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Geophysical Investigation of the Precambrian Iron Ore Deposit in the Area Around Tajimi, Kogi State, North Central Nigeria

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ABSTRACT

This study involves geological and geophysical investigations aimed at delineating extent of the Precambrian iron ore deposits in the Tajimi area, Kogi State, North Central Nigeria. The research integrates field geological mapping on the scale of 1: 50,000 surveys, comprising the Vertical Electrical Sounding (VES) survey and airborne magnetic surveys to identify the iron ore and determine their lateral and vertical extents. The geological study reveals a Precambrian iron ore deposit. Geoelectrical data were interpreted to delineate resistivity anomalies indicative of iron ore mineralization, with low-resistivity zones correlating with ferruginous zones and high-resistivity layers representing overburden or non-ore-bearing Formations; while low low-resistivity layers represents the ore-bearing Lithology. The combined geologic and geophysical approach (Source Parameter Imaging, 3D Euler Deconvolution and Analytical Signal) enabled the estimation of the deposit's thickness at the edge of the iron ore deposit in contacts with the surrounding basement rocks. Magnetic Reduction to Equator and Regional-residual separation were carried out on the acquired magnetic data to centre magnetic anomaly peaks over the iron ore bodies and expunge noise backgrounds respectively. Horizontal and Vertical Derivatives (VD & HD), for delineation of lineaments of magnetic sources, subsurface structures presenting as faults, folds and contacts or lithologic boundaries, were employed in the study as well as Source Parameter Imaging, Euler Deconvolution and 3D Magnetic Inversion techniques for determining both the lateral and depth extents of the iron ore deposits in the study environs. The thin lateritic topsoil, approximately 0.5–1.91 m thick, with resistivity range between 150 Ωm to 600 Ωm is composed of lateritic sand, overlying the low resistivity layer which represents the iron ore spans between 1.78-1.88m thick and having resistivity values between 42–241 Ωm. This continues till VES five with very low resistivity and thickness of 0.43 m. The weathered/partly weathered fresh basement with thickness ad infinitum, showed resistivity range between 419 Ωm to 4492 Ωm. The various resistivities (the five VES points) values were summed, with an average of 1.2 m thick. Airborne magnetic results revealed dominant NE-SW and NW-SE structural trends from Horizontal and Vertical Derivative plots, NW-SE/NE-SW trending lithologic contact.

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INTRODUCTION

Iron ore remains one of the most vital ore mineral, serving as a primary raw material in steel production which is fundamental to infrastructural development, manufacturing, and various technological applications (Fadare, 2022). Globally, the demand for iron ore has surged significantly over the past decades, driven by the rapid growth of economies and the expansion of construction and manufacturing sectors (Akande, 2018). Nigeria, positioned as an emerging economy with vast mineral resources, has been actively exploring and harnessing its mineral wealth to diversify its economy beyond oil. Among these mineral resources, iron ore deposits hold considerable promise for local steel industry development and export potential.

Exploration for iron ore has been carried out using magnetic methods since the early 1900s. Both aerial and ground-based magnetic techniques are commonly used for the detection of iron ore (Akinola *et.al*., 2017). Aerial techniques tend to be used at the reconnaissance stage, whereas ground-based techniques may be used for target appraisal (Bayowa *et.al*., 2016). An aeromagnetic survey for iron ore was carried out in some parts of Nigeria by the Geological Survey of Nigeria in 1963, which led to the delineation of notable occurrences of Banded Iron Formation (BIF) in some areas such as Itakpe, Ajabanoko, Ochokochoko, and Tajimi among others (Alabi *et.al.*, 2019).

The study area is underlain by Precambrian rocks of the Basement Complex. Over twenty mineral deposits of potential economic value have so far been reported in Kogi State and iron ore deposit is of the prominent mineral deposit in the state. Exploration by the Geological Survey of Nigeria in 1963, delineated notable occurrences of Banded Iron Formation (BIF) in localities like Itakpe, Ajabanoko, Ochokochoko, and Tajimi among others (Amadi *et.al., 2020*).

Magnetic survey sets out to investigate subsurface geology on the basis of anomalies yielding various magnetic intensities, recorded in nanotesla, as a result of the magnetic properties associated with the ores or the host rocks (Anakwaba, 2016). Magnetization contrasts between rocks with different magnetic properties aids to reveal geological boundaries between sedimentary rocks and the magnetic Basement. Most rocks contain magnetite, hematite or other magnetic material, and will produce disturbances in the local magnetic field. Because of this, most soils and many man-made objects that contain nickel or iron have magnetic properties detectable by a sensitive magnetometer, because they create local or regional anomalies in the earth's main field. Anomalies are revealed by systematic measurement of the variation in magnetic field strength. Causative factors of the varying magnetic fields can be further determined by ground-truthing using any preferred magnetometer especially the proton procession magnetometer (Balogun, *et. al., 2017*).

Electrical resistivity surveying is based on the principle that the distribution of electrical potential in the ground around a current-carrying electrode depends on the electrical resistivities and distribution of the surrounding soils and rocks (Wightman, 2018). The usual practice in the field is to apply an electrical Direct Current (D.C) between two electrodes implanted in the ground, and measure the difference of potential between two additional electrodes.

