Application of Different Electrode Array in Delineating Cassiterite Bearing Layer for A Two-Dimensional Tomography Survey Within Pingel Village of Bauchi State

Joseph Orojah Osumeje[1], Daniel Eshimiakhe[1], Olufemi Felix Ojo[2]

[1] Department of Physics,
Ahmadu Bello University,
Zaria, Kaduna state,
Nigeria.

[2] Department of Geology,
Ekiti State University,
Ado-Ekiti State, Ekiti State,
Nigeria.

Email: josumejeh@yahoo.com

Abstract

Electrical resistivity method consist of various arrays that had been successfully applied in mineral explorations. Three important electrode arrays in 2D imaging surveys were tested in this study by creating a tomography of the subsurface to determine which array is the most successful in defining the cassiterite bearing layer. These arrays are Wenner, Schlumberger and Dipole - dipole. The numerical modeling was created through vertical fracture zone and correlated with a representative lithology of the area produced by using tape to measure depths to different lithology at an exposed mining pit. The results showed that the Schlumberger is the most suitable electrode array that can resolve both vertical and horizontal structures present in the subsurface. It was also obvious that the Schlumberger is a better array that images the vertical and horizontal contacts and represented these geological structures more accurately than the Wenner and Dipole-dipole arrays.

Key Words: Array, Tomography, Cassiterite, Fracture, Schlumberger

INTRODUCTION

Geophysics is a discipline that gives information about the earths subsurface without necessarily indulging in the invasive digging of the earth's surface. Its' survey involves measuring the physical properties of the ground (or structure) to determine any variations (anomalies) in the background readings. For geophysical technique to be useful in mineral exploration, contrast must exist in the physical properties of the rocks concerned that are related directly or indirectly to the presence of economically significant mineral. Also, the suitability of a method depends on the sites' peculiar conditions and the composition of target features.

2D resistivity imaging is one of the electrical survey techniques. It is based on an old technique called Pseudo-section. This technique had been used until the early 1990s, and it includes the using of Vertical Electrical Sounding (VES) and Constant Separation Traverse (CST) techniques together to determine the lateral and vertical changes of subsurface apparent

resistivity in the same time (Barker, 1991). The 2D resistivity imaging technique is developed in the last decade, as a result of the advances in the field equipment design capability and computer algorithms to become one of the most significant electrical survey techniques because it gives very approximate image of the underground structures (Loke, et al., 2020). However, there are 92 electrode arrays used in the electrical resistivity method (Szalai & Szarka, 2008). But the types of these arrays that are the most commonly used in 2D imaging surveys do not exceed ten arrays. These arrays are Wenner-Schlumberger, Wenner, Dipole – Dipole, Pole-Dipole, Pole-Pole, and Multiple gradient arrays (Loke, 2003).

The best choice of array for a 2D imaging surveys depends on different factors, such as the investigation depth, sensitivity function that is connected with type of structure to be mapped, vertical and horizontal data coverage and the resolution of array. In addition to, the sensitivity of resistivity meter and background noise level (Loke, et al., 2017) talked about the effect of the inversion to the mapping of prominent geological structures. Depending on these factors, there are many studies that have been carried out to determine which of these arrays respond best in imaging shallow targets in different situations (Reiser *et al.*, 2009). These studies indicated that the higher resolution and high sensitivity to geologic detail for shallow investigation offered by the Dipole-dipole array outweighed the fact that it used more measurements than the Wenner or Wenner-Schlumberger arrays. Oyeyemi et al., (2022), used six electrical resistivity array configuration to carry out a Numerical modeling analysis that would be suitable for water explorations. They were able to show that the most suitable arrays for dyke and graben structures are Wenner alpha, the Wenner beta is the most suitable for the horst structure, while the Schlumberger array was the best for both sub-vertical and vertical structures.

