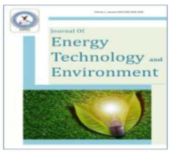
Journal of Energy Technology and Environment Vol. 6(1) 2024 pp. 1 - 9 ISSN-2682-583x

NIPES

Journal of Energy Technology and Environment

Journal homepage: www.nipesjournals.org.ng



Application of 2D Electrical Resistivity Tomography (ERT) for the Assessment of Sulphide Mineral Occurrences. A Case Study of Nkarasi, Ikom, Cross River State, South-South, Nigeria.

John Osariere Airen* and Peacy Sunny Iyere
Department of Physics, Faculty of Physical Sciences, University of Benin, Benin City, Nigeria
*Corresponding Author Email: osariere.airen@uniben.edu (+234-803-959-1347)

Article information

Article History
Received: 1 January 2024
Revised: 28 January 2024
Accepted: 3 February 2024
Available online: 15 March 2024

Keywords:
sulphide, geoelectric, wenner, mineral exploration, sandstone

OpenAIRE

https://doi.org/10.5281/zenodo.10822982

https://nipesjournals.org.ng

Abstract

The Electrical Resistivity Tomography (ERT) technique adopting Wenner electrode configuration was carried out at Nkarasi, Ikom in Cross River State, Nigeria with the aim of locating sulphide mineral occurrences within the study area. Six 200 m long 2D profiles were occupied within the site and a total depth of about 39.6 m was probed. The data were inverted using the finite element method. This process yielded 2D electrical tomograms along all the profiles. The result of the investigation showed that broadly, a maximum of three geoelectric zones could be delineated to the depth of investigation. These include the overburden material, weathered/fractured sandstone and fresh sandstone zones. The target of the investigation is the fractured zone which can serve as the mineralized zone within the study area. The interpretation of the result indicated that almost all the resistivity structures identified weathered/fractured zones along the profiles. This result showed that the study area has great prospects for hosting the suspected sulphide mineral. In addition to this, the result showed that the adopted technique/method is appropriate for the preliminary mineral exploration activities within the study area and any other area having similar geology.

1. Introduction

The earth's subsurface is made up of different geologic materials occurring at various depths. Geophysicists use geophysical techniques to investigate the surface by making physical measurements at the surface. They use these measurements to map subsurface rocks and their fluids at all scales and describe the subsurface rocks in physical terms, i.e., velocity, density, electrical resistivity, magnetism, etc. [1].

With the expansion of technology around the world, the quest for minerals is taking centre stage. In this setting, “Minerals” can allude to distinctive shake sorts and dregs but more likely commodities such as gold, copper, press etc. In expansion to the nonstop request from “normal” worldwide improvement, driven by extending communities and the related increase in framework and shopper merchandise, there are frequent spikes in requests to cover sudden development ranges.

Mineral resources can be described as beneficial subsurface features whose natural habitat is the earth. They include solid metallic minerals such as, iron ore, zinc etc., solid non-metallic minerals like limestone, marble etc., liquid minerals such as oil, water etc., and gaseous minerals like gasses in buried cavities. Mineral exploration has been in existence for a long time. Its method, however, had been only drilling using percussion bits [2]. This posed a lot of risks as explorers could easily and ignorantly get exposed to dangerous materials underground. Also, it was uneconomical since the decision as to where to drill was taken like a gamble because there was no prior information about the actual location of the concealed mineral before drilling. Later, in the early years of the twentieth century, the continued efforts by explorers to look for more effective, less risky and more economical techniques of sub-surface exploration led to the advent of geophysical exploration [2]. The application of different geophysical techniques in mineral exploration has yielded mixed results, as it depends on the contrast in the physical properties of the target zones and host rocks [3]; [4]; [5].

Electrical Resistivity Tomography (ERT) is the most commonly used geophysical method for imaging subsurface features and mapping geological variations. It can detect subsurface sulfide mineral distribution by studying the nature of the flow of electricity in the earth, for being uniquely able to see a large range of magnitudes which can vary up to 20 orders [6]. This method can delineate the various sources of mineralization according to their types [7]. The resistivity method is used to map spatial variations in subsurface electrical conductivity, while the induced polarization (IP) method is used to map changes in chargeability.

Electrical resistivity imaging (ERI) is frequently used in imaging subsurface structures and processes [8]; [9]. It has been successfully applied in soft rock exploration [10]; [11], [12], where Electrical resistivity imaging (ERI) data allowed for a detailed characterization of the deposits, superior to what could have been achieved using conventional tools, and hence improved resource estimates. However, its application in hard rock exploration has been limited so far due to the difficulty of achieving good galvanic coupling of electrodes with very resistive surface materials. Examples indicating that Electrical resistivity imaging (ERI) electrode arrays can operate effectively in resistive environments have been shown mainly in permafrost studies, where ERT has been used to image permafrost degradation within rock masses [13], [14]; [15]; [16]; [17], [18] ; [19]; [20], but also in urban and tunnel engineering problems [21]; [22]; [23],[24]. Similarly, [25] used cross-borehole electrical resistivity to image solute transport along fractures and bedding planes in a limestone quarry.

