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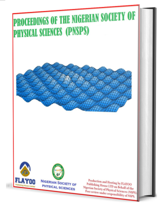

Investigation of fault zone and its environmental impact in Ilorin, North Central, Nigeria

R. O. Agboola[a,*], L. A. Sunmonu[b], M. A. Adabanija[c], N. K. Olasunkanmi[d], K. O. Suleman[e]

[a]*Department of Physical Sciences, Al-Hikmah University, Ilorin, Kwara State, Nigeria*
[b]*Department of Pure and Applied Physics, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria*
[c]*Department of Earth Sciences, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria*
[d]*Physics and Material Science Department, Kwara State University, Malete, Nigeria*
[e]*Department of Physics, Nigeria Maritime University Okerenkoko, Delta State, Nigeria*

A B S T R A C T

A series of Seismic activities are being experienced in some part of Nigeria with the obvious threat to lives and properties. This study therefore investigated and identified localized fault zone believed to be pathway to seismic activities in Ilorin. For this purpose, high resolution aeromagnetic data of Ilorin, obtained from Nigerian Geological Survey Agency were processed and interpreted using Geosoft Oasis Montaj 6.4.2 data processing and analysis software package. The Reduced to Equator (RTE)-Residual Magnetic Anomaly (RMA) maps were obtained from step by step filtering of magnetic intensity maps, the geological features were examined using Analytic Signal Amplitude (ASA). Lineaments were extracted from Total Horizontal Derivatives (THD) map.The process was then subjected to depth continuation process to obtain localized fault zones The Upward continuation process employed, showed the region of consistent high magnetic amplitude or increasing amplitude on the upward depth continued map of the study area as region of deep depth to magnetic sources, indicating intrusion. The minor or localized faults were captured with decreasing magnetic amplitude at UC height of 5000 m at the depth of 2,500m in the area under study. The superposition of the lineaments obtained from THD map on the RTE-RMA and geological maps revealed ductile and brittle deformations and a set of dextral localized faults of varied orientations. These identified localized faults within the study area could serve as pathway to Seismic activities leading to earth tremor as a threat to human existence.

Keywords: Upward continuation, Seismic, Magnetic amplitude, Epicenter, Total horizontal derivatives.

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1. INTRODUCTION

A fault is a planar fracture or discontinuity in a volume of rock across which there has been significant displacement as a result of rock-mass movements. Large faults within the Earth's crust result from the action of plate tectonic forces, with the largest forming the boundaries between the plates, such as the megathrust faults of subduction zones or transform faults [1]. Energy release associated with rapid movement on active faults is the cause of most observed earthquakes. Faults may also displace slowly, by aseismic creep. Due to friction and the rigidity of the constituent rocks, the two sides of a fault cannot always glide or flow past each other easily, and so occasionally all movement

*Corresponding Author Tel. No.: +234-703-2699-394.
e-mail: roagboola@alhikmah.edu.ng, agboridwan@gmail.com (R. O. Agboola)

stops. The regions of higher friction along a fault plane, where it becomes locked, are called asperities. Stress is built up when a fault is locked, and when it reaches a level that exceeds the strength threshold, the fault ruptures and the accumulated strain energy is released in part as seismic waves, forming an earthquake [2].

On a regional scale, West Africa was not known to be seismogenic, because of this, most people tend to believe that seismic activities are confined to North Africa and the surrounding areas of the rift valley system in East Africa [3]. Historical and recent seismicity data do indicate that disastrous earthquakes have occurred in other parts of Africa far away from the Atlas Mountain region and also in the areas far from the rift valley system [3]. Initially, Nigeria was not considered seismogenic, however, recent findings have shown that Nigeria may not be completely free from earthquakes [4–6]. Recent reviews of earthquake occurrences and observations in Nigeria have shown that several minor tremors had been experienced in some parts of the country. The intensities of these events ranged from III to VI based on the modified Mercalli Intensity Scale. Most of these occurrences which are possible mechanisms have been examined to include regional stresses created by Nigeria's position between two cratons and zone of weakness resulting from magmatic intrusions and other tectonic activities in the sediments [5].

