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Integrated Geophysical Methods for Post Construction Studies: Case Study of Omuo Comprehensive High School, Omuo Ekiti, Southwestern, Nigeria

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Abstract- An integrated geophysical survey was carried out within the Precambrian Basement Complex of Omuo Comprehensive High School and its environ in Omuo-Ekiti, Ekiti State, South-west Nigeria to assess buildings in the area that are intensively affected by cracks resulting in structural instability. The geophysical methods adopted for the investigation are the Very Low Frequency Electromagnetic (VLF-EM), Magnetic, 2-D electrical resistivity profiling using the dipole-dipole array and Vertical Electrical Soundings (VES) using the Schlumberger array. The traverses were established E – W direction cutting across geologic strike. A total of five traverses were established with length ranging from 130 – 200m and of varying inter-traverse spacing. The station interval is 10m. Also, a total of thirty-five (35) VES stations were occupied covering the entire study area. The acquired data were processed and interpreted integrally to elucidate the shallow subsurface geology of the study area. The results were qualitatively and quantitatively interpreted and are presented as sounding curves and geo-electric sections. The magnetic interpretation shows relatively uneven bedrock topography with variable overburden thicknesses of between 5m – 15m. However, the VLF-EM results reveal ten (10) conductive zones which manifest as low resistivity zones in the generated geo-electric sections. The characteristic sounding curves obtained from the study area are H, HA, KH, HK, KHK, HAK and QH.

Keywords: structural instability, lateral inhomogeneity. incompetent materials.

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INTEGRATEDGEOPHYSICALMETHODSFORPOSTCONSTRUCTIONSTUDIESCASESTUDYOFOMUOCOMPREHENSIVEHIGHSCHOOL, OMUOEKITI, SOUTHWESTERN, NIGERIA

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Integrated Geophysical Methods for Post Construction Studies: Case Study of Omuo Comprehensive High School, Omuo Ekiti, Southwestern, Nigeria

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Abstract- An integrated geophysical survey was carried out within the Precambrian Basement Complex of Omuo Comprehensive High School and its environ in Omuo-Ekiti, Ekiti State, South-west Nigeria to assess buildings in the area that are intensively affected by cracks resulting in structural instability. The geophysical methods adopted for the investigation are the Very Low Frequency Electromagnetic (VLF-EM), Magnetic, 2-D electrical resistivity profiling using the dipole-dipole array and Vertical Electrical Soundings (VES) using the Schlumberger array. The traverses were established E – W direction cutting across geologic strike. A total of five traverses were established with length ranging from 130 – 200m and of varying inter-traverse spacing. The station interval is 10m. Also, a total of thirty-five (35) VES stations were occupied covering the entire study area. The acquired data were processed and interpreted integrally to elucidate the shallow subsurface geology of the study area. The results were qualitatively and quantitatively interpreted and are presented as sounding curves and geo-electric sections. The magnetic interpretation shows relatively uneven bedrock topography with variable overburden thicknesses of between 5m – 15m. However, the VLF-EM results reveal ten (10) conductive zones which manifest as low resistivity zones in the generated geo-electric sections. The characteristic sounding curves obtained from the study area are H, HA, KH, HK, KHK, HAK and QH. The geo-electric sections reveal four subsurface layers which include: The topsoil, with resistivity values ranging from 104 – 4656 ohm-m and thickness of between 0.4 – 1.6 m. The weathered layer is characterized by resistivity values varying from 57 – 381 ohm-m and thicknesses of between 0.2 – 9.0 m. The fractured basements were identified beneath traverses 1, 2 and 5 with resistivity values of 109 - 709 ohm-m and depth range of 5.5 – 15.8m. The fresh basement has resistivity values of between 1110 - ∞ ohm-m with depth to bedrock between 4.0 – 28.3 m. The 2-D resistivity structures generally reveal lineament structures (faults) that are observed at depth of 10m across the study area. The integrated interpretation led to the delineation of near surface structures (such as faults and fracture zones), incompetent (Clay) materials and lateral in-homogeneity. These features are the main reasons for the subsurface instability thereby resulting to cracking of the buildings in the study area.

Keywords: structural instability, lateral inhomogeneity, incompetent materials.

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I. Introduction

Incessant failure of buildings has often dominated headlines in Nigeria in recent times and this has generated concerns prompting the entire citizenry to continue to ponder on the causes of the failures of buildings in most part of the country. Previous works over the years in geosciences have attributed these failures to lateral inhomogeneity of the subsurface, differential settlement and failure due to the presence of geologic structures such as faults, joints, cavities e.t.c beneath the buildings (Adelusi et.al. 2013, Akintorinwa et.al. 2009, Ako and Olorunfemi, 1989). Geophysical methods such as the Electrical Resistivity (ER), Seismic Refraction, Electromagnetic (EM), Magnetic and Ground Penetrating Radar (GPR) have been found useful in engineering site investigation (Akintorinwa and Adeusi, 2009). The research examines the use of geophysical methods for post construction studies in and around Omuo Comprehensive High School, Omuo Ekiti, Southwest, Nigeria. This becomes imperative due to the (failure) of buildings in the school and its environs.