Electrical resistivity imaging (tomography) is a method by which 2D images of subsurface resistivity distribution are generated [26]. With this method, features with resistivity properties that differ from those of the surrounding material may be located and characterized in terms of electrical resistivity, and depth of burial. The electrical resistivity tomography is carried out by using computer-controlled measurement systems connected to multi-electrode arrays.

The study area Nkarasi community, Ikom Local Government area of Cross River State has been seen with the presence of outcrops over the years. Identifying potential sulphide minerals deposits that are essential for industry and economic growth of the nation, the study area (virgin area) was selected for geophysical investigation. Also, the presence of some sulphide minerals in the form of outcrops that are sparsely distributed in the study area during the reconnaissance survey formed part of the motivation for this research, hence, this informed the application of 2D resistivity imaging to evaluate the Sulphide deposit in the study area and also to determine the lateral extent of the sulphide deposit. This was chosen because it has proven successful in identifying sulphide deposits, on the basis of the resistivity contrast that exists between sulphide/iron ore deposits and surrounding formation within the study area [27].

1.1 Location and Geology of the Area

Nkarasi community, Ikom Local Government area of Cross River is located on longitudes 008° 42' 08.52" E to 008° 42' 18.9" E and latitudes 06° 17' 08.9" N to 06° 06' 23.7" N. The study area has a minimum elevation of 124 m and a maximum elevation of 130 m. Like most parts of southeastern Nigeria, the study region is characterized by a tropical climate having distinct alternating dry and wet seasons. According to [28]; [29], the area is associated with warm temperatures that range between 26 °C to 32 °C and a bimodal rainfall pattern averaging approximately 2,300 mm annually, while the annual mean daily relative humidity and evaporation is in the range 76 – 86% and 3.85 mm/day respectively. Moist, evergreen forest-type vegetation exists in unaltered areas, while herbs, shrubs and few trees are cultivated in the altered portions of the area. Thick, riparian forest fringes most streams of the area. The geological map of the southern Cross River is shown in Figure 1. The topography of the area is typified by plains under 150 m above sea level which dominates the land surface of the area. In terms of sediments, the study area is underlain by Cretaceous Sedimentary rock deposits, comprising sandstones, limestones, marlstones and shales [30].