In this study, magnetic method was employed using aeromagnetic data because it provides a means for seeing through surficial layers such as sand, vegetation and water and also a powerful tool for delineating crystalline basement beneath cover rocks and estimating depths to magnetic sources. Ref. [7] asserted that aeromagnetic data can be used in mapping magnetic basement, underlying sedimentary rocks and delineating igneous bodies within sedimentary sections as well as locating lineaments and structures. Airborne geophysics forms a critical component of geological mapping and mineral resource inventory programmes in many countries.

The study aimed at investigating the localized faults zone of Ilorin in the North-central parts of Nigeria due to incessant increase in the numbers of quarry industries and borehole drillings, with a view to establish its environmental impact on the inhabitants of the area, through interpretations of high resolution aeromagnetic data of the area. Aeromagnetic data sheet of Ilorin (sheet 223) was adopted.

2. DESCRIPTION AND GEOLOGY OF STUDY AREA

Ilorin (Figure 1) is located in Kwara state within the North-central part of Nigeria and bounded by Latitude 8°8′0 – 8°24′0-8°24′0N and Longitude 4°32′12- 4°57′6E. The area is underlain by various rock types, such as Migmatite, Granite gneiss, Magmatic gneiss, Undifferentiated schist, banded gneiss/biotite gneiss, Porphyritic granite, Silicified quartz including quartz vein, Quartzite, Massive and Schistose also occurring as ridges

3. MATERIALS AND METHOD

Total Field Intensity Aeromagnetic (TMI) data set of Ilorin (sheet 223) was acquired using Scintrex CS3 cesium vapor magnetometer by Fugro Airborne Survey Limited for Nigerian Geological Survey Agency [8]. The survey was conducted in drape mode using real time differential GPS at a sensor mean terrain clearance of 75 m. Traverse and tie line spacing were 500 m and 2000 m, respectively, while flight and tie line directions were

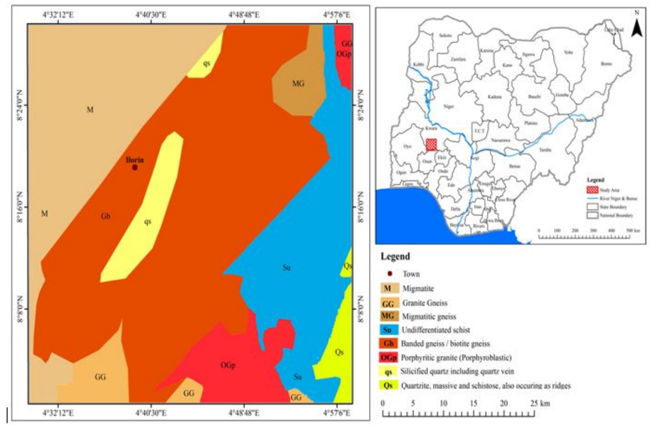


Figure 1. Geological map of Ilorin (modified after NGSA, 2009).

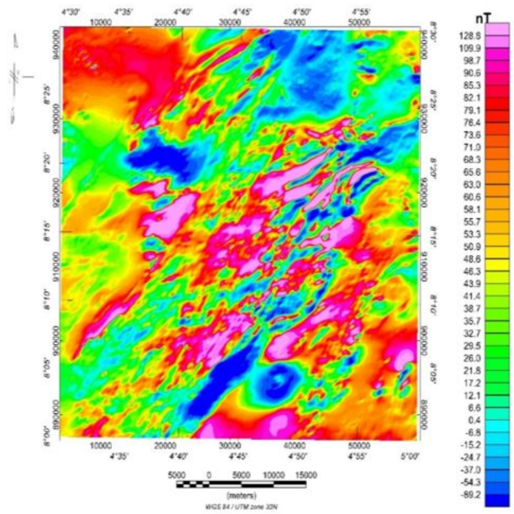


Figure 2. Total magnetic intensity (TMI).

