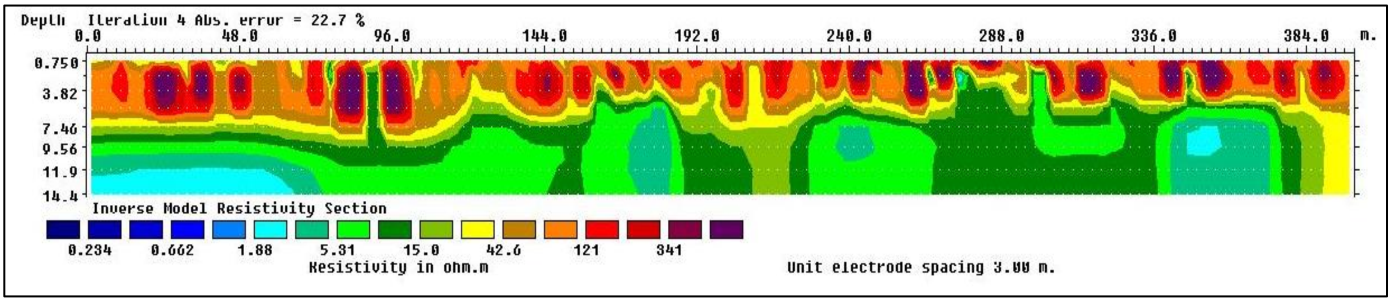

Fig 8 Inverted 2D Resistivity Section for Profile Four

VI. CONCLUSION

In this study, using Resistivity tomography is a valuable tool for characterizing basement structures associated with mineralization. Its non-invasive nature, high resolution, and ability to provide real-time data which make it an indispensable technique in modern mineral exploration campaigns. The Electrical Resistivity Tomography showed the detailed lithology's when compared with the borehole log of the study area. The high resistivity zones which correspond to gneiss quartz bearing veins, moderately resistivity layer reveal the concealed features of weathered/ fracture formation and the low resistivities indicate hydrothermal zones of clay minerals. As technology advances and methodologies evolve, integrating resistivity tomography with geological data prove to be promising which aided in revealing the mineral potential zones.

ACKNOWLEDGMENTS

We acknowledge that this research project was sponsored by the Tertiary Education Trust Fund (TET Fund), Nigeria through the Institution Based Research (IBR) intervention, Adamu Augie College of Education, 2023.The authors wish to thank the Geography Department, Bayero University, Kano for providing the equipment for the study.

REFERENCES

[1]. Augie, A.I., Salako, K.A., Rafiu,A.A. and Jimoh, M.O (2023) Geophysical Magnetic Data Analyses Of The Geological Structures With Mineralization Potentials Over The Southern Part Of Kebbi, Nw Nigeria *Mining Science, Vol. 29, 2022, 179–203* Mining Science (Previously Prace Naukowe Instytutu Gornictwa Politechniki Wroclawskiej, Issn 0370-0798) Www.Miningscience.Pwr.Edu.Pl Issn 2300-9586 (Print) Issn 2353-5423 (Online)

[2]. Batista-Rodrıguez, J. A., Caballero, A., Perez-Flores, M., Carmenates, A., and Almaguer, Y. (2017). 3D Inversion of Aeromagnetic Data on Las Tablas District, Panama. *Journal of Applied Geophysics*. https://doi.org/10.1016/j.jappgeo.2017.01.018

[3]. Bawa, Y.I, Saleh, M. Ridwan, M.M and Abdullahi, D. (2022). Application Of Sponteneous Potential Method To Delineate Subsurface Salinization Level In Fadama Areas Of Kurfi Town, Sokoto State Nigeria: Book of proceedings of the 1st Faculty of Science International Conference FSIC (2022), 64 - 71:ISBN:9789787946589

[4]. Bawa, Y.I Augie, A.I. and Saleh, M. (2020). 2D Geo-Electrical Assessment of Subsurface Salinization on Perennial Agricultural Activities atKurfiFadama Sokoto NW Nigeria. Savanna Journal of Basic and Applied Sciences (December, 2020), 2(2): 144-152.P:ISSN 2695-2335 | E:ISSN 2705-3164

[5]. Chifu E. N., Idi1, B. Y. Terhemba, B.S. Idowu, I. I. and Abdullahi S.S. (2019). Applications of Aeromagnetic and Electrical Resistivity Data for Mapping Spatial Distribution of Groundwater Potentials of Dutse, Jigawa State, Nigeria Modern Applied Science; Vol. 13, No. 2; 2019: ISSN 1913-1844 E-ISSN 1913-1852 Published by Canadian Center of Science and Education

[6]. Emujakporue, G., Ofoha, C., and Kiani, I. (2017). Investigation into the basement morphology and tectonic lineament using aeromagnetic anomalies of Parts of Sokoto Basin, North Western, Nigeria. *Egyptian Journal of Petroleum.*https://doi.org/10.1016/j.ejpe.2017.10.003

[7]. Guo, W. W., Dentith, M. C., Xu, J.L, and Ren F.S. (1999). Geophysical exploration for gold in Gansu Province, China *Explor. Geophys.* **30** 76–82

[8]. Liu H.T., Liu, J.M., Yu, C.M., Ye, J., and Zeng, Q.D. (2006). Integrated geological and geophysical exploration for concealed ores beneath cover in the Chaihulanzi goldfield, northern China *Geophys. Prospect.* **54** 605–21Liu H T, Liu J M, Yu C M, Ye J and Zeng Q D 2006 Integrated geological and geophysical exploration for concealed ores beneath cover in the Chaihulanzi goldfield, northern China *Geophys. Prospect.* **54** 605–21

[9]. Obaje, N. G. (2009). *Geology and Mineral Resources of Nigeria Lecture Notes in Earth Sciences*. Springer,Springer-Verlag Berlin Heidelberg.

[10]. Osinowo O, Akanji, A., and Olayinka A. (2013). Application of high resolution aeromagnetic data for basement topography mapping of Siluko and environs, southwestern Nigeria. *Journal of African Earth Sciences*. https://doi.org/10.1016/j.jafrearsci.2013.11.005.

[11]. Qingdong, Z., Yuanchao, S., Tiebing, L., Guangming, L., Qirui, Z., Kunfa, S., Hongchen, L., Xiuying, S. and Jinzhong, Y. (2004). Geophysical exploration for interlayer slip breccia gold deposits: example from Pengjiakuang gold deposit, Shandong Province, China *Geophys. Prospect.* **52** 97–108

[12]. Reynolds, J. M. (1997). An Introduction to Applied and Environmental Geophysics. John Wiley and Sons Ltd.

[13]. Tawey, M.D., Adesoji, I.A. and Oziofu, E.A (2023). Comparative Depth to Magnetic Source Analysis of Shanga (Sheet 96), North-western Nigeria Using Aeromagnetic Data: 69; Vol. 12, No. 1 African Journal of Environmental Sciences & Renewable Energy ISSN: 2617-3072X www.afropolitanjournals.com

[14]. Tripp, G.I, and Vearncombe, J.R. (2004). Fault/fracture density and mineralization: a contouring method for targeting in gold exploration *J. Struct. Geol.* **26** 1087–108