



An Integrated Aeromagnetic and Resistivity Investigation of Groundwater in Tarauni Local Government Area, Kano State, Nigeria



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ABSTRACT

The study assess the intense issue of groundwater potential in Tarauni, Kano state Nigeria with a focus on indicators of groundwater that show its presence. The research deploys two geophysical techniques; Aeromagnetic method and Vertical Electrical Sounding [VES] Techniques; Sheet 81 of Aeromagnetic data was acquired from Nigerian Geological Survey Agency [NGSA]. The Vertical Electrical Sounding was taken at 30 different locations of the study area. The aeromagnetic data is processed and interpreted using Oasis Montaj and ARCGIS softwares, and the results of the Aeromagnetic data analysis were used to outline six maps: Total Magnetic Intensity, Residual, First Vertical Derivative, Lineament, Rose diagram, Source Parameter Imaging map, in which six major lineament orientations were revealed. The major lineament trends directions are: N-S, NE-SW, ENE-WSW, WNW-ESE directions. Minor trends directions were also revealed which are: NW-SE and NNE-SSW. The lineament which shows fault or fold were used to indicate groundwater presence in the study area. The resistivity data from Vertical Electrical Sounding were interpreted using IP2WIN software which indicates three-four layers with distinct resistivity values, depth and thickness. The first layer is sandy clay soil, second layer is mostly clayey and third layer is a weathered basement, and in some VES points fourth layer is the weathered basement which has good groundwater potentials. VES4, VES16, VES17, VES18, VES19, VES20, VES21, VES25, VES26, VES27, VES29, VES30 have the best aquifer and hence recommended as suitable points for groundwater exploration. The study shows a good relationship between aeromagnetic indicators of groundwater and vertical electrical sounding indicators which underscores the significance of the geological structures as groundwater pathways.

Keywords:

Aeromagnetic,
Resistivity,
Groundwater.

INTRODUCTION

Findings from a published study indicate that a substantial proportion of households in Kano metropolis experience severe water scarcity, despite considerable government investment in water supply projects. Consequently, many residents depend on alternative sources such as domestic water vendors, rainwater harvesting, boreholes, and hand-dug wells. However, these sources are often characterized by inadequate hygienic practices, posing potential health risks (Auwal, 2021). This situation highlights the pressing need for improved water resource management, better infrastructure development, and effective service delivery systems to ensure consistent access to safe and reliable water for all residents (Auwal, 2021).

Globally, about 2.2 billion people continue to face challenges in accessing safe drinking water. The availability of water alone is insufficient; it must also meet standards of safety, accessibility, and affordability. Safe drinking water should originate from protected sources such as wells, taps, or hand pumps, and must be free from pathogens and harmful chemical substances. In addition, it should be accessible for at least 12 hours daily and located within or near households. In many regions, the responsibility of water collection falls primarily on women and children, exposing them to physical strain, safety concerns, and other vulnerabilities (WHO, 2022). Water scarcity is particularly pronounced in developing countries, where approximately 67% of the rural population lacks access to safe water supply.

In such settings, groundwater represents a widely utilized and dependable resource. It is especially critical in arid and semi-arid regions, where it often serves as the only reliable source of water. Despite its importance, groundwater recharge is difficult to quantify directly, and long-term data on recharge and discharge processes remain limited (WHO, 2022).

Groundwater therefore remains one of the most essential and reliable water sources for various human activities, including domestic consumption, agriculture, and industrial operations (Yar, 2020). Its sustainable management is crucial for addressing ongoing water scarcity challenges and ensuring long-term water security.

Its needs is expected to grow considerably in the near future, as it is safe and desired for its quality drinking water resource. When utilised reasonably and sustainably, groundwater would make a significant contribution to solving the study area water crises. With the increase in population, industrialization, and agricultural growth, the needs for portable and safe drinking water is expected to grow exponentially.

In developing countries, the availability of potable water has become a critical and urgent problem, and it is a matter of great concern for both urban and rural communities. About 80% of all diseases in Kano are

caused by unsafe water and poor sanitation. Water resources in Kano play a central role in promoting living standards, enhancing economic growth, providing food security and livelihoods, and alleviating poverty. Like most parts of the world, Nigeria is experiencing population growth and an associated increase in demand for food production. Consequently, the rising demand for water places stress on available water resources.

Since groundwater cannot be easily located, a variety of scientific techniques are needed to provide information concerning its occurrence and location. Techniques such as geophysical surveys, remote sensing, and hydrogeological mapping are essential for identifying potential groundwater reserves. The use of these advanced methods can help in planning and managing groundwater resources more effectively, ensuring a sustainable supply for future generations.

Sustainable groundwater management is vital for ensuring long-term water availability and quality, which is key to the well-being of communities in Kano State and beyond. Effective management strategies should focus on several critical areas:

Study Area

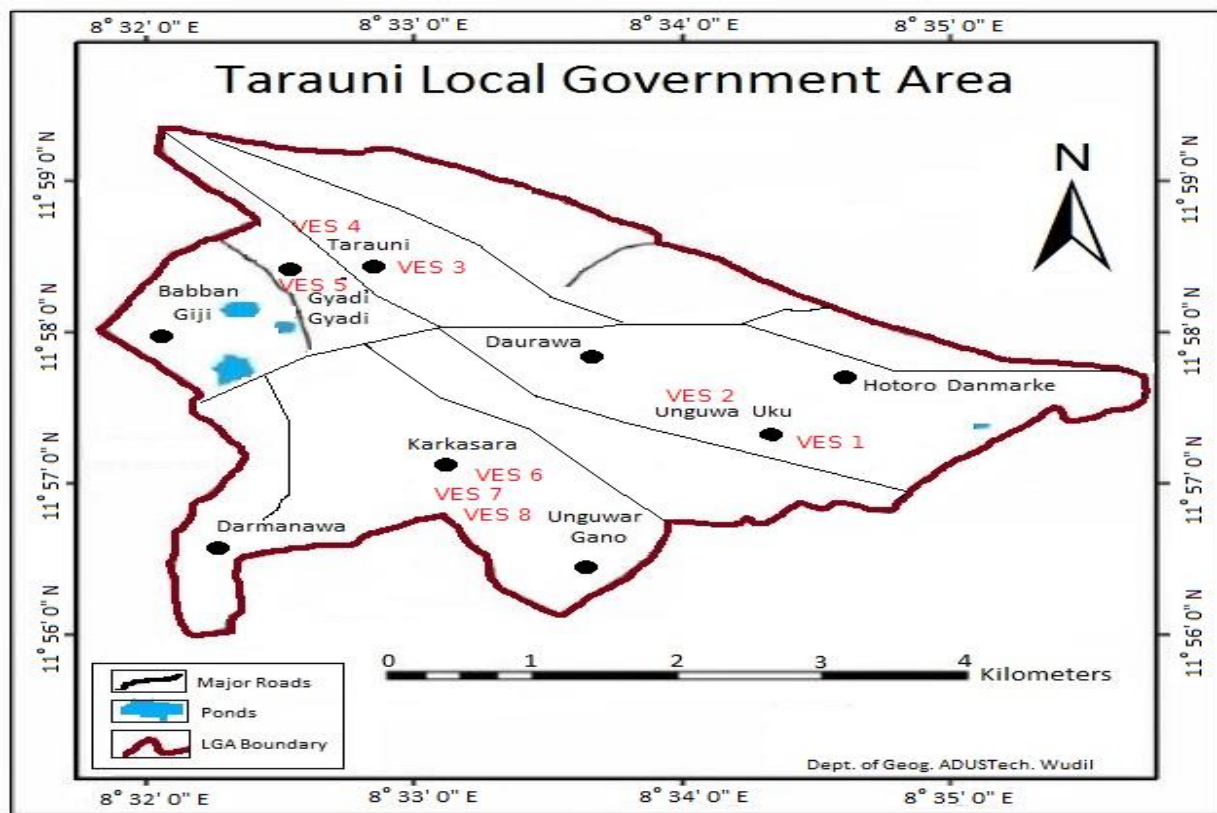


Figure 1: Geographical Map of Tarauni with VES points. (Department of Geography ADUSTech. Wudil, 2024)

Geophysical surveys employing aeromagnetic and resistivity methods have significantly contributed to understanding the geological and hydrogeological characteristics of Kano, Nigeria. This literature reviews examines recent studies that have utilized this methods, highlighting their applications, findings and implications for resource assessment and environmental management. Aeromagnetic surveys have been instrumental in mapping subsurface geological structures and identifying groundwater potential resources in Nigeria. For example, a study by (Aroyehun, 2022)

The study was conducted to investigate the causes of reported borehole failure in parts of the Federal Polytechnic Ado Campus using the aeromagnetic geophysical method. The geophysical data were processed to enhance shallow anomalies through various enhancement techniques, including derivatives, continuation, analytic, and wavelength filters. It was observed that the rocks underlying the area possess similar magnetic susceptibility; hence, the Earth's magnetic response is mainly controlled by sediment thickness (depth to basement) and suspected linear structures. The probable depth to the magnetic basement within the study area was found to range from 8 m to 74 m, as revealed by analytic depth and radial spectrum depth methods, and this result is consistent with previous geophysical studies in the area. The northern part of the study area is characterized by a shallower basement depth of 8–24 m, while the southern part is characterized by a deeper basement ranging from 30–74 m. Linear structures such as lineaments, faults, and fractures were found to be evenly distributed across the study area; however, higher groundwater potential is associated with the southern part of the area. Consequently, future campus development is recommended to be focused on the southern part of the study area to accommodate the increasing student population. Overall, it can be deduced that basement depth and linear structures are the major factors controlling groundwater potential within the Nigerian Basement Complex.

Olasunkanmi, 2020, studied the boundaries of magnetic units, depth to magnetic sources, lithologic unit geometry and associated structural features of Kaoje and its surroundings through the interpretation of high resolution aeromagnetic survey and geologic field mapping. He concluded that magnetization of the iron ore originate from magmatic bodies beneath the sedimentary rocks which formed the corresponding spherical geologic model within the northwest and southwest of the study area at depth ranging from 0 to 225m. The structural analysis of the magnetic data was crucial in identifying zones of potential faults for groundwater accumulation. Resistivity surveys have also played a crucial role in assessing groundwater potential resources and environmental implication in Kano. In the study by Rilwanu, 2019 who employed electrical resistivity

method to characterized aquifer system and evaluate groundwater potentials in the study area. The findings underscored the importance of resistivity survey in delineating subsurface lithological variations and assessing groundwater quality and quantity.

A study by Muhammad, 2016, indicated a direct correlation between water supply and hydrogeological characteristics of his study locations. He identified areas featuring a water table ranging from 456 to 507m.

Integrated geophysical techniques combining both aeromagnetic and resistivity method have provided comprehensive insights into Kano geological and hydrogeological settings. Research by Akinbulejo, 2022 using integrated aeromagnetic and resistivity data mapped the geological structure of the study area and identified sustainable groundwater zones in the study region.

Abdou Raouf, in 2023. delineate the subsurface structures and hydrogeological features of the hard rock aquifers in the Adamawa region by using an integrated approach comprising remote sensing aeromagnetic, and vertical electrical sounding application. This work was a good point that the two method can be used to study the groundwater potential of an area.

Leonard O. Ohenhen, in 2023. used multiple geophysical methods such as electrical resistivity and 2-D seismic reflection with borehole data, able to provide a robust interpretation of weathered basement aquifers and potential target zones for groundwater exploration, in tropical and inter-tropical environments. It was found out that strong correlations between the independent datasets, allowed to identify the four commonly known layers of the basement weathering profile.

MATERIALS AND METHODS

The sheet 81 of aeromagnetic data was obtained from National Geological Survey Agency, Abuja. The survey was conducted in three phases between 2005 and 2010 under a major project titled Sustainable Management for Mineral Resources, implemented through FUGRO Airborne Surveys. Data acquisition was carried out along a network of northeast–southwest (NE–SW) oriented flight lines, spaced at 500m intervals, with an average 9° elevation of approximately 152m above ground level.

The dataset for Tarauni Local Government Area (L.G.A) was extracted from Wudil Sheet 81 and recorded in a digitized format as X, Y, Z text files. Prior to analysis, the raw magnetic data were corrected by removing the geomagnetic gradient using the International Geomagnetic Reference Field (IGRF) model for 2010, with a reference intensity value of 33,095 nT (nanotesla). The average magnetic inclination across the survey area

varies from about 9° in the northern part to approximately 0° in the southern part.