AL-Saady, et al., (2022), also used three array configuration to detect weak subsurface zones. Their results showed that the Wenner-Schlumberger configuration probed deepest, the Wenner configuration has the highest signal strength but the dipole-dipole configuration which is more sensitive the vertical and horizontal structures, generated the most sensitive image showing several distinct weak zones, which is optimum for subsurface mapping.

For the purpose of this research, Electrical resistivity method was used to characterize cassiterite (tin ore) in Magama Gumau-Pingel, Toro local government, Bauchi state, Nigeria. Therefore, we have evaluated these arrays through a theoretical comparison that depends on synthetic model, then the results are compared with published field results of several authors to determine which arrays are the most successful in defining the vertical and horizontal contacts in deep investigations in 2D imaging surveys.

LOCATION, VEGETATION AND GEOLOGY OF THE STUDY AREA
The study area is situated in Pingel village, Toro local government area of Bauchi state Nigeria; approximately one hour thirty minutes' drive from Magama-Gumau military check-point along Bauchi-Zaria road. Its geographical coordinates are Latitude $10^0 20' 00'' N$ to $10^0 22' 00'' N$ and Longitude $9^0 5' 00'' E$ to $9^0 7' 00'' E$ (Figure 1). The area is characterized by two season, wet and dry. The wet season lasts between April and October, with August having the highest precipitation while the dry season extents from November to March. The mean annual surface temperature varies from about 25^0C to 35^0C. The temperatures generally fall in July and August periods of the year corresponding to the peak of rainy season, as well as in December and January periods corresponding to the peak of harmattan in the area. The vegetation here is that of Sudan Savannah characterized by grasses, shrubs, thorns and scattered trees.
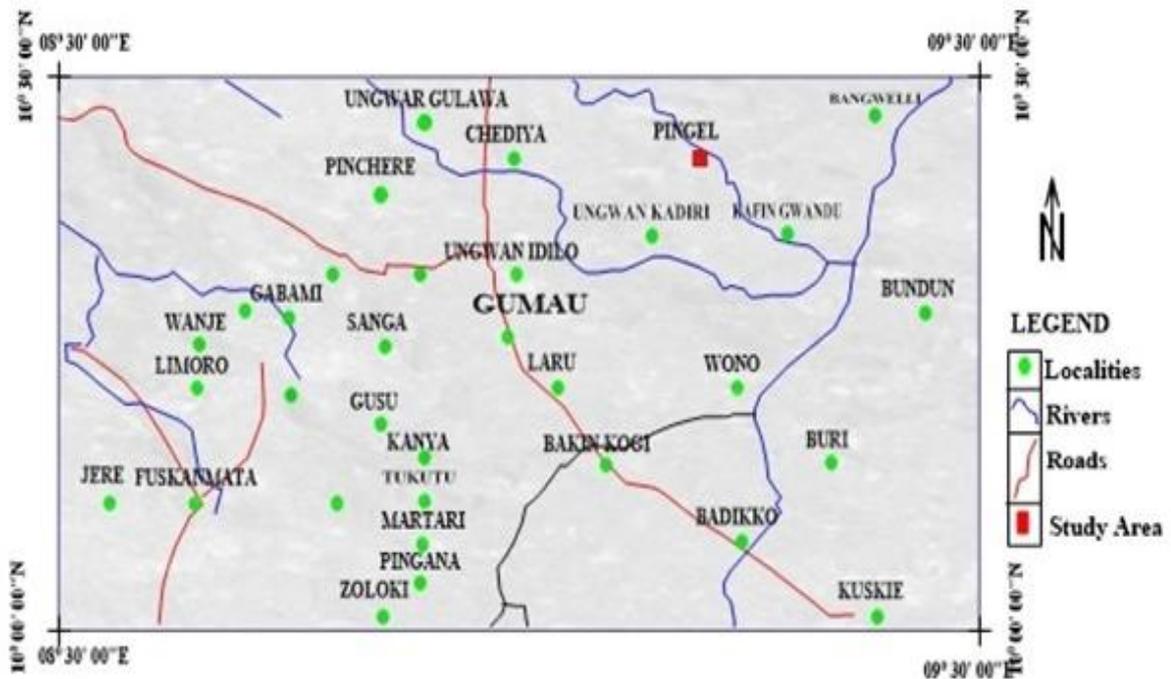
Figure 1: Location map of the study area.

