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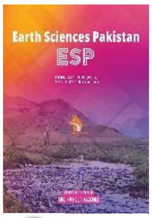

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RESEARCH ARTICLE

APPLICATION OF SOURCE PARAMETER IMAGING TECHNIQUE TO THE COMPOSITE AEROMAGNETIC DATA OF EKITI STATE FOR MAGNETIC BASEMENT DEPTH DETERMINATION AND ITS IMPLICATIONS FOR GROUNDWATER RESOURCE EXPLORATION

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ABSTRACT

The source parameter imaging technique was used for the composite Ekiti State's aeromagnetic data to determine the depth of the magnetic basement at different locations in the research area. Determining basement depth in this type of terrain is essential for groundwater exploration which is crucial for sustenance of life. The aeromagnetic data covering the entire state were processed using the oasis montaj 8.4 software. Firstly, the first order polynomial fitting method was used for the regional - residual separation of the total magnetic field intensity data before the application of the reduction to equator transformation filter on the residual component. The data were further enhanced by using upward continuation smoothing filter to remove the effect of the short-wavelength noise from the data. The depth of the magnetic basement, derived from the source parameter imaging technique, ranges from 116 m to 658 m, which indicate the depths to the top of the magnetic sources within the basement rocks in the study area.

KEYWORDS

Aeromagnetic Data, Ekiti, Exploration, Groundwater, Source Parameter Imaging, Magnetic Basement,

1. Introduction

Source parameter imaging is a commonly utilized method for estimating depth in aeromagnetic data processing. It entails computing the second-order derivatives of the total magnetic field intensity and leveraging the local wavenumber to quickly calculate the depth of buried magnetic sources (Thurston and Smith, 1997). This method is recognized as a quick, straightforward, and reliable approach for depth estimation, independent of magnetic inclination, declination, dip, strike, or remanent magnetization. Its accuracy has been shown to be within ±20% based on testing with drill-hole data and offers a more comprehensive set of consistent solution points. In current studies, this method has been widely utilized to determine magnetic basement depths (Salako, 2014).

Aeromagnetic data for Nigeria is accessible through the Nigerian Geological Survey Agency (NGSA), where data for specific locations can also be requested. The availability of this data enables the analysis of subsurface structures and magnetic basement depths across any region in the country by applying suitable geophysical interpretation techniques. Typically, the datasets are presented in grid format, facilitating swift interpretation of magnetic source locations and depths (Salawu et al., 2019a). The depth to the basement is crucial in exploration activities and is frequently one of the most valuable insights derived from aeromagnetic data (Eze and Ugwu, 2022). So, understanding basement depth in the research area is essential for groundwater exploration, mineral exploration and construction of engineering structures such as bridges, skyscrapers, or dams (Adagunodo et al., 2018; Ejiga et al., 2024; Izuwa et al., 2024). The composite Ekiti State's aeromagnetic data were thoroughly examined to determine the depths of the magnetic basement.at various points across the region.

2. Geographical Location and Geology of The Study Area

The area of study falls within the Nigeria's basement complex, situated between latitudes 7°15ꞌ and 8°5ꞌ N, and longitudes 4°5ꞌ and 5°45ꞌ E, covering an area of 5,435 square kilometers. To the south, it borders Ondo State; to the north, Kwara State; to the east, Kogi State; and to the west, Osun State. (Figure 1). The rock units found within this area include porphyritic granite, fine- to medium-grained granite, granite gneiss, schist/quartz schist, migmatites, and charnockite. The gneisses and migmatites are so closely interrelated that they are difficult to distinguish in the field. The gneisses and migmatite rock formations are widespread and make up the majority of the rocks in the study area (Talabi and Tijani, 2011).

3. Materials and Methods

The soft copies of digital aeromagnetic data of Ekiti state were procured from the Nigeria Geological Survey Agency (NGSA), Abuja, Nigeria. The study area is represented by eight aeromagnetic map sheets: Osi sheet, Isanlu sheet, Ilesha sheet, Ado-Ekiti sheet, Ikole sheet, Ondo sheet, Akure sheet, and Owo sheet. The data, provided in grid format, were made available in the Universal Transverse Mercator (UTM) projection with the WGS84/UTM Zone 32N coordinate system and retrieved using GEOSOFT Oasis Montaj software, since the data were in GEOSOFT grid file configuration. The coordinates of the total magnetic intensity data were transformed from UTM Zone 32N to UTM Zone 31N of the Greenwich Mercator, as Ekiti State is located in the UTM Zone 31N (figure 2). This was

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required to ensure that the data coordinates matched their true locations. The aeromagnetic data collected underwent on-board processing, including magnetic compensation, verification and editing, diurnal correction, tie line adjustments, and micro leveling. Additionally, the regional geomagnetic field was eliminated from the data.

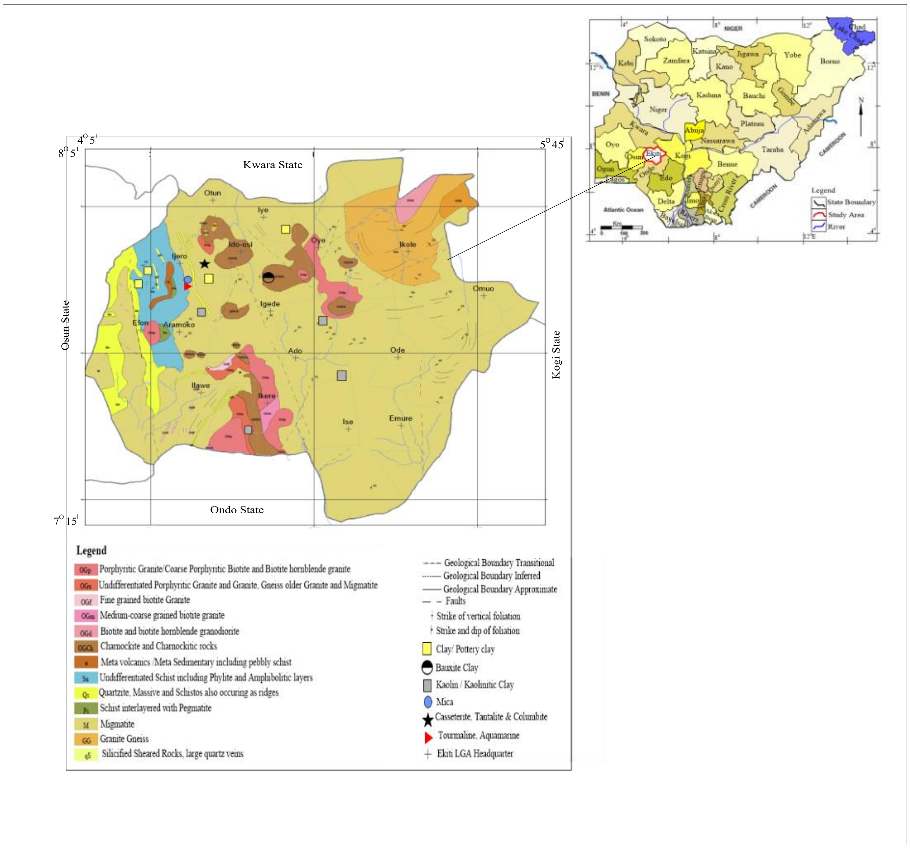

Figure 1: Geology and Location of the study area (Ojo et al., 2024)

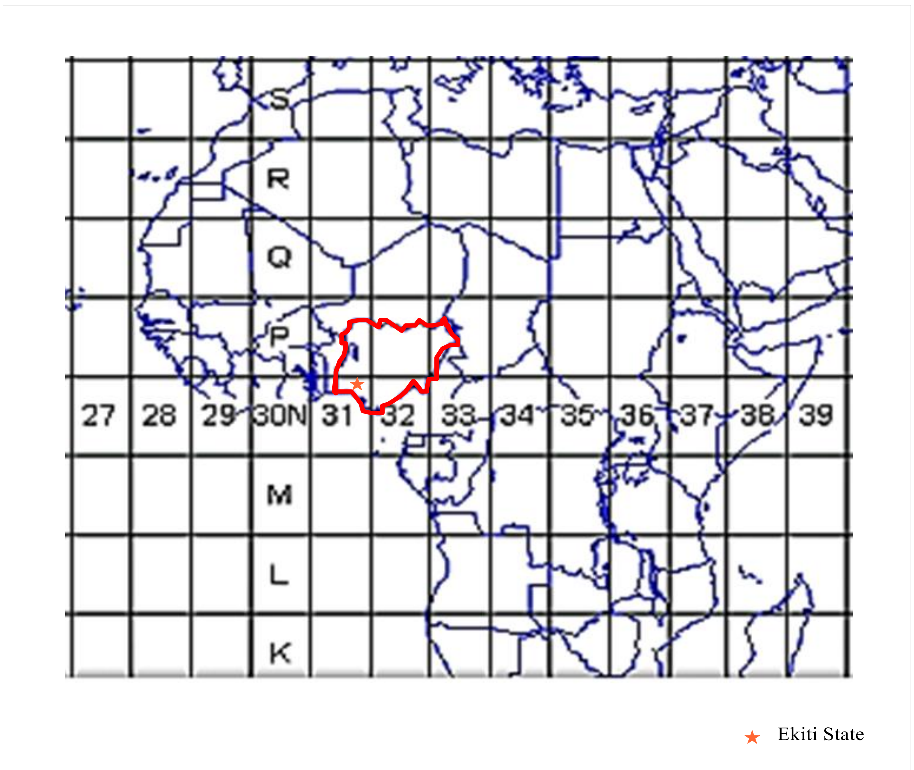

Figure 2: UTM grid zones showing the location of Ekiti State (modified after DMAP, 2019).

4. Results and Discussion

4.1 Total Magnetic Field Intensity

The magnetic field intensity data recorded in geophysical surveys represent the combined magnetic fields from various sources, along with the signature of the subsurface magnetic polarization effects being studied. The magnetic field intensity map (figure 3) of the area of study was created using the total magnetic intensity grid data provided by the Nigerian Geological Survey Agency (Ojo and Osazuwa, 2021). The map shows that the study area is segmented into regions with both positive and negative magnetic values, spanning from -126.96 nT to 168.07 nT. The regions with positive values are identified as high magnetic anomalies, while those with negative values are considered low magnetic anomalies. The western part of the study area displays more prominent high magnetic anomalies.

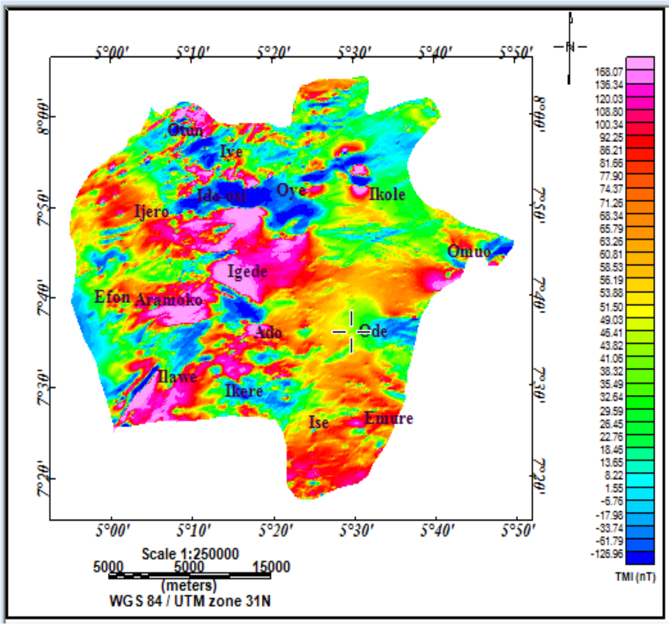

Figure 3: Map of the total magnetic intensity for Ekiti State.

4.2 Residual Magnetic Intensity

The initial step in analyzing magnetic data is to eliminate the regional field, allowing attention to be directed toward the residual anomalies, which are the main focus of interest (Kearey et al., 2002). The regional and residual components were separated by utilizing a two-dimensional, first-order polynomial (trend surface) on the total magnetic field intensity data. in the study area using the least-squares method. Figure 4 displays the residual magnetic intensity (RMI) map of Ekiti State, with field values varying from -166.21 nT to 126.69 nT. The residual image highlights clearer shallow anomalies that were difficult to identify in the total magnetic intensity image.

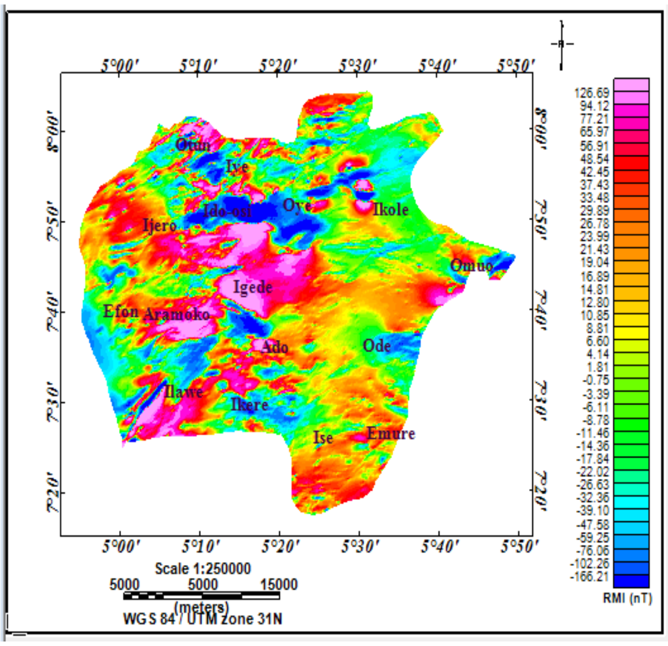

Figure 4: Map of the residual magnetic intensity for Ekiti State.

4.3 Adjustment to the Magnetic Equator

The residual magnetic intensity data was reduced to magnetic equator to account for the effect of latitude and reposition the anomalies so that their crests are evenly centered over their respective sources, as the research area is situated in the low latitude region. The reduction to equator (RTE) transformation filter was used on the residual magnetic intensity data with the help of GEOSOFT Oasis Montaj software, with -10.4840 and -1.4430 representing the inclination and declination, respectively, of the geomagnetic field parameters at the central location of the study area. The RTE map (Figure 5) reveals value variations ranging from -161.27 nT to 129.14 nT, with the magnetic anomalies being more prominent in the central region of the study area.

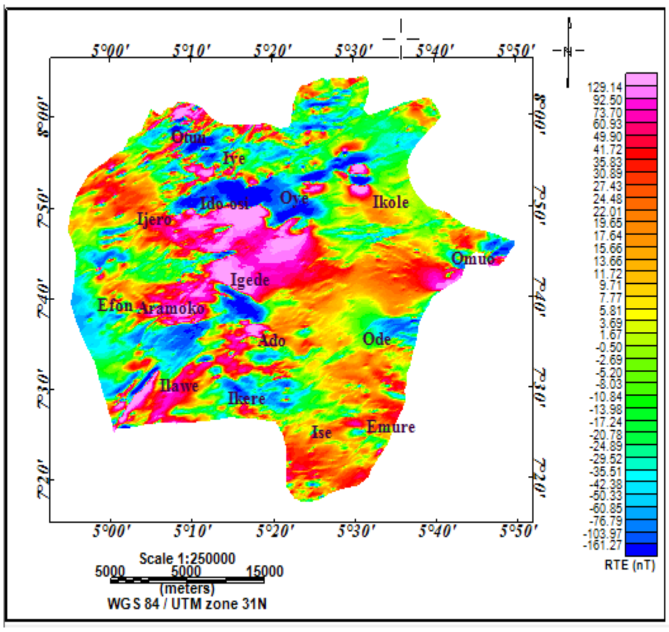

Figure 5: Map of the Reduction to Equator for Ekiti State

4.4 Upward Continuation

Upward continuation is a data enhancement technique used to reduce short-wavelength noise and highlight longer-wavelength features in potential field data. This filter is regarded as clean because it generates minimal side effects, eliminating the need for additional corrective filters or processes. Consequently, it is often employed to minimize or eliminate the impact from shallow sources and noise within data grids (GEOSOF, 2005). In this work, noise filtering was performed by upward continuing the reduced-to-equator (RTE) data to 100 m, matching the grid cell size of the data, to enhance the signal-to-noise ratio. A careful observation of the map generated from the upward-continued grid (Figure 6) shows the absence of some structures, which could be regarded as noise, that were present in the RTE map.

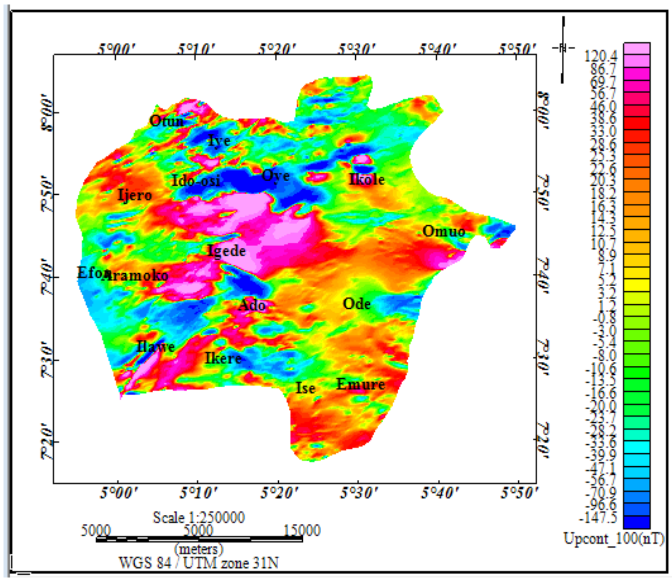

Figure 6: Upward Continuation_100m map of Ekiti State

4.5 Source parameter imaging (SPI)

The source parameter imaging (SPI) technique was implemented on the upward-continued RTE magnetic data of the study area to estimate various depths of magnetic sources using GEOSOFT Oasis Montaj software. The SPI.GX extension of the software initially calculates the Tilt derivative (A) and the local wavenumber (K), identifying the peak values K_{max}, which are subsequently used to derive depth solutions and store them in a database (Blakely and Simpson, 1986). The vertical gradient is calculated in the frequency domain, while the horizontal derivatives are determined perpendicular to the strike direction employing the least-squares technique (Marwan and Yahia, 2017). The depth of the source edge is determined by taking the reciprocal of the local wavenumber, expressed as:

$$\text{Depth} = \frac{1}{K_{max}} \quad (1)$$

$$K = \sqrt{\left(\frac{dA}{dx}\right)^2 + \left(\frac{dA}{dy}\right)^2} \quad (2)$$

$$A = \arctan\left(\frac{{dM}/{dz}}{\sqrt{\left({dM}/{dx}\right)^2 + \left({dM}/{dy}\right)^2}}\right) \quad (3)$$

where M represents the magnetic field anomaly grid (Blakely and Simpson, 1986).

The SPI map for the area of study was created from the computed depth solution with SPI.GX extension of the GEOSOFT Oasis Montaj software. The map illustrates variations in the depths of magnetic sources, ranging from 116.9 m to 658.5 m (Figure 7).

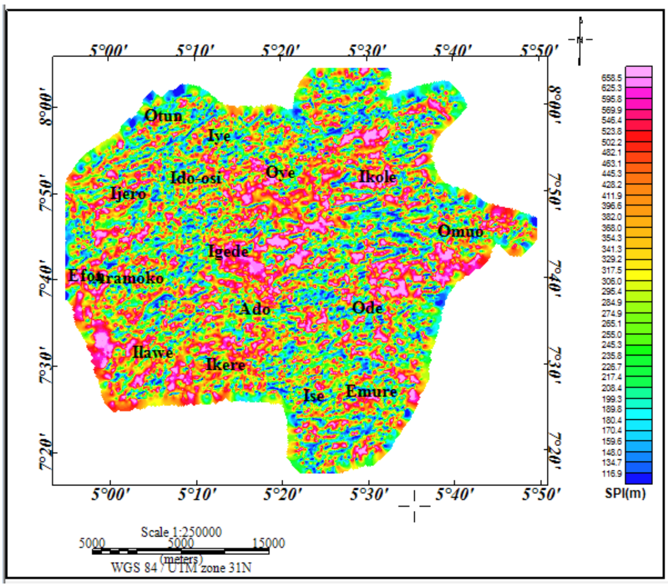

Figure 7: Source parameter imaging map

4.6 Groundwater potential Assessment

The findings on the spatial variation in basement depth indicate areas of both shallow and deep basement. The topographic map of the basement surface for the study area, generated from the SPI depth values, shows the fluctuating characteristics of the basement surface (Figure 8). The deep basement areas have a thicker overburden that can store significant groundwater due to their associated thick weathered zones, which enhance recharge potential. In contrast, areas with a shallow magnetic basement have a thin overburden, resulting in limited aquifer potential. The minimal thickness of the weathered layer restricts groundwater storage and reduces recharge potential.

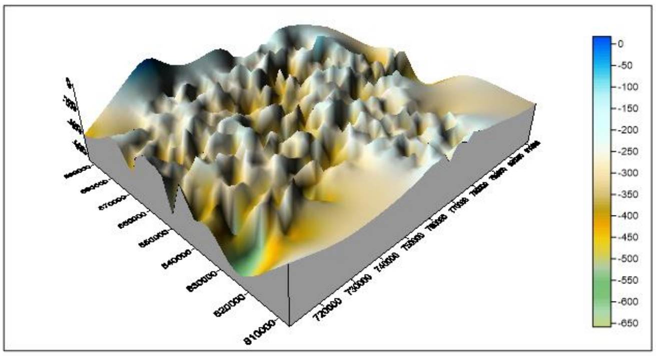

Figure 8: Surface plot of the basement depth

5. Conclusion and Recommendation

The basement depth at various points within the area of study can be easily inferred from the SPI map. The area can be classified into zones of shallow, medium, and deep basement depths. Great depths to the basement are predominantly located in the central and southwestern regions of the research area, while most other areas fall within the shallow to medium depth range. Understanding basement depth is crucial for groundwater exploration in this region. Attention should be focused on areas with deep basement depths, complemented by integrating other geophysical or geological methods, such as resistivity or hydrological modelling, to enhance groundwater exploration efforts.

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