II. Description of the Study Area

The study area is Omuo Comprehensive High School, Omuo Ekiti. The site occupies an area of about 204,375m^2. It lies between latitudes 07^o 44'.787"N and 07^o 44'919N", and longitudes 005^{0}42".934'E and 005^{0}43'.042E" (Fig. 1). The relief of the area is a low-lying type with a relatively undulating topography.

a) Geophysical Investigation

The geophysical investigation involved the Magnetic method, very low frequency electromagnetic method and electrical resistivity methods. The electrical resistivity method adopts both the vertical electrical sounding and dipole-dipole techniques for the purpose of this study. Magnetic and VLF-EM measurements were made at 10m interval along five (5) traverses established perpendicular to the geologic strike in the E-W direction with traverse length ranging from 130-200m.

The electrical resistivity method adopts two configurations for this study. 2-D profiling using the

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dipole-dipole array, and vertical electrical soundings using the Schlumberger array. A total of thirty five (35) stations were occupied (Fig. 3.). The ohmega resistivity meter was used in data collection.

b) Data Processing and Interpretation

Magnetic method involves the plotting the relative magnetic intensity against station positions after drift has been corrected for. Automated Euler 1.0 software (Durrheim and Cooper, 1998) was used to estimate the depth to probable fracture zones in the study locations. The corresponding geomagnetic sections were generated using the Surfer 10 software.

EM data can be interpreted via qualitative and quantitative means. The acquired data was downloaded from the VLF-EM equipment (ABEM WADI). The data processing involves the plotting of the percentage ratio of the vertical component and the horizontal component of the field (raw) real and Q-factor.

$$\text{Q-factor; } Q = (Q_4 + Q_3) - (Q_2 + Q_1) \qquad (1)$$

(Where Q is EM data and the subscript are station positions) was performed on the raw real data which is then plotted against distance. The peak positive Q-factor are identified as probable fracture zones on the profiles. Qualitatively, 2-D models of the VLF-EM data were obtained by using the Karous-Hjelt (KH) filter (Karous and Hjelt, 1983).

Vertical Electrical Sounding (VES) data interpretation is completely quantitative via partial curve matching technique (Keller and Frischknecht, 1966), which involves segment by segment interpretation of field curves starting from small electrode spacing and progress gradually to large electrode spacing. The partial curve matching can be regarded as preliminary interpretation of the field curves, which produces the geo-electric parameters needed for forward modelling. WinRESIST version 1.0 (Vander Velpen, 1988) was used to perform the computer iteration(s). The resultant geo-electric parameters obtained from the iteration were used to establish the geo-electric sections.

The dipole-dipole data is interpreted via inverse modelling (automatic interpretation) using Dippro™ SOFTWARE which is followed by qualitative interpretation of the generated pseudo-sections.

III. Results and Discussion

Integrated geophysical approach using magnetic, VLF-EM and Electrical Resistivity Methods involving vertical electrical Sounding (VES) and 2-D dipole-dipole techniques allows the delineation of structures and or materials responsible for the cracks observed on block 1 and block 3 in the study area. The Magnetic profile along traverse three (3) shows variable anomaly signatures at 20 – 35m, 60 – 70m, 110m – 125m. The corresponding geomagnetic sections reveals a relatively thick overburden of about 12m which thinned out at distance of 60 – 80m;. (Figure 4a). The 1-D Euler deconvolution software estimates depth to probable fracture zones of 12m and 10.5m at distance 22m and 70m respectively (Table 1).

The VLF –EM profile along this traverse shows peak positive amplitude of the Q-factor indicative of conductive zones designated as CZ_5 and CZ_6 occurred at distances of approximately 36m and 104m across the traverse. The 2-D model of the VLF-EM along the traverse 3 identifies zones conductive features between 10 – 65m and 100 – 130m along the traverse. These zones agree with the delineated conductive zones on the VLF-EM profile (figure 4b).

The geo-electric section along traverse three (Figure 4c.) has four VES stations, which include stations 1, 2, 3 and 4 moving from west to east. Three prominent geologic layers were delineated. The layers include topsoil layer, the weathered layer and the fresh basement. The resistivity values of the topsoil range from 112 – 1673 ohm-m, with thickness varying from 0.5 – 1.0m and is also presumed to be lateritic, clay, sandy clay and clayey sand. The second layer which is the weathered layer has resistivity ranging from 81 – 163 ohm-m with thickness variation of 1.6 – 9.1m; it is however presumed to be clay/lateritic materials. The resistivity range of the fresh basement is between 2488 - ∞ ohm-m, with a depth to bedrock range of 3.1 – 12.1m. There exists thick overburden in the western flank of the section between VES stations 1 – 2 of the traverse. However, the failed segment of block 1 as shown on the data acquisition map is situated between VES 2 and VES 3.