Electrical resistivity profiling is simply a two-dimensional resistivity method, where an image representing a slice of the earth is created and electrical property contrasts are used to interpret differing geological or hydrogeological conditions (Allisson, 2019), The geological formations of the subsurface determine the distribution of electric potential because interstitial water containing dissolved ions, contribute to the conduction of electricity (Botu *et.al., 2019*). The sensitivity and resolution of the resistivity profile decreases with depth and deeper targets need to be larger in order to be accurately resolved. Due to the efficiency of this technique in probing greater depths via increased current electrode spread, its usefulness for evaluating underlying materials which contribute significantly to lower resistivity values, cannot be overlooked (Chukwu *et .al., 2018*).

The findings suggest the presence of significant iron ore deposits within the study area, which could serve as a foundation for sustainable mineral exploitation. This integrated methodology underscores the importance of combining geological mapping with geophysical techniques in mineral exploration, especially in regions with limited prior exploration data, and contributes to the broader understanding of mineralization processes in the study area.

This study adopts integrated airborne magnetic and ground electrical resistivity surveys around Tajimi village, with view to investigate the occurrence and subsurface geometry of the Precambrian iron ore deposits in the area.

The primary aim of this project is to carry out the geophysical investigation of the Precambrian iron ore deposit in the area around Tajimi, Kogi State, North central Nigeria, thereby providing valuable geological and geophysical insights to guide mineral exploration and sustainable resource development.

This shall be achieved through the following objectives:

i. To characterize the geological setting of the Tajimi area, including lithology, structural features, and mineralization patterns related to iron ore deposits.

ii. To apply geo-electric methods (such as Vertical Electrical Sounding or other appropriate techniques) to delineate subsurface stratigraphy and identify conductive zones associated with iron mineralization.
   a. Interpretation of airborne magnetic data of the study area
   b. To estimate depth, and a modelled ore geometry of the iron ore deposits

iii. To integrate geological and geophysical data for accurate estimation of the depth, thickness, and extent of the iron ore deposits.

iv. To interpret the geophysical data in conjunction with geological information to produce a reliable model of the iron ore deposit.

Iron ore is a critical raw material in the global steel industry, underpinning infrastructure development, technological advancement, and economic growth. Nigeria, endowed with diverse mineral resources, has immense potential for iron ore deposits, particularly within the Bida Basin in North Central Nigeria. Despite this potential, the precise delineation, evaluation, and quantification of iron ore deposits in the region remain limited, hampering sustainable mining development and resource management.

Historically, mineral exploration in Nigeria has relied heavily on surface geological mapping and traditional sampling techniques, which often lack the spatial resolution necessary for accurate estimation of subsurface mineralization. As a result, many prospective deposits remain underexplored or underutilized, leading to inefficient resource extraction and economic losses (Aminu et al., 2018). The Bida Basin, characterized by complex geological Formations including banded iron formations (BIFs), metavolcanics, and sedimentary units, presents both opportunities and challenges for mineral exploration (Ojo et al., 2016). The presence of BIFs in the region suggests potential iron ore deposits; however, their extent, grade, and depth are not well defined. The problem then centers on the lack of detailed, reliable data for the identification, delineation, and estimation of iron ore deposits in Tajimi, Bida Basin. This knowledge gap constrains mineral resource management and sustainable development efforts, necessitating a scientifically rigorous exploration approach that combines geological mapping with geophysical techniques to produce accurate, cost-effective deposit estimates.

Location of Study

The study area falls within the Geological Survey Map sheet 227 of Koton-karfe which spans between Longitude $06^{0}35'$ $00''$ E to $06^{0}40'$ $00''$ E and Latitude $08^{0}00'$ $0''$ N to $08^{0}04'$ $00''$ N on a scale of 1:50,000 (Figure 1). It is accessible by minor roads and foot paths. The scope of the study involves the interpretation of airborne magnetic data, to delineate the Precambrian iron ore geometry around Tajimi environs.

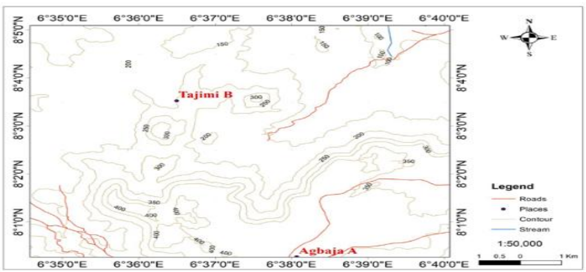

Figure 1: Topographic Map of Tajimi (The Study Area)

Geology of the Study Area

This section reviews the Geology of the study area and with useful and associative terms, gives a broad picture of the basis of the research by referring to similar results and unsolved problems within the topic's window, concept of the basis of the research work, and ideal chosen tools for the achievement of the research. The literature is reviewed under the Conceptual, Theoretical and Empirical frameworks.