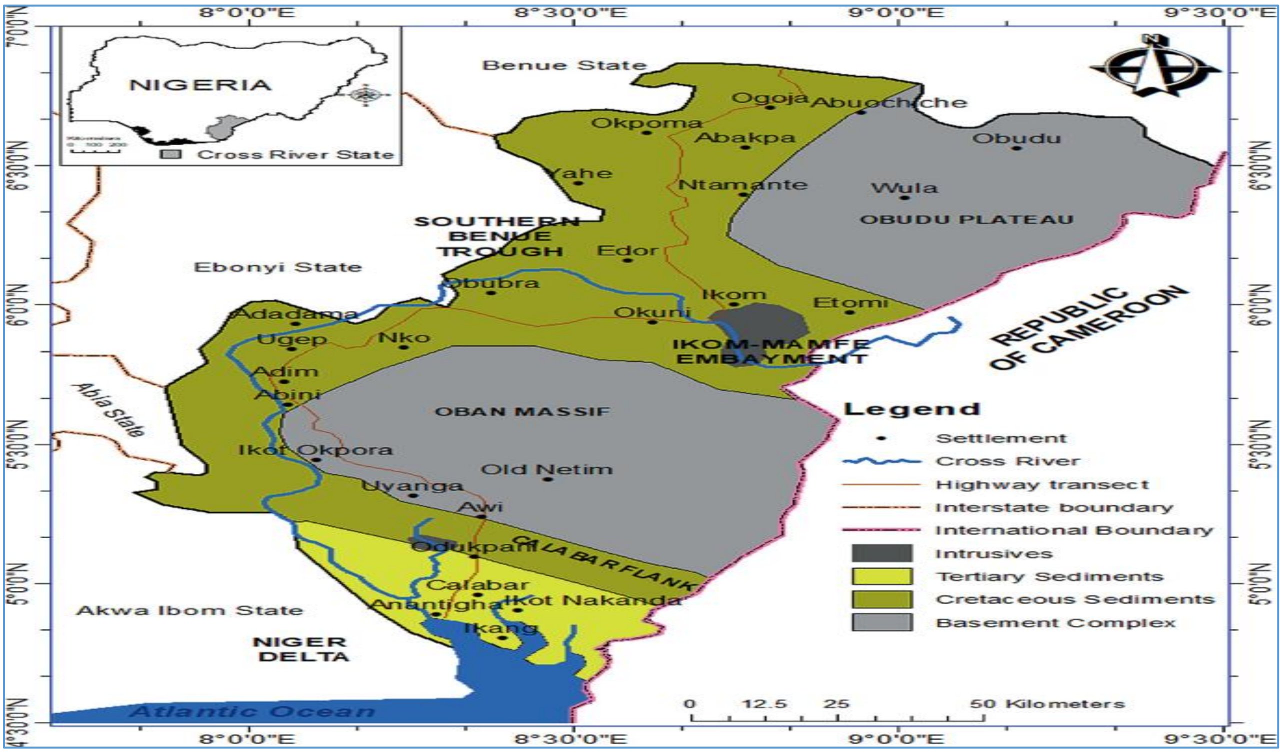


Figure 1. Geological map of southern cross river [31].

2. Materials and Methods

Electrical resistivity techniques have over the years being employed for measuring the true resistivity of the subsurface. Ground apparent resistivity is related to various geological parameters such as mineral and fluid content, porosity and degree of water saturation present in rock. Resistivity-related investigations are conducted by passing current into the subsurface using two

current electrodes, while the ground response i.e., the potential difference is measured using two inner electrodes called potential electrodes. To investigate the subsurface for sulphide mineral exploration, it is best to employ the electrical resistivity method.
The common electrode array used in resistivity includes Wenner array, dipole-dipole array, Schlumberger array, pole-pole array and gradient array.

For this study, six (6) 2D traverses were acquired using the Wenner array configuration. This electrode configuration was well suited for constant separation data acquisition so that many data points could be recorded simultaneously for each current injection. Measurements were made at sequences of electrodes at 10, 20, 30, 40, 50 and 60 m intervals using four (4) electrodes spaced 10 m apart with a maximum length of 200 m each. RES2DINV software was used for the inversion of the 2D apparent resistivity data. RES2DINV is a powerful 2D inversion software for ERT and IP data. The software offers a simple workflow from data import to inversion and visualization, while still offering full control over inversion parameters for advanced users. The software is designed to interpolate and interpret field data of electrical geophysical prospecting of electrical resistivity and induced polarization. The inversion of the resisitivity and IP data is conducted by the least-square method involving finite-element and finite-difference methods.The field data pseudo section and the 2D resistivity structure were produced after running the inversion of the raw data to filter out noise.

3. Results and Discussion

The resistivity image developed along traverse one is represented in figure 2 below. The profile stretches over 200 m horizontal distance and a depth of investigation of about 39.6 m was investigated. The lowest resistivity along the profile is < 5.14 ohm-m and a maximum resistivity of about 5863 ohm-m was obtained. Three subsurface lithologies were identified on the resistivity structure. The first extends from the surface to about 12.8 m across the profile. This is the overburden material. The resistivity distribution ranges from 38.4 – 5863 ohm-m. The second subsurface material is designated as the fractured sandstone. It showed very low resistivity values from as low as < 5.14 ohm-m to about 38.4 ohm-m. The last major geoelectric layer is suspected to be fresh sandstone with resistivity ranging from about 38.4 – 287 ohm-m. The fractured zone of the sandstone could host the Sulphide mineral.