The 2-D resistivity structure along traverse 3 is as shown in figure 4d. The model shows thick conductive overburden (>10m) towards the western flank of the traverse with resistivity ranging from 45-219 ohm-m. The very conductive overburden at the western flank is presumed to be clay/lateritic clayey while the eastern flank shows that competent bedrock is closer to the surface. However, the resistivity structure shows uneven bedrock.

Correlating the geophysical methods employed along this traverse especially the 2-D models generated from the VLF-EM and dipole-dipole techniques, traverse three is a highly fractured zone with portion of classroom designated as block 1 constructed on this fracture. These structures contribute a great deal to the cracks observed on the classroom block (figure 5). The presence of clay materials beneath VES 2 could also be a contributor to the cracks observed on block 1.

Along traverse four, the magnetic profile delineates probable fracture zones that could be inimical to engineering works between distance 15m – 20m, 50m-70m, 90m-110m, and 130-180m. The geomagnetic section in traverse 4 distinctly shows a relatively thin overburden at the western part between 0-100m and thickens eastward confirming the fracture

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zones that are more deeply seated at distances 160m and 180m respectively (figure 6a). The 1-D Euler deconvolution software delineates five probable fracture zones of depths of about 6m, 8m,10m, 15m and 15m at distances 18m,60m,80m, 160m and 180m respectively.

The VLF-EM profile and its corresponding 2-D model along Traverse 4 (Figure 6b) reveals two positive peak anomalies on the Q-factor which manifest as CZ_7 and CZ_8 at the approximate distance of 75m and 130m respectively along the traverse in the study area. The model shows zones of conductive features between 70 – 90m and 110 – 150m along the traverse. Also, zones of linear resistive features distinctly manifest between 70 – 120m and 150 – 180m along the same traverse.

The geo-electric section along traverse four, with eight VES stations include stations 1, 2, 3, 4, 5, 6, 7 and 8. Three distinct geologic layers were delineated which include: the topsoil, the weathered layer and the fresh basement. The topsoil has resistivity values in the range of 15 – 1100 ohm-m and the thickness varies from 0.5 – 2.4m. The weathered layer has resistivity values which range from 57 – 244 ohm-m, with thickness of between 3.1 – 6.6m. The fresh basement has resistivity values varying from 1243 - ∞ ohm-m (figure 6c). The depth to bedrock varies from 4.0 – 12.0m. The section generally has thin overburden but valley-like depression exist around VES 5 of the traverse. Also, the failed segment of block 3 is located along traverse 4; between VES 2 – VES 4.

2-D resistivity structure along traverse 4 (Figure 6d) shows thick conductive overburden within a hollow-like (basement depression) structure that has a span of between 60 – 148m within the station range of 6 - 15; which is an evidence of faults, fractured zones or buried channels. Along this traverse, the basement is close to the surface at both ends of the traverse (i.e. at the western and the eastern flanks).

Integrated geophysical method employed for this work clearly showed that they complement each other along this traverse as revealed by the resistive zone delineated at the eastern segment which is distinct on the 2-D model of the VLF-EM method at distance 150-180m. This portion coincides with the highly resistive zone delineated on the 2-D resistivity pseudo section with resistivity of about 1822 ohm-m. These zones are also found to be outside the depression that is obvious on the geo-electric section. However, distances 150-180m are delineated to be probable fracture zones on the geomagnetic sections but the deep seated nature of the fracture zones could be responsible for the high resistivity observed on the VLF and 2D- resistivity pseudo sections. The conductive zones observed on the 2-D models of the VLF corresponds to the fracture zones delineated on the geomagnetic sections, depression on the geo-electric section and fracture zones which corresponds to low resistivity delineated on the 2-D pseudosection. A portion of block 3 between VES 2 and VES 4 falls on the fracture zones towards the east with a little portion erected on a competent bed rock. This explains why a portion of the building is stable and the part on the fracture and depressed zone giving way (figure 7).

IV. Conclusions

An integrated geophysical survey was carried out around Omuo Comprehensive High School, Omuo Ekiti, Ekiti State; where buildings in the study area were severely damaged by a series of cracks as pronounced on the walls of the buildings which affect their stability. The objective is to investigate the cause(s) of building failures in the area whether it is precipitated by geological factors or otherwise. In doing this, three surface geophysical methods were used in this study: 2 – D resistivity profiling using dipole – dipole and Schlumberger arrays, magnetic and very low frequency electromagnetic (VLF-EM). The geophysical data collected using these methods were processed and interpreted to image the subsurface structures of the investigated area. However, various anomalous zones were delineated by the three geophysical methods and from the comprehensive interpretation it is deduced that: the failures of the buildings arise from three factors which are incompetent clay materials, near surface structures such as fractures/faults and lateral in-homogeneity.