In the dataset, the X and Y coordinates represent the longitude and latitude of the study area in meters, respectively, while the Z values correspond to the measured magnetic field intensity expressed in nanotesla.

Interpretation of Aeromagnetic Anomalies

In geophysical data analysis, derivatives of gridded datasets are commonly employed to enhance high wave-number components of the magnetic field, effectively emphasizing shallow subsurface features while attenuating long-wavelength anomalies associated with deeper sources. The application of higher-order derivatives can further amplify these near-surface responses. However, due to issues related to noise amplification and interpretational reliability, analysis is typically limited to the first vertical derivative (FVD) and the second vertical derivative (SVD).

Beyond vertical derivatives, several other mathematical transformations are utilized as interpretative tools for identifying and delineating magnetic anomalies. One of the most widely used among these is the analytic signal amplitude (AS), which is expressed as follows (Whitehead, 2008):

$$\text{Analytic Signal} \\ (\text{AS})(x,y) = \sqrt{\left(\frac{\delta T}{\delta x}\right)^2 + \left(\frac{\delta y}{\delta y}\right)^2 + \left(\frac{\delta z}{\delta z}\right)^2} \quad (1)$$

With T measured field, AS is analytic signal amplitude and x,y,z are the positions at which the total field T is measured while $\frac{\delta T}{\delta x}$, $\frac{\delta T}{\delta y}$ are the horizontal derivatives and $\frac{\delta T}{\delta z}$ is the vertical derivative of T.

The analytic signal is used to locate the edges of magnetic source bodies, particularly where remanence and low magnetic latitude complicate interpretation. Another tool suitable in enhancing the mapping of shallow structures is called Tilt Derivatives, TDR (whitehead, 2008) defined as; (Whitehead, 2008)

$$TDR = \arctan\left(\frac{VDR}{THDR}\right) \quad (2)$$

Where VDR and THDR are respectively the first vertical and total horizontal derivatives of the total magnetic intensity T, with THDR expressed as;

$$THDR = \sqrt{\left(\frac{\delta T}{\delta x}\right)^2 + \left(\frac{\delta T}{\delta y}\right)^2} \quad (3)$$

These equations were the basis upon which the Oasis Montaj software was used to analyze, filter and process the magnetic data of the study area in order to extract

useful information such as ternary images, and FVD map gives a guides in delineating the lineaments map of the study area.

Aeromagnetic Data Processing Tools

The softwares use to process aeromagnetic data were:

a) Oasis montaj software by Geosoft:

This software, along with its associated extension packages such as Magnetic Map Tools (MAGMAP) and Source Edge Detection (SED) tools, was employed to process, filter, and transform the original Total Magnetic Intensity (TMI) grids into other grid forms.

b) ArcGIS software by ESRI Inc.:

ArcGIS was used to relate and overlay various layers of information, such as geology, and delineate structural features during the interpretation process. This was performed on-screen in ArcMap, and hardcopies of the results were produced directly from the software.

Analysis of Aeromagnetic Data

The analysis of maps derived from aeromagnetic data involved reviewing the maps produced from magnetic anomalies, inspecting hardcopies of the images, and using other relevant data to define several parameters. These parameters included:

i) Boundaries of magnetic units:

Determining the extents of different magnetic units within the study area.

ii) Structural dislocations affecting the morphology of magnetic units:

Identifying and analyzing structural features that disrupt or modify the magnetic units.

iii) Depths and attitudes of magnetic units:

Estimating the depths and orientations of the magnetic units.

Additionally, the interpretation method was able to define further parameters:

iv) Superposition of magnetic units:

Understanding how different magnetic units overlap or intersect each other.

v) Lithological units:

Identifying different types of rock units based on their magnetic properties.

vi) Structural synthesis relating to the distribution of inferred structures:

Combining structural information to understand the overall geological setting and the distribution of inferred structures.

Procedure For Aeromagnetic Data Processing

The Total Magnetic Field Intensity (TMI) grid was processed using Oasis montaj software by Geosoft Inc. The steps involved were:

a) Processing the TMI grid and generating the First Vertical Derivative (1VD) grid:

Using the MAGMAP extension within Oasis montaj, the TMI grid was processed to produce the 1VD grid.

b) Extracting lineaments from the 1VD grid using ArcGIS software:

ArcGIS, a Geographic Information System (GIS) software, was used to combine spatial and attribute magnetic datasets for processing and management purposes. The software organized the magnetic data as lines, points, and polygons within a geo-database. The lineaments, which are line attributes, were extracted through digitization.

These tools and methods provided a comprehensive approach to processing and interpreting aeromagnetic data, enabling detailed geological and structural analysis of the study area. The combination of Oasis montaj for initial data processing and ArcGIS for spatial analysis and visualization facilitated a thorough understanding of the subsurface geological features that are significant for groundwater accumulation.

Source Parameter Image Grid Map of the Study Area

The source parameter imaging (SPI) technique is a complex method that involves several processes, requiring mathematical transformations applied to various grids. In this approach, the magnetic residual data serves as the initial input into Oasis montaj software version 8.4, where parameters dx, dy, and dz are processed.

Initially, the magnetic residual data undergoes transformation within Oasis montaj software, generating output grids for dx, dy, and dz parameters. These output grids are then utilized as inputs for the SPI handling tool found in the software's menu bar, which facilitates the creation of a source parameter imaging grid map.

It's crucial to note that the SPI method primarily utilizes first-order derivatives, as higher derivative orders can increase sensitivity to noise. Therefore, careful filtering of the data was conducted to ensure accurate estimation of the local wave number. This filtering process plays a critical role in achieving reliable depth estimates from the digitized aeromagnetic data, thereby enabling quantitative determination of the depth to magnetic sources.

Moreover, the SPI technique allows for detailed analysis of the subsurface geological structures by providing insight into the structural distribution and depth of magnetic anomalies. By integrating advanced mathematical processing techniques and GIS capabilities, such as those offered by Oasis montaj and ArcGIS, geoscientists can enhance their understanding of the geological features and resource potential of the study area.

Data Analysis

Qualitative as well as quantitative interpretations were employed in this work. Qualitative interpretation of the

field data was first carried out by inspecting the total magnetic intensity (TMI) grid of the study area. The total magnetic intensity map of the area was produced into maps which are in color aggregate.

First Vertical Derivatives

The First Vertical Derivative (FVD) being among vertical derivative filter tend to sharpen the edges of anomalies and enhance shallow features. The first vertical derivative map is much more responsive to local influences than to broad or regional effects and therefore tends to give more sharper picture than the map of the total field intensity (Reynolds, 1998). Thus, the more smaller anomalies are more readily apparent in area of strong regional disturbances. In fact, the FVD is used to delineate high frequency features more clearly where they are shadowed by large amplitude, low frequency anomalies. They also tend to thin the widths of anomalies and also recognize or detect contacts/boundaries of geological bodies more precisely (Cooper and Cowan, 2004). The FVD is expressed as:

$$FVD = (\partial T / \partial z) \quad (4)$$

The computation of the FVD in this study was performed in the frequency domain using the fast Fourier transform (FFT) technique. Accordingly, the digitized residual magnetic intensity values were transformed in to the frequency domain using the FFT. The Fourier transformed data was multiplied with the FVD filter (i.e. k_n , where $n = 1$ and k is the wave number) and subsequently inversely Fourier transformed in to the space domain to obtain the FVD values. The initial stages of quantitative magnetic data interpretation involved the application of mathematical filters (reduction to pole, upward-downward continuation, first vertical derivative and horizontal derivative) to observed data. The specific goals of these filters varies depending on the situation. The general purpose is to enhance anomalies of interest and to gain some basic information on source location or magnetization. The upward projection/continuation operation smoothen the anomalies obtained at the ground surface by projecting the surface mathematically upward above the original datum (Reeves, 2005). By implementation of reduction to pole on both the amplitude and phase spectra of the original TMI grid, the shapes of the magnetic anomalies were simplified so that they appeared like the positive anomalies located directly above the source expected for induce magnetized bodies at the magnetic pole where the angle of inclination is 90° and zero declination.

The derivative helped to sharpen the edges of anomaly and enhanced shallow features (Reeves, 2005). This includes first and second vertical derivatives, and horizontal derivative. Computation of the first vertical derivative in an aeromagnetic survey is equivalent to

observing the vertical gradient with a magnetic gradiometer with advantages of sharpening the edges of magnetic anomalies, enhancing shallow magnetic sources, suppressing deeper magnetic sources and giving a better resolution of closely-spaced sources. Horizontal derivative was also calculated in the x and y directions.

Lineament Analysis

Lineament analysis involves examining both surface and subsurface structural features in terms of their spatial and orientational distributions. Spatial analysis of lineaments will focus on analysis of locations and patterns of lineaments across the study area, while orientational analysis measures the azimuths of these lineaments relative to geographical north.

During orientational analysis, the azimuths of lineaments are measured and categorized into angular intervals. This data is then visualized using rose diagrams, which display the frequency and distribution of lineament orientations. Rose diagrams are essential tools for further interpreting the structural trends and alignments within geological formations.

Rose Diagrams

In rose diagrams, directional analysis categorizes major and minor orientations of lineament trends based on their azimuths. The trends are organized into class intervals typically spanning 10-15 degrees, providing a clear representation of the predominant directions of structural features.

Each segment in a rose diagram represents the frequency of occurrences falling within a specific angular range, displayed as bars of varying length around a circle. This visual arrangement allows geoscientists to quickly identify dominant orientations and patterns in the distribution of lineaments across the landscape.

In addition, rose diagrams include concentric circles that serve as scaled controls, helping to compare the relative frequencies of observations in each angular class interval. The length of each bar within the diagram correlates directly with the number of lineament occurrences recorded for that specific direction, providing a quantitative basis for structural analysis.

In summary, lineament analysis, supported by tools like rose diagrams, is crucial for understanding the structural characteristics and tectonic history of geological formations. By analyzing spatial and orientational distributions, geoscientists gain valuable insights into the geological complexities and potential mineral resources of the surveyed area.

Electrical Resistivity Method

Materials

The materials used in the field work include the following

- Ammeter for current measurement
- Voltage source (batteries) for measuring potential difference

- Global positioning system (GPS) for identification of VES points
- Datum peg serve as site specific vertical reference point
- Hammer for nailing electrode in to ground
- Wires for connecting various tools
- Measuring tape for measuring distance
- Terrameter use to measure resistivity
- The electrode (current and potential)

Schlumberger Configuration

The schematic schlumberger array comprises of a collinear electrode system in which both the current (A and B) and potential electrodes (M and N) are kept in a straight line mostly along the strike of the suspected anomaly. When taking measurements, the current electrode spacing are increased progressively to enable the current to penetrate deeper layers of the subsurface.

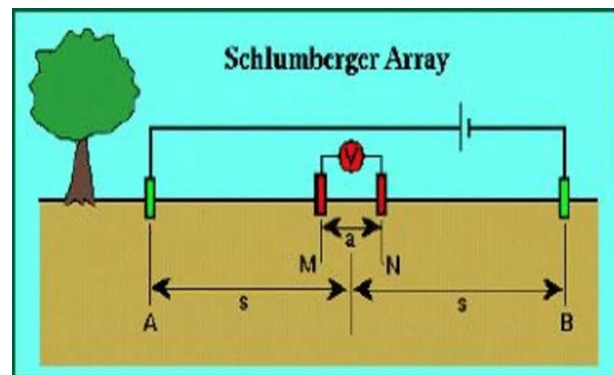


Figure 2; A schematic diagram of a schlumberger array of configuration.

Each time a current is sent into the ground through the current electrode (A and B), the potential difference between the two non-polarizable electrode (M and N) on the surface are use to measure the resistivity from the input current. (Rahmani, 2020)

$$\rho_a = \frac{\pi(s^2 - a/4) \cdot \Delta V}{I} = K_F \frac{\Delta V}{I} \quad (5)$$

Where ρ_a is given as the resistivity s and a are the distance between the electrode and potential, V is the voltage, I is the current and K_F is the geometric factor which is given by Keller and Frischknecht, 1996. As;

$$K_F = \frac{\pi(s^2 - \frac{a^2}{4})}{a} \quad (6)$$

With all parameters having usual meaning.

RESULTS AND DISCUSSION

In the course of this study, several schematic maps were generated, including the Total Magnetic Intensity map, Residual map, First Vertical Derivative map, Lineament map, Rose diagram, Source Parameter Imaging map.