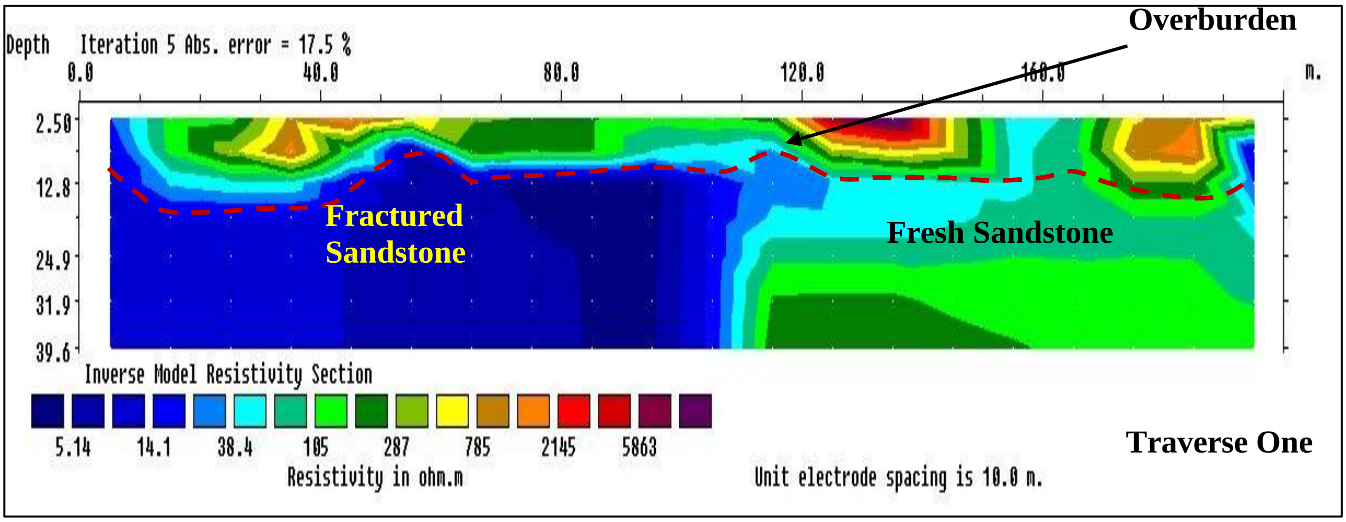


Figure 2. 2D along Traverse 1

The resistivity structure generated along traverse two is represented as shown in figure 3. The profile is 200 m long and a depth of about 39.6 m was probed. The lowest resistivity along the profile is < 0.431 ohm-m and a maximum resistivity of about 348 ohm-m was recorded. The subsurface beneath the profile could be broadly divided into two zones composing of the overburden material (51.4 – 348 ohm-m) which extended to a maximum depth of about 25 m in places. The second division is the weathered zone with resistivity values ranging from 2.92 – 51.4 ohm-m. The first extends from the surface to about 12.8 m across the profile. This is the overburden material. The resistivity distribution ranges from 38.4 – 5863 ohm-m. The second subsurface zone showed widely varying resistivity regions which indicated high level of weathering. This zone could play host to the sulphide mineral.

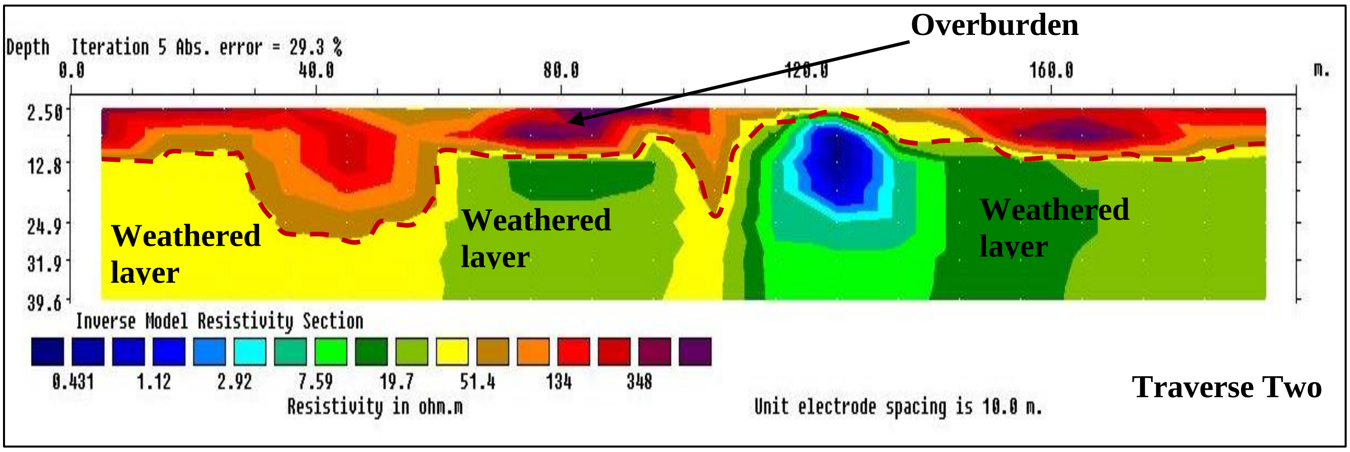


Figure 3. 2D along Traverse 2

The ERT image generated over traverse three (figure 4) is 200 m long with a depth of investigation reaching about 39.6 m. The resistivity value obtained within this resistivity structure shows a range < 10.3 - 322 ohm-m. The subsurface beneath the profile could be broadly divided into two zones. The first zone extends from 0 – 80 m along the profile. Its resistivity falls between 10.3 27.5 ohm-m. This is suspected to be a fracture/weathered region. The second division with resistivity values ranging from 44.9 – 322 ohm-m is thought to be composed of sandstone which is suspected to be the country rock within the study area. The fractured/weathered zone could be further investigated as this could play host to the sulphide mineral.