References Références Referencias

1. *Adelusi A.O., Akinlalu A.A and Nwachukwu A.I. (2013):* Integrated geophysical investigation for post-construction studies of buildings around School of Science area, Federal University of Technology, Akure, Southwestern, Nigeria.
2. *Afolabi, O., Olorunfemi, M. O., Olagunju, A. O. and Afolayan, J. F. (2004):* Resource Quantification of a Kaolin Deposit Using Electrical Resistivity Method – Case Study from Ikere Ekiti, Southwest Nigeria. Ife Journal of Science, Vol. 6 (1), pp. 35 – 40.
3. *Agunloye, O. (1984):* Soil Aggressivity along Steel Pipeline Routes at Ajaokuta. Nigerian Journal of Mining and Geology, Vol. 21 (1 & 2), pp 7 – 101.
4. *Akintorinwa, O. J. and Adeusi, F. A (2009):* Integration of Geophysical and Geotechnical Investigations for a Proposed Lecture Room Complex at the Federal University of Technology, Akure, SW, Nigeria. Journal of Applied Sciences Vol. 2(3), pp 241 – 254.
5. *Ako, B. D and Olorunfemi, M. O. (1989):* Geoelectric Survey for Groundwater in the Newer Basalts of Vom, Plateau State. Journal of Mining and Geology, Vol. 25, Nos 1 & 2, pp. 247- 250.
6. *Dippro for Windows (2000):* DipproTM Version 4.0 Processing and Interpretation software for Dipole – Dipole electrical resistivity data. KIGAM, Daejon, South Korea.

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7. *Durrheim R. J. And Cooper G. R. J. (1998):* Euldep: A Program for the Euler Deconvolution of Magnetic and Gravity Data. Computers & Geosciences Vol. 24, No. 6, Pp. 545±550, 1998 Elsevier Science Ltd.
8. *Henriet, J. P. (1976):* Direct Application of the Dar Zarrouk Parameters in Groundwater Surveys. Geophysical Prospecting, Vol. 24, pp. 334 – 353.
9. *Karous, M. and Hjelt, S.E. (1983):* "Linear Filter of VLF Dip-Angle Measurements". Geophysical Prospecting. 31:782-794.
10. *Keller, G.V. and Frischknecht, F.C. (1966):* Electrical Methods in Geophysical Prospecting. Pergaman Press: New York. NY.
11. *Momoh, L.O., Akintorinwa, O. J and Olorunfemi, M. O. (2008):* Geophysical Investigation of Highway Failure – A case Study from the Basement Complex Terrain of Southwestern Nigeria. Journal of Applied Sciences Vol. 4 (6), pp 637 – 648.
12. *Olaseinde, P. I. (1989):* Elucidating Fracture Pattern in the Nigeria Basement Complex using Electrical Resistivity Method. Angew. Geowiss. Heft 8.S, pp 109 – 120.
13. *Olorunfemi, M. O., Fatoba, J. O. and Ademilua, L. O. (2005):* Integrated VLF – Electromagnetic and Electrical Resistivity Survey for Groundwater in a Crystalline Basement Complex Terrain of Southwestern Nigeria. Global Journal of Geological Sciences, Vol. 3 (1), pp. 309 – 317.
14. *Olorunfemi, M. O., Olarewaju, V. O. and Avci, M. (1986):* Geophysical Investigation of a Fault Zone – Case History from Ile – Ife, Southwest, Nigeria. Geophysical Prospecting, Vol. 34, no. 8, pp 1277 – 1284.
15. *Omosuyi, G. O., Adegoke, A. O., and Adelusi, A. O. (2008):* Interpretation of Electromagnetic and Geoelectric Sounding Data for Groundwater Resources around Obanla-Obakekere, near Akure, Southwestern Nigeria. Pacific Journal of Science and Technology, Vol. 9 (2), pp. 509 – 525.
16. *Palacky, G. J., Ritsema, I. L. and de Jong, S. J. (1981):* Electromagnetic Prospecting for Groundwater in Precambrian Terrains in the Republic of Upper Volta. Geophysical Prospecting, Vol. 29, pp. 932 – 955.
17. *Rahaman, M. A. (1989):* Review of Basement Geology of Southwestern Nigeria. In Geology of Nigeria (Kogbe, C./Ed). Elizabethan publication Co. Nigeria pp. 41 – 58.
18. *Rahaman, M. A. (1988):* Recent Advances in the Study of the Basement Complexes of Nigeria. Precambrian Geology of Nigeria. Geological Survey of Nigeria, pp 11 – 41.
19. *Vander Velpen BPA (2004):* WinRESIST Version 1.0 Resistivity Depth Sounding Interpretation Software. M. Sc Research Project, ITC, Delf Netherland.