About half of the total area of Nigeria's landmass is underlain by rocks of the Precambrian age known in the country as the Basement Complex (Fig.2) and it is situated within the PAN African mobile belt and sandwiched between the West African Craton to the West, the Tuareq Shield to the North and the Congo Craton to the southeast. There is almost an equal division between the crystalline basement rocks and Cretaceous to Quaternary sediments and volcanics. The Basement complex is commonly described under three lithologic group; Migmatitie Gneiss Complex group, Schist belts and Older Granites and the Migmatite gneiss complex which is believed to be the oldest rocks of the Nigeria Basement Complex.

The study area is underlain by crystalline rocks of the Precambrian Basement Complex of Nigeria. It is specifically underlain by meta-sedimentary and meta-volcanic rocks of Igara, Kabba, and Jakura regions (Opara and Chukwu, 2016). The dominant lithological units are the gneiss-schist suites (migmatite and biotite gneisses) which are regionally emplaced, granites, pegmatites and ferruginous quartzites, which is the source of iron ore mineralization in the area, (Bayowa *et.al.* 2016). Mineralization of iron ore, gold vein emplacements are generally confined within the N-S. NNE-SSW, NNW-SSE and NW-SE and to a lesser extent, E-W trending structures, with the N-S structures marked by considerable shearing and brecciations (Okunola, 2008; Kolawole *et.al.* 2017).

i. *Gneiss-Schist Suites*

The study area falls within the Igarra-Kabba-Lokoja schist belts, which have the features to host important economic minerals, and they constitute major lithostratigraphic units necessary to unravel the geochemical and geodynamic evolution of the basement complex (Ekwueme, 2003; Danbatta, 2008; Ekwueme and Ephraim, 2005).

Migmatite and Biotite Gneisses

They are foliated fine to medium grained rocks and foliated in a general NW-SE and minorly, NE-SW trend.

ii. ***Granites***

They exist mostly as granitic plutons and are unfoliated, occurring as fresh basements. Dominant minerals present are feldspar and quartz grains. The granites occur as fine-medium-foliated granites.

iii. Pegmatites and ferruginous quartzites

The supracrustal rocks are highly weathered of quartz mica schists, usually domicile in low flat valleys. The pegmatites present are barren to un-barren (Atodo *et al.*, 2024).

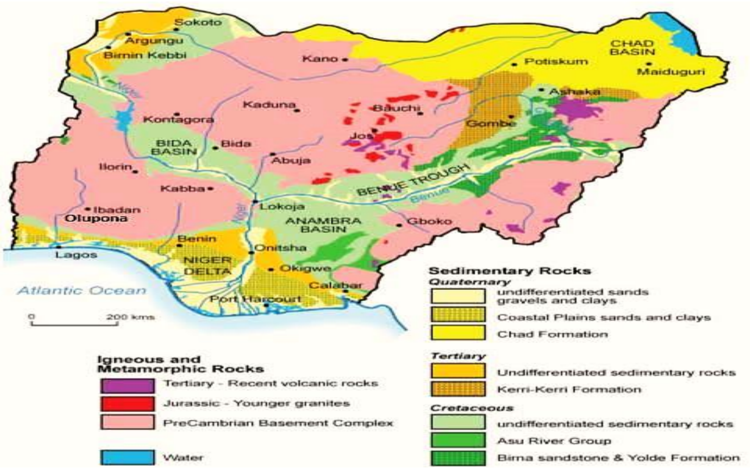

Figure 2: Geologic Map of Nigeria Showing the Sedimentary Basins and the Basement Complexes (Adapted from Okiyi, 2021)

MATERIALS AND METHODS

Methodology

The field work started with a reconnaissance survey of the area through access roads, dried drainage channels and settlement paths/routes. It also involves taking note of the minor and major geologic outcrops around areas suspected to be of interest to iron ore deposits. Their locations were also noted with the global positioning system (GPS) and as such, complemented the secondary data of re-digitized geologic map of the area, which was used as an integral part of the study as well.

This study employed airborne magnetic and ground resistivity survey techniques. The essence of VES survey in the study area is to determine the thickness of the iron ore deposits that have been exposed on the surface. The airborne magnetic survey was done to determine the iron ore deposit: its thickness and lateral extent. Geological information allows structural features to be unravelled during mapping; VES was integrated with Aeromagnetic data to produce a model of the subsurface to enhance interpretation. 3D Euler deconvolution, 3D magnetic inversion local wavenumber methods were used to determine thickness and lateral extent of the magnetic contact.

Airborne Data Acquisition

The Airborne magnetic survey data was obtained from the Nigerian Geological Survey Agency (NGSA), a parastatal of Ministry of Mines and Steel Development (Reford, 2010). The survey was carried out by World Bank through Sustainable Management of Mineral Resources Project (SMMRP) representing 44% national coverage of Benue Trough, parts of South West, Middle Belt up to parts of North Western regions of the country and obtained data magnetic data, alongside radiometric, gravity and electromagnetic data which were flown at 500 m line spacing, 80 m terrain clearance generating a total of about 2 million line-km (2000

m) data in a NE-SW direction and recorded at 0.1s interval, making it a high resolution airborne data. This phase 1 survey was conducted from 2005 to 2007 and also interpreted by FUGRO. The acquisition of this data has helped to re-invigorate the solid mineral sector via the dependability of these high resolution data for exploration and research purposes. The International Geomagnetic Reference Field model of 2015 referenced to 1984's world geodetic system was used to remove the geomagnetic gradient. The International Geomagnetic Reference Field (IGRF) was expunged, and 33,000nT was added to yield the accurate total magnetic field intensity (TMI) map of the study site. The obtained total magnetic intensity data was geo-referenced to the Universal Transverse Mercator coordinate system for effective comparison with the geological map of the area.

