Regional Structural Architecture of Part of Northern Nigeria Basement Complex inferred from Upward Continuation of Magnetic Field Intensity Data

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Abstract. 2–D upward continuation of total magnetic field intensity data at Katsina area Northern Nigeria Basement Complex, aimed at identifying major regional features, has been carried out and interpreted in this study. The significance is to update the existing geology map of Nigeria and to guide further exploration studies in the area. Data for six aeromagnetic field maps were merged to form the composite data. 2–D upward continuation at various planes of observation was applied to the gridded magnetic field intensity data after coordinates were first converted (from degrees to meters) to understake anomalies due to shallow features. The plane was 15 km above the ground level. The continuation results revealed a high magnetic region at center surrounded by low magnetic parts, especially at the southern part. Corroboration with geology suggested that the high magnetic region could be a central structural uplift of the bedrock, highly rich in magnetic minerals. The low magnetic area at southern part is interpreted as sedimentary deposit, extended from the prominent Bornu Basin. The south – eastern part of the study area is moderately magnetic in nature, and corresponds to the metamorphic rocks of the Kazaure schist belt.

1. Introduction
Magnetic method provides a means for probing the Earth’s subsurface by taking advantage of the contrast in magnetic susceptibility of underlying materials [1, 2]. Techniques are now available to acquire magnetic data on land [3], at sea [4] and in air [5]. Cost effectiveness and operational speed obtained in aeromagnetic surveys, especially for large scale investigations, have made it a very attractive tool for mineral prospecting [6], ground water [7] and structural studies [8]. The difficulty associated with the effect of shallow ensembles and noise in grid in interpretation of potential field (magnetic and gravity) data to probe deeper subsurface structures of the earth is well known in geophysics. A couple of filters capable of isolating anomalies of interest are readily available to mitigate some these problems. Of these filters, upward continuation is proven to be suitable and straightforward, for it does not other step operation to be carried out. The technique reduces the effect of short wavelength features due shallow sources and noise in grids to a certain level, thereby enhancing large scale, primary features of the study area [9].
It is convenient to implement upward continuation on magnetic field data for the fact that potential fields generally obey Laplace’s equation. This permits us to determine the field over an arbitrary surface if the field is known completely over another surface. Following the method of Grant and West [10], we have for upward continuation, the following relation (Equation 1)

\[
F(x', y', -h) = \frac{h}{2\pi} \iiint \frac{F(x, y, 0) \, dx \, dy}{(x-x')^2 + (y-y')^2 + h^2}^{1/2}
\]

The left side of the equation is the total field at the point \(F(x', y', -h)\) above the surface on which \(F(x, y, 0)\) is known. The calculation procedure is to replace the integral with a weighted sum of values taken on a regular grid.

The area under investigation exactly match one such complex cases that can be resolved using upward continuation, for it encompasses granitic rocks, schist belt and sedimentary formation with no clear boundaries. Detailed information about the area is limited as previous studies solely concentrated on depth to basement estimation [2] and surface geological mapping [11]. More efforts to exactly delineate the different geological features of the area are required to update the existing geology map and to guide further exploration studies in the area. This forms the major objective this research.

2. The study area

The study area is part of the Northern Nigerian Basement Complex (Fig. 1) and covers an estimated area of about 4170 km\(^2\) bounded by longitudes 7°00' and 8°30'; and latitudes 12°30' and 13°30'. It includes Katsina, Jibiya, Dankama, Daura, Ruma, and Kazaure towns; represented covered respectively by sheets No. 14, 15, 16, 33, 34 and 35 of aeromagnetic data maps published by the Nigerian Geological Survey. It is characterized by two distinct climatic conditions; dry season which usually heralded by the dry Harmattan wind, occurs between November and March. Rainy season lasts between June and October. Vegetation is typically savannah with isolated trees among stunted shrubs [2].

![Figure 1. Geology map of the study area.](image)
The area is dominated mainly by crystalline basement rocks as migmatite–gneiss–granite complex with older granite at the western part of the area. Cretaceous sediments of Gundumi formations are also noticeable at extreme northern part of the study area. Also present in the study area, are schist rocks of the Wonaka and Kazaure Shist Belts that appear at the western and south–eastern parts of the area respectively. The top soil is merely light brown to dark grey with topography which is generally undulating on a height of about 576 meters above sea level [12].

