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International Journal of Earth Sciences Knowledge and Applications
www.ijeska.com

Research Article

e-ISSN: 2687-5993

# Evaluation of Gold Mineralization Potential Using Electrical Resistivity Method Along River Chanchaga, Minna, North Central Nigeria

**Alabi Olawale Oluwakayode[1], Benjamin Odey Omang[1], Bawallah Musa Adesola[2], Ilugbo Stephen Olubusola[3]***

[1]*Department of Geology, University of Calabar, Cross River State, Nigeria*
[2]*Department of Applied Geophysics, Federal University of Technology Akure, Ondo State, Nigeria*
[3]*Department of Physics, Lead City University Ibadan, Oyo State, Nigeria*

**INFORMATION**

**Article history**
Received 22 February 2021
Revised 07 May 2021
Accepted 08 May 2021
Available 15 July 2021

**Keywords**
Gold
Dipole-Dipole
Lateral Horizontal Profiling
Vertical Electrical Sounding
Total Longitudinal Conductance

**Contact**
*Ilugbo Stephen Olubusola
bussytex4peace44@gmail.com

**ABSTRACT**

Geophysical evaluation of gold mineralization potential within Minna has been carried out using three principal techniques namely; dipole-dipole, lateral horizontal profiling of a = 5, 10, 15 and 20 m as well as Vertical Electrical Sounding. This approach displays structural evaluation of lateral extent of the gold mineralization layer setting as well as layer stratification. Total longitudinal conductance was used as one of the major factors due to lack of chargeability equipment to determine the nature and mode of occurrence of the gold deposits. The gold deposits was found within highly weathered schist material which has been completely weathered into clay, and its presence within clayey horizon been responsible for high total longitudinal conductance within the region of its occurrence in contrast with areas of very little or non-gold mineralization The study further reveals that the Minna gold deposit are of shallow horizon in nature which exist between 0.8 m to less than 5 m in most cases. Due to shallow depth of penetration, they are easily eroded along the surrounding stream and river; hence, the investigated area could be categorized as alluvia deposits.

## 1. Introduction

The search for gold deposit anywhere in the world is either directed at sedimentary environment or basement complex region within faulted zones, dyke or major veins/rock boundaries, joints and many atimes as products of highly weathered geologic material that are subsequently eroded into streams, rivers and are often describe as alluvia/alluvium deposits (Ilugbo et al., 2020; Bawallah et al., 2019; Ozegin et al., 2019a; Ozegin et al., 2019b; Akinlalu et al., 2018; Ilugbo et al., 2018; Olomo et al., 2018). Therefore, gold deposits are located either along faulted zones, veins/joints or highly weathered basement or sedimentary geologic materials which may be products of volcanic activities, metamorphism or products of sedimentary processes leading to development of gold bearing formations or a stage of supergene mineralization arising from many years of weathering activities (Guo et al., 1999; Sultan et al., 2009; Liu et al., 2006).

The Minna gold deposit like most other deposit in Nigeria are products of tectonic activities resulting into basement rock formations (Figs. 1 and 2), leading to high degree of weathering and are found mainly along schist veins that has undergone high degree of weathering resulting into clayey formation and hence, the bulk of the gold deposits in Minna environment are found mainly within the schist veins formation, especially those that has undergone a high degree of weathering that has result into clay; which is closely related with the mode and occurrence of Ilesha gold deposit. The preliminary studies of Minna gold deposit have been found to exist mainly within the highly weathered schist formation (clayey formation). Hence, a geophysical principle base on Electrical Resistivity contrast has been adopted for the evaluation of gold deposit and identification of mineralized zone/gold bearing formation along River Chanchaga, Minna schist environment.

Fig. 1. Local miners at work within the study location

## 2. Site Description and Geology of the Study Area

The study area, which covers an area of about 8 square kilometres, is part of Chanchaga Local Government Area of Niger State, North-central Nigeria. It is located between latitudes 9°31'18" to 9° 34'39"N and longitudes 6°33'25" to 6°35'10"E (Fig. 3). The study area is accessible through the Minna – Paiko road and other unpaved roads that network movement in and out of the city. The relief of the study area is relatively flat and rocky at the river channel drained by River Chanchaga. Chanchaga area falls within the Guinea Savanna Belt, it is covered with grassland which is basically used for agricultural purposes. The area is also characterized by two climatic seasons, each season lasting for about six months, the total annual rainfall of the area is between 1200 mm in the north to 1600 mm in the south, the dry season begins in November and usually ends in March, the dry season is characterized by the N – E trade wind that blows across the Sahara Desert (Ajibade et al., 2008).

Fig. 2. Local miners at work within the study location

Minna is underlain by rocks belonging to the Basement Complex system of Nigeria, these comprises the migmatite-gneisscomplex, the Older Granite and schist belt. The migmatite-gneiss complex is composed of migmatites of various structures and composition but predominantly with tonalitic or amphibolitic paleosome and granitic, pegmatitic or aplitícleucosme. The Older Granite comprises rocks whose texture varies from medium-grained to coarsely-porphyritic; and composition varies from granite to tonalite (Grant, 1978), they form rugged topography and inselbergs. Grant (1978) identified four generations of structures for Kushaka and Birnin Gwari Schist Formation and the Zungeru Mylonite (Ajibade et al., 1987). The field relation shows that the schist belts are intruded and separated by the rocks of migmatite-gneiss complex and granitic rocks (Ajibade et al., 1987). Chanchaga area consists predominantly of granite and schist (Alabi, 2011), the granitic unit outcropped in the central and northern parts of the area while the schist is confined to the southern part (Fig. 4).