Analysis of Airborne Magnetic Data

Several reductions were made on the magnetic data for easy and straight forward interpretations, which include, regional-residual separation, reduction to equator, vertical and horizontal derivatives, analytical signal, Source Parameter Imaging, Euler Deconvolution, magnetic lineament extraction and 3D Magnetic Inversion techniques. To improve aeromagnetic data quality for better understanding of the earth's subsurface, various analyses were carried out on the TMI (Hildenbrand *et.al.*, 2000; Hinze *et.al*., 2005; Amigun *et.al*., 2012; Faruwa *et.al*., 2021). These analyses are; Regional-Residual Separation, Reduction To Equator (RTE), Vertical and Horizontal derivatives, Analytic Signal, Standard Euler Deconvolution, Spectral Analysis, Magnetic lineament Extraction, Source Parameter Imaging (SPI) etc.

Ground Resistivity Data Acquisition

VES Data Acquisition and Processing

The geophysical survey was carried out using a DDR3 Sensor Terrameter to obtain the resistivity at five (5) locations using vertical electrical soundings (VES) within the study area. Vertical electrical soundings (VES) were carried out to determine the different elements of overburden, and the depth to basement. Schlumberger electrode array was employed with the half-current electrode ($\frac{AB}{2}$) spread ranging from 1m to 200m and the half potential electrodes $\frac{MN}{2}$ (fig.3), ranging from 0.5m to 15m. Acquisition of the resistivity data started from lower electrode spacing of 1m and potential electrode at 0.5m to higher electrode spacing. The current electrode spacing was increased

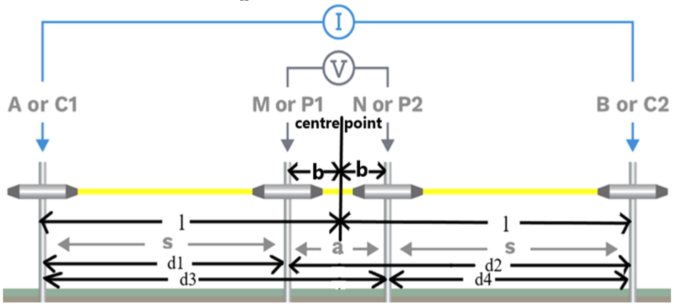

Figure 3: Electrode Configuration Adapted from Okiyi, 2021 (Modified after Telford *et.al.,* 1990)

G (Geometric Factor) = $\frac{\pi[l^2-b^2]}{2b}$ (1)

$\rho_a = G*R$ (2)

continuously while the potential electrode spacing was kept constant until a lower resistance value was noticed after which the potential electrode spacing was changed. This process was repeated for all the 15 surveyed locations. The measured resistance (R) to current sent to ground was used to determine the geometric factor, G, (eqn.1) and the apparent resistivity, ρ_a,, (eqn. 2)

With the electrodes close together, the largest fraction of current flows in the uppermost layers and a total value of the shallower subsurface resistivity were obtained. As the electrodes spacing (current and potential electrodes) subsequently becomes larger, resistivity of deeper layers was determined. Thus, the electric resistivity was determined as a function of the electrode separation or pacing as described by Zohdy (1989). Usually, the potential electrodes are in line between the current electrodes, but in principle, they can be located anywhere. The current used is either direct current, commutated direct current (i.e., a square-wave alternating current), or AC of low frequency (typically about 20Hz). All analysis and interpretation are done based on direct currents. The distribution of potential can be related theoretically to ground resistivities and their distribution for some simple cases, notably, the case of a horizontally stratified ground and the case of homogeneous masses separated by vertical planes (e.g., a vertical fault with a large throw or a vertical dike). For other kinds of resistivity distributions, interpretation is usually done by qualitative comparison of observed response with that of idealized hypothetical models or based on empirical methods.

Resistivity is fundamentally related to Ohm's Law measuring Resistance. Resistance is defined as the voltage divided by the current

R = V/I (3)

The value of a material's resistance depends on the resistivity of that material. Resistivity is the value of resisting power of a certain material to the flow of a moving current. Resistivity (ρ) values are related by the equation describing current refraction. The product of the G factor and true resistance gives the apparent resistivity values which are plotted against electrode separation AB/2 (m) on a log-log graph sheet, to give a resultant field curve. Modelling of the filtered and smoothened curve is done with view to delineate suspected layers with their corresponding depths (m) pari passu curve matching rules. Resistivity and thickness parameters from each layer of the field curve were obtained from several re-iterations on the WINRes model software. Semi-qualitative/quantitative approach involves computer assisted processes such as forward modelling for plotting of VES curves and 2-D inversion for generation of subsurface images.