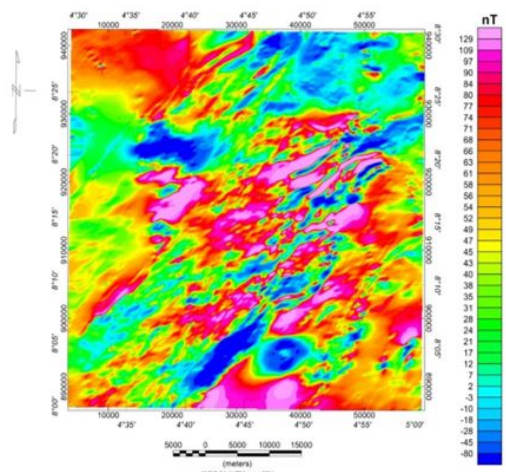


Figure 3. Reduction to equator (RTE)-residual anomaly map of Ilorin.

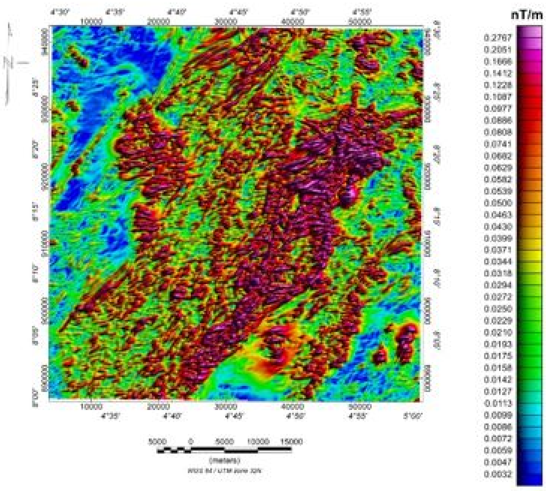


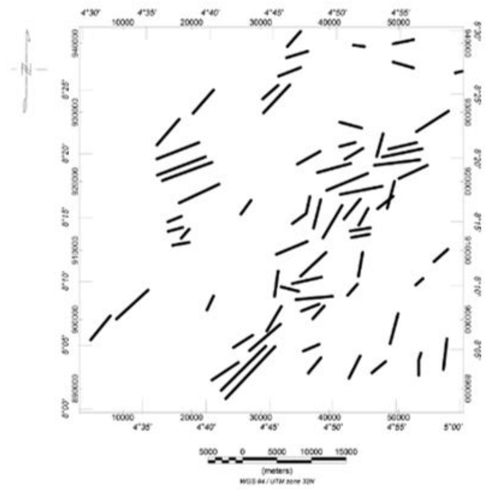
Figure 4. Horizontal gradient magnitude of Ilorin.

NW-SE and NE-SW respectively [8]. The data were de-cultured, leveled, corrected for International Geomagnetic Reference Field (IGRF), gridded at an appropriate cell size that enhances anomaly details and reduces possible noise and latitude effects [9]. The Total Magnetic Intensity (TMI) anomaly map was enhanced in order to image subsurface geological structure of the study area by applying several standard derivative and match filtering techniques. The total field data were recorded profile by profile in Excel format and delivered in Oasis Montaj^{TM} grid (x, y, z) file Format, where x is the geographic easting value (longitude), y is the geographic northing value (latitude), with both in Universal Transverse Marcator (UTM) convention and z magnetic intensity value. The bounding geographic coordinates were converted into degrees using Rockware^{TM} 15 software so that the resultant maps can be compared with geological map of the area for interpretation purposes. Reduced to Equator (RTE)-Residual Magnetic Anomaly (RMA) map was obtained from step by step filtering of magnetic intensity map.This was adopted because Nigeria is found in the low latitudes or to be closer to the Equator. It was then subjected to various data filtering and processing tools involving, Horizontal Derivative. Total horizontal derivative (THDR)/ Horizontal Gradient Magnitude (HGM) was applied on the RTE-RMA to delineate boundaries of intrusive bodies, faults and other lateral changes, anomaly texture, anomaly pattern discontinuities, enhancement of lineaments and geologic contacts using edge detection techniques. Lineaments were then extracted from Total Horizontal Derivatives (THD) map. Upward continuation (UC) was carried out on the RTE-RMA map of the area, to discriminate against shallow and deeper magnetic sources, respectively.