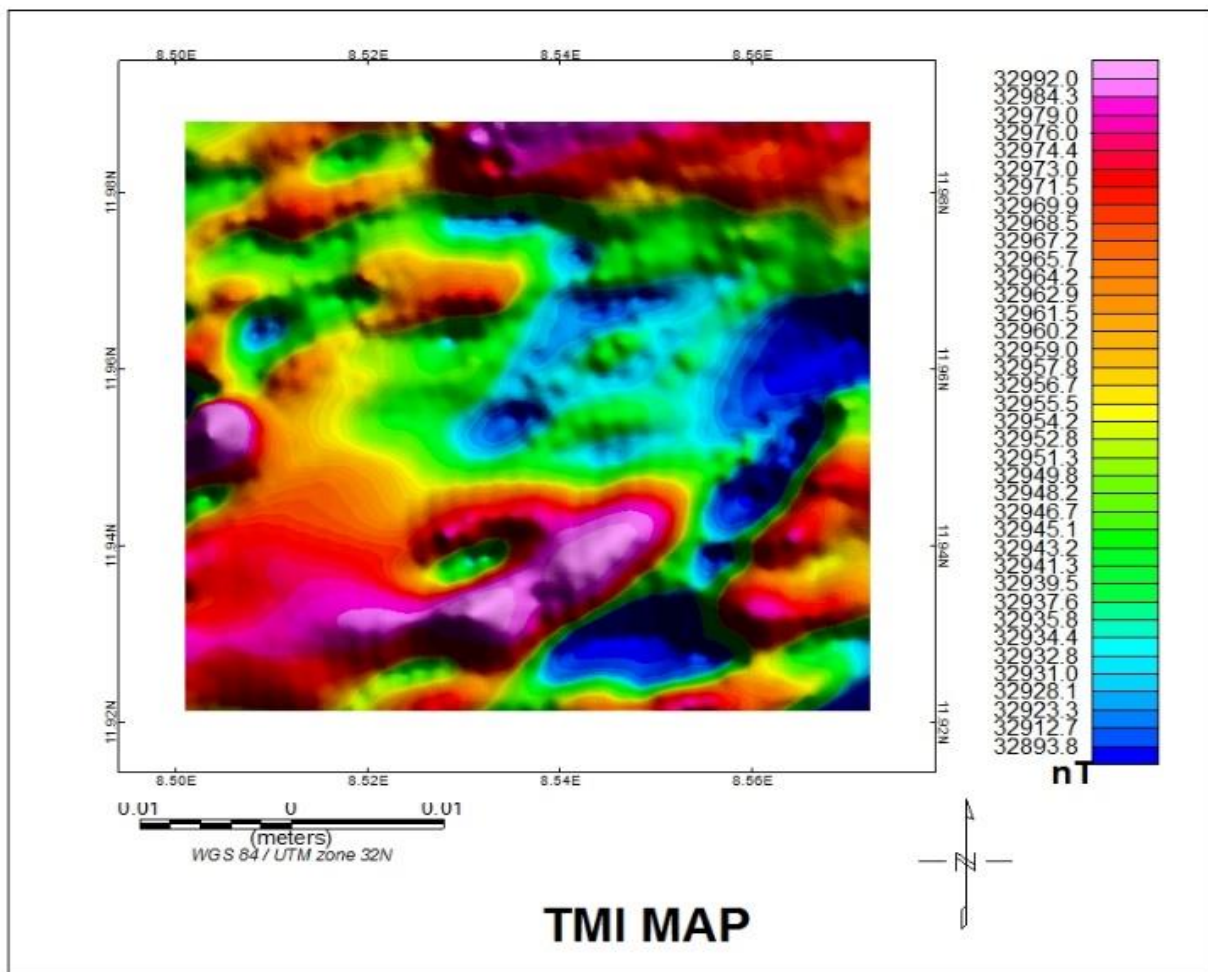


Figure 3: Total Magnetic Intensity Map of the Study Area

Total Magnetic Intensity Map:

Figure 3 displays a The color shaded Total Magnetic Intensity (TMI) map of the study area illustrates variations in the magnetic field distribution. High magnetic intensity zones are represented by red shades, while low-intensity regions appear in blue. Intermediate colors, such as yellow and light green, indicate areas of moderate magnetic field intensity.

The TMI anomaly map reveals anomalies of varying wavelengths, including short-wavelength anomalies associated with high wave numbers, medium-wavelength anomalies with moderate wave numbers, and long-wavelength anomalies characterized by low wave numbers.

Each of these wavelength categories provides valuable insights into the nature and depth of underlying geological structures and magnetic sources within the surveyed area.

Within the study area, magnetic intensity values range from 32,893.8 nT to 32,992.0 nT. The highest TMI anomalies, ranging between 32,962.9 nT and 32,992.0 nT, extend from the eastern to the western portions of the area, trending in a southeast–southwest (SE–SW) direction. Additionally, another prominent anomaly, with values between 32,956.7 nT and 32,992.0 nT, is observed in the eastern part of the study area, extending from the northwest toward the southwest.