VES Data Processing

Data obtained from the field were loaded to computer software (IP2Win) for the iterative modelling based on linear filter theory (Zohdy, 1989). The computer software generated plots of apparent resistivity (ρ_a) against half-electrode spacing

($\frac{AB}{2}$) which produced a smooth curve with individual geo-electrical parameters such as; layer resistivity, layer thickness and depth. Thirty (30) computer iterations were performed on each data set to obtain a smooth curve with a root mean square (RMS) error of less than 10%.

3D Magnetic Inversion

3D magnetic inversion is a geophysical data processing technique used to interpret magnetic survey data to obtain a three-dimensional subsurface distribution of magnetic susceptibility or magnetization (Osagie & Nnaji *,2017*). It helps geoscientists understand the underground geological structures, mineral deposits, or hydrocarbon reservoirs by transforming measured magnetic anomalies into a model of the subsurface which can then be interpreted therein.

3D magnetic inversion attempts to find the subsurface magnetic source distribution that best fits the observed magnetic field data. It does this by iteratively adjusting a model of magnetic susceptibility (or magnetization) within the subsurface volume until the calculated magnetic field from the model matches the measured field (Ozo & Ugochukwu, 2018).

When magnetic surveys are conducted, measurements of the magnetic field are taken at the surface or above the Earth's surface (Opara & Chukwu., *2016*). These measurements include anomalies—variations from the Earth's main magnetic field—that are caused by subsurface magnetic materials such as iron ore. However, these anomalies are indirect and convoluted representations of the underlying structures.

Mathematical Framework

The magnetic field **d** measured at the surface was modeled as:

$d = G(m) + \varepsilon$

d: Observed magnetic data

G: Forward operator that models the magnetic response of a subsurface susceptibility distribution m

m: Model parameters (magnetic susceptibility distribution in 3D space)

ε: Measurement noise

The goal is to invert for m given d.

Inversion Algorithm

Minimizing an objective function combining data misfit and regularization:

$\Phi(m) = \|dobs - G(m)\|2 + \lambda R(m)$

where:

dobs: observed data

G(m): predicted data from model

R(m): regularization term (e.g., smoothing constraints)

λ: regularization parameter controlling the trade-off

Interpreting 3D magnetic inversion results involves understanding the relationship between the observed magnetic data and the subsurface magnetic sources (Gana, 2018). It's not simply about finding "the answer"; it's a process of evaluating the geological plausibility and consistency of the model. It is an iterative process requiring a combination of geological knowledge, geophysical expertise, and careful evaluation of the model against other data (Maku & Oyetunji, 2017). Visual inspection, comparison with other data, and sensitivity analysis are crucial steps in ensuring a reliable and meaningful interpretation.

RESULTS AND DISCUSSION

The interpreted VES data characterizes the delineated subsurface layers into four (fig. 4-8); these are the top soil, anomalous low resistivity layer (iron ore zone), fractured/weathered basement and the fresh basement. The topsoil, composed of lateritic sand is 0.17–0.6 m thick and has a resistivity range of 150-505 Ωm and the second layer of thickness ranging between 0.40-0.91 m and resistivity range of 113-839 Ωm, which is interpreted as the Precambrian Iron ore deposit. The third layer represents the weathered/partly weathered basement, occurring between 6.78 - 21.9 m with an apparent resistivity of 12.2-54.64 Ωm. The fourth layer has a much higher resistivity values than the previous layers, with resistivity value range of 1508-20320 Ωm.

The dominant curve is the H-Type Curve whose frequency has over 50% occurrence in the work.