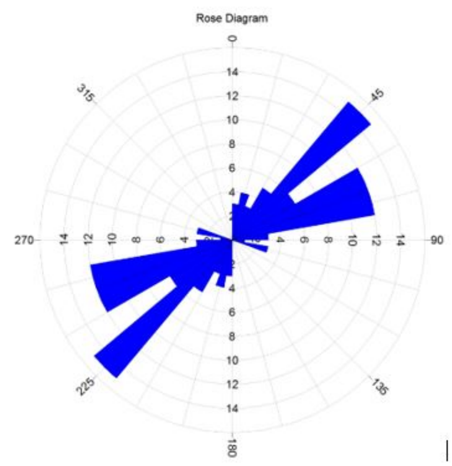
4. RESULTS AND DISCUSSION

4.1. TOTAL MAGNETIC INTENSITY (TMI)

The Total Magnetic Intensity (TMI) and Reduced to Equator (RTE)-Residual magnetic anomaly (RMA) maps of, Ilorin (Figures 2 and 3), show the magnetic contrast that is attributable to the lithological setting of the areas. The RTE-RMA map (Figure 3) shows no discrete variation in magnetic signature of the TMI



(a)



(b)

Figure 5. (a) Magnetic lineament map of Ilorin, (b) Rose diagram of Ilorin.

(Figure 2) but realigned the magnetic intensity as expected in the low latitude [10, 11], upon which Nigeria is located.

4.2. DERIVATIVES

The derivatives in both horizontal (x) and vertical (z) directions sharpen the edges of magnetic anomalies and give clearer contrast between the geologic units and causative structures such as lineaments/faults joints, e.t.c [12, 13]. The Horizontal Gradient Magnitude (Figure 4) were applied on the RTE-RMA gridded data and enhanced shallow wavelength features, resulting to near surface structures, giving rise to a better and clearer picture of the subsurface [14]. The techniques were adopted to map and delineate structures (lineaments/faults, joints, among others) in the area and classify them base on their trends, occurrences [15]. The Horizontal Gradient Magnitude (HGM) map of Ilorin (Figure 4) depicts a pink colour as the area which the derivative attains maximum value of 0.2764 nTm^{-1} and the magnetic susceptibility is the highest occurred in Northeast-Southwestern part of the map