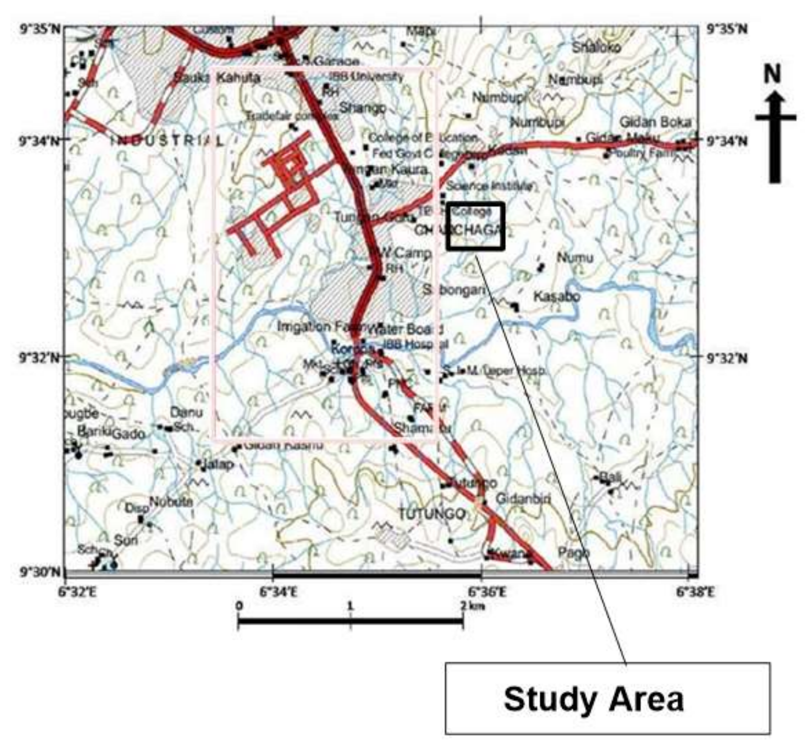


Fig. 3. Location map of the study area

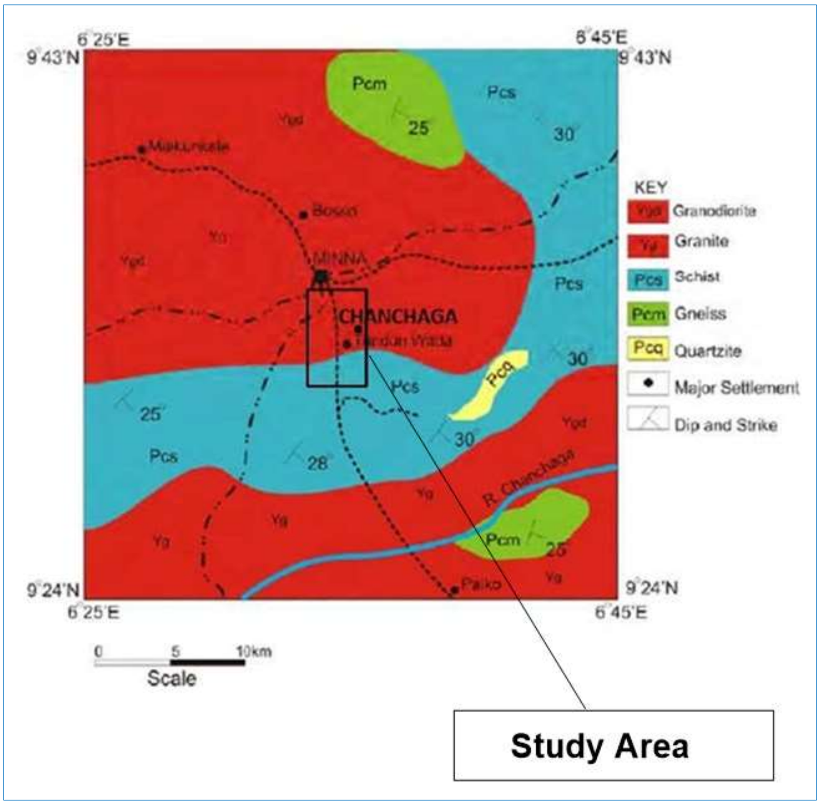


Fig. 3. Geological map of the study area

## 3. Research Methodology

In this study, three electrical resistivity techniques were used, viz; Vertical Electrical Sounding (VES), 2-D Electrical Resistivity Tomography (ERT) and Horizontal Profiling (HP) with the corresponding configurations, been of Schlumberger, Dipole-Dipole and Wenner electrode arrays respectively (Fig. 5). Fifteen (15) sounding stations were occupied along the three traverses, and the current electrode spacing (AB/2) was varied from 1 to 100 m. To process the electrical resistivity data, the apparent resistivity values were plotted against the electrode spread (AB/2). This was subsequently interpreted quantitatively using the partial curve matching method and computer-assisted 1-D forward modeling with WinResist 1.0 version software. The results from the VES interpretation were used to determined second order parameters such as the total longitudinal conductance (s). The dipole-dipole data were inverted using 2-D subsurface images using the DIPPRO™ 4.0 inversion software. The inter-electrode spacing of 5 m was adopted while inter-dipole expansion factor (n) was varied from 1 to 5. Lateral Resistivity Profiling (LRP) techniques was taken at a = 5, 10, 15, and 20 m which give useful information on the nature and trends of the sub-surface and structural trends and the data obtained were inverted using 2-D subsurface images using the Resis2D software. Resistivity values were obtained by taking readings using the Omega resistivity meter. The results from the three techniques were integrated together to evaluate the existence and occurrence of gold mineralization potential.

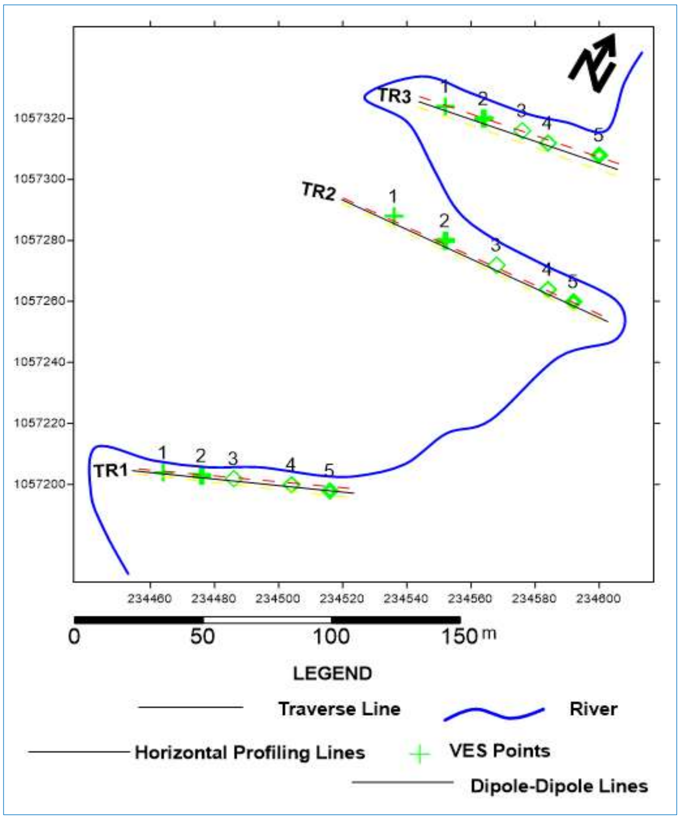


Fig. 5. Data Acquisition Map of the study area

## 4. Results and Discussion

### 4.1. Dipole-Dipole Psedosection

#### 4.1.1. Dipole-Dipole Psedosection along Traverse One

Fig. 6 shows the 2D resistivity imaging of the study location on traverse one taken along East to West direction. The information obtained revealed that the gold mineralization along this location is of near surface occurrence concentrated mainly within a distance between 20-35 m along the profile to a depth extent of 3 m, this may be partially accountable for its exploitation through manual efforts. Furthermore, distance between 40-50 m was also observed as a major weak zone that host the presence of gold mineralization deposit.

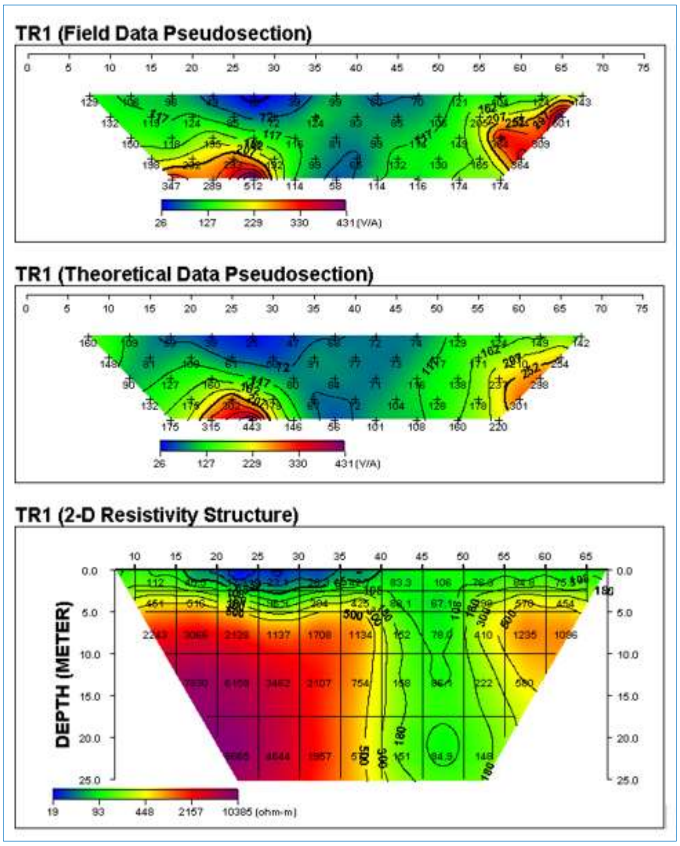


Fig. 6. Dipole-Dipole Psedosection along Traverse One

#### 4.1.2. Dipole-Dipole Psedosection along Traverse Two

Fig. 7 displays 2D resistivity imaging which further classified the gold mineralization of the study area to be that of near surface occurrence as exhibited between 55-70 m towards the western part of the profile and depth extent of about 3 m, and with resistivity variations ranging between 20-75 Ωm.