The rocks in the study area, which is situated at the Younger granite province, is intruded into an undifferentiated amphibolite grade basement composed of migmatites and granitic gneisses (Umar, et al., 2017). Three major igneous units common to the younger granite suite make up the exposure and exhibit sharp mutual contacts (Turner, 1983). In chronological order these are volcanics, biotite granite and albite riebeckite granite. Remnants of an initial volcanic phase are preserved as a narrow outcrop of explosion breccia 600 m long and up to 60 m wide composed entirely of basement rock fragments up to 0.3 m in diameter along the southern flank of the complex (Jacobson and MacLeod, 1977). The main intrusive forms 80% of the exposed complex and is nonporphyritic fine- to medium-grained biotite granite which has a homogeneous macroscopic texture and composition (Jacobson & MacLeod, 1977). Its well-developed north-northwest joint system controls drainage in the immediate vicinity of its outcrop. The most prominent of this lineation occurs as a broad steep-sided flat-bottomed valley up to 1 km wide containing an under-fit stream which drains to the northwest from the central part of the biotite granite exposure. Preliminary interpretation of aerial photographs of this feature suggests that it may be a fault or shear zone (Opara, et al., 2015). The biotite granite is the source rock for the tin deposits mined on a very small scale in the area although Okobi, *et al.,* (2019) noted that the complex exhibited excessive tin mineralization for its outcrop size. Tin deposits are typically associated with biotite granite throughout the Younger Granite Province.
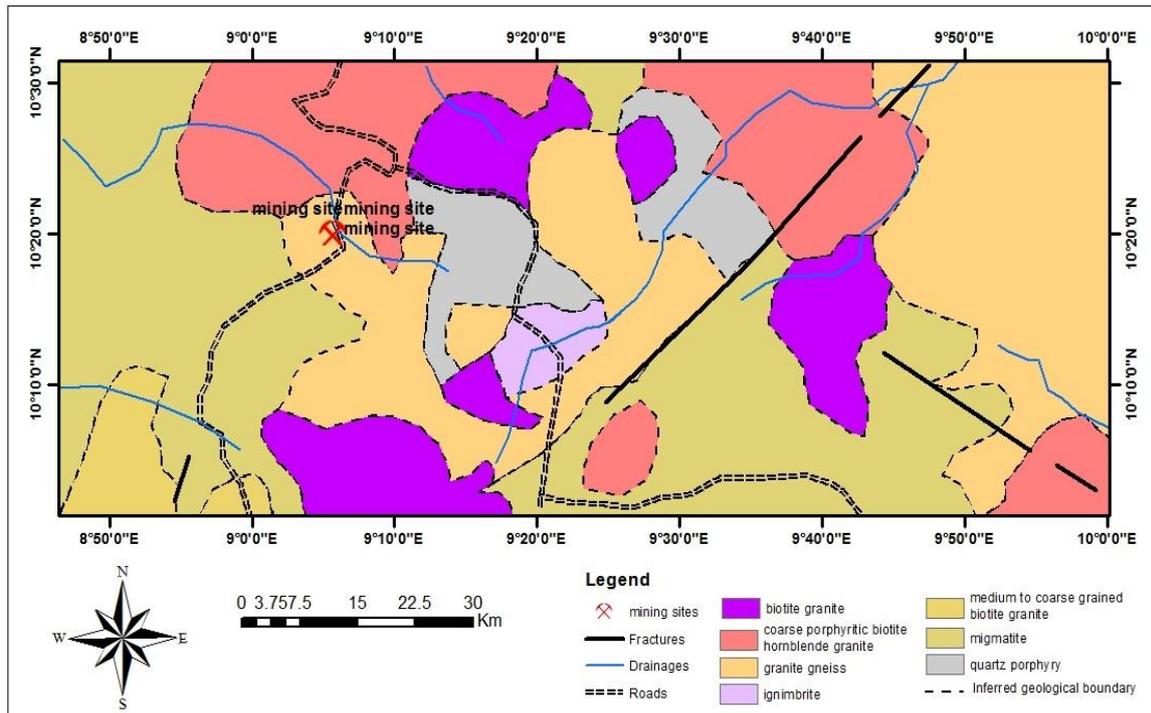
Figure 2: Geological Map of the Study Area. (Source: Nigerian shape file, Nigerian Geological Survey Agency 2014).