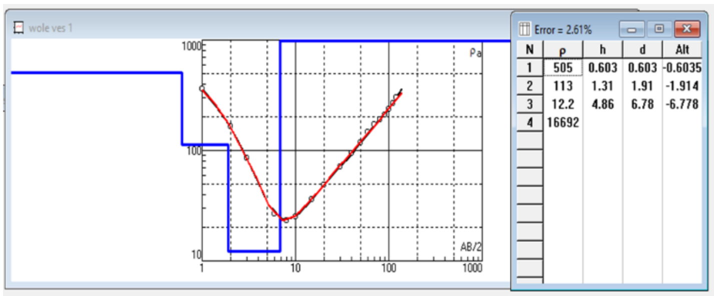

Figure 4: VES Curve at Location 1

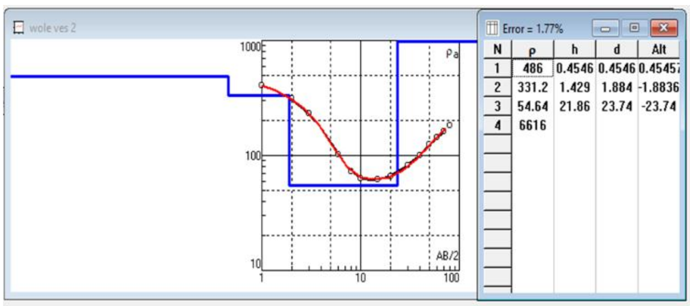

Figure 5: VES Curve at Location 2

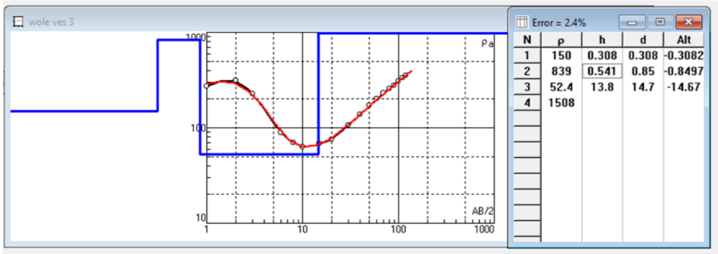

Figure 6: VES Curve at Location 3

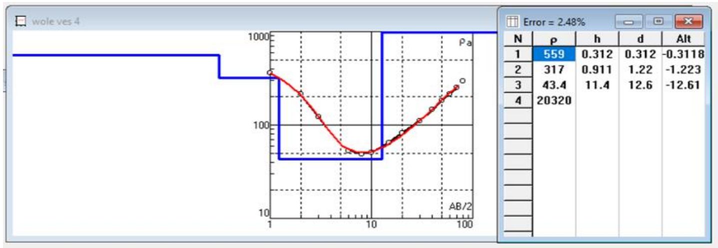

Figure 7: VES Curve at Location 4

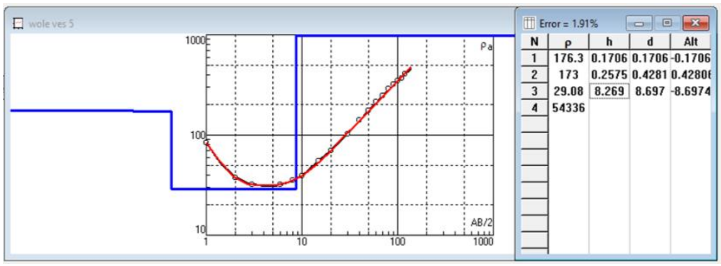

Figure 8: VES Curve at Location 5

Discussion of RTE-TMI Results

The TMI Map (fig. 9) of the study area have value ranges between –162.7nT to 50.7nT, indicating positive (high) and negative (low) magnetic anomalies in the study area. Since Nigeria is situated very close to the Earth's equator, the geomagnetic field's inclination and declination vary in low magnetic latitudes from the equator to the pole (Abubakar, 2024). A reduced-to-the-equator (RTE) correction is performed on the TMI whose regional magnetic field must have been separated from the residual anomaly (fig.5), to place the peaks of magnetic anomalies above their source.

From the RME map (Fig. 10), high magnetic anomaly is diagnostic of magnetic minerals, intrusives and shallow localized bodies. Areas with low magnetic susceptibilities typify low magnetic minerals. High magnetic intensities are seen basically in the Eastern parts of the study area, influenced by the presence of Oolitic ironstones in the granitic environment. These factors significantly control the magnetic relief of the Study Area. High magnetic intensities as much as 68.3nT have a nearly elliptical North-easterly trend, in the Southeastern part of the area. Elliptical contours are often indicative of surface/sub-surface intrusions (Udensi &Akanbi, 2006). These anomalies are likely influenced by lateritic concretionary Iron (Fe) laden with subsurface intrusions. Negative anomalies ranging from -135 to -61 nT are observed on the Western and Northeastern part of the Study area. The low magnetic relief are diagnostic of granitic-gneiss basements, as a series of closed lows depict linear trends which initiate fault zones (Hudson & Fishman, 1990). The varying magnetic highs and lows stem from the contrasting lithologies and ferro-magnetic minerals in them.