3. Methodology
Total magnetic field intensity of sheets 14, 15, 16, 33, 34 and 35 published by the Geological Survey Agency of Nigeria were obtained compiled and interpreted in this study. Each map was digitized on a 3 x 3 km² grid system on a tracing paper to form a 19 x 19 square grid layout. At grid points where contour lines do not cross, visual interpolation to the nearest contour lines was made to estimate the magnetic value of the grid point. This method allowed the coordinates of each grid point to be determined very easily considering the manner they were spaced at regular intervals. The data generated each of the six maps were collected and recorded in a 19 by 19 coding sheet. Each sheet was specified by its boundary coordinate, the map’s number and name of the town it represented. These values were then recontoured and the emerging maps each was then put side by side with the corresponding fundamental map to trace and correct errors introduced in the process of digitization. After digitizing the data, a composite map of the study area was then generated by joining the six aeromagnetic maps forming the study area. The maps were arranged in such a way that the adjacent coordinates of any two neighboring maps were the same and therefore in merging these maps, all the magnetic values with same coordinates were averaged in order not allow more than one data point with same coordinates. These entries were carried out in Microsoft Excel environment and a total of two thousand and thirty-five (2035) data points were entered in 37 (rows) by 55 (columns).

The total magnetic field data was then gridded and plotted after coordinates conversion (degrees to meters) in preparation for the upward continuation, using the Oasis montaj software package. The technique reduces the effect of short wavelength features due shallow sources and noise in grids to a certain level, thereby enhancing large scale features of the study area. Upward continuation of the magnetic field intensity data was carried out at various planes of observation. The planes were at 2 km, 5 km, 10 km 15 km and 20 km above the Earth’s surface.

4. Result and discussion
Figure 2 shows the composite map of the total magnetic field intensity of the study area. Portions on this map that are colored red represent areas of high magnetic intensity, whereas those in blue correspond to the areas of low magnetic field intensity. Superimposed with these portions are areas of intermediate field intensities represented by colors of yellow and pale green that appear everywhere in the study map. Low magnetic field intensity at northern (top) part of the map confirms the presence of a part of the Cretaceous sediments of Gundumi formations in the area. Traces of red colors in this region, which are an indication of high magnetic field intensity, may be as a result of shallower disturbances and noise in the data. The red colour at eastern region of the map indicate the presence of high magnetic intensity rocks. They correspond to the highly magnetized crystalline basement rocks (migmatite-gneiss-granite complex) in the area. Deep blue at the south-eastern part of the map may indicate the presence of part of the Kazaure Schist Belt. To the western parts of the map, a superposition of intermediate to high magnetic intensities is noticed, which is also due to the presence of crystalline basement rocks.
Figure 2. Magnetic field anomaly contour map of the study area.

To identify the regional structures, the field was continued at 15 km plane of observation. The method highlights the effect of deeper sources and suppresses those of shallower sources such as scattered local disturbances and noise. Figures 3 gives the result of the filtering process. The result indicates a structural upliftment of high magnetic field intensity at the central part of the map. The magnetic effect is more pronounced at the eastern part of the structure. This may be attributed to the presence of migmatite-gneiss complex in the crystalline basement rocks at the region [13]. This may be interpreted as thus the mineral deposits are either at considerably larger scale or relatively close to the surface. In the same manner, the blue colored region at extreme northern part of the map indicates the signature of low magnetic sediments of Gundumi formations [12]. Another low magnetic (blue colored) portion is also noticeable at the south-eastern part of the figures, this could be due to the presence of part of the metamorphic rocks of Kazaure Schist Belt in the region [11].
5. Conclusion
Six aeromagnetic data maps covering part of Northern Nigeria basement complex were analyzed and interpreted in this study. Magnetic closures of both high and low were connected to the presence of ore bodies in the area and regional anomalies trend in the ENE-WSW direction. The total magnetic field was continued at 15 km above the surface of the Earth to remove noise and local disturbances, in which a critical was observed at 15 km. The continuation process showed well seated structural of high magnetic intensity at the central part of the study area. The persistence of this high intensity closure, especially around latitude 12.9°N and longitude 8°E may indicate an upliftment of basement or the presence of ferrigeneous minerals. This information will help Nigerian Geological Survey to update the existing geology map of country. It will also provide guide for future exploration studies in the area.

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