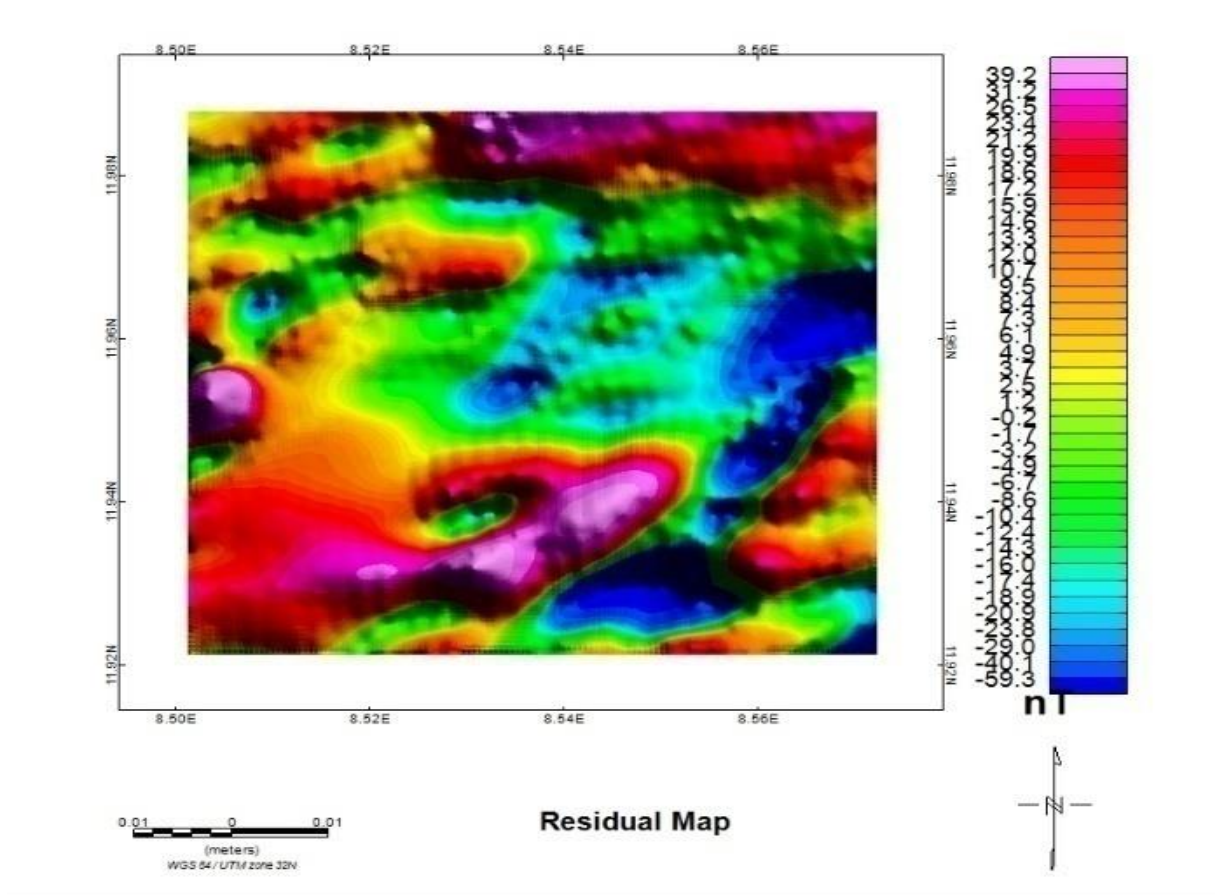


Figure 4: Residual map of the Study Area

The Residual Magnetic Map of the Study Area

The residual magnetic map closely resembles the Total Magnetic Intensity (TMI) map, although certain features are absent, suggesting that the residual field predominantly reflects contributions from the basement structures. As with the TMI map, a colour scale is employed in which red denotes areas of high magnetic intensity, while blue represents zones of low intensity. Steep magnetic gradients are observed across the study area, with the highest value of 39.2 nT occurring within the southwest southeast region, and the lowest value of -59.3 nT recorded in the northeastern and southeastern parts.

The general trend of the residual magnetic anomalies is oriented along a southeast–southwest direction, extending toward the extreme western part of the study area. Long-wavelength anomalies, which are typically associated with deeper-seated basement features,

are dominant in the northern, eastern, and southern regions. In contrast, short wavelength anomalies indicative of relatively shallow sources are more prominent along the northeastern and southeastern margins.

As illustrated in Figure 4, the magnetic intensity values range from -59.3 nT to 39.2 nT, clearly distinguishing areas of low magnetic response (depicted in blue) from zones of high magnetic response (shown in pink). Interpretation of magnetic data generally begins with the separation of broad, smooth regional fields attributed to deep crustal sources from localized anomalies of geological significance. These regional magnetic trends reflect large scale crustal homogeneity, and their proper delineation is essential for understanding subsurface structures and assessing the mineral potential of the study area.

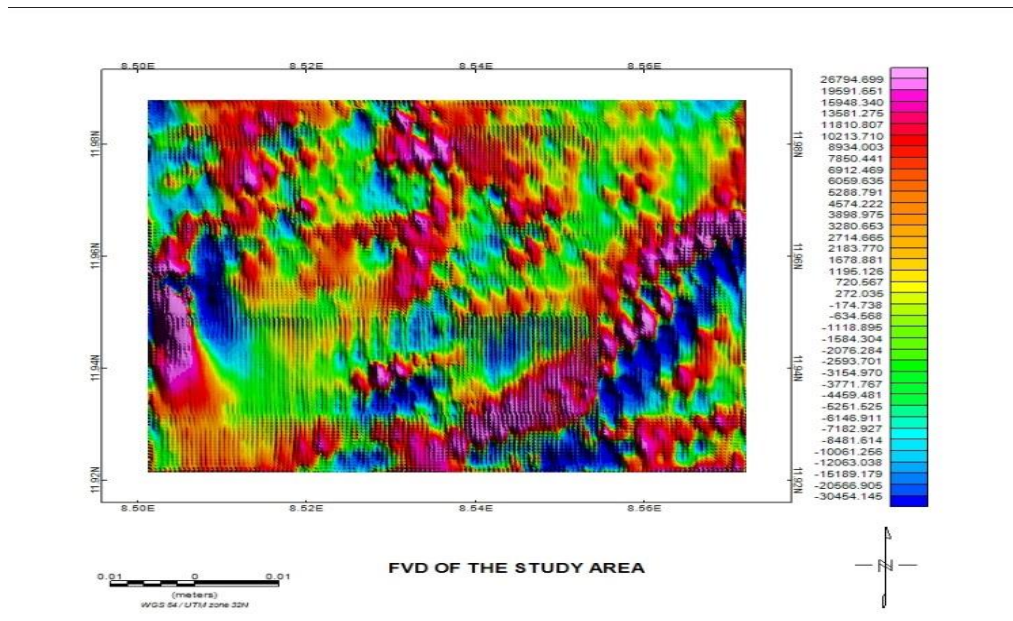


Figure 5: First Vertical Derivative Map of the Study Area (Unit in nano Tesla)

First Vertical Derivative Map.

The First Vertical Derivative (FVD) map improves the clarity of magnetic anomalies by emphasizing variations in the vertical component of the Earth’s magnetic field. This enhancement allows for more precise identification of anomaly boundaries and structural features, particularly those exhibiting a NE–SW orientation, which

is typical of the basement complex in northern Nigeria. Figure 5 illustrates a color-shaded first vertical derivative map of the study area, where lower values are represented in blue and higher values in pink, providing a more refined depiction of magnetic field variations.