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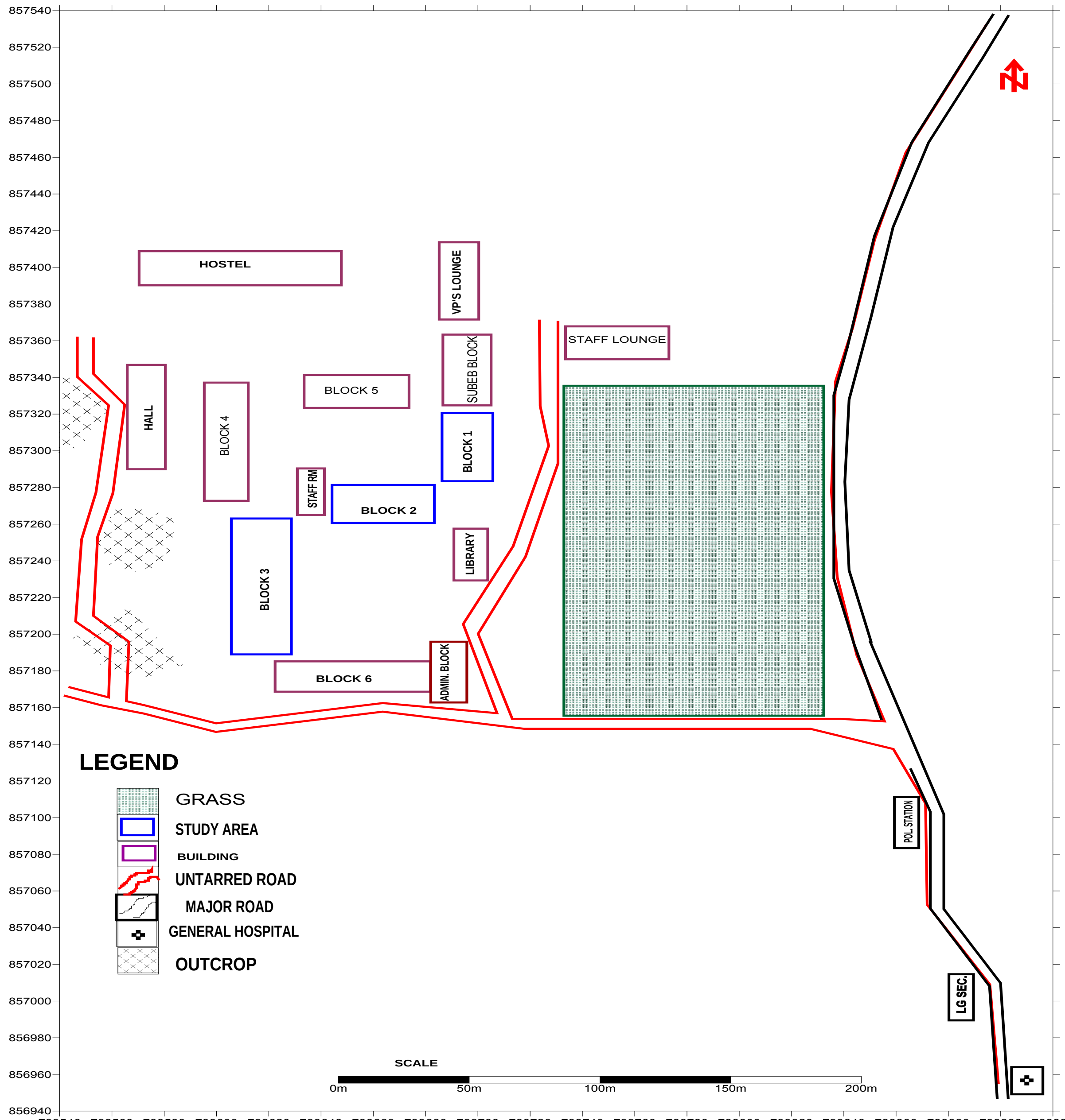

Figure 1 : Base Map of the Study Location

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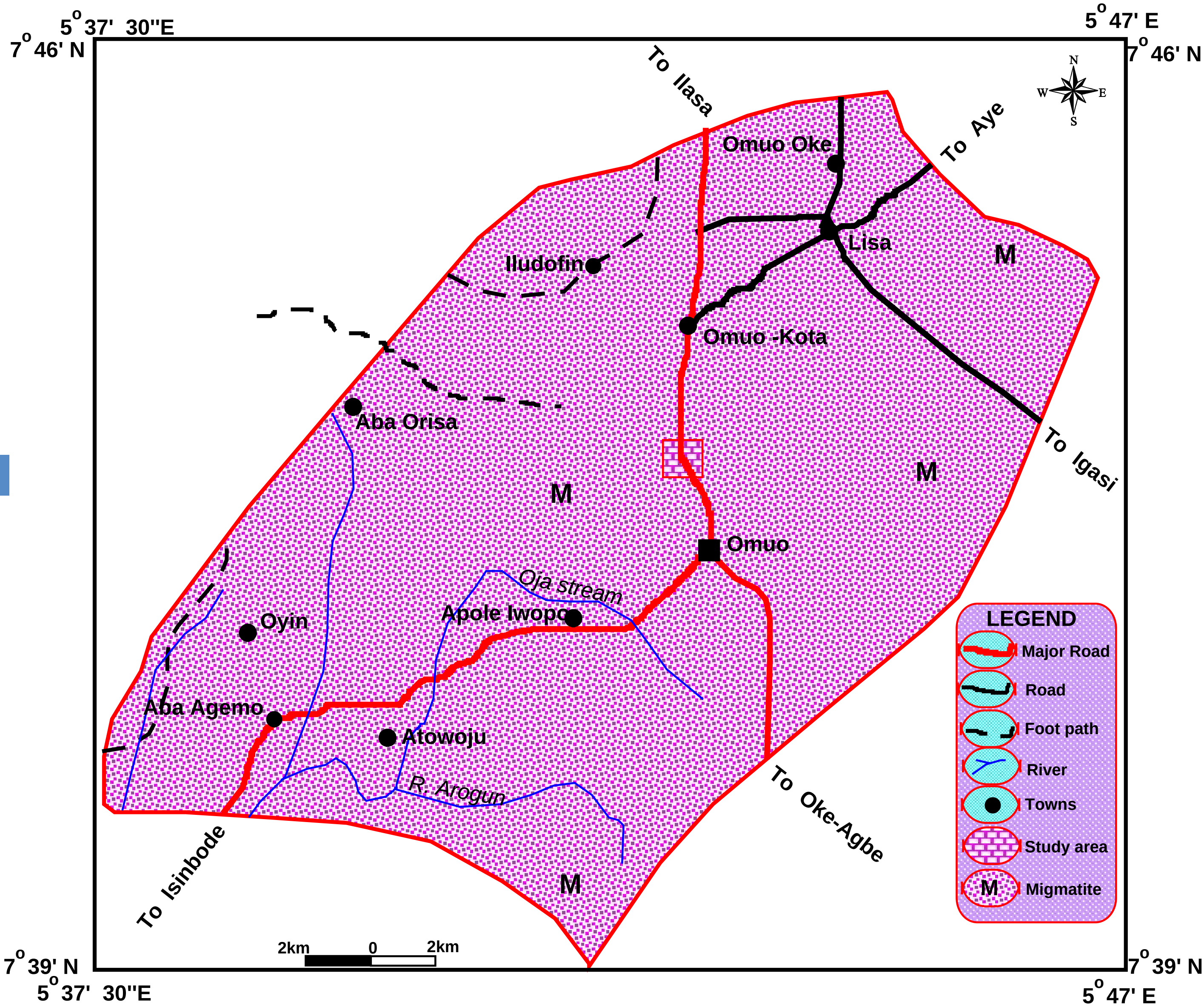

Figure 2 : Geological Map of Omuo Area (after Malomo; 2006)

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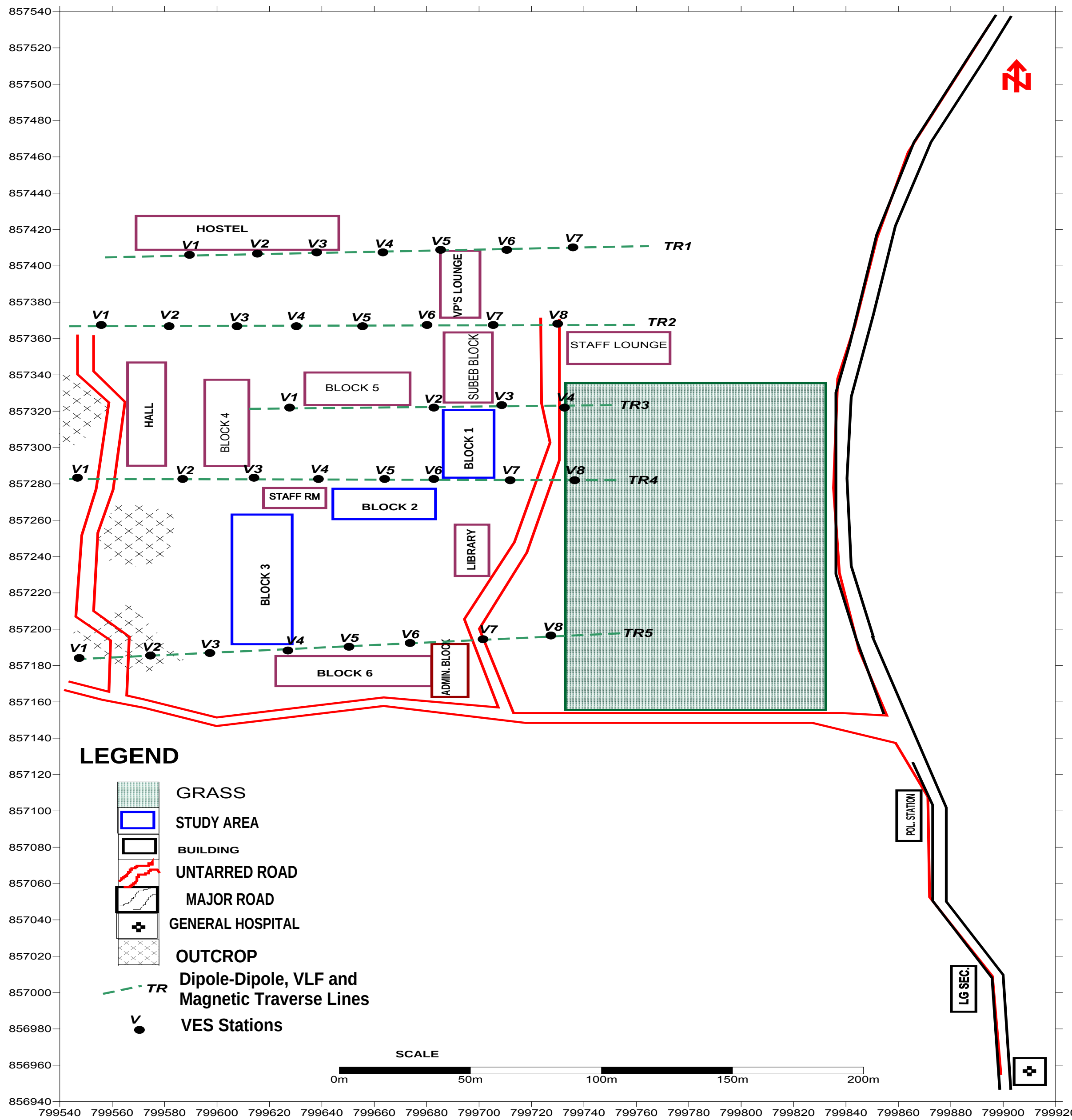

Figure 3 : Data Acquisition Map of the Study Area

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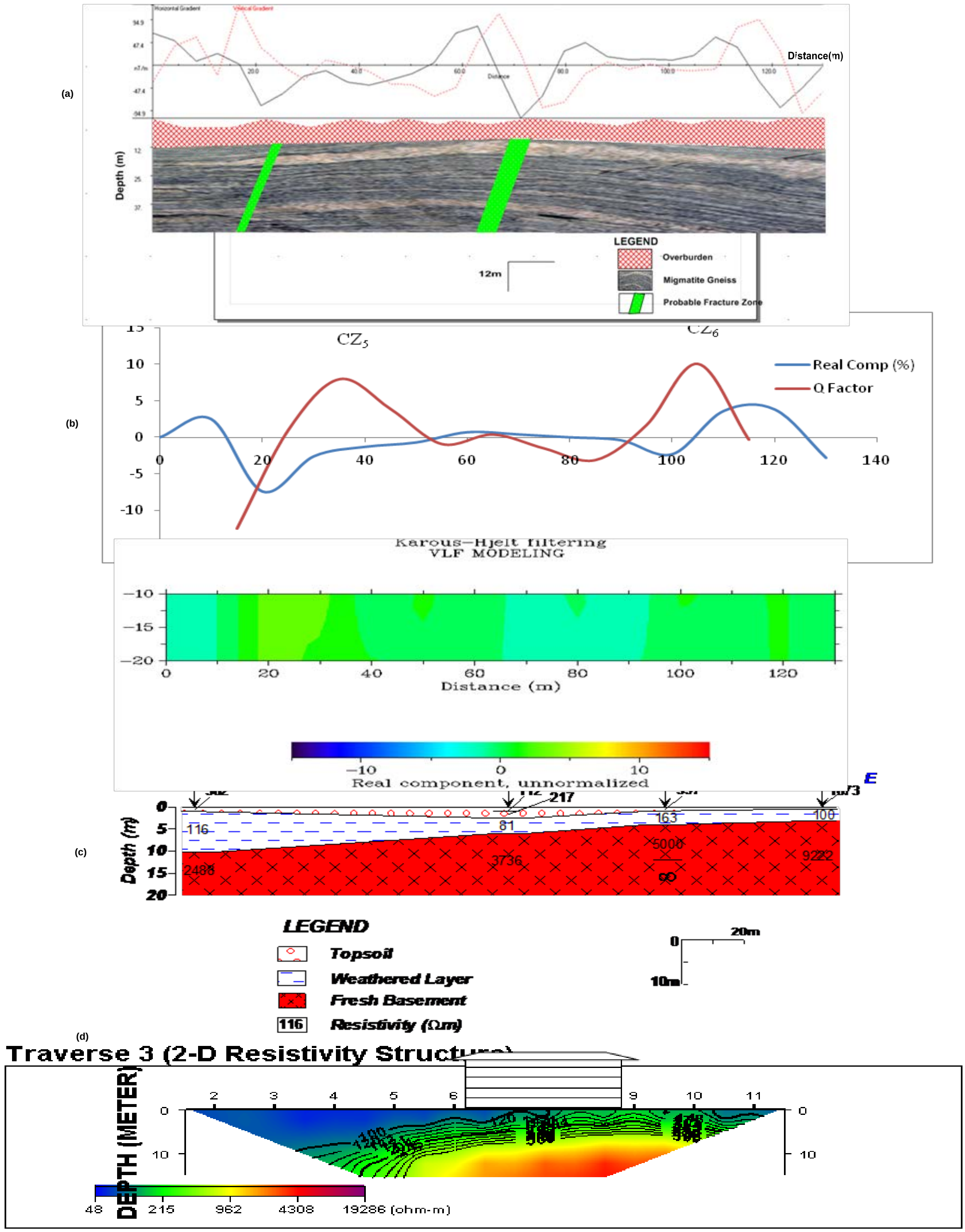

