Science World Journal Vol. 20(No 1) 2025 https://dx.doi.org/10.4314/swj.v20i1.32
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University

INVESTIGATION OF GROUNDWATER POTENTIAL IN TARAUNI LGA USING INTEGRATED GEOPHYSICAL TECHNIQUES

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ABSTRACT

The study addresses the critical issue of groundwater potential in Tarauni LGA, Kano state Nigeria with focus on groundwater indicators that show its presence. The research employs one geophysical technique; the Aeromagnetic survey Technique; Sheet 81 of Aeromagnetic data was obtained from the Nigerian Geological Survey Agency [NGSA]. Tarauni was extracted from Wudil sheet 81 using ArcGIS software record in digitized form [X,Y,Z text file after removing the aeromagnetic gradient from the raw data using the International Geomagnetic Reference Field [IGRF], 2010 with an intensity of 33095nT with average magnetic inclination across the survey area was 9° In the north to 0° In the south The aeromagnetic data is processed and interpreted using Oasis Montaj software and the results of the Aeromagnetic data analysis of seven maps were extracted which are; First Vertical Derivative, Lineament map, Rose diagram, and Source Parameter Imaging, from which six major lineament orientations are revealed, the major lineaments trends are in NS, NE-SW, ENE-WSW, WNW-ESE directions. Minor trends were also identified in NW-SE and NNE SSW. The lineament shows good groundwater potential in the study area with sedimentation of 4 meter which is found in NE-SW part of the study area.

Keywords: Groundwater, Aeromagnetic, First Vertical Derivative, Lineament, International Geomagnetic Reference Field, ArcGis, Oasis Montaj.

INTRODUCTION

Groundwater is an important supplement to the non-availability of surface water, but it has become a scarce resource in most communities in Nigeria. Surface water, where available, is usually seasonal and prone to contamination due to anthropogenic influences (Sunkari et al., 2019; Lapworth, 2017). Groundwater is a highly valuable resource to address this issue, and it must be explored to develop a management plan that also considers city planning and primarily sustains life(Lapworth, 2017).

Groundwater is typically retained in sediment or along fracture and weathered parts of indulated rocks under considerable hydrostatic pressure (Yusuf et al., 2022) t is a vital component of the hydrologic cycle, accounting for approximately 22% of the world's fresh water resources. In Kano State, Nigeria, groundwater is an essential source of water supply for domestic, agricultural, and industrial purposes. It is found in the weathered and fractured basement rocks as well as in the sedimentary formations (Yusuf et al., 2022). The hydraulic conductivity and transmissivity of the aquifers in Kano State vary widely, indicating diverse hydrogeological conditions (Oladapo et al., 2020). Groundwater in Kano State generally ranges from acidic to neutral, with some areas showing elevated levels of total dissolved solids, iron, and manganese (Adeyemi et al., 2021).

Globally, water is obtainable as either groundwater or surface water. Water extracted from the ground, known as groundwater, serves three main purposes: domestic, agricultural, and industrial uses (UN, 2020). It is particularly advantageous as a source of potable water because it is typically free from biological and chemical contaminants, requiring little to no purification before use. Groundwater maintains a constant temperature and chemical composition and has a far greater storage potential compared to surface water (WHO, 2023).

Given its numerous benefits, groundwater has gained increased recognition in many parts of the world. Water is an essential resource for livelihood, and its importance cannot be overstated. However, it is concerning that this crucial resource is becoming increasingly scarce (WHO, 2023).

Findings from a published paper revealed that there is a serious scarcity of water for the vast majority of households in Kano metropolis, despite significant government expenditure on water projects in the state. Residents of metropolitan Kano rely on domestic water vendors, rainwater harvesting, boreholes, and hand-dug wells, among other sources, many of which lack proper hygienic practices (Aminu et al., 2021). This scarcity underscores the need for improved water management and infrastructure to ensure a reliable and safe water supply for all residents(Aminu et al., 2021).

The global population of 2.2 billion people still faces significant challenges in accessing safe drinking water. It is not sufficient for water to be available; it must also be safe, accessible, and affordable. Safe drinking water should come from sources such as wells, taps, or hand pumps, and it must be free from faecal and chemical contamination. Additionally, it should be readily available for at least 12 hours a day and located within the premises of a child's home or within a reasonable distance (WHO, 2023). In many countries, children and women are the primary carriers of water for their families, exposing them to numerous safety risks and vulnerabilities (UNICEF, 2023).

Water scarcity is more intense in developing countries, where statistics show that 67% of the rural population lacks access to a safe water supply (UNICEF, 2023). Groundwater is a highly desired, widespread, and extensively used water resource. It is especially valuable to residents of dry regions, often being the only reliable water resource available to them. Groundwater recharge cannot be directly measured, and observed recharge and discharge rates over extended periods are rare (Moeck et al., 2020).

Groundwater is one of the most imperative and reliable sources of water for human activities, including drinking, agriculture, industrial

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use, and other domestic purposes (P. Yar, 2020). Its importance is expected to grow considerably in the future, as it is a safe and high-quality drinking water resource. When used reasonably and sustainably, groundwater can make a significant contribution to solving regional water crises. With the increasing population, industrialization, and agricultural growth, the demand for potable water supply has increased beyond human perception (WHO, 2022).

MATERIALS AND METHODS

Aeromagnetic Data Acquisition

The sheet 81 of aeromagnetic data was obtained from National Geological Survey Agency, Abuja. This survey was conducted in three phases between 2005 and 2010 as part of a major project known as the Sustainable Management for Mineral Resources by FURGO Airborne surveys. The survey was carried out along a series of NE - SW lines with a spacing of 2km and an average flight elevation of 152m above the ground level. Tarauni L.G.A data was extracted from Wudil Sheet 81 recorded in digitized form (X, Y, Z text file) after removing the geomagnetic gradient from the raw data using International Geomagnetic Reference Field (IGRF), 2010, with intensity of 33095 nT (Nanotesla) with average magnetic inclination across the survey area was from 9^0 in the north to 0^0 in the south. The X and Y represent the longitude and latitude of Tarauni L.G.A in meters respectively, while the Z represents the magnetic field intensity measured in Nanotesla.

Magnetic Anomaly

Magnetic data provide an insight into subsurface structures, the composition of the earth's crust and the distribution of magnetic minerals (primarily magnetic source) into the crust (whitehead, 2008). The application of magnetic data has been to detect igneous intrusions and to determine the depth to the magnetic sources.

The information obtained by the application of the magnetic method depends on the contrast in the magnetic properties of the types of rocks in the survey area. Most common rock forming minerals exhibit only limited magnetic properties. The magnetic response of rock is usually due to the presence of magnetic minerals such as magnetite, pyrrhotite, ilmenite, franklinite, and specular hematite. The magnetic properties of rocks arise almost entirely from the widely distributed mineral magnetite. The fundamental rock parameter in the magnetic prospecting is the magnetic susceptibility. The magnetization of a rock material is determined by its magnetic susceptibility *k* which is proportional factor, by which the induced intensity of the magnetization is related with the strength of magnetization force H of the inducing field. This proportionality between the magnetization and the magnetizing field H is expressed as

$$M = KH \qquad (1)$$

Where M is the magnetization per unit volume and the magnetizing field H are both measured in [A/m], *k (magnetic susceptibility)* is dimensionless. In CGS unit, Magnetization is measured in emu cm-3. Magnetic susceptibility can vary as much as four to six orders of magnitude and this variations exist between different types of rocks. Large variation also occur given the rock type. Basement rocks have usually high magnetic susceptibility due to their high magnetite content, whereas sedimentary rocks have much lower susceptibility. Metamorphic rock exhibit variable magnetic character. Generally, basic igneous rocks have higher magnetic content than acid igneous rocks. In general, the magnetic susceptivity of the rock shows wide variation even within the same rock type because this is a property that depends on the lithology (whitehead, 2008).

The measured field in magnetic survey is normally the total magnetic field, which is the magnetic intensity (measured in nano tesla) including the effect of magnetization M. it can be written by consideration of equation (1) as;

$$B = \mu_o (H + M) = \mu_o(1 + k)H = \mu_o \mu H \qquad (2)$$

B,H and M are vectors, μ_o= 4π×10-7N/A² (newtons per ampere squared) is the permeability of free space. Magnetized matter can be considered as an assortment of microscopic magnetic dipoles which results from the magnetic moments of individual atoms and dipole. Magnetization is defined as volume density of magnetic anomalies; there are two types of magnetization namely induced magnetization Mind which is the magnetic response produced by induction of an externally applied field, depends on *k* and the strength of the applied field and varies, when the external field is switched off equation (2.1)

The other is the residual magnetism, called remanence or remanent magnetization, Mrem is the inherited, permanent magnetization of the rock, which remains even when the external field is removed (Kearey et al, 2002). The total magnetization is therefore, the sum of the induced and remanent magnetization.

Analysis of an aeromagnetic data is also useful in the identification of magnetic anomaly of the earth material, the depth to the source of the magnetic anomaly as well as investigating other variables like magnetic susceptibility variation etc. useful information on source magnetic anomaly could be used to derive simple models or filtered appropriately for expressions of faults and other magnetic plate sources. Depending on the nature and types of filtering techniques, magnetic data can map the geology data of an area.

Interpretation of Magnetic Anomaly

Most of the maps of the total magnetic intensity (TMI) and its derivatives are presented as shaded relief maps to improve the visibility of the features inside the maps. In geophysical analysis, the gridded data derivatives are used to enforce high wave number components of the spectrum by suppressing deep-seated long wavelength anomalies. The components can even be increased by higher-order derivatives. However, due to limitations of significance, usually only the first vertical (FVD) and second vertical (SVD) are applied. In addition to vertical derivatives, a variety of functions maybe used as tools to locate and interpret magnetic anomalies.

These include analytic signal amplitude AS (whitehead, 2008) expressed as;

$$AS\ (xy) = \sqrt{\left(\frac{\delta T}{\delta x}\right)^2 + \left(\frac{\delta T}{\delta y}\right)^2 + \left(\frac{\delta T}{\delta z}\right)^2} \qquad (3)$$

With T measured field, AS is analytic signal amplitude and x,y,z are the positions at which the total field T is measured in nano tesla 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).

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

https://dx.doi.org/10.4314/swj.v20i1.32

ternary images, and FVD map serve as a guides in delineating the lineaments and drainages of the study area.

RESULTS AND DISCUSION

Seven schematic maps were extracted in the course of the present study in which are Total Magnetic Intensity, Residual map, first vertical derivative, lineament maps, rose diagram, source parameter imaging, geomorphological map and drainage map.

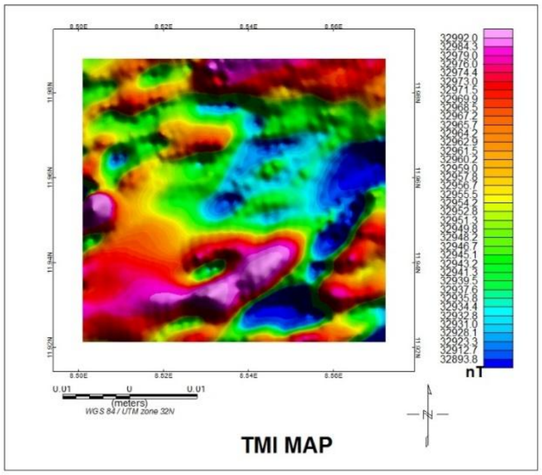

Figure 3: Total Magnetic Intensity Map of the Study Area

Figure 3 displays a color-shaded map illustrating the total magnetic field intensity (TMI) values across the study area. Areas shaded in red indicate high magnetic intensity, while blue areas represent low magnetic field intensity. Intermediate colors such as yellow and pale green denote regions with moderate field intensities.

The TMI anomaly map shows anomalies with varying wavelengths: short-wavelength anomalies characterized by high wave numbers, medium-wavelength anomalies with moderate wave numbers, and long-wavelength anomalies with low wave numbers. Each wavelength category offers insights into different geological features and magnetic anomalies present within the surveyed region.

In the study area, magnetic anomalies range in intensity from 32893.8 to 32992.0 nT and are predominantly oriented along SE-SW and E-W directions. The highest TMI anomaly, ranging from 32962.9 nT to 32992.0 nT, extends from the eastern to western parts, following the SE-SW direction. Another significant anomaly, with TMI values between 32956.7 nT and 32992.0 nT, spans from the northwest to the southwest in the eastern part of the area.

These anomalies exhibit short wavelengths in the northeastern, southeastern, western, and southern sectors, aligning predominantly along NE-SW or E-W directions. Conversely, anomalies with lower TMI values, ranging from 32956.7 nT to 32937.6 nT, are more prevalent in the northern to southern half, trending NE-SE.

Specifically, anomalies with lower TMI values manifest as long wavelengths in the northern to southern regions, medium wavelengths around the center, and short wavelengths in the southeastern part of the study area. This variation in TMI values and wavelengths provides significant insights into the spatial distribution and characteristics of magnetic anomalies throughout the surveyed region. These findings are crucial for understanding the geological structure and potential groundwater resources in the area.

The high magnetic intensity observed in the eastern-western part of the study area corresponds to the presence of Granite Gneiss complexes and Magnetites, which exhibit high magnetization properties. Conversely, the low TMI values in the north-southern region correlate with Migmatite Gneiss, suggesting a significant loss of magnetization likely due to processes like contact metamorphism or intense heating. Similarly, the northwestern part of the map, characterized by high magnetization, aligns with the presence of granites, basalts, and migmatites.

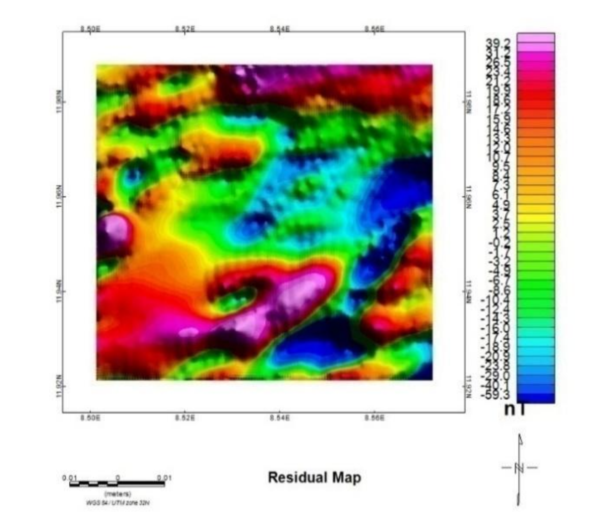

Figure 4: Residual map of the Study Area

The residual magnetic map displays a strong resemblance to the total magnetic intensity map, albeit with some features absent, indicating that the residual map primarily reflects contributions from the basement. Similar to the TMI map, the residual map uses a color scale where red represents high magnetic intensity and blue indicates low intensity. Steep gradients are distributed throughout the area, with the highest intensity of 39.2 nT observed in the southwest-southeast region and the lowest value of -59.3 nT recorded in the northeast and southeast parts of the study area.

The overall trend of the residual magnetic intensity anomalies follows a southeast-southwest and extreme western direction. Long-wavelength anomalies, indicative of deeper-seated basement structures, dominate the northern, eastern, and southern parts of the study area, while short-wavelength anomalies are more pronounced along the northeastern and southeastern borders.

Figure 4 of the study area reveals that magnetic field intensities range from -59.3 nT (minimum) to 39.2 nT (maximum), highlighting areas with low (blue color) and high (pink color) magnetic signatures. Magnetic data interpretation typically begins with techniques to separate smooth, presumed deep-seated regional effects from localized anomalies of geological interest. Regional magnetic fields, characterized by broad trends that extend over large areas, are influenced by deeper crustal homogeneities (Nettleton, 1971).

Understanding these magnetic anomalies is crucial for delineating geological structures and potential mineral resources in the study area. The variations in magnetic intensity and wavelength provide valuable insights into the geological processes and history shaping the region's subsurface characteristics.

First Vertical Derivatives

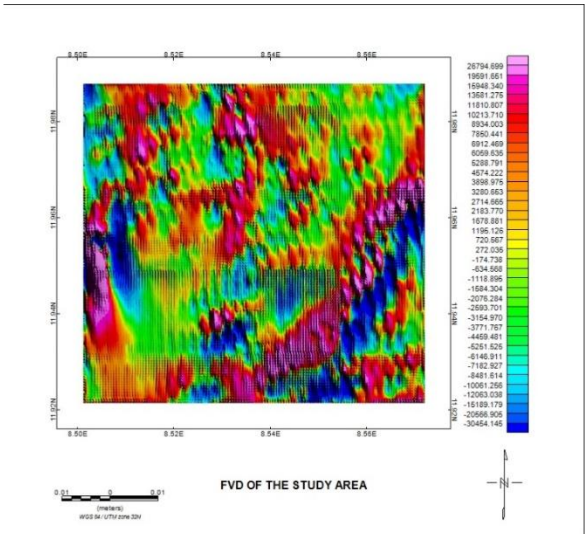

Figure 5; FVD Of The Study Area

The First Vertical Derivative (FVD) map enhances anomaly visibility by illustrating how the Earth's total magnetic field changes vertically. It provides a clearer delineation of anomaly edges, particularly highlighting their predominant NE-SW orientation typical of the northern Nigeria basement complex. Figure 4.3 depicts a color-shaded FVD map of the study area, where blue indicates lower values and pink denotes higher values, offering a detailed representation of magnetic field variations.

Furthermore, Figure 6 presents the inferred lineaments, digitized on-screen to create a structural map of magnetic lineaments. These features are crucial for interpreting the structural characteristics and geological context influencing magnetic anomalies throughout the surveyed region. Understanding these lineaments aids in identifying potential geological structures and mineralization zones beneath the surface.

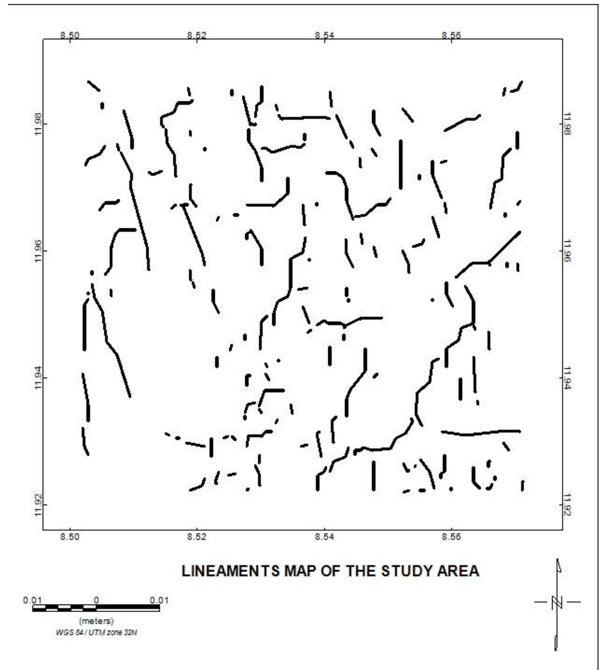

Figure 6: Lineaments Map of the study Area

The lineament map, obtained from the FVD is shown in Figure 6. The lineaments were inferred to be caused by faults and/ or contacts due to their linear nature. As can be seen in the Rose Diagram in Figure 7, the lineaments are widely spread out in the study area with the density of the lineaments being higher in the Northern half than the Southern half. However, the lineaments seem to be few in the upper part of the Eastern half of the study area.

The lineaments which are linear features on the earth crust are related to faults, fold and fractures that gives clue for explorations of groundwater potential and other mineral deposit. In aeromagnetic surveys, lineament are can be expressed as traces on the earth surface of planar breaks in the earth crust. The lineament map of the study was extracted from first vertical derivatives grid (figure 5) using ArcGis software and is presented in figure 3

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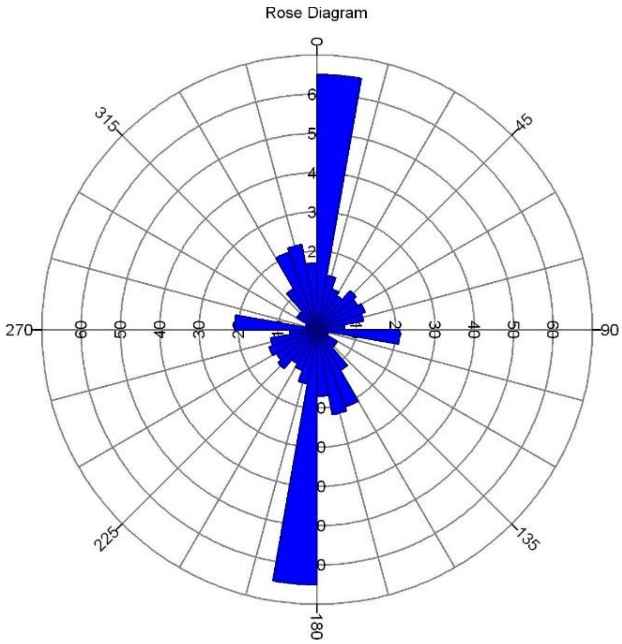

Figure 7: Rose Diagram of the Lineament Map

To examine the trends of the FVD (magnetic) lineaments across the study area. The orientations of these lineaments in relation to geographical north were measured, and their directions were further analyzed using the rose diagram shown in Figure 5.

The rose diagram (Figure 7) reveals that the lineaments predominantly trend along N-S and NE-SW directions, with decreasing predominance in that order. Major trends identified include N-S, NE-SW, ENE-WSW, and WNW-ESE directions, highlighting their significance in the regional geological context. Conversely, NW-SE and NNE-SSW trends are considered minor within the study area, although they also contribute to the overall structural complexity.

These directional analyses provide essential insights into the geological structures underlying the magnetic anomalies, contributing to a better understanding of the region's geological framework and potential mineralization zones. Understanding these orientations is crucial for interpreting the tectonic history and structural evolution of the surveyed area.

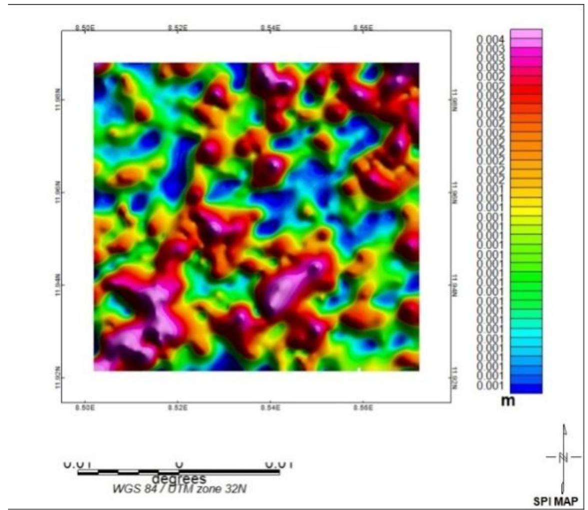

Figure 8; Source Parameter Imaging

The result of the Source Parameter Imaging (SPI) shown in figure 8 has its highest Sedimentary thickness of about 1-4m from chad sediments which could be found at NE - SW part of the study area and at northern and western parts of which could be sufficient for groundwater prospecting.

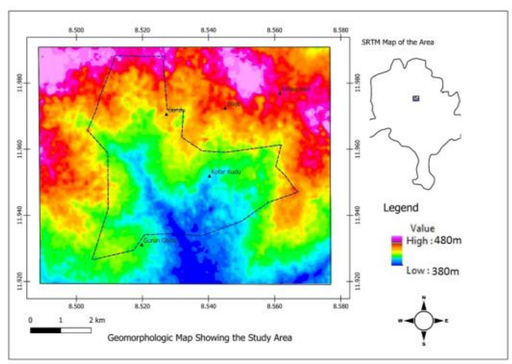

Figure 9; Geomorphologic Map Showing the Study Area

The geomorphologic map was extracted using a shuttle radar topographic mission (SRTM). The area appears to have a gentle slope with a gradual increase in elevation from 380 meters to 480 meters. The area has a moderate relief with a total elevation difference of 100 meters.

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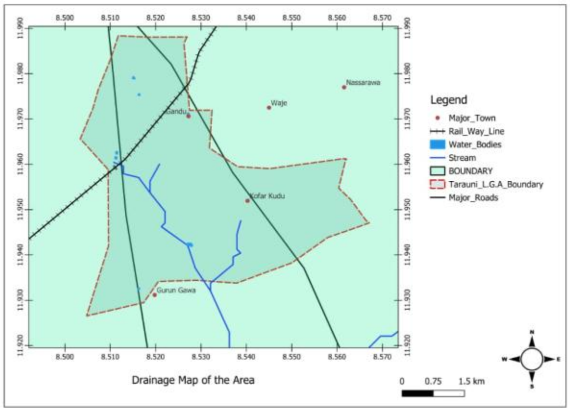

Figure 10; Drainage Map of the Study Area

The drainage of the study area was extracted from the geomorphological map. The map shows the drainage pattern of the head stream rise from the south, southeast, southwest and west which drain to the south and from geomorphologic map it is shown that these areas of the study area has low elevation

General Discussion of the results

Groundwater is found in either basement rocks or sedimentary rocks, the study area comprises of both basement rocks and sedimentary. The source parameter image shows its highest sedimentary thickness of 4 meter which is found at NE-SW parts of the study area and at the northern and western parts which is sufficient for groundwater exploration. With the lineaments Structural lineament orientation suggested that they were products of pan – African orogeny (NE-SW, NW-SE and NNE-SSW trends) and pre-pan African orogeny (NNW-SSE and E-W trends) showing presence of groundwater potential in the study area.

Conclusion

From the conducted research the aim and objective of the research were achieved and hence the conclusion. The study identified a relatively high magnitude of positive magnetic values ranging 32893.8 to 32992.0nT. These features are consistent with the geological and geochemical characteristics of the igneous rocks in the sedimentary section of the basin (Okereafor et al., 2020) Visual studies of total aeromagnetic intensity map and residual aeromagnetic intensity map some parts of SE is underlain by cretaceous sedimentary rocks had low and smooth magnetic intensity, whereas the north east , the north extreme of the area and the western are part underlain by the Precambrian basement rocks (migmatites, gneiss older granites) and Jurassic younger granites had high complex magnetic intensity. Structural lineament orientation suggested that they were products of pan – African orogeny (NE-SW, NW-SE and NNE-SSW trends) and pre-pan African orogeny (NNW-SSE and E-W trends). Magnetic source bodies (and possibly sediment thickness) depth estimated across the sedimentary part of the area using Source Parameter Imaging (SPI) method, indicating two depth source models. Deeper sources varied from 2m to 4m, while shallower sources 1m. This showed that the sedimentary cover was generally low and hence it is good for groundwater potential, and from the lineament map the lineaments of the study area were determined and also the trends of those lineaments.

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