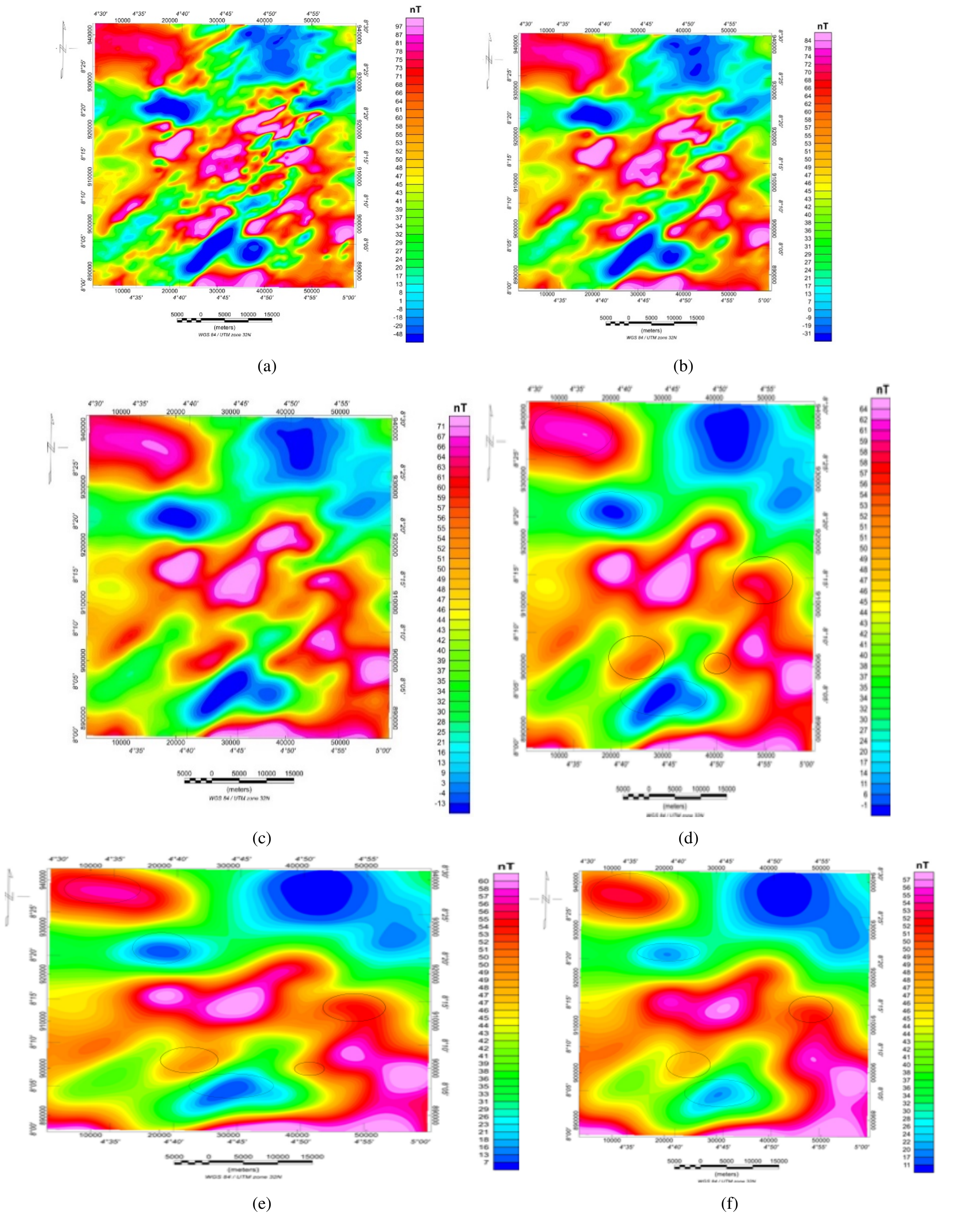


Figure 6. Fault Detection at Depths: (a) 500 m (b) 1000 m (c) 2000 m (d) 3000 m (e) 4000 m (f) 5000 m: obtained from Upward Continuation Process of RTE-RMA Map of Ilorin.

4.3. MAGNETIC LINEAMENT

The magnetic lineaments map extracted from HGM (THDR) and rose diagram obtained showing trends and orientation of the lineaments are depicted in Figure 5. The lineaments obtained from Ilorin map indicated lengths in the range of 1.0 and 9.0 km (Fig-

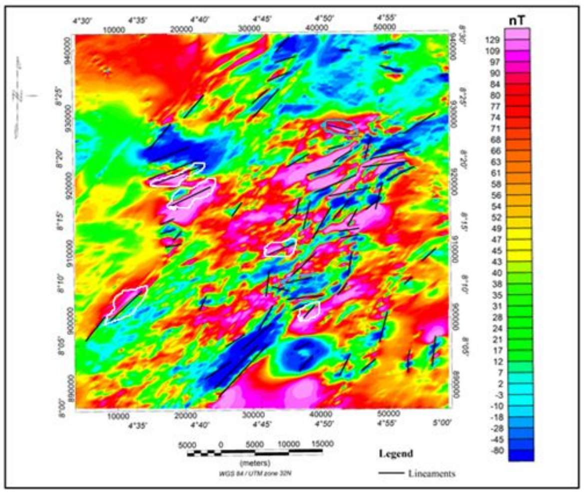


Figure 7. Lineament map overlain on RTE-RMA map.

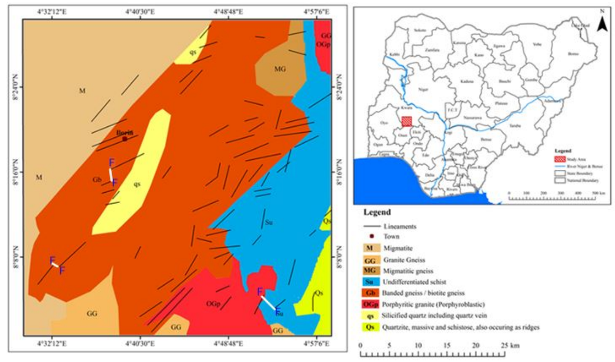


Figure 8. Lineament map overlain on geological map of the study area.

ure 5) and the structural style as shown by rose diagram are in the E-W, NE-SW and NW-SE orientation (Figure 5) with NE-SW as most prominent structure while lineaments with the NW –SE orientation showing the least. For a study area, there are numerous orientations or trends of lineaments (fractures). However, it is always difficult to know which orientation is more dominant or common. The Rose diagram was adopted to summarise the orientation of all the lineaments in the study area, thereby showing the orientation of lineaments that are dominant and those that are less common in the area.