#### 4.1.3. Dipole-Dipole Psedosection along Traverse Three

Fig. 8 exhibits 2D resistivity imaging along traverse three taken along the upper flank of the study area. It was further established that the gold mineralization of the study area is not massive but shallow occurrence with a depth of about 3 m, with lateral extent between 50-70 m, and resistivity variation ranging from 20-65 Ωm.

### 4.2. LRP

#### 4.2.1. LRP along Traverse One

Fig. 9 displays 2D Wenner Resistivity Imaging with a = 5 m, 10 m, 15 m and 20 m. it exhibits additional information about the structural settings of the gold deposit within the study area. The findings from this approach revealed that though the gold deposit is of shallow horizon with a depth slightly above 6 m while the extent of its occurrence almost covers the entire profile. The deposit was concentrated mainly between 10 to 45 m along the profile, and with resistivity variations ranging between 20-75 Ωm.

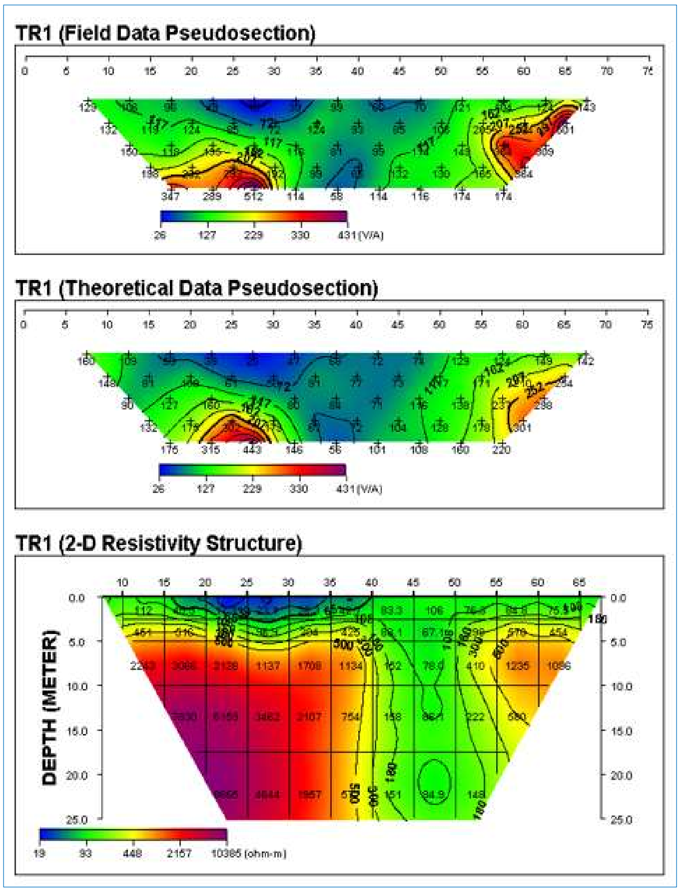


Fig. 7. Dipole-Dipole Psedosection along Traverse Two

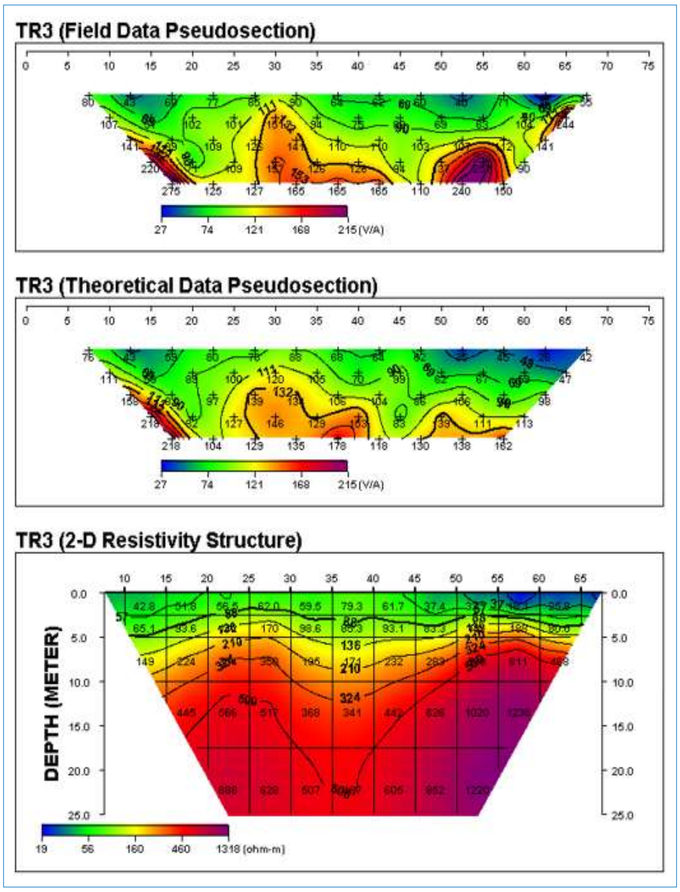


Fig. 8. Dipole-Dipole Psedosection along Traverse Three

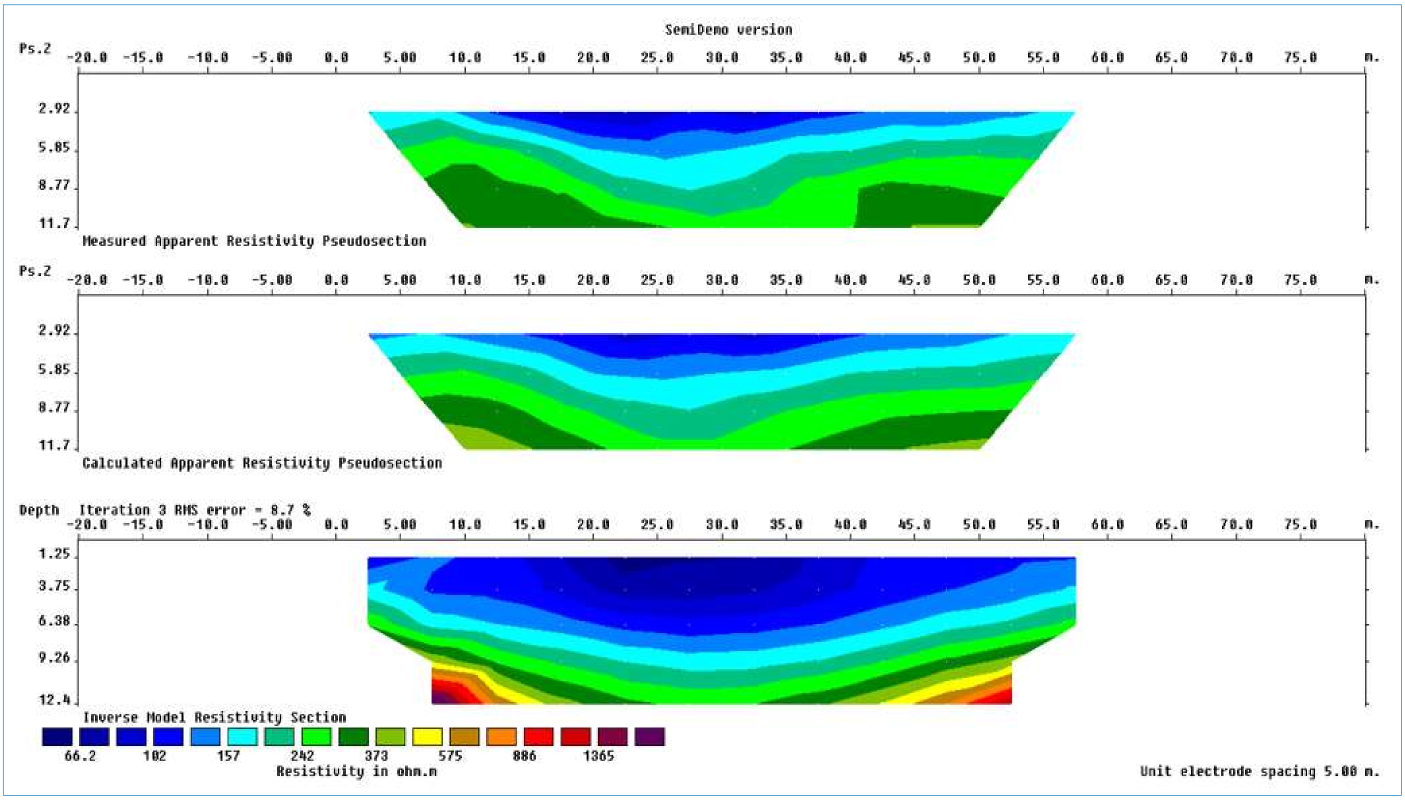


Fig. 9. Lateral Resistivity Profiling along Traverse One

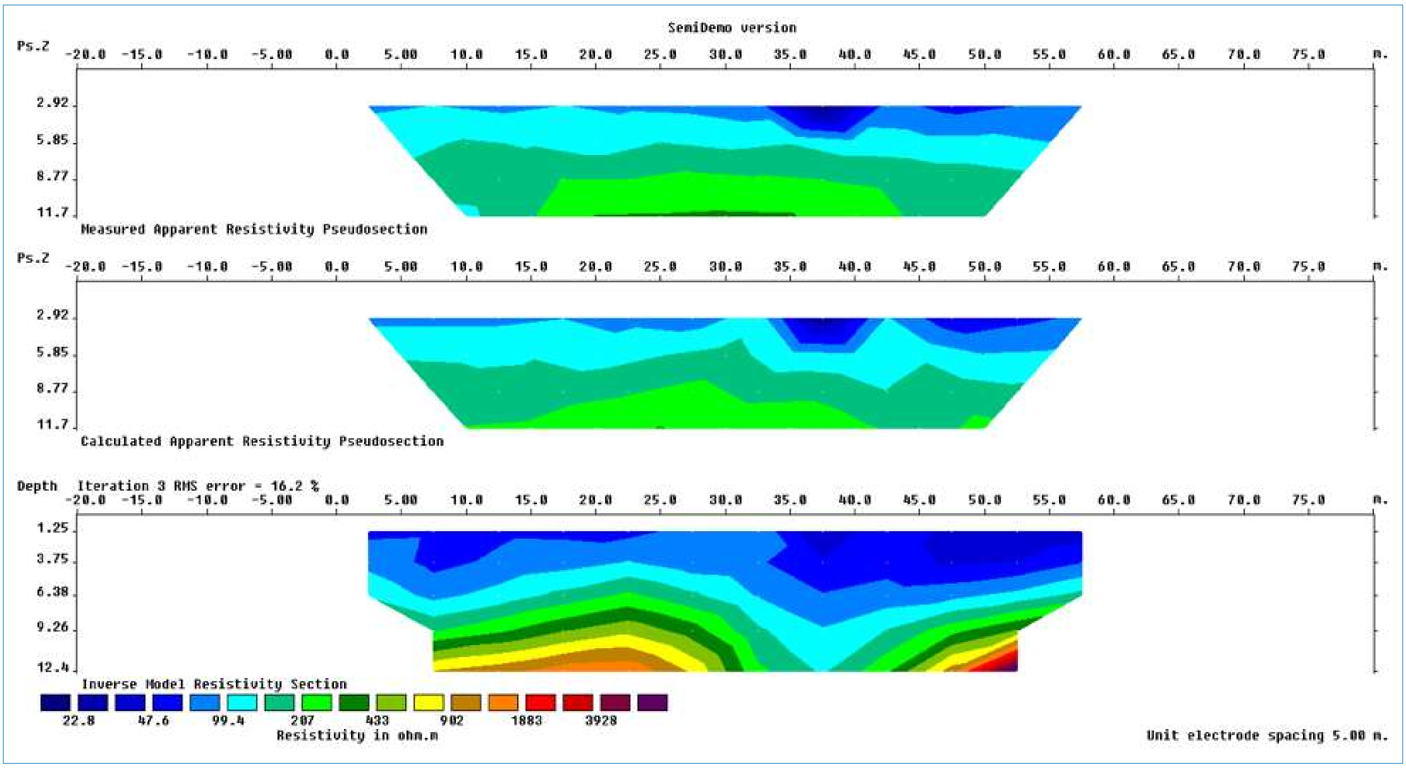


Fig. 10. Lateral Resistivity Profiling along Traverse Two

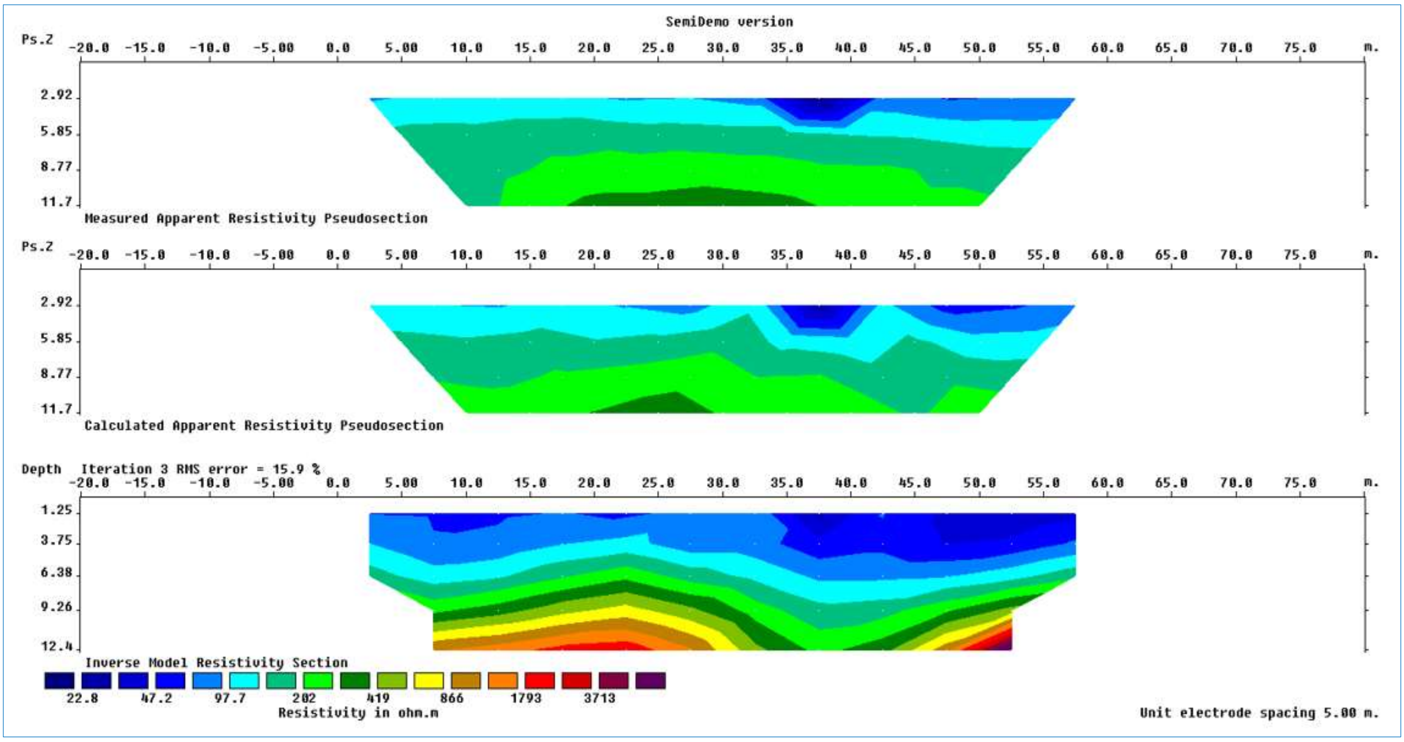


Fig. 9. Lateral Resistivity Profiling along Traverse Three

**4.2.2. Lateral Resistivity Profiling along Traverse Two**

Wenner 2D imaging along the profile two (Fig. 10) also characterized that gold deposit of the study area is a near surface occurrence with resistivity parameters ranging from 20 to 99.4 Ωm and the depth extent of about 4 m and the lateral extent almost covering the entire profile. The deposit was concentrated mainly between 35 to 60 m along the profile.

**4.2.3. Lateral Resistivity Profiling along Traverse Three**

Fig. 11 shows 2D Wenner imaging of profile three within the study location. The results obtained from this profile further reveals that the area is characterized by shallow occurring gold deposit/mineralization with resistivity parameters ranging from 20 to 97.7 Ωm and depth extent of less than 5 m. The deposit was concentrated mainly between 25 to 60 m along the profile.

### 4.3. Vertical Electrical Sounding

#### 4.3.1. Geoelectric Section along Traverse One

Fig. 12 shows the geoelectric section across traverse one taking along E-W direction, it was characterized by geoelectric layers comprising of the topsoil with layer resistivity ranging from 67 to 105 Ωm indicative of clay horizon with layer thickness 0.5 to 1.9 m. the second layer is also clayey in nature considered as the highly weathered layer with layer resistivity of 54-83 Ωm and thickness ranges from 1.5-3.8 m. It was reveals that the gold mineralization is of shallow occurrence and it was hosted by highly weathered schist with resistivity response emanating from the combination of both gold mineralization and the host rock, the highly weathered schist with resistivity values ranging from 20-60 Ωm.

Hence, resistivity response above 60 Ωm to a maximum of 80 Ωm was considered as sparse gold mineralization, whereas, the high and sparse area of concentration was found to exist within this second layer formation. Underlying this layer is partially weathered layer with resistivity values ranging from 805-845 Ωm with thickness between 3.1-14.6 m while the weathered/fractured basement has a resistivity values ranging from 75-289 Ωm which is an indicative of gradual deformation of the underlying geologic material, arising from further weathering processes.

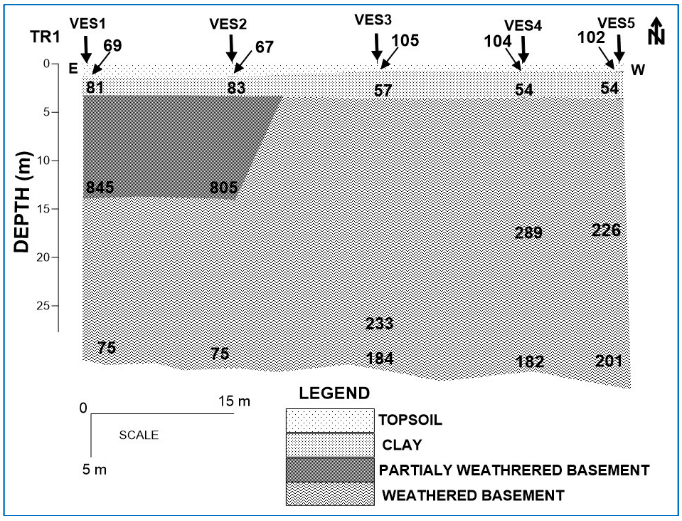


Fig. 12. Geoelectric section along Traverse One

#### 4.3.2. Geoelectric Section along Traverse Two

Fig. 13 displays the geoelectric section across traverse two with four geoelectric units. These comprises of the topsoil with resistivity values ranging from 66-125 Ωm with thickness varying from 0.8-1.9 m. Underlain by highly weathered layer with resistivity values ranging from 50-203 Ωm with thickness varying from 0.8-7.3 m. the region within this layer has resistivity values ranging from 50-55 Ωm at the western part of this layer was considered as the highest concentration/presence of gold mineralization. This is as a result of the inherent nature of the gold occurrence in which the gold concentration is hosted within the schist that has been completely weathered into clay, and hence, during heavy rainfall occasioned by strong erosion being shallow occurring mineralization, they are transported down the river channel and bed, meanwhile they are sometimes found as alluvial deposits.

Furthermore, the third and fourth geoelectric unit along this traverse considered as the partially weathered basement and fresh basement with resistivity values ranging from 391-1258 Ωm.

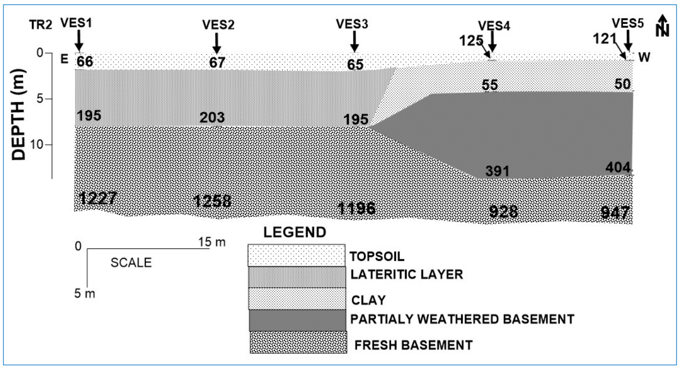


Fig. 13. Geoelectric section along Traverse Two

#### 4.3.3. Geoelectric Section along Traverse Three

This traverse was also considered along east-west direction (Fig. 14) with three to four geoelectric units which comprises of topsoil with resistivity values ranging from 58-121 Ωm and layer thickness varies from 0.5-2.1 m. the second layer has resistivity values ranging from 40-208 Ωm with thickness varying from 0.9-7.1 m, the western part of this layer is an area of interest with extremely low resistivity arising from the inherent nature of the gold mineralization of the study area, where the mineral deposit is hosted within the completely weathered schist into clay, and both gold presence and the highly weathered schist are a controlling factor for the extremely low resistivity nature of this region, which could have given rise to high chargeability characteristics of gold deposit environment in a typical basement complex region with the host rock been of metamorphic origin as the case of Minna gold deposit found within the highly weathered schist. Follow by other layers considered as partially weathered basement and fresh basement with resistivity values ranging from 410-1330 Ωm.

### 4.4. Geoelectric Maps

#### 4.4.1. Overburden Thickness Map

Fig. 15 displays the overburden thickness map of the study area, which can be used to characterize the investigated area into three regions. These includes region of high overburden thickness with depth to basement ranging from 18-27 m which lies within Northeastern part, while moderate overburden thickness was observed along the Northeastern,

eastern and southeastern parts with depth to the basement ranging from 12-17 m. the rest of the investigated area could be considered as region of low/shallow overburden thickness and this is the region where the presence of gold mineralization is highly pronounced and most probably account for shallow lying gold mineralization within the study location. Hence, the heavy presence of activities of the local miners was very prominent within the area (Fig. 16).

