Research Article

Interpretation of Aeromagnetic Data around Kafanchan Area, Northwestern Nigeria

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Abstract

Aeromagnetic data of Kafanchan (Sheet 167) and Jema'a (Sheet 188), bound by latitudes 9˚00' N and 10˚00' N, and longitude 8˚00' E and 8˚30' E, were combined and interpreted with the intention of delineating and characterizing faults that exist within the area. Polynomial fitting technique was applied on the total magnetic intensity (TMI) field data in order to separate the residual anomaly from the regional field. The result indicated a NE-SW trend in deep seated structures. The result of the Second vertical derivative and analytic signal filters, applied on the residual magnetic anomaly, revealed the presence of several criss-crossing faults mostly trending in the NE-SW direction. Werner deconvolution technique was used to quantitatively estimate the depth to magnetic source. This revealed depth to source ranging from 100 m to 2,300 m. Suspected faults zones within the area have depths between 100 m and 500 m while areas with high magnetization are at depths between 500 to 1,000 m.

Keywords: Faults, Analytic Signal, Werner Deconvolution, Magnetization.

Introduction

Faults are planar fracture or discontinuity in a volume of rock, across which there has been significant displacement as a result of rock-mass movement. They are caused principally by tectonic activities. The study of faults cannot be overemphasized principally because such studies serve as guide for several man-made and natural occurrences. Faulting controls the distribution of valuable materials. Similarly, faults and fractures play an important role in groundwater mobility and the general availability of water. Regional fault analysis is required for the localization and building of large human-made structures, such as dams and nuclear power plants, and earthquake possibilities [1]. The study of regional fault systems requires appropriate scientific approach and the magnetic technique has been applied by several authors for such studies [2-3].

The Nigerian basement complex was affected by the Pan-African orogeny of 600 Ma ± 50. This orogenic episode was accompanied by a regional metamorphism, migmatization and extensive granitization and gneissification which produced syntectonic granites and homogeneous gneisses [4]. The end of the orogeny was marked by faulting and fracturing [5-6]. Although the study area is believed to fall within the stable African tectonic plate and hence aseismic, recent earth tremor experienced within parts of the area has called for studies on the fault structures within the area. Furthermore, in view of the recent drive by the Federal government of Nigeria to focus on solid mineral exploration and exploitation, it is important that areas with mineral potentials be mapped. Valuable ore minerals commonly occur in veins or are precipitated from hydrothermal fluids that were focused along fault zones, because fracturing provides enhanced permeability. Thus, fault breccias are commonly targets for mineral exploration.

Materials and method

Location and Geology of the Area

The study area is bound by latitudes 9˚00' N and 10˚00' N, and longitudes 8˚00 ' E and 8˚30' E. It falls predominantly in Kaduna State, Northwestern Nigeria while a little portion (the Southern part) lies within Nassarawa state (North central Nigeria). It is part of the tropical climatic belt of Nigeria with distinct dry and wet seasons.

The study area falls within the Northern Nigeria basement complex made up of the Migmatite-Gneiss Complex, the Schist Belts and the Older Granites. It was affected by the 600 Ma Pan-African orogeny and it occupies the reactivated region which resulted from plate collision between the passive continental margin of the West African craton and the active Pharusian continental margin. According to [7], the area was affected by two successive phases of intense deformation which resulted in tight isoclinals folding trending in East-Northeast-West-Southwest and North-South axes. