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Geophysical Investigation of Fracture Distribution in the premises of Nigerian Stored Products Research Institute (NSPRI), Ilorin

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Abstract
This work aimed at studying the geological fracture system in the study area. It gives an insight into the proper infrastructural planning such as the location of high-rise buildings, septic tank locations, groundwater exploration, etc. Aeromagnetic and Very Low Frequency (VLF) techniques were employed to investigate fractures within the Nigeria Stored Product Research Institute (NSPRI) premises in Ilorin. A reconnaissance magnetic anomaly map encompassing longitude 4°33'10" - 4°33'30" and latitude 8°27'10" - 8°27'40" was generated from aeromagnetic secondary data collected by the Nigerian Geological Survey Agency (NGSA) via aero-surveys over the Nigeria surface area. Conversion to data format and data processing were accomplished utilizing *Oasis Montaj 6.4.2* 9(HJ) software. Analysis revealed a series of minor fracture signatures and lineament trends with two major northeast-trending fractures, 401 m and 560 m long, in the premises of NSPRI. For confirmation three VLF profiles were run across the major strike of the detected major fractures. The real component signal of the first profile ranges from (-56 to 66 %), second (-18 to 18 %), and third (-12 to 20 %) while the imaginary component signal of the first profile ranges from (-16 to 20 %), second (-27 to 4 %) and the third (-13 to 21 %). Interpretations, using karous-Hjelt filtering software, show real and imaginary crossovers which is a signature of fractures on these three profiles. This confirmed the two prominent fractures earlier detected. In conclusion, the area shows that there are minor fractures in the NW - SE and SW - NE directions and two major fractures are in the direction of NW - SE direction and VLF-EM survey confirms the presence of the two major fractures detected in the area.

Keywords: NSPRI; Aeromagnetics; VLF-EM; Fracture; Real and Imaginary components

1. Introduction

The geophysical survey involves investigating the physical properties of rocks for information on mineral deposits, groundwater, and geological structures, and to map landfill site boundaries, fill thickness, and fluid flow direction, to mention a few. Geophysical methods include gravity, magnetic, seismic, radiometric, and electrical techniques (Telford et al 2004; Kearey et al; and Dobrin et al., 1988). These techniques can use natural fields within the Earth or require the introduction of artificial fields. Analyzing these measurements reveals variations in the Earth's interior's physical properties both vertically and laterally (Meju, 2000; Benson et al., 1997). This work involves using geophysical techniques to investigate geological structures beneath the Earth's surface through a study called "Fracture Distribution Studies." These studies typically involve investigating trends and signatures of fractures within the subsurface. Fracture distribution can be studied both geologically and geophysically. Geophysical methods are advantageous as they allow for subsurface investigation without excavation, which can be costly and disruptive.

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For this research, the Aeromagnetic and Very Low Frequency Electromagnetic (VLF-EM) methods are applied to investigate fracture distribution. VLF-EM is a sophisticated technique employed in geotechnical engineering, borehole engineering, and construction to assess subsurface fractures (Olatunji, S. 2012). This method involves measuring magnetic susceptibility and conductivity to gather valuable data about fracture trends and signatures. Understanding the complexity and significance of this method is crucial for ensuring the safety and longevity of various construction projects, including buildings, bridges, dams, and infrastructure developments.

This work aimed at the Geophysical investigation of fracture distribution in other to give an insight into the proper infrastructural planning such as the location of high-rise buildings, septic tank location, and groundwater exploration, in the Nigerian Stored Product Research Institute via the application of geophysical methods. Consequently, the identified magnetic anomaly distribution and fracture distribution were confirmed using VLF-EM ground-truthing. The conductive subsurface areas that could be detrimental to the foundation of the buildings but could be suitable for groundwater exploitation were identified from the 2D models from the VLF-EM data.

Study Location

The study location is NSPRI premise, a research institute situated at Wara-Osin Egbejila ward in the southern flank of the Ilorin West local government area of Kwara State, Nigeria. The survey lies between longitude 4°33'10" - 4°33'30" and latitude 8°27'10" - 8°27'40" (Figure 1).

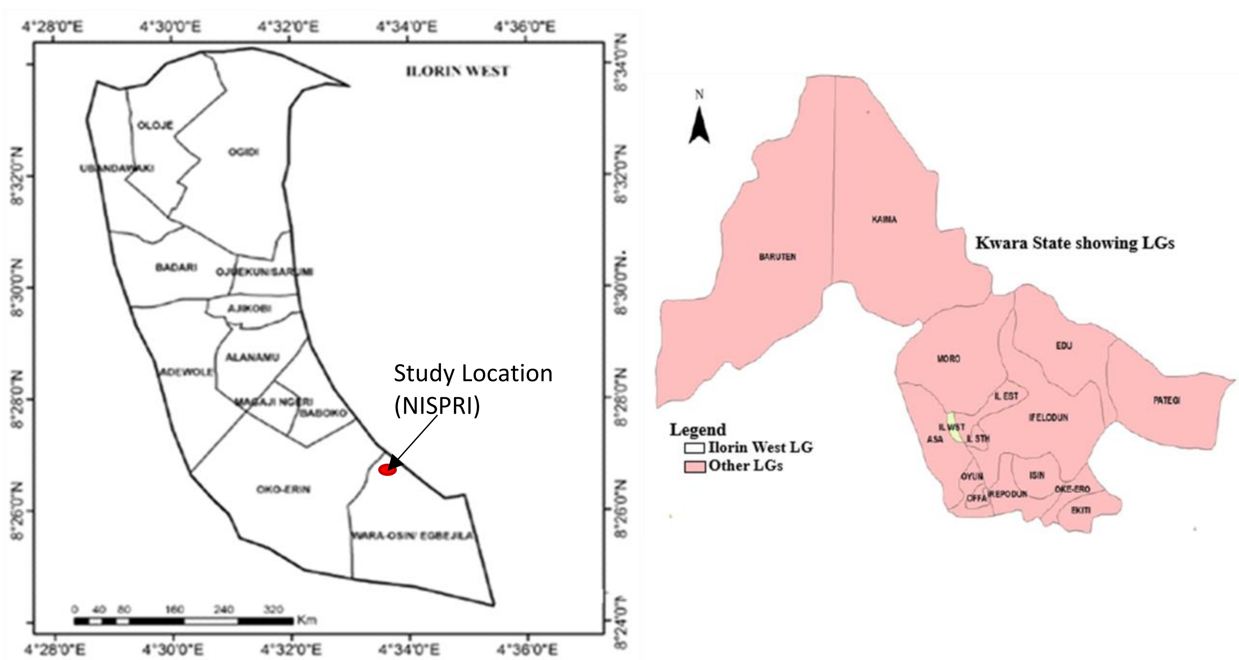


Figure 1: Study Area

2. Material and Methods

Geophysical investigation of fracture distribution in the premise of the Nigerian Stored Product Research Institute (NSPRI) employed the use of Aeromagnetic and VLF-EM techniques. Also, various equipment and materials were used for the collection of data from different locations in the study area and these materials correspond to the geophysical methods that are to be applied.

Materials

High-resolution aeromagnetic data acquired using Scrintrex CS3 Cesium Vapour Magnetometer and processed by Furgo Airborne was obtained from the Nigeria Geological Survey Agency in 2019 (MMSD, 2019). The data were systematically obtained using a Scintrex CS3 Cesium vapour magnetometer, which is highly sensitive and measures in the of pT (1Pt = 0.001 nT) in a 1 Hz measuring bandwidth, with a sensitivity that does not decline when the detected ambient field drops. Fixed-wing (Cessna) aircraft conducted the aeromagnetic survey, which covered a total of 235,000 line kilometres with a flight spacing of 200 meters and terrain clearance of 80 meters. The flight direction was NW-SE (135) with a flight-line spacing of 200 meters and a tie-line direction of NE-SE (45) (Olawumi et al., 2021).

The equipment used in this study is a VLF receiver known as EM-16R. It is an analogue instrument built by a Canadian company that has access to military-owned transmitters with the use of microchips. The code on the chip used in this study is encrypted NAA 24KHz. EM-16R is a small hand-held device incorporating two orthogonal aerials that can be tuned to the particular frequencies of the transmitters (Olsson 1. 2013; Michael et al. 2013). Part of the EM-16R receiver includes; an inclinometer used in measuring the in-phase components having a graduated scale of -150 to +150 and a quad dial used in measuring the out-phase components having a graduated scale of -44 to +44. Other supporting instruments include a tape rule for distance measurement and a Global Positioning System (GPS) for reading coordinates.

Methods

The aeromagnetic survey is one of the common types of geophysical survey carried out using a magnetometer aboard or towed behind an aircraft. The principle is similar to that of magnetic survey carried out with a hand-held magnetometer, but allows much larger areas of the earth's surface to be covered quickly for regional reconnaissance. The aircraft typically flies in a grid-like pattern with height and line spacing determining the resolution of the data and the survey of the cost per unit area (Olawumi et al., 2021). Surveys along profiles or grids determine the strength of the geomagnetic field at particular points by measuring spatial variation in the Earth's magnetic field (Onwuemesi, 1995). As the aircraft flies, the magnetometer records any variations in the intensity of the ambient magnetic field due to the temporal effects of the constantly varying solar wind and spatial variations in the earth's magnetic field; the latter being due to both the regional magnetic fields and the local effects of magnetic minerals in the earth's crust. By subtracting the solar and regional effects, the resulting aeromagnetic map gives the magnetic anomalies due to the fracture distribution in the upper levels of the crust. Ofoegbu (1988) and Salawu et al (2019) reported that roughly about 60 per cent of magnetic surveys are carried out for regional geological mapping and mineral exploration.

The Very Low Frequency Electromagnetic (VLF-EM) technique is a geophysical method used to investigate subsurface structures and map conductivity variations (Fraser, 1989). This technique, according to Micheal et al (2013); and Olatunji and Fauzan (2022), involves measuring the electromagnetic signals that are present in the subsurface due to the interaction of the Earth's magnetic field with the electrical current in the ionosphere. Powerful VLF transmitters worldwide emit continuous electromagnetic waves with frequencies typically ranging from 15 Hz to 30 kHz (Roy, K.K. 2020). These signals propagate through the Earth's atmosphere and penetrate the subsurface. When the VLF signal encounters conductive materials underground, it induces electrical currents (eddy currents) within them. The strength of these induced currents depends on the electrical conductivity of the subsurface materials, such as rocks, minerals, and water-bearing formations. These eddy currents generate secondary magnetic fields that interact with the primary VLF signal, causing detectable variations in the amplitude and phase of the received VLF signal at the Earth's surface (Salami, N.B et al., 2019).

3. Results and Discussion

Typically field models generated from the processed Aeromagnetic and VLF-EM Data obtained in the area are shown in Figures 2,3,4 and 5.

3.1 Aeromagnetic Results

The model in Figure 2, is from an Aeromagnetic Data sheet that was processed using *Oasis Montaj*. This model shows salient features that interest us. One of the features is the variations in magnetic anomaly denoted by the legend beside. It is seen above that the point of high closure ranges from light purple to light yellow and low closure ranges from light green to deep blue. The lineaments in Figure 3 are obtained using the central exploration target. The point of low anomaly contains minor fractures in which 57% trends NW-SE and 43% trends NE-SW. Also, the point of high magnetic anomaly tends to have two prominent Fractures which are called the MAJOR FRACTURE. These two major magnetic anomalies range from 0.76 nT to 1.29 nT. The reason behind the two prominent fractures is likely because of the high magnetic anomaly in that region.

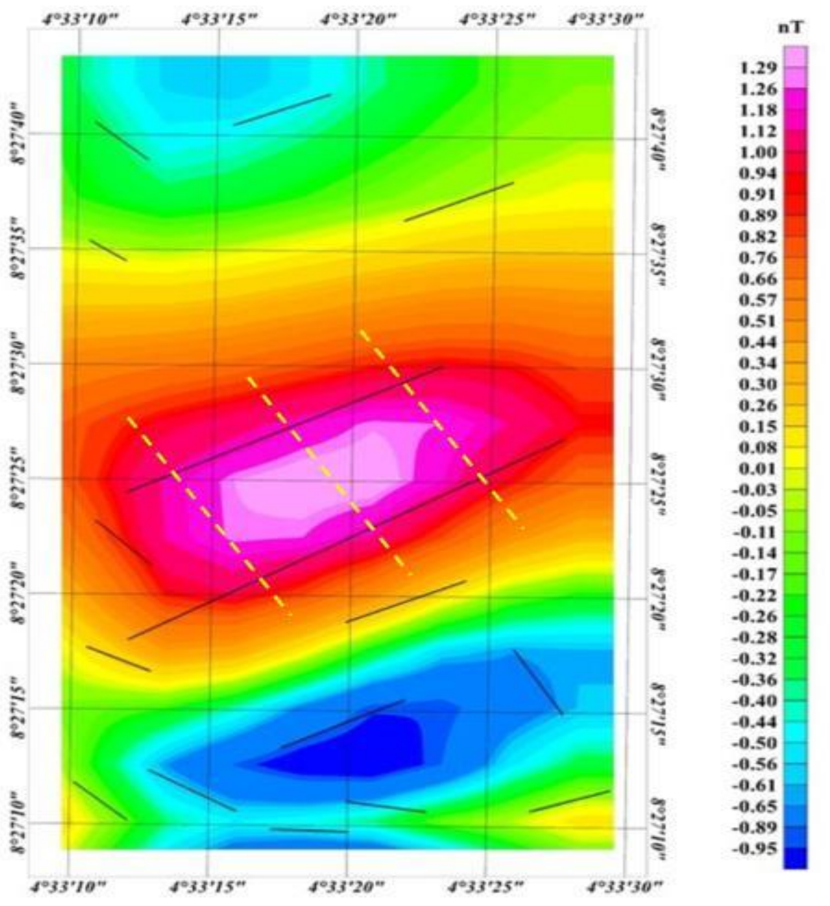
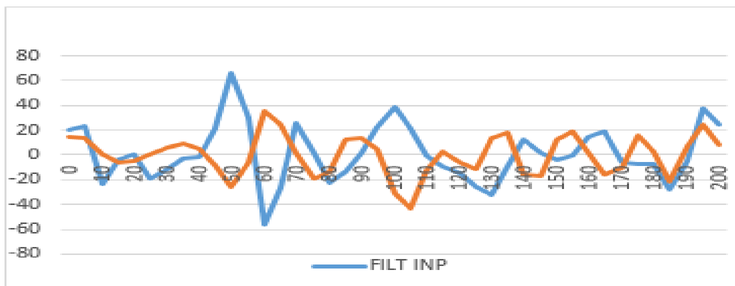


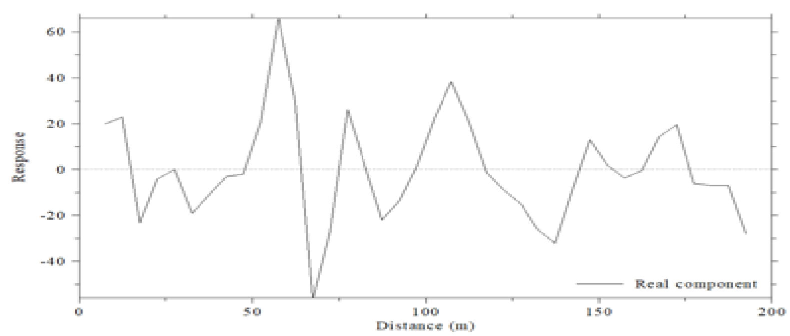
Figure 2: Residual Intensity Anomaly Distribution

3.2 VLF-EM Results

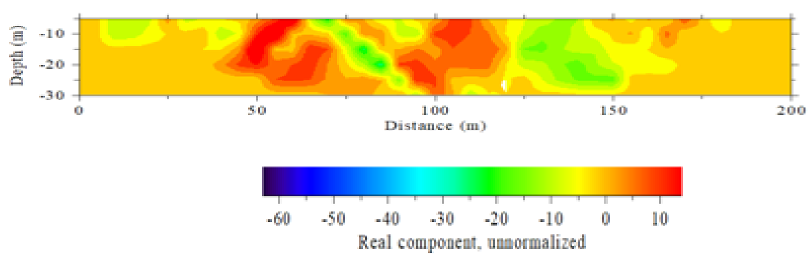
Figure 3 displays three different models obtained for VLF-EM profile 1. The first model, processed using Excel, contains FILTERED in-phase and out-of-phase data plotted against location numbers, indicating a one-dimensional (1D) perspective. This filtering was done using FRAZER FILTERING TECHNIQUES. The crossover points, or intersections at locations 5 m, 14 m, 42 m, 58 m, 70 m, 80 m, 92 m, 111 m, 138 m, 145 m, 160 m, and 170 m, suggest fracture zones. The positive peaks of the FILTERED in-phase data, represented by the blue legend, indicate conductive zones located at locations 50 m, 71 m, and 100 m. The second model, also in 1D, was processed using Karous Hjelt filtering software. This model shows in-phase values similar to those in the Excel model, with both indicating the same conductive zones at the same location. Complementing these 1D images, there is a two-dimensional (2D) model, also processed using Karous Hjelt filtering software. The 2D model (Figure 3c) provides more detailed information about the location, legends, and depths of the fracture and conductive zones, as shown in Table 1.



a. Filtered real and filtered imaginary



b. Frazer Filter in-phase plot



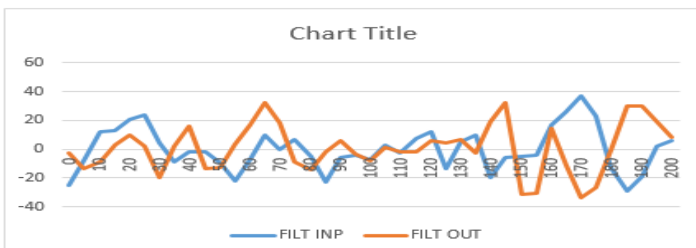
c. 2D cross-section equivalence of VLF response

Figure 3: Typical VLF-EM Model for Profile 1

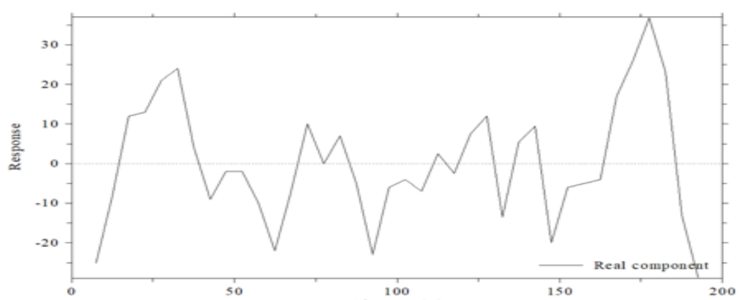
TABLE 1: Summary of 2D Cross-section Equivalence of VLF Response along Profile 1

FRACTURE ZONE	Location (m)	5 -14	40 - 42	68 – 92	125 -165
	Thickness (m)	12	5	28	28
	Legend	Lemon	Lemon	Lemon	Lemon
CONDUCTIVE ZONES	Location (m)	40 -71		90 -115	
	Thickness (m)	28		30	
	Legend	Red		Light Red	

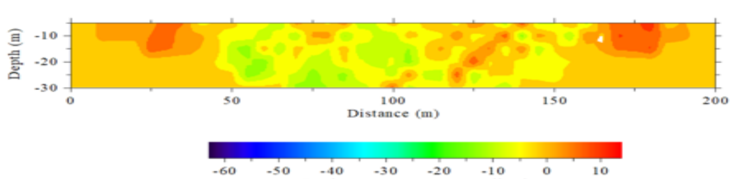
Figure 4 displays three different models for VLF-EM on profile 2. The first model, processed using Excel, contains FILTERED in-phase and out-of-phase data plotted against location numbers, indicating a one-dimensional (1D) perspective. The crossover points, or intersections at locations 32 m, 45 m, 75 m, 122 m,128 m, 148 m, and 180 m suggest fracture zones. The positive peaks of the FILTERED in-phase data, represented by the blue legend, indicate conductive zones located at locations 25 m and 174 m. The second model, also in 1D, was processed using Karous Hjelt filtering software. This model shows FILTERED in-phase values similar to those in the Excel model, with both indicating the same conductive zones at the same locations. Complementing these 1D images, there is a two-dimensional (2D) model, also processed using Karous Hjelt filtering software. The 2D model (Figure 4c) provides more detailed information about the location, legends, and depths of the fracture and conductive zones, as shown in Table 2.



a. Filtered real and filtered imaginary



b. Frazer Filter in-phase plot



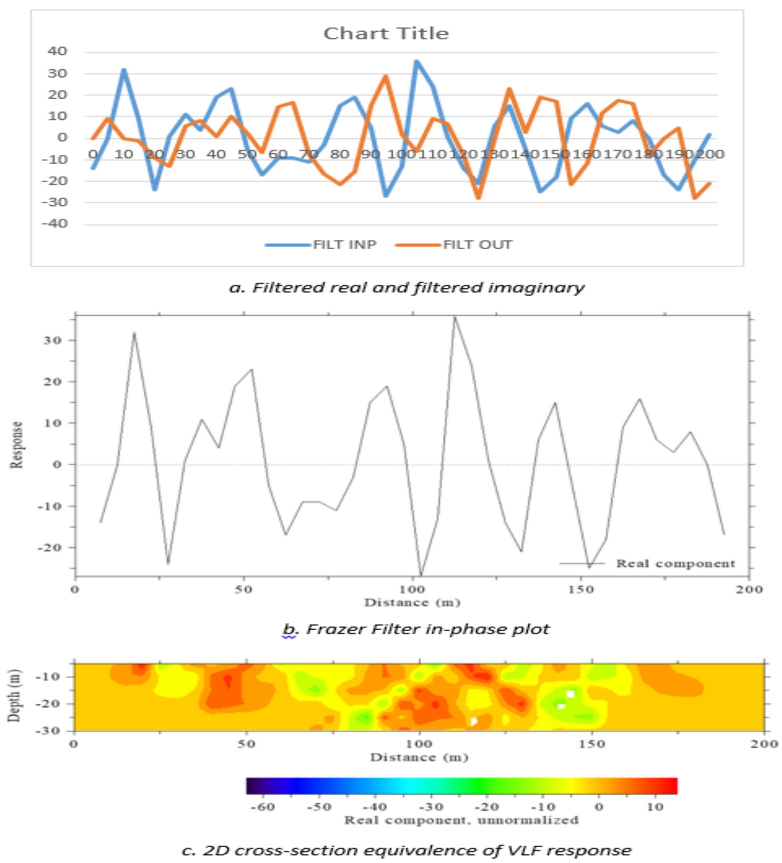
c. 2D cross-section equivalence of VLF response

Figure 4: Typical VLF-EM Model for Profile 2

TABLE 2: Summary of 2D Cross-section Equivalence of VLF Response along Profile 2

FRACTURE ZONE	Location (m)	50 - 62	68 - 91	80 -107
	Thickness (m)	27	15	28
	Legend	Lemon	Lemon	Lemon
CONDUCTIVE ZONES	Location (m)	25 - 30		162 -170
	Thickness (m)	18		19
	Legend	Light Red		Light Red

VLF-EM results for profile 3 are shown in Figure 5. The first model, processed using Excel, contains FILTERED in-phase and out-of-phase data plotted against location numbers, indicating a one-dimensional (1D) perspective. The crossover points, or intersections at locations 25 m and 174 m, suggest fracture zones, Olatunji, S. (2012). The positive peaks of the in-phase data, represented by the blue legend, indicate conductive zones located at locations 10 m, 45 m, 85 m, and 120 m. The second model, also in 1D, was processed using Karous Hjelt filtering software. This model shows FILTERED in-phase values similar to those in the Excel model, with both indicating the same conductive zones at the same locations. Complementing these 1D images, there is a two-dimensional (2D) model, also processed using Karous Hjelt filtering software. The 2D model (Figure 5c) provides more detailed information about the location, legends, and depths of the fracture and conductive zones, as shown in Table 3.



a. Filtered real and filtered imaginary

b. Frazer Filter in-phase plot

c. 2D cross-section equivalence of VLF response

Figure 5: Typical Vlf-EM Model for Profile 3

TABLE 3: Summary of 2D Cross-section Equivalence of VLF Response along Profile 3

FRACTURE ZONE	Location (m)	65 -70	77 - 84	125 -130	135 -152
	Thickness (m)	10	8	6	12
	Legend	Lemon	Lemon	Lemon	Lemon
CONDUCTIVE ZONES	Location (m)	22	45	78 -90	120
	Thickness (m)	2	5	20	7
	Legend	Red	Red	Light Red	Light Red

4. Conclusion

Subsurface fracture distribution plays crucial roles in the area of infrastructural development such as high-rise buildings, sewage system location groundwater exploration and so forth. The work was tailored towards the estimation of fracture distribution using magnetic and electrical geophysical techniques. The results show that minor and major fractures are present in the area. The minor fracture distribution is that 57% trend NW-SE and 43% trends NE-SW and coincide with magnetic anomaly low ranging from 0.08 - 0.95 nT in the area. Also, the point of high magnetic anomaly range of 0.76 - 1.29 nT coincides with two prominent major fractures trending NE-SW at the central part of the area.

The VLF-EM profiles taken across the strikes of the major fractures acted as ground truthing for confirmation. There are a series of inphase/outphase crossover points indicating possible multiple fractures as detected with magnetic results. Further, the prominent crossovers matched with the locations of the major fractures detected in the magnetic results. The Frazer's filtered responses confirmed some conductive fractured points in the subsurface.

In conclusion, as the fracture-prone areas could be inimical to high-rise structures and sewage locations, the conductive fracture zones stand a better chance of groundwater exploration and exploitation in the study area.

Reference

Dobrin M.B. and Savit, C.H., (1988): Introduction to geophysical prospecting. Fourth Edition, McGraw-Hill Book Co.

Fraser, D. C., (1989). Contouring of VLF –EM Data, Geophysics. Vol. 54. No.2. P.245-253

Kearey P., Brooks M., and Hill I., (2002): An Introduction to Geophysical Exploration. Third Edition, Blackwell Science Ltd.

Michael G.A., Abong A.A. and Obi D.A. (2013). Fracture zone detection using very low frequency (VLF) electromagnetic method in part of Oban Massif, Southern Nigeria. Adv. Appl. Sci. Res., 4(6): 104-121

Ofoegbu, C. O. (1988). An aeromagnetic study of part of the Upper Benue Trough, Nigeria. Journal of African Earth Science. 7. Pp. 77-90

Olatunji S, Fauzan A. O. (2022). Geophysical assessment of groundwater contaminations from leachate intrusion in Amoyo dumpsite. J. Fundam. Appl. Sci., 2022, 14(1), 181-209.

Olawumi, H.B., Olatunji, S. Jimoh, A. Abubakar H.O. (2021) Aeromagnetic and Resistivity Tomography Technique for Investigating Leakage Paths In apodu Dam, Ilorin Sheet 201, Southwestern Nigeria. The Nexus (Science Edition). 1(1); 24-29

Olatunji, S. (2012). Electromagnetic Characterization of the Fracture System Within Older Granite of North Central Nigeria; Science Focus. 17. 2328-2334

Olsson, L. (2013). Mapping of fracture zones using the very low frequency (VLF) Method in Änggårdsbergen, Gothenburg https://www.academia.edu/7182383/Mapping_of_fracture_zones_using_the_very_low_frequency_VLF_method_in

Onwuemesi, A. G. (1995). Interpretation of magnetic anomalies from the Anambra Basin of Southeastern Nigeria. Ph. D. Thesis, Nnamdi Azikiwe University, Awka. Anambra State. Pp, 12-55

Roy, K. K. (2020): Natural Electromagnetic Fields in Pure and Applied Geophysics. Springer

Salawu, N.B., Olatunji, S., Adebiyi, L.S. *Olasunkanmi, N. K., Dada, S. S. (2019)* Edge detection and magnetic basement depth of Danko area, northwestern Nigeria, from low-latitude aeromagnetic anomaly data. *SN Appl. Sci.* **1**, 1056. https://doi.org/10.1007/s42452-019-1090-3

Telford WM, Geldart LP and Sheriff RE 2004 Applied Geophysics, 2nd edn. Cambridge University Press, Cambridge