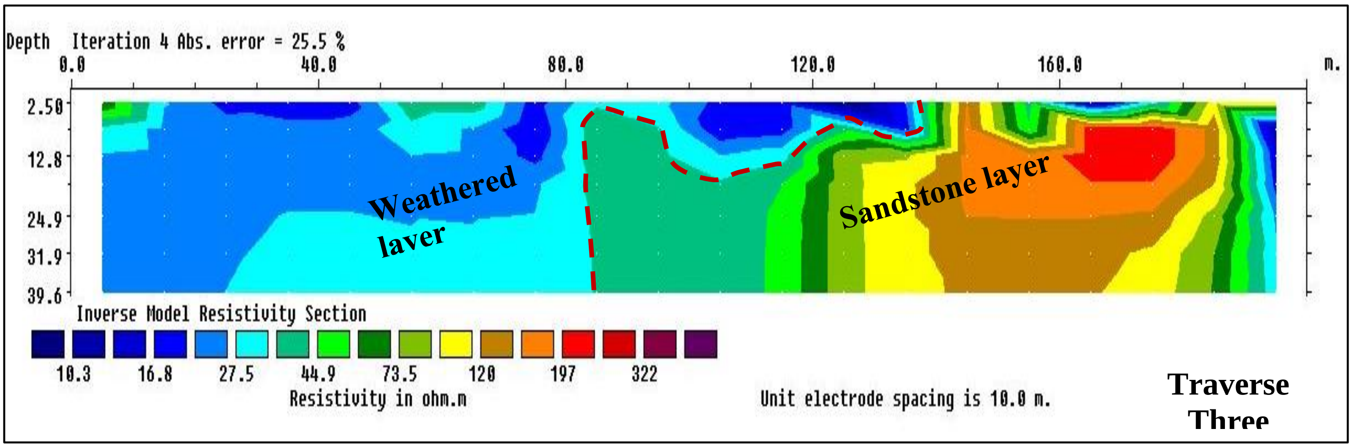


Figure 4. 2D along Traverse 3

The resistivity image developed along traverse four is represented in figure 5 below. The profile stretches over 200 m horizontal distance and a depth of investigation of about 39.6 m was investigated. The lowest resistivity along the profile is < 1.50 ohm-m and a maximum resistivity of about 1000 ohm-m was obtained. Two geoelectric zones could be identified beneath the profile. The first extends from the surface to about 0 - 120 m across the profile. This is suspected to be weathered/fractured sandstone region. The resistivity distribution ranges from 1.50 – 61.6 ohm-m. The second subsurface material is designated as the fresh sandstone. It showed resistivity values from 156 ohm-m to about 1000 ohm-m. The fractured zone of the sandstone could host the Sulphide mineral.

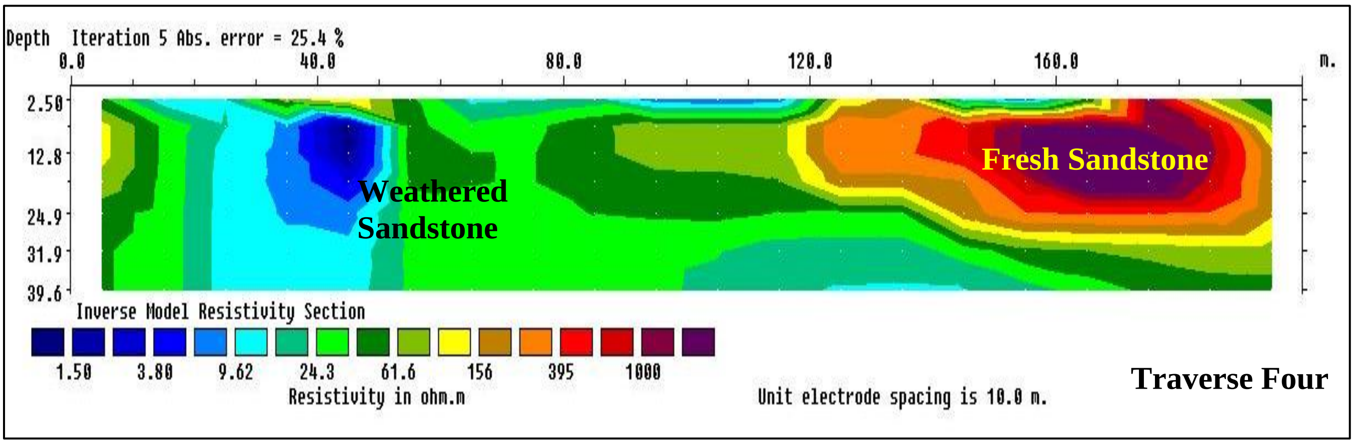


Figure 5. 2D along Traverse 4

The resistivity image developed along traverse five is represented in figure 6 below. The profile stretches over 200 m horizontal distance and a depth of investigation of about 39.6 m was investigated. The lowest resistivity along the profile is < 11.5 ohm-m and a maximum resistivity of about 548 ohm-m was obtained. Three subsurface lithologies were identified on the resistivity structure. The first extends from the surface to about 12.8 m across the profile. This is the overburden material. The resistivity distribution ranges from 60.2 – 548 ohm-m. The second subsurface material is designated as fractured sandstone. It showed a very low resistivity values from as low as < 11.5 ohm-m to about 34.6 ohm-m. The last major geoelectric layer is suspected to be fresh sandstone with resistivity ranging from about 105 – 315 ohm-m. The fractured zone of the sandstone could host the Sulphide mineral.