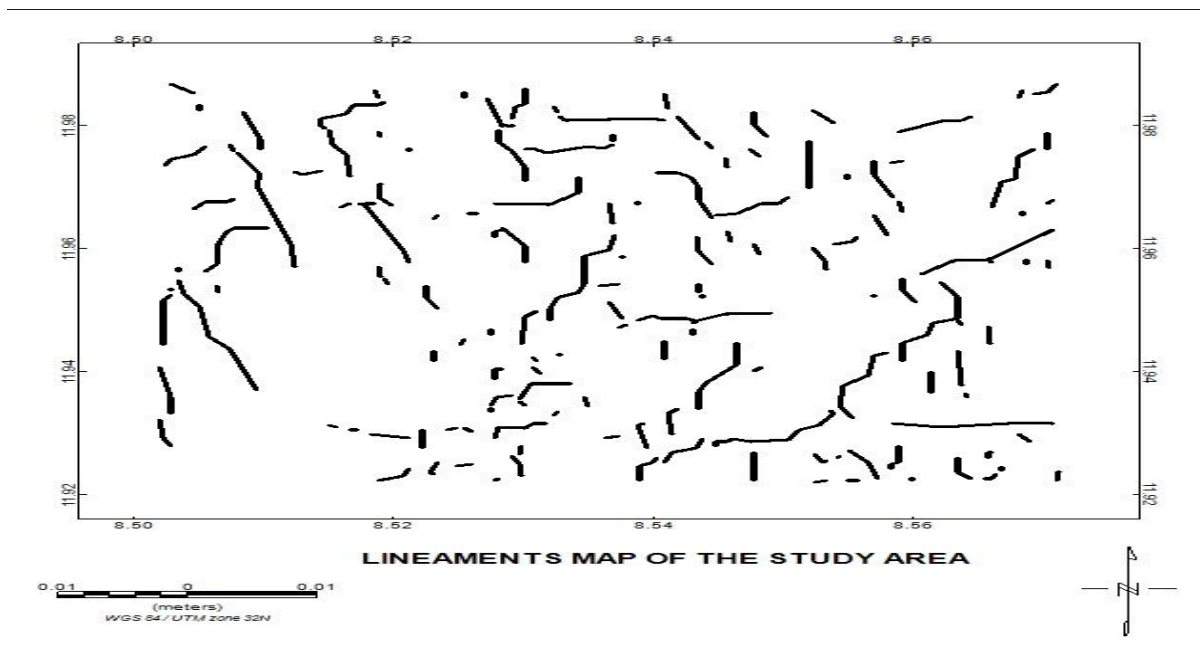


Figure 6 Lineament Map of the Study Area

LINEAMENT OF THE STUDY AREA

Figure 6 presents the inferred lineaments, which were digitized on-screen to produce a structural map of magnetic lineaments within the study area. These lineaments are essential for interpreting the structural framework and geological conditions that control the distribution of magnetic anomalies across the surveyed region. Their analysis provides valuable insights into subsurface geological structures and potential zones of groundwater. And subsequently, shows significant geologic faults and direction of flow of the potential groundwater of the study area.

The lineament map was derived from the First Vertical Derivative (FVD) grid (Figure 5) using ArcGIS software and is displayed in Figure 6. The extracted lineaments, characterized by their linear geometry, are interpreted to represent geological features such as faults and lithological contacts. These structures are widely distributed across most parts of the study area, although they appear less dense in the upper portion of the eastern sector. And subsequently, shows significant geologic faults and direction of flow of the potential groundwater. Lineaments, as linear features on the Earth's crust, are commonly associated with faults, fractures, and folds, and they play a significant role in indicating zones of groundwater potential as well as mineral deposits. In aeromagnetic surveys, they are typically expressed as surface manifestations of subsurface planar discontinuities. Consequently, the mapped lineaments provide a useful basis for understanding the structural controls on both groundwater occurrence and mineralization within the study area.

Rose Diagram

To analyze the orientation of magnetic lineaments derived from the First Vertical Derivative (FVD) across the study area, the directions of these lineaments relative to geographic north were measured and summarized using a rose diagram, as shown in Figure 7.

The rose diagram indicates that the lineaments predominantly trend in the N-S and NE-SW directions. Other notable trends include ENE-WSW and WNW-ESE, which are significant in understanding the regional geological framework. Minor trends, such as NW-SE and NNE-SSW, are less prominent but still contribute to the overall structural complexity of the area.

These directional patterns provide critical information on the orientation and distribution of subsurface geological structures associated with the magnetic anomalies. Interpreting these lineament trends is essential for understanding the tectonic history, structural evolution, and potential groundwater zones within the study area.