Figure 4 : (a) Ground Magnetic Profile and its Corresponding Geomagnetic Section (b) VLF-EM Profile and its KH Section, (c) Geo-Electric Section and (d) 2-D Resistivity Image along Traverse 3 respectively

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Figure 5 : Showing the Cracks in the Building Named Block 1 Located Along Traverse 3

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(a)

(b)

(c)

(d)

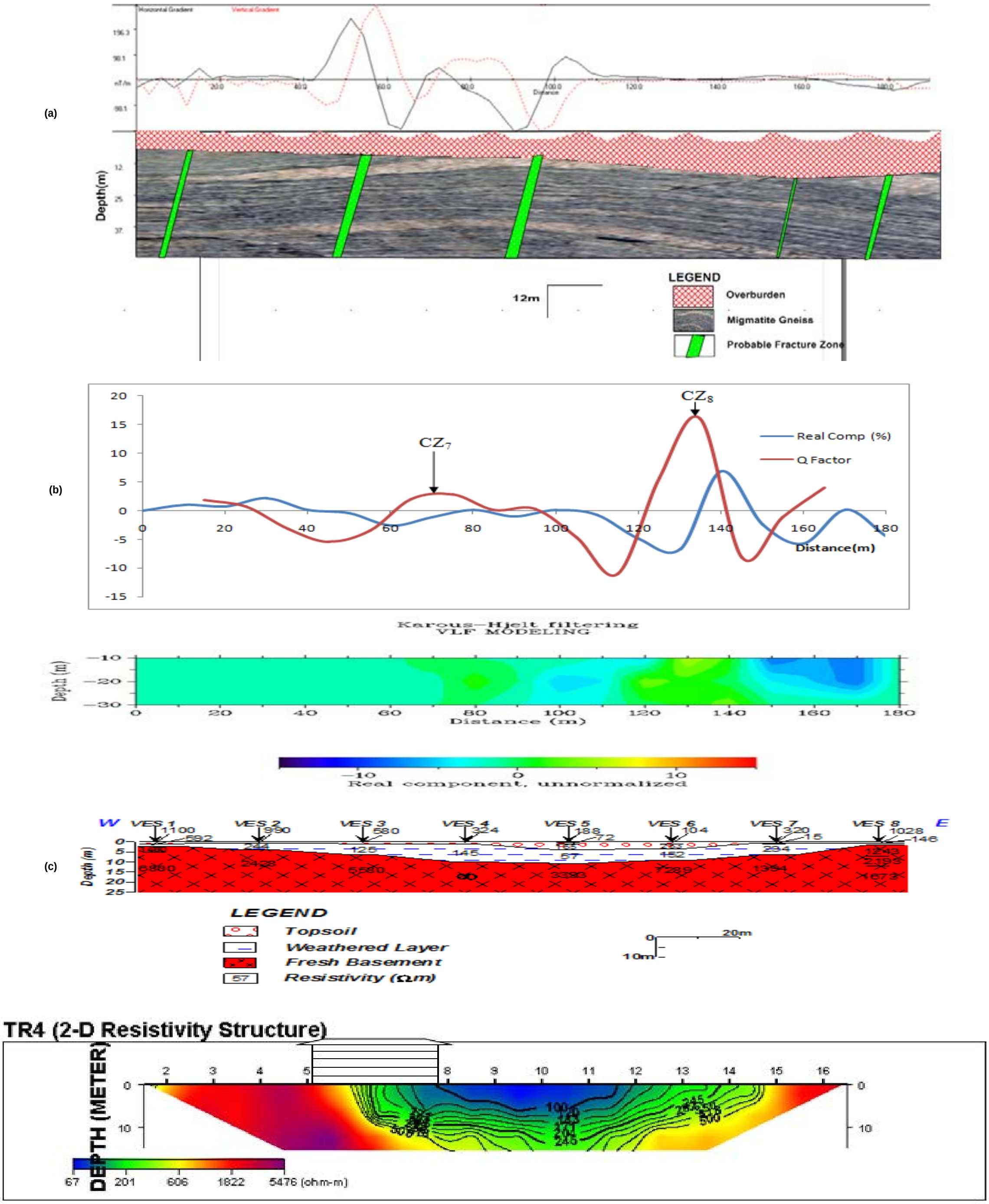

Figure 6 : (a) Ground Magnetic Profile and its Corresponding Geomagnetic Section (b) VLF-EM Profile and its KH Section, (c) Geo-Electric Section and (d) 2-D Resistivity Image along Traverse 4 respectively

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Figure 7 : Showing the Cracks in the Building Named Block 3 Located Along Traverse 4

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