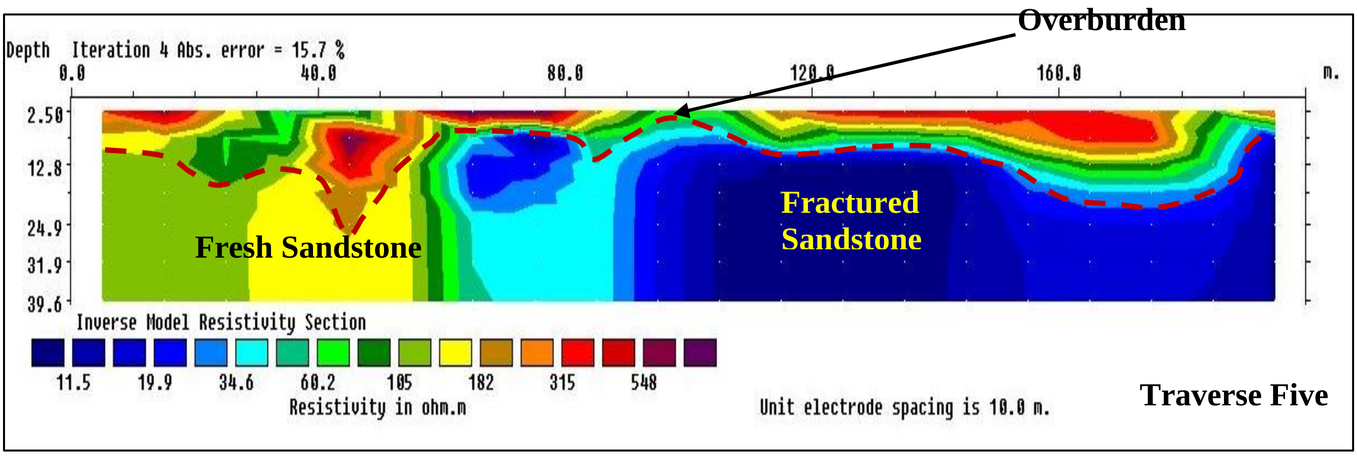


Figure 6. 2D along Traverse 5

The resistivity structure generated along traverse six is represented as shown in figure 7. The profile is 200 m long and a depth of about 39.6 m was mapped. The lowest resistivity along the profile is < 6.61 ohm-m and a maximum resistivity of about 508 ohm-m was recorded. The subsurface beneath the profile could be broadly divide into three zones composing of the overburden material (6.61 – 508 ohm-m) which extended to a maximum depth of about 12.8 m in places. The second division is the weathered sandstone with resistivity values ranging from 45.2 – 85.9 ohm-m. The last major geoelectric layer is suspected to be fresh sandstone with resistivity values ranging from about 85.9 – 163 ohm-m. The second subsurface zone showed varying resistivity regions which indicated high level of weathering. This zone could play host to the sulphide mineral.