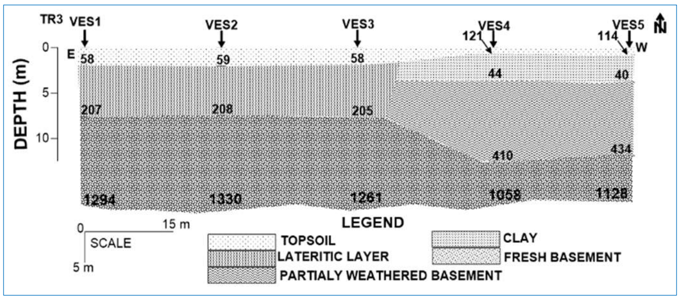


Fig. 14. Geoelectric section along Traverse Two

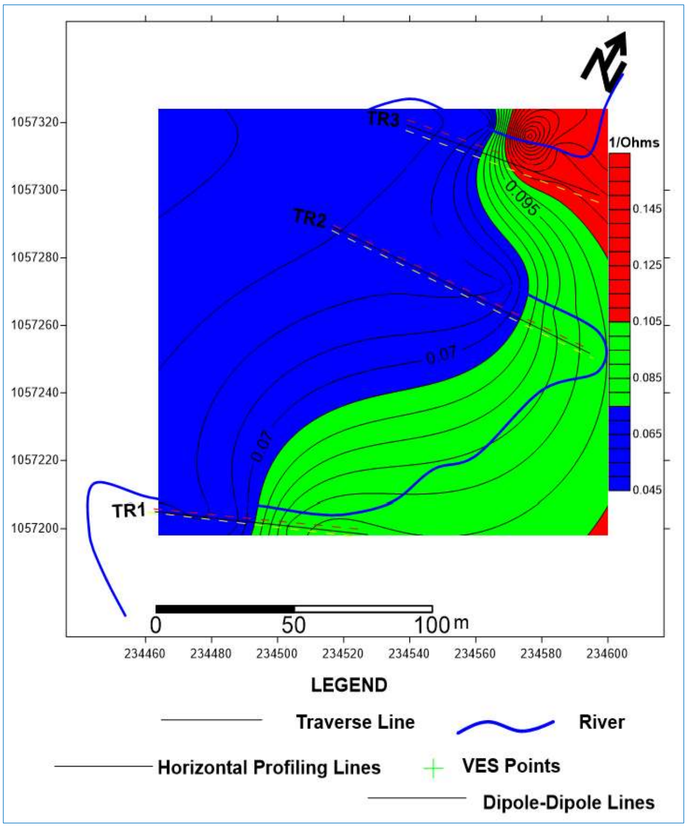


Fig. 15. Overburden Thickness Map of the study area

Fig. 16. Local miners at work within the study location

## 4.4.2. Total Longitudinal Conductance Map

Fig.17 illustrates the total longitudinal conductance which becomes more relevant to the study as a result of the depositional environment of the gold deposit within the research location, the gold mineralization was observed to be domicile within highly weathered schist. Most often of which have been completely weathered into clay, so in the absence of chargeability equipment to determining chargeability parameters which could have been very useful to the study.

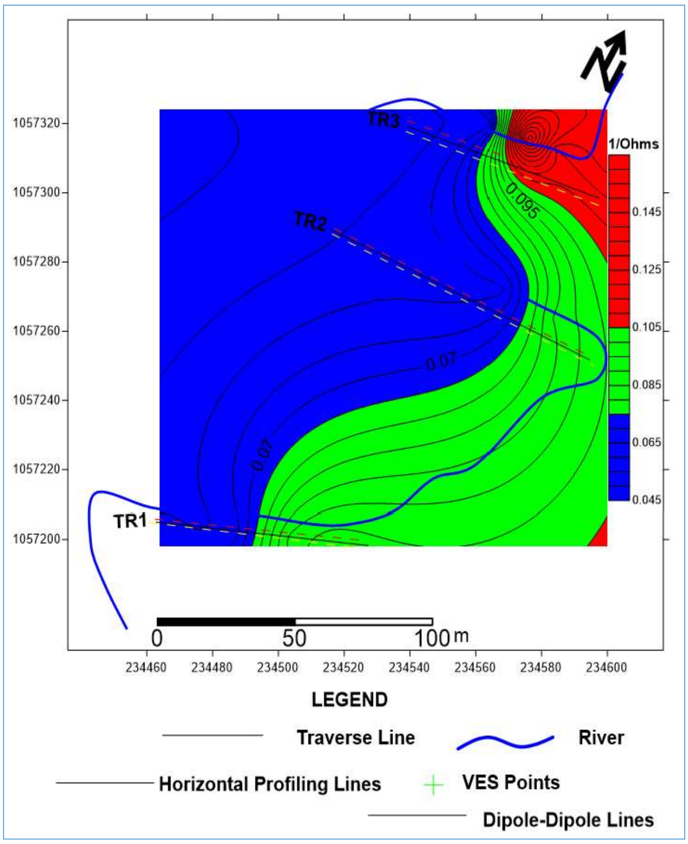


Fig. 17. Total Longitudinal Conductance Map of the study area

Total longitudinal conductance also becomes relevant as an alternative control factors to explain the degree of weathering into clay which is the host geologic material for Minna gold deposit. Therefore, it was observed that total longitudinal conductance exhibits effective correlation with the 2D dipole-dipole and lateral horizontal imaging that the gold deposits within the area is of shallow/low lying occurrence, and the deposit occur within schist veins that have been completely weathered into clay. Hence, target zone for any gold exploration/exploitation within the investigated location should be directed towards the schist veins that have heavily weathered into clay and are of shallow horizon.