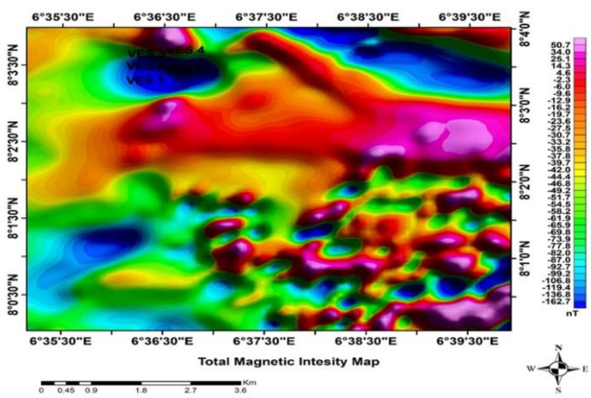

Figure 9: Total Magnetic Intensity Map of the Study Area

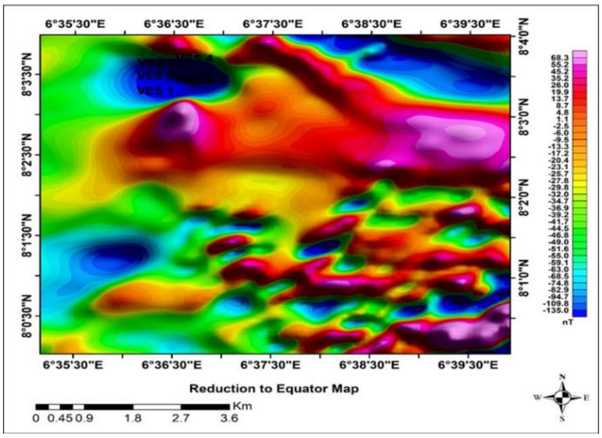

Figure 10: Reduce to Magnetic Equator Map of the Study Area

Discussion of Euler Results

Past literature reviews establish structural indices of 3D Standard Euler deconvolution of aeromagnetic data for contacts as N=0, narrow 2D sills and dykes as N=1 and horizontal cylinder, vertical pipes, lines, thin bed fault and spheres as N=2, based on certain criteria or attributes (Thompson, 1982 & Reid, 2007). Solutions obtained for N=1 structural index in Figure 8 shows the dominant NE-SW trend of ironstone emplacement from fractured and weathered gneissic and granitic basement, with the rest of 0, 2 and 3 showing very poor solution clusters, hence, were overlooked. The maximum depth range of >243m were obtained and best solution clusters for mafic sills and dykes with maximum depth range >243m were best obtained with a structural index of 1.

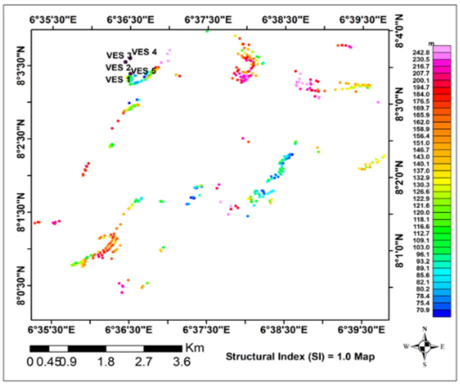

Figure 11: 3D Euler Depth Solution

Discussion of Analytic Signal Result

The analytical signal is very effective in mapping subsurface magnetic faults and contacts (Hsu *et.al*., 1998), edges with anomalous sources, and lithological contacts dependent on the magnetization of various rock compositions (Faruwa *et.al*., 2021). The lithologic boundaries or contacts, separating high magnetic anomalies from the low anomalies, trend in the NW-SE direction (fig. 12), but mainly in the NE-SW direction. Just like the derivative maps, analytic signal discriminates between basement and sedimentary environments.

The analytic signal map shows maximum amplitude of >1.00 nT/m and exhibits maxima over magnetization contrasts and is also independent of ambient magnetic field and source magnetization directions.

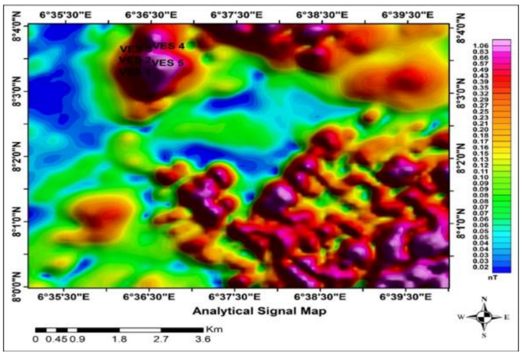

Figure 12: Analytical Signal Map of the Study Area

Discussion of 3D Magnetic Inversion Result

An optimal model derived by regularized inversion with $\hat{\alpha}^{S2} = 0.90$ using weighting function w^{S2} . **a** perspective view of the optimum model which displays all non-zero model elements, **b** total field anomaly computed by this model, and **c** histogram of the residuals.

Before performing the 3D magnetic inversion finally, the regional component was removed by applying trend surface analysis (Bordet *et. al.*, 1992). The regional anomaly **t** was assumed to be expressible by the following linear equations:

$\mathbf{t} = c0 + c1\mathbf{x} + c2\mathbf{y}$,

where **x** and **y** are the coordinates of the observation points. The coefficients c0 , c1 , and c2 were estimated by least squares fitting. Figure 13 shows the trend removed anomaly by subtracting **t** from the data of TAJIMI, the study area. These data were used as the input data of our inversion.

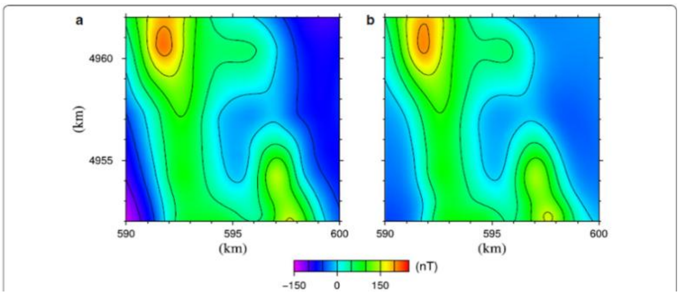

Figure 13: The Magnetic Anomaly of the Field

From figure 14, **a** is the magnetic anomaly in the area from which the linear trend has been removed. The original data are a portion of the Aeromagnetic Anomalies Database of Nigerian Geological Survey Agency (NGSA), b is the magnetic anomaly recovered by the optimal model. The coordinate system of these figures is Universal Transverse Mercator (UTM), and the colour scale indicates the magnetic anomaly in nano-Tesla (nT).