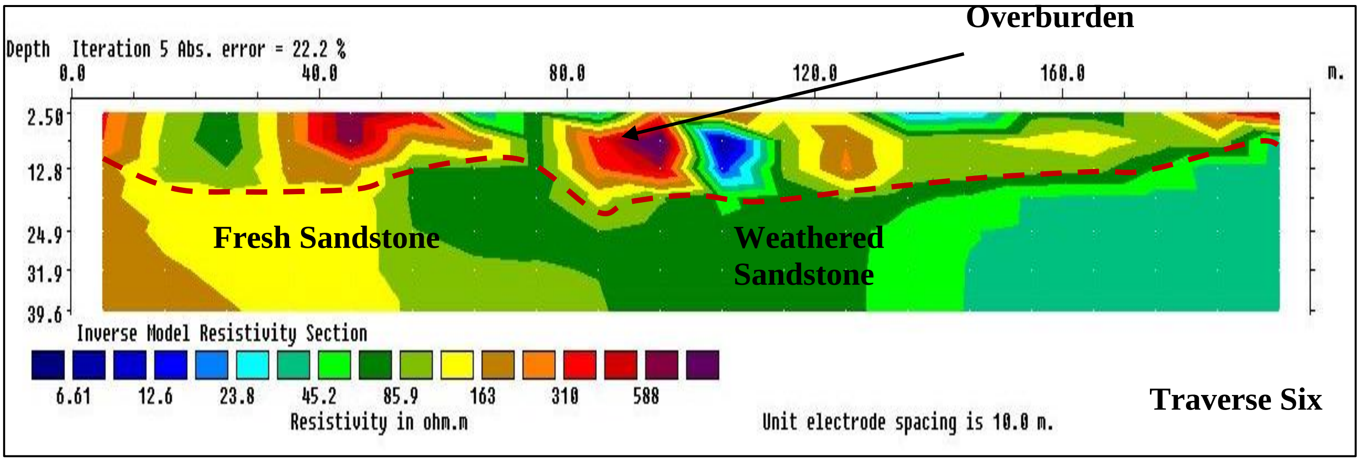


Figure 7. 2D along Traverse 6

4. Conclusion

A geophysical investigation involving electrical resistivity tomography (ERT) has been carried out at Nkarasi, Ikom local Government, Cross-river State with the aim of locating Sulphide mineral occurrences within the study area. 2D Wenner array was adopted for the investigation. Six 2D profiles were occupied. The total length of the profiles was 200 m and a depth of 39.6 m was investigated. A maximum of three geoelectric zones including the overburden material, weathered/fractured zone and the fresh sandstone zones were identified. The result of the study showed that almost all the tomograms mapped weathered/fractured sandstone zones. This fractured zone could serve as a host for the mineral of interest. In addition, the result also showed that the adopted technique is very appropriate for preliminary mineral exploration work.

5. Acknowledgments

The authors are grateful to students of the 2021/2022 set of the Department of Physics, University of Benin, Nigeria, for their assistance in the field during data acquisition.

6. Declaration of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1]. Airen, O.J. (2020). The Use of 2-Dimensional Electrical Resistivity Tomography to Investigate the Subsurface Geology in College of Education, Abudu, Orhionmwon Local Government Area of Edo State, Nigeria. Journal of the Nigerian Association of Mathematical Physics, 58: 109-116.

[2]. Idowu, T.O. (2006). Prediction of gravity anomalies for geophysical Exploration FUTA Journal of the Environment, 1(1): 34-45.

[3]. Moreira, C.A., Paes, R.A.S., Ilha, L.M., and da Cruz Bittencourt, J. (2019). Reassessment of copper mineral occurrence through electrical tomography and pseudo 3D modeling in Camaquã Sedimentary Basin, Southern Brazil. Pure and Applied Geophysics, 176: 737-750.

[4]. Ramazi, H. and Mostafaie, K. (2013). Application of integrated geoelectrical methods in Marand (Iran) manganese deposit exploration. Arabian Journal of Geosciences, 6; 2961-2970. http://dx.doi.org/10.1007/s12517-012-0537-2.

[5]. Salmirinne, H. and Turunen, P. (2007). Ground geophysical characteristics of gold targets in the Central Lapland Greenstone Belt. Geological Survey of Finland, Special Paper, **44**, 209-223.

[6]. Morgan, L.A. (2012). Geophysical Characteristics of Volcanogenic Massive Sulfide Deposits. Volcanogenic Massive Sulfide Occurrence Model. US Geological Survey, Reston, VA, 115: 131.

[7]. Evrard, M., Dumont, G., Hermans, T., Chouteau, M., Francis, O., Pirard, E. and Nguyen, F. (2018). Geophysical Investigation of the Pb–Zn Deposit of Lontzen–Poppelsberg, Belgium. Minerals; 8(6): 233. DOI: https://doi.org/10.3390/min8060233.

[8]. Loke, M.H., Chambers, J.E., Rucker, D.F., Kuras, O. and Wilkinson, P.B. (2013). Recent developments in the direct-current geoelectrical imaging method. J. Appl. Geophys., 95: 135–156.

[9]. Binley, A., Hubbard, S.S., Huisman, J.A., Revil, A., Robinson, D.A., Singha, K. and Slater, L.D. (2015). The emergence of hydrogeophysics for improved understanding of subsurface processes over multiple scales. Water Resour. Res., 51, 3837–3866.

[10]. Magnusson, M.K., Fernlund, J.M. and Dahlin, T. (2010). Geoelectrical imaging in the interpretation of geological conditions affecting quarry operations. Bull. Eng. Geol. Environ., 69, 465–486.

[11]. Chambers, J.E., Wilkinson, P.B., Wardrop, D., Hameed, A., Hill, I., Jeffrey, C., Loke, M.H., Meldrum, P.I., Kuras, O. and Cave, M. (2012). Bedrock detection beneath river terrace deposits using three-dimensional electrical resistivity tomography. Geomorphology, 177–178, 17–25.

[12]. Chambers, J.E., Wilkinson, P.B., Penn, S., Meldrum, P.I., Kuras, O., Loke, M.H. and Gunn, D.A. (2013). River terrace sand and gravel deposit reserve estimation using three-dimensional electrical resistivity tomography for bedrock surface detection. J. Appl. Geophys., 93, 25–32

[13]. Hauck, C. (2002). Frozen ground monitoring using DC resistivity tomography. Geophys. Res. Lett., 29, 10–13.