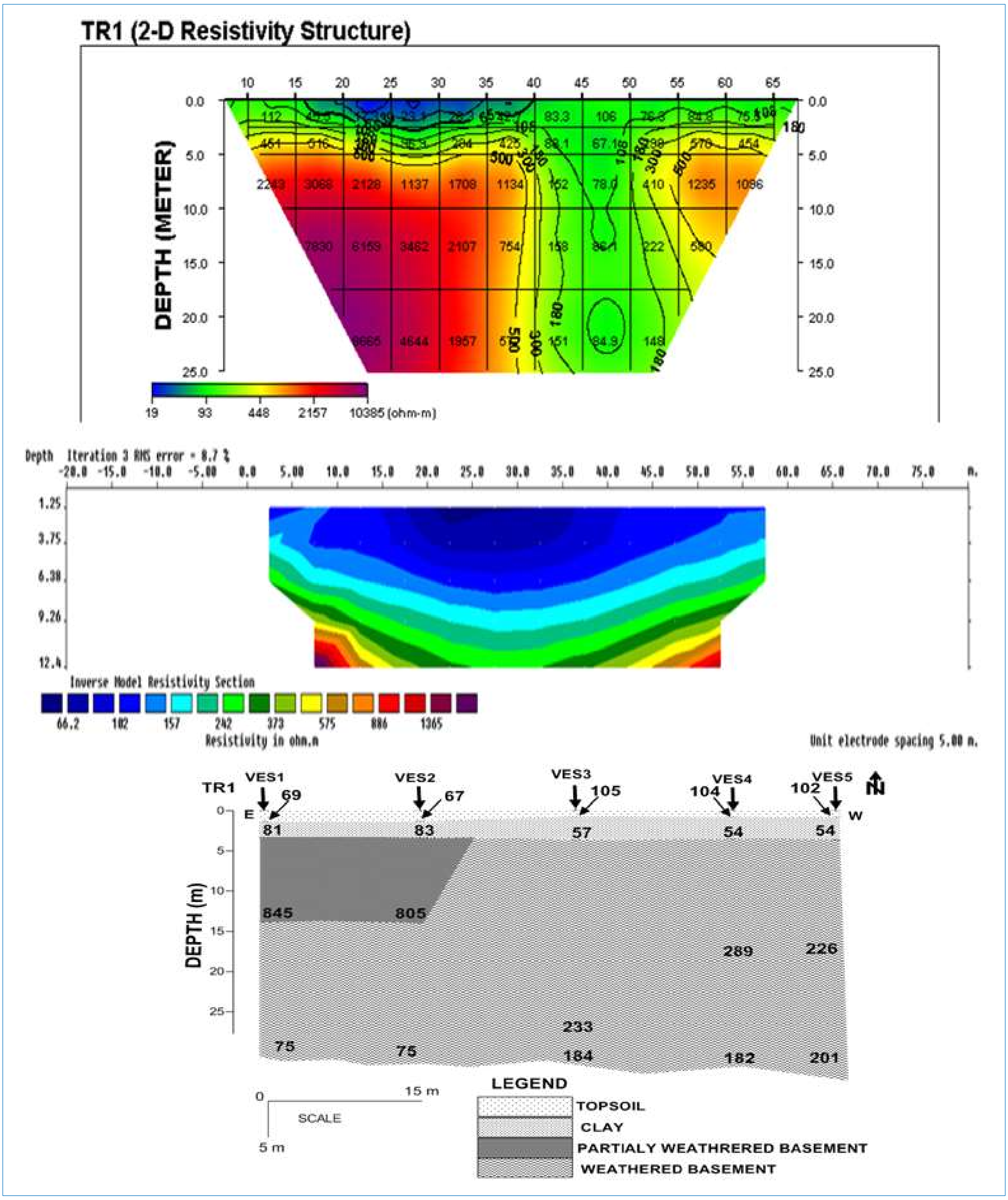


Fig. 18. Correlation of 2D Dipole-Dipole Pseudosection, 2D Lateral Resistivity Imaging and Geoelectric Section along Traverse One

## 4.5. Correlation of Results

### 4.5.1. Traverse one

The three approaches that were considered for this study gave relevant and useful information about the nature of the gold mineralization of the study area. They effectively classified the area as shallow lying gold mineralization occurrence. However, the 2D lateral imaging further identified the area as shallow lying gold mineralization occurrence but with wider extension and greater concentration towards the centre of the profile (Fig. 18).

**4.5.2. Traverse Two**

The 2D resistivity structure, 2D lateral imaging and geoelectric section established effective correlation indicating that from 50 m towards the western part of the profile was identified as region of low-lying gold mineralization potential (Fig. 19).

**4.5.3. Traverse Three**

The correlation of 2D resistivity structure, 2D lateral imaging and geoelectric section across traverse three of the investigated area effectively identified the active region in term of gold mineralization which exist between 50 m to the end of the western region.

It also allowed for the zoning of the profile into region of sparse mineralization and region of heavy gold mineralization both of which are of shallow occurrences (Fig. 20).

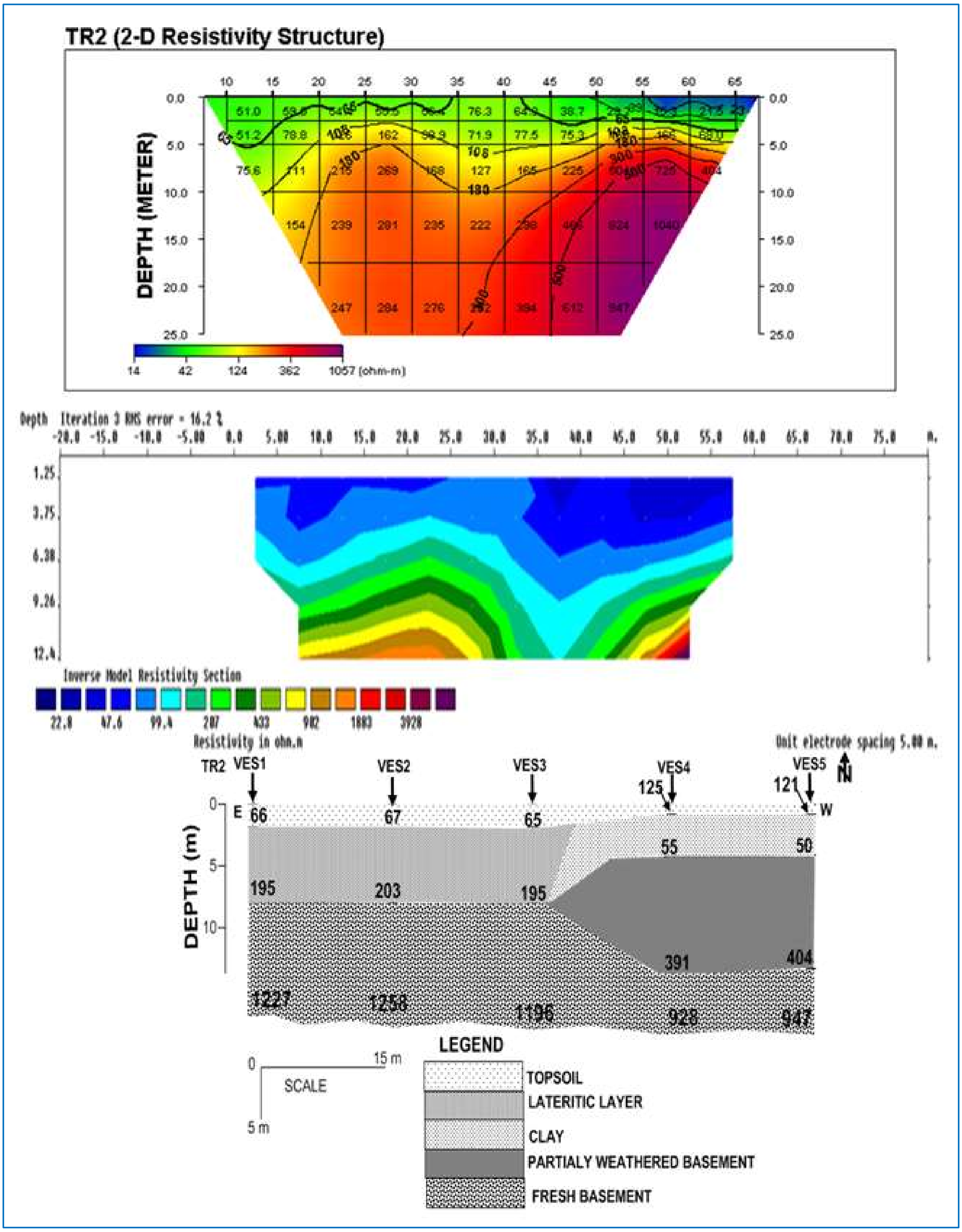


Fig. 19. Correlation of 2D Dipole-Dipole Pseudosection, 2D Lateral Resistivity Imaging and Geoelectric Section along Traverse Two

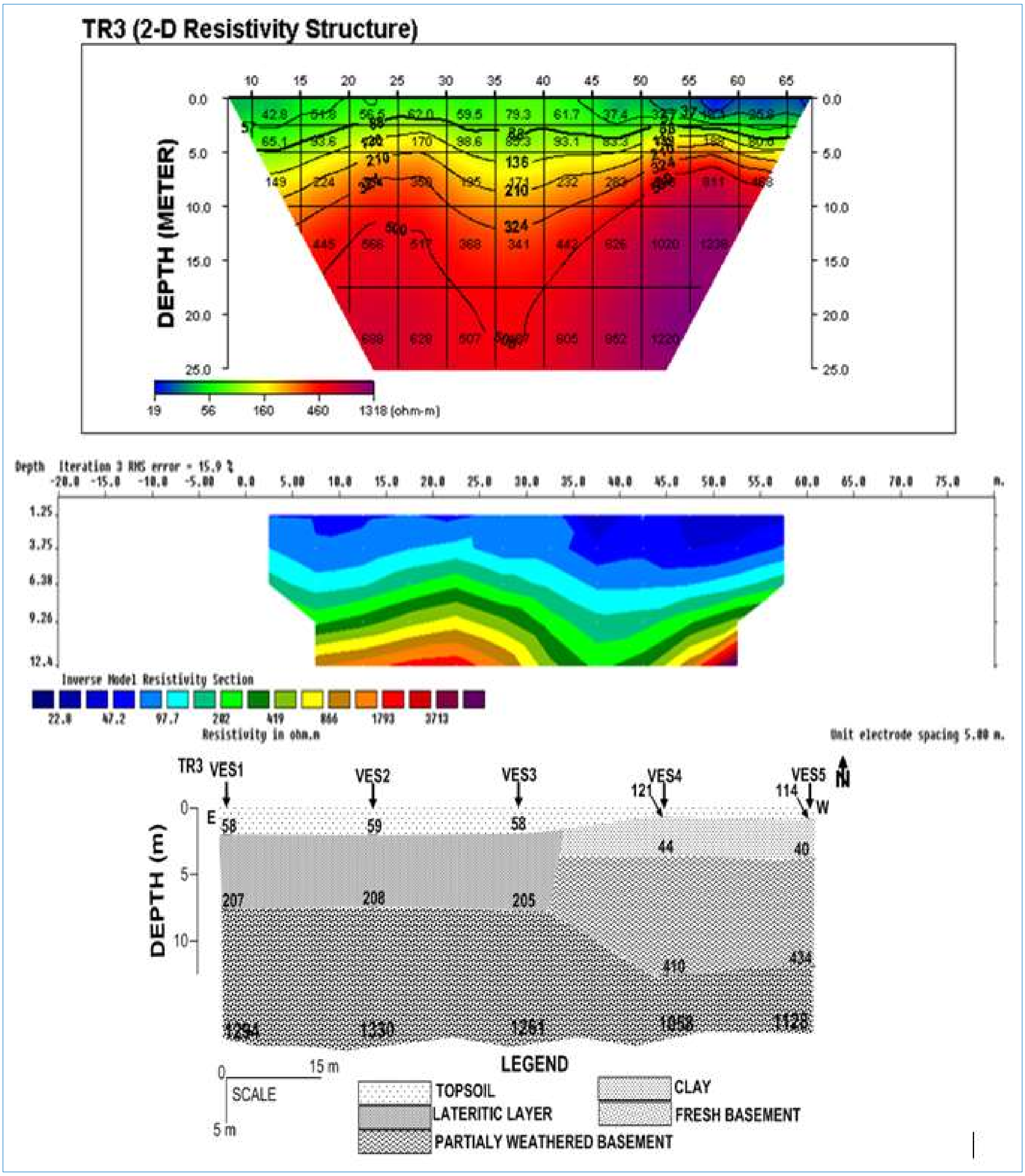


Fig. 20. Correlation of 2D Dipole-Dipole Pseudosection, 2D Lateral Resistivity Imaging and Geoelectric Section along Traverse Three

## 5. Conclusion

The findings have revealed that Minna gold deposits can be mapped using geophysical approach as well as the technique and approach adopted for this study. It has also been established that the gold mineralization and deposit of Minna is of shallow lying occurrence and are found mainly within the highly weathered clayey schist, most of which drained off by erosion into the rivers and surrounding streams which was identified as stream sediments and alluvia deposits.

The research shows that the origin of the deposit can be traceable to metamorphism or metamorphic activities and subsequent weathering processes. The Minna gold mineral deposit could be of high interest; if it is properly developed and harnessed.

## Data Availability Statement

The authors confirm that the data supporting the findings of the study are available within the article and its supplementary materials. Authors have declared that no competing interests exist and the data was not use as an avenue for any litigation but for the advancement of knowledge.


## Acknowledgement

The authors gratefully acknowledge Prof. Aina A.O. for his valuable contribution at improving the quality of this research work.

## References

Ajibade, A.C., Anyanwu, N.P.C., Okoro, A.U., Nwajide, C.S., 2008. The geology of Minna area (Explanation of 1:250,000 Sheet 42, Minna). Bulletin No. 43. Nigeria: Nigerian Geological Survey Agency Publication; 112 pp.

Ajibade, A.C., Woakes, M., Rahaman, M.A., 1987. Proterozoic crustal development in the Pan Africanregime of Nigeria. In: Kroner, A. (ed.) Proterozoic Crustal Evolution. American Geophysical Union, Geo-dynamic Series17, 259-271.

Alabi, A.A., 2011. Geology and environmental impact assessment and benefit of granitic rocks of Minna area, Northwestern Nigeria. Ethiopian Journal of Environmental Studies and Management 4 (4), 39-45.

Akinlalu, A.A., Adelusi, A.O., Olayanju, G.M., Adiat, K.A.N., Omosuyi, G.O., Anifowose, A.Y.B., Akeredolu, B.E., 2018. Aeromagnetic mapping of basement structures and mineralisation characterisation of Ilesa Schist Belt, Southwestern Nigeria. Journal of African Earth Sciences 138, 383-391.

Bawallah, M.A., Ayuks, M.A., Ilugbo, S.O., Ozegin, K.O., Oyedele, A.A., Aigbedion, I., Aina, A.O., Whetode, J.M., Ladipo, K.O., 2019. Geodynamics and its implications to environmental protection: A case study of Aule area, Akure, Ondo State, Southwestern, Nigeria. Applied Journal of Physical Science 1 (3), 37-53.

Grant, N.K., 1978. Structural distinction between a metasedimentary cover and an underlying basement in the 600 myr old Pan-African domain of northwest Nigeria. Geological Society of America Bulletin 89 (1), 50-58.

Guo, W.W., Dentith, M.C., Xu, J.L., Ren, F.S., 1999. Geophysical exploration for gold in Gansu Province, China. Exploration Geophysics 30 (2), 76-82.

Ilugbo, S.O., Edunjobi, H.O., Adewoye, O.E., Alabi, T.O., Aladeboyeje, A.I., Olutomilola, O.O., Owolabi, D.T., 2020. Structural Analysis Using Integrated Aeromagnetic Data and Landsat Imagery in a Basement Complex Terrain, Southwestern Nigeria. Asian Journal of Geological Research 3 (2), 17-33.

Ilugbo, S.O., Adebo, A.B., Ajayi, O.A., Adewumi, O.O., Edunjobi, H.O., 2018. Geophysical and geotechnical studies of a proposed structure at Akure, Southwestern Nigeria. Journal of Engineering Research and Reports 2 (2), 1-12.

Liu, H.T., Liu, J.M., Yu, C.M., Ye, J., Zeng, Q.D., 2006. Integrated geological and geophysical exploration for concealed ores beneath cover in the Chaihulanzi Goldfield, Northern China. Geophysical Prospecting 54 (5), 605-621.

Olomo, K.O., Olayanju, G.M., Adiat, K.A.N., Akinlalu, A.A., 2018. Integrated approach involving aeromagnetic and landsat for delineating structures and its implication on mineralization. International Journal of Scientific & Technology Research 7 (2), 208-217.

Ozegin, K.O., Bawallah, M.A., Ilugbo, S.O., Olaogun, S.O., Oyedele, A.A., Iluore, K., 2019a. Susceptibility test for road construction: A case study of Shake Road, Irrua, Edo State. Global Journal of Science Frontier Research: H Environment & Earth Science 19 (1), 45-53.

Ozegin, K.O., Bawallah, M.A., Ilugbo, S.O., Oyedele, A.A., Oladeji, J.F., 2019b. Effect of Geodynamic Activities on an Existing Dam: A Case Study of Ojirami Dam, Southern Nigeria. Journal of Geoscience and Environment Protection, 7 (9), 200-213.

Sultan, A.S., Salah, A., Fernando, M.S., Ahmad, S.H., 2009. Geophysical exploration for gold and associated minerals, case study: Wadi El Beida area, South Eastern Desert, Egypt. Journal of Geophysics and Engineering 6 (4), 325-335.