MATERIALS AND METHODS

The study area was chosen to pass along a point with an exposed subsurface that reveals different layers, including that which is rich in cassiterite. The Wenner, Schlumberger and Dipole-Dipole electrode configurations were used for data acquisition at this site to determine the most suitable resistivity array for the exploration of the subsurface layer that is rich in cassiterite within the area.

Interpretation of geophysical data entails expressing information acquired from geophysical field measurements into a clear geological term. To obtain such geological results, available and reliable geological controls are necessary for a reliable interpretation of geophysical data. Such controls are often obtained from borehole data or results of previous works within such an area and a good knowledge of the geology of the area. Unfortunately, no borehole information and/or previous studies had been carried out within the area of study. However, a representative lithology of the area has been produced by using tape to measure depths to different lithology at an exposed mining pit (figure 3). The top soil comprises mainly of the overburden (laterite and clay), cassiterite bearing layer and the granitic rock.
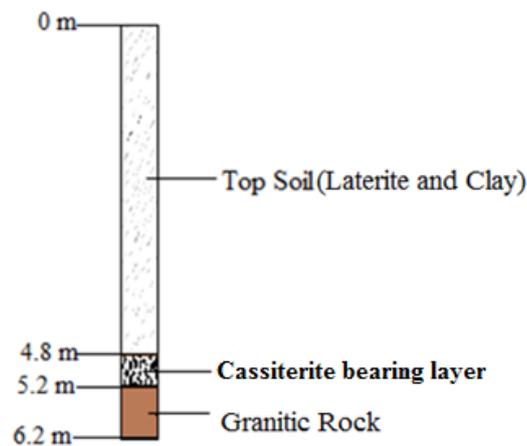
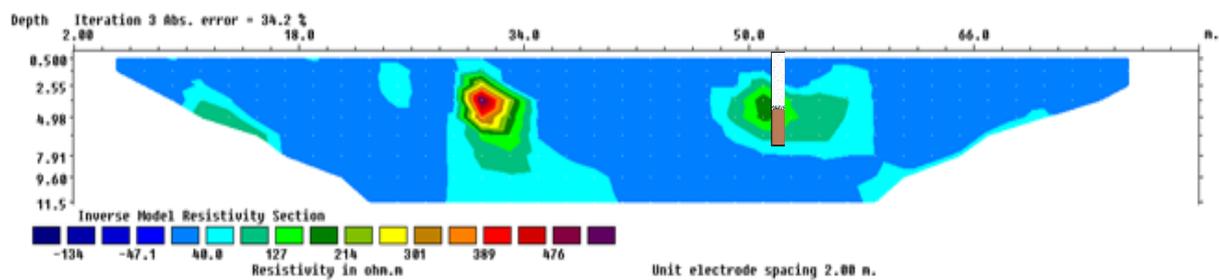Figure 3: Lithological log of Pingel Village.