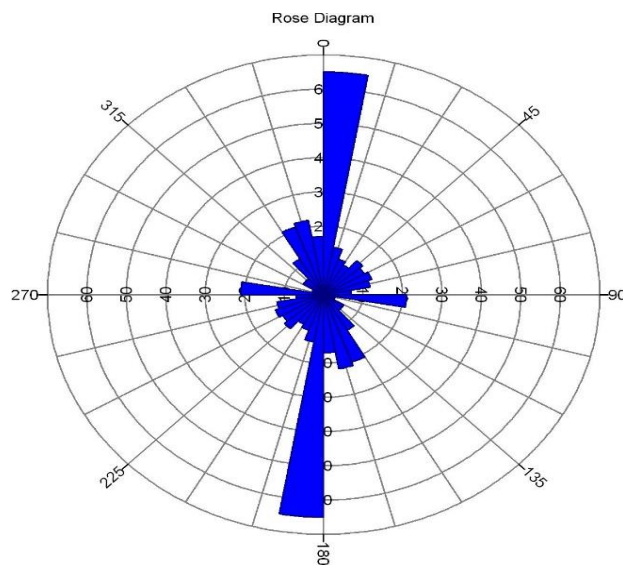


Figure 7: Rose Diagram

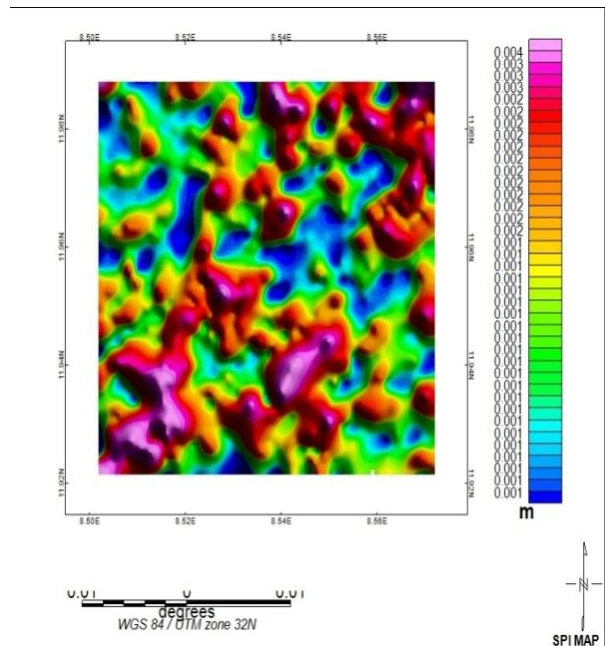


Figure 8: Source Parameter Imaging
The Source Parameter Imaging (SPI) Map
The Source Parameter Imaging (SPI) shown in figure 6 shows the thickness of about 1-4m of the sediments found at NE - SW part and at northern and western parts of the study area. This could be sufficient for groundwater prospecting.

VES 1;

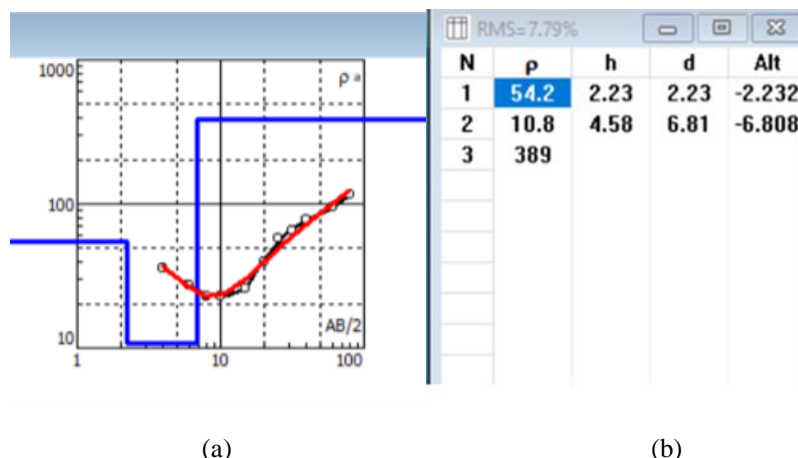


Figure 9: (a) Iterated Curve with Layered Resistivity Models (b) For VES1

Figure 9 shows the iterated field curve and model for VES1 station. The shape of curve is H-type curve and VES point is underlain by three geo electric layer with resistivity of 54.2Ωm, 10.8Ωm and 389Ωm for the first,

second and third layer respectively. The figure also revealed that the first layer has thickness (h) of 2.23 and the second layer has thickness (h) of 4.58. The third layer is not completely penetrated. Table 4.3 shows the summary of the result of the interpretation of the VES1 point.

Table 1 Result of the interpretation for VES1 point

Layer	Resistivity(Ω-m)	Thickness(m)	Depth (m)	Lithology
1	54.2	2.23	2.23	Sandy soil
2	10.8	4.58	6.8	Loamy soil
3	389			Crystalline fractured basement
4				

Geo electric section is obtained from the result of interpreted sounding curves, in which a layer is characterized by its resistivity (ρ) and thickness (h) (Abubakar, 2016)

The results of the resistivity VES survey revealed that the area is predominantly underlain by three to four layer subsurface structure. The curves obtained in the study area are H and A curves. The resistivity values for the top layer range from 27Ωm to 62Ωm. The resistivity value of the top layer suggests that the area is covered by sandy, loamy or clay. The resistivity value of the second layer ranges from 18Ωm to 16927Ωm suggest that the lithology for the layer is loamy, crystalline rock, laterite soil and clay. The thickness of the second layer ranges from 4.5m to 59.2m. The third layer is considered to be fresh basement while in some VES having four layers, the fourth layer is considered to be fresh basement. The third or fourth layer is made up of weathered or fracture basement which suggests that the third or fourth layer are made up of fresh basement. The above interpretation applies to the rest of VES data.

CONCLUSION

The hydrogeological features of groundwater potentials of Tarauni LGA, Kano State were studied from the conducted research using Aeromagnetic Data and Vertical Electrical sounding. The study revealed

relatively high positive magnetic values, ranging from 32,893.8 nT to 32,992.0 nT. These regions reflect the lithological variations in igneous rocks with sedimentary section and are composed of narrow closely spaced. Visual analysis of the Total Magnetic Intensity (TMI) and Residual Magnetic Intensity maps indicates that portions of the southeastern area are underlain by sedimentary rocks, characterized by low and smooth magnetic intensity. In contrast, the northeastern, northwestern, and western parts of the study area, which are underlain by basement rocks such as migmatites, gneisses, older granites, and younger granites, exhibit higher and more complex magnetic intensities.

Structural lineament analysis suggests that some trends—NE–SW, NW–SE, and NNE–SSW—are associated with Pan-African orogeny, while others—NNW–SSE and E–W—are related to pre–Pan-African tectonic events. Depth estimations of magnetic source bodies, and by implication sediment thickness, were conducted over the sedimentary portions using the Source Parameter Imaging (SPI) method. Two depth models were identified: deeper sources ranging from 0.002 km to 0.004 km, and shallower sources at approximately 0.001 km. These results indicate that the sedimentary cover in the area is relatively thin, suggesting favorable conditions for groundwater potential.

Additionally, the lineament map was used to delineate structural features and analyze their orientations, providing further insight into the geological framework and structural controls within the study area. The 30 VES points are has mainly 3 layers with some of these third layers having high resistivity value and also low resistivity value with of potential ground water some of these third layer is also considered to be weathered basement the second layer is considered to be region of an underground water potential having thickness ranging from 18m – 59.2m and geologic layers of each VES points were outlined using an adopted table with each VES having it pseudo curve with most VES having A and H curve hence, the area has a good groundwater potentials.

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Basement Complex: Comprising Precambrian rocks, including granite, gneiss, and schist, which form the foundation of the region (Obaje, 2009).