[14]. Hauck, C., Vonder Muhll, D. and Maurer, H. (2003). Using DC resistivity tomography to detect and characterize mountain permafrost. Geophys. Prospect. 2003, 51, 273–284.

[15]. Sass, O. (2004). Rock moisture fluctuations during freeze-thaw cycles: Preliminary results from electrical resistivity measurements. Polar Geogr., 28, 13–31.

[16]. Krautblatter, M. and Hauck, C. (2007). Electrical resistivity tomography monitoring of permafrost in solid rock walls. J. Geophys. Res., 112, 1–14.

[17]. Hilbich, C., Fuss, C. and Hauck, C. (2011). Automated Time-lapse ERT for Improved Process Analysis and Monitoring of Frozen Ground. Permafrost Periglac 22, 306-319.

[18]. Hilbich, C., Hauck, C., Hoelzle, M., Scherler, M., Schudel, L., Völksch, I., Vonder Mühll, D. and Mäusbacher, R. (2008). Monitoring Mountain permafrost evolution using electrical resistivity tomography: A 7-year study of seasonal, annual, and long-term variations at Schilthorn, Swiss Alps. J. Geophys. Res., 113.

[19]. Krautblatter, M., Verleysdonk, S., Flores-Orozco, A. and Kemna, A. (2010). Temperature-calibrated imaging of seasonal changes in permafrost rock walls by quantitative electrical resistivity tomography (Zugspitze, German/Austrian Alps). J. Geophys. Res., 115, 1–15.

[20]. Murton, J.B., Kuras, O., Krautblatter, M., Cane, T., Tschofen, D., Uhlemann, S., Schober, S. and Watson, P. (2016). Monitoring rock freezing and thawing by novel geoelectrical and acoustic techniques. J. Geophys. Res. Earth Surf., 121, 2309–2332.

[21]. Lesparre, N., Boyle, A., Grychtol, B., Cabrera, J., Marteau, J. and Adler, A. (2016). Electrical resistivity imaging in transmission between surface and underground tunnel for fault characterization. J. Appl. Geophys., 128, 163–178.

[22]. Gaafar, I. (2015). Integration of geophysical and geological data for delimitation of mineralized zones in Um Naggat area, Central Eastern Desert, Egypt. NRIAG Journal of Astronomy and Geophysics, 4(1), 86–99.

[23]. Batayneh, A.T. (2006). Resistivity Tomography as an aid to planning gas pipeline construction, Risha Area, North-East Jordan. Near Surface Geophysics, **4**, 313-319.

[24]. Hilbich, C., Fuss, C. and Hauck, C. (2011). Automated Time-lapse ERT for Improved Process Analysis and Monitoring of Frozen Ground. Permafr. Periglac. Process. 2011, 22, 306–319, doi:10.1002/ppp.732.

[25]. Lawan A.M, Usman A, Raimi J. and Ahmed A.L. (2021) Characterization of Iron Ore Deposit using 2D Resistivity Imaging and Induced Polarization Techniques at Diddaye-Potiskum Area, Northeastern Nigeria. J Geol Geophys. 10:99

[26]. Ephraim, B.E. and Ajayi, I.O. (2014) Geoenvironmental Assessments of Heavy Metals in Surface Sediments from Some Creeks of the Great Kwa River, Southeastern Nigeria. Journal of Environment and Earth Science, 4 (21): 15-26
[27]. Ephraim, B.E. and Ajayi, I.O. (2015) Compositional evaluation and quality status of surface waters of Mbat-Abiati and Oberekkai Creeks of the Great Kwa River, Southeastern Nigeria. Advances in Applied Science Research, 6 (6): 36-46.
[28]. Reijers, T.J.A. and Petters, S.W. (1987). Depositional environments and diagenesis of Albian carbonates on the Calabar Flank, SE Nigeria. Journal of Petroleum Geology, 10, 283-294.
[29]. Milsom, J. (2003). Applied Geophysics, 3rd edition, John Wiley & Sons Ltd., 83-126
[30]. Robinson, J., Johnson, T. and Slater, L. (2015). Challenges and opportunities for fractured rock imaging using 3D cross-borehole electrical resistivity. Geophysics, 80, E49–E61.
[31]. Ekwere, A.S. (2023). Geology, Geomorphology and Evolution of the Landscapes of Cross River Region, South-Eastern Nigeria. In: Faniran, A., Jeje, L.k., Fashae, O.A., Olusola, A.O. (eds) Landscapes and Landforms of Nigeria. World Geomorphological Landscapes. Springer, Cham. https://doi.org/10.1007/978-3-031-17972-3_15