Figure 4: Result of 2D Inversion of the Dipole-Dipole Array Data with Lithological Log   along Test Profile.
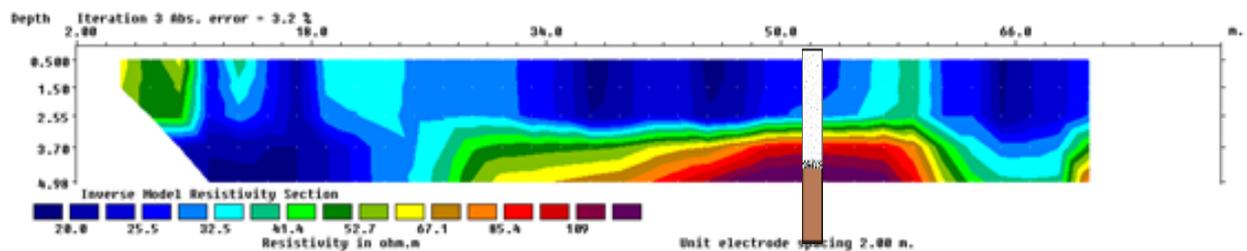

Figure 5: Result of 2D Inversion of the Wenner Array Data with Lithological Log along   the Test Profile.
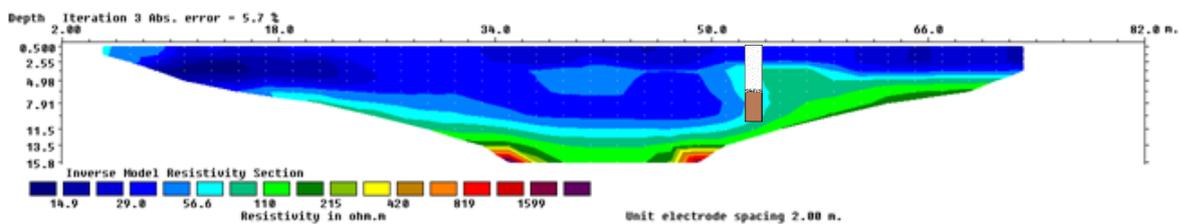

Figure 6: Result of 2D Inversion of the Schlumberger Array Data with Lithological Log   along Test Site**.**

DISCUSSION

Lithological information and representative resistivity values of earth materials used in this study in classifing the geologic layers were derived from Akanbi *et al.*, (2017), and are as follows; 1 to 300 Ωm as overburden resistivity; 300 to 400 Ωm as weathered granite resistivity; 400 to 600 Ωm as cassiterite bearing layers resistivity and > 600 Ωm as granitic rocks and fresh

basement resistivity. Cassiterite is dispersed in multitudinous, narrow greisen veins and quartz stringers in the roof zones of biotite granite intrusions, and usually entrapped within parent rock beneath an impermeable cover of roof rock dykes i.e. the biotite granite intrusions (Okobi *et al.,* 2019; Obaje, 2009). Erosion of these rocks over time would have rapidly uncovered some extensive area of cassiterite bearing granite and thus facilitate wide distribution of cassiterite in the surrounding drainage system.

The result of the 2D electrical resistivity inversion reveals three to four layers in the surveyed area. The lithological log, which was dug at a lateral distance of 55 m along the profile, is posted on each inversion model. This is to show the positive correlation between the log and the inversion model. The inverse model of the Dipole-dipole array after three iterations gave a good representation model of the subsurface, but it presented a less accurate image of the vertical fracture zone and cassiterite bearing layer as compared with the borehole log. This model reveals that the Dipole-dipole array is more sensitive to horizontal changes (two small cavities) in subsurface resistivities, and it is less sensitive to vertical changes (large cavity). The inversion model of the Wenner array gives a good fit of the subsurface, but also does not correlate with the lithological borehole log in depicting the cassiterite layer. Based on the result gotten from the inversion model of the test site, the Schlumberger array proved to be a better representation of the cassiterite bearing layers. This is because, the Schlumberger array gives a better representation of layered earth i.e. gives a clearer depiction of the earth's lithology.