4.4. UPWARD CONTINUATION (UC)

Upward Continuation (UC) process was employed to assess the effect of deeper sources and in the other way round attenuating the effect of shallower short-wavelength features [11, 16]. Conspicuously, the regions of consistent high magnetic amplitude or increasing amplitude on the upward depth continued map of Ilorin (Figure 6 a-f), are identified regions of deep depth to magnetic sources, indicating intrusion. The areas which experienced sharp changes from high amplitude anomaly to low amplitude anomaly simply refers to as region of decreasing magnetic amplitude depicted with black circular shapes (Figure 6d-f) on the upward depth continued map are identified as localized fault zones and are at different depth in the subsurface, applying the rule of thumb by Ref. [17] (The data depth continued at a height of z corresponds to the depth of z/2). Existence of faults was observed on the Upward Continued map of Ilorin (Figure 6d-f), in the Northeastern and Southwestern part of the area in the data depth range of 3000 to 5000 m (1,500 to 2,500 m).

4.5. LINEAMENTS

Lineaments extracted from horizontal gradient magnitude (HGM) map were overlain on the corresponding RTE-RMA anomaly map using Arc-GIS 10.3 software to obtain the map in Figure 7. The identified points or region where the magnetic lineaments are in concordance with the anomalies as depicted with white solid shape (Figure 7), located in the Northeast-Southwest (NE-SW) of the map, are geologically characterized as ductile deformation zone, while regions where the magnetic lineament are in discordance or their features cross cut the magnetic anomalies as represented with sky-blue solid shape(Figure 7), observed in the Northwest-Southeast (NW-SE) are geologically characterized as brittle deformation zones [17]. The observed associated geological features are either folds or representing the internal fabric of the rock units for ductile deformation zones or fractures/faults for brittle deformation zones.

Further investigation carried out to establish the localized faults was overlain of the extracted lineament on the geological map of the study area using Arc-GIS 10.3 and suffer 12 softwares to obtain magnetic fault map shown in Figure 8. The obtained faults are depicted in white line shape in the Northwest-Southeast (NW-SE) orientation (Figure 8). Based on orientations of magnetic faults obtained from the superposition of the extracted lineaments on the geological map of the study area, set of dextral (anti-clockwise rotation) faults were recognized, trending NW-SE. These faults display a major role in the tectonic activity of the area.

5. CONCLUSION

High resolution aeromagnetic data sheet of Ilorin (sheet 223), was processed, enhanced and interpreted using Geosoft Oasis Montaj 6.4.2 software purposely to investigate the localized fault in the area under study. The Upward continuation process employed conspicuously showed, the region of consistent high magnetic amplitude or increasing amplitude on the upward depth continued map of the study area as region of deep depth to magnetic sources, indicating intrusion. The minor or localized faults were captured with decreasing magnetic amplitude at UC height of 5000 m at the depth of 2,500m in the area under study. Magnetic faults obtained from the superposition of the extracted lineaments on the geological map of the study area, showed a set of dextral (anti-clockwise rotation) faults, trending NW-SE. These faults display a major role in the tectonic activity of the area. Conclusively, these identified localized faults within the study area could serve as conduit pipe for seismic energy from the epicenter. However, it is recommended that ground motion triggering equipment/infrastructures such as Nuclear Power Station, Railway line, among others should not be sited on the identified fault zones to avoid potential risk.

DATA AVAILABILITY

The data used in the study were obtained from the Nigerian Geological Survey Agency, NGSA. Airborne geophysical survey total magnetic intensity map (2009). https://ngsa.gov.ng/airborne-magnetic-data.

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