The slice of the optimal model and recovered anomaly by this model is shown in Fig. 18.

The depth of each slice of Fig. 18 is (a) 200 m, (b) 400 m, (c) 600 m, and (d) 800 m, respectively. On each figure, the location of the exposed belts is displayed in black solid lines. As shown in this figure, a focused model was obtained exhibiting two high-magnetization areas extending north to south. From here, we can see that, these two magnetization areas correspond well to the locations where two serpentine belts are exposed on the surface, and this suggests that the estimation of the subsurface magnetic structure has been successfully conducted.

Next, focusing on the magnetization intensity, the estimated magnetization of this area has a maximum of about 10 A/m. In this area, Obaje (2009) measured the susceptibility of major rock samples near the surface and reported that the average susceptibility of the belt is 20×10^{-3} SI unit. Thus, if geomagnetic intensity is 51,000 nT, the induced magnetization is about 1 A/m, which is 10 times smaller than the estimated value. Therefore, it can be considered that the magnetic susceptibility of the sample near the ground surface was weakened by weathering (Oyewole, 2020). Or, while the rock magnetization of this area was assumed to be only the induced magnetization, it is thought that the component of the remnant magnetization is also included (Smith *et al., 1998*).

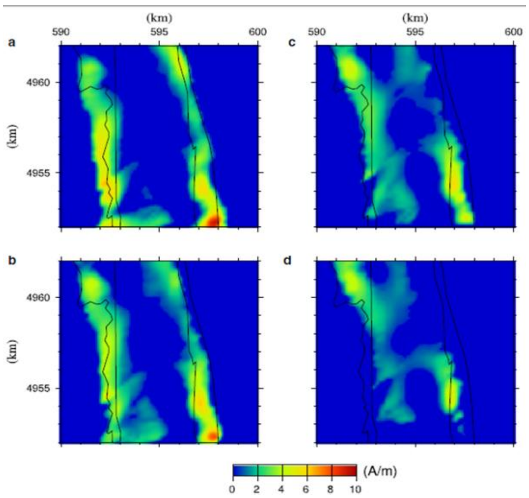

Figure 14: The Final 3D Magnetic Inversion Model of the Study Area

CONCLUSION

In conclusion, the inversion method to obtain a 3D magnetic susceptibility distribution has been presented which incorporates a sparseness constraint based on regularization. In order to improve the depth resolution of the model, an appropriate weighting function (W^{S1} and W^{S2}) was used to detect presence of an anomaly which are magnetite, iron ore, pegmatite etc. and their respective trends were discovered but the thickness and depth needs to be integrated using Euler deconvolution, Local Wavenumber number of magnetic contact depth determination. From the inversion the more mineral trending NS is iron ore with cyan coloration, other minerals from the inversion are paucity and infinitesimal of

the same trend and or irregular trends as indicated by yellow and orange colour towards S-Eastern Part of the Study area.
The variation in the magnitude of the earth's magnetic field as shown in (Fig. 14) is to detect local changes in the properties of the underlying geology and show that there is sizeable quantity of different magnetic deposit structures in Tajimi.
Fig. 14 shows the general magnetic susceptibility of the basement rocks and the inheritance variation. The North-eastern and North-western part of the study area indicate a higher concentration of magnetically susceptible mineral (principally iron ore and magnetite). Also, and south-western parts and North-Central part of the area under consideration are dominated with broad magnetic lows (low magnetic concentration) and therefore lower susceptibility. Magnetic response is measured in nano Tesla. The range of values is from a low of -11.0nT to a high of 102.7 nT. Horizontal Gradient technique and Local wavenumber method (also known as Source Parameter Image method) were used on the gridded data of the area under consideration.
The investigation demonstrated that the Tajimi area within the Bida Basin possesses geologic and geophysical signatures consistent with the presence of iron ore deposits. The resistivity surveys effectively delineated subsurface anomalies correlated with mineralized zones, and these anomalies align with geological structures conducive to mineral accumulation, such as faults and fractures. While the study provides promising indications of potential iron ore deposits, the results are preliminary and require further validation through detailed drilling, sampling, and laboratory analyses. The integration of geophysical data with geological mapping enhances confidence in the interpretation, but definitive confirmation of resource quantity and quality necessitates comprehensive exploration. Overall, the findings suggest that Tajimi holds potential as a viable site for iron ore extraction, contributing to Nigeria's mineral resource development. However, careful planning and further assessments are essential to confirm economic feasibility and environmental sustainability.
A transformation and interpretation of airborne magnetic data and VES data and air-borne were used to evaluate new and existing iron ore fields in parts of Tajimi. This research has shown good responses to surface and deep seated dense lineations, moderate to high anomalous magnetic fields supporting the fact of the prospectivity and viability of the study area for iron ore deposits.

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