CONCLUSION

This comparison made between the three electrical resistivity arrays showed some important results. The Dipole-Dipole array was less accurate in imaging the vertical structures (vertical fracture zone and large cavity) due to these structures are intrusions with horizontal sedimentary layers. The Wenner array was inexact in imaging the vertical fracture zone, cavities and horizontal sedimentary layers. So, this array is not recommended for deep investigation in presence of such geological structures. The Schlumberger is the most suitable electrode array when both vertical and horizontal structures are present in the subsurface. It defined both the vertical and horizontal contacts and it represented the vertical fracture zone and cassiterite more accurately than the Wenner and Dipole-dipole arrays. All arrays are not imaging the actual extension of fracture zone with depth. This indicates that the sensitivity and resolution of arrays are decreasing in the areas that have high resistivity contrasts in subsurface layers.

REFERENCES

Akanbi, E. S., Ugodulunwa, F. X. O. and Gyang, B. N. (2017). 2-D Electrical Resistivity Survey for Cassiterite Potential Mapping in Jos-Bukuru Area, North Central, Nigeria, *Journal of Geography, Environment and Earth Science International*, 10(1): 1-12.

Al-Saady, H. A., Karim, H. H., and AL-Menshed, F. H. (2022). Comparison of Three Electrical Resistivity Arrays to Investigate Weak Zones in Soil, Along a Profile Southeast Baghdad City, Iraq, *Iraqi Journal of Science,* 63(11): 4793-4798

Barker, R.D., (1991)**.** Depth of investigation of collinear symmetrical four-electrode arrays. *Geophysics*, 54:1031-1037.

Loke, M.H., I. Acworth and T. Dahlin, (2003). A comparison of smooth and blocky inversion methods in 2D electrical imaging surveys. *Explor. Geophys*, 34:182-187.

Loke, M. H., Wilkinson, P. B., Chambers, J. E., & Meldrum, P. I. (2017). Rapid inversion of

data from 2D resistivity surveys with electrode displacements. *Geophysical Prospecting, 66(3), 579–594.*

Loke, M.H., Papadopoulos, N., Wilkinson, P.B., Oikonomou, D., Simyrdanis, K., Rucker, D., (2020). The inversion of data from very large 3-D ERT mobile surveys. *Geophys. Prospect.* 68, 2579–2597

Jacobson, R.R.E. and Macleod, W.N. (1977) Geology of the Liruei, Banke and Adjacent Younger Granite Ring Complexes. Bulletin of Geological Survey of Nigeria, 33, 1-117

Obaje N. G. (2009). *Geology and Mineral Resources of Nigeria.* Springer-Verleg Berlin Heidelberg.

Okobi, C.M., Ogunbajo, M.I., Amadi, A.N., Unuevho, C.I., Ako, T.A., Ayeni, J.K. and Alaku, I.O., (2019). Geochemistry and Petrogenesis of Granitic Rocks in Bishini Sheet 165 SW, North-Central Nigeria, *Journal of Mining and Geology*, 55(1):1 – 15.

Oyeyemi, K.D., Aizebeokhai, A. P., and Metwaly, M., (2022). Assessing the suitable electrical resistivity arrays for characterization of basement aquifers using numerical modeling, *Heliyon (ScienceDirect),* 8(2022):e09427.

Reiser. F., Dalsegg. E., Dahlin. T., Guri. V., GanerØd., RØnning.J. S., 2009. Resistivity modeling of fracture zones and horizontal layers in bedrock. *Geological survey of Norway.* Report, 120p.

Szalai, S., Szarka, L., 2008. On the classification of surface geoelectric arrays. *Geophysical Prospecting*, 56 (2):159–175.

Turner DC. (1983). Upper Proterozoic Schist Belts in the Nigerian Sector of the Pan-African Province of West Africa. *Precambrian Resources*, 21: 55-79. https://doi.org/10.1016/0301-9268(83)90005-0

Umar, M., Ahmed, A. L., Balarabe, B. and Adamu, A., (2017). Electrical Resistivity Investigation of Sub-surface Topography of Rafin-Bareda as a tool for Groundwater Exploration in Dutsen-Wai, Nigeria, *FUW Trends in Science & Technology Journal*, 2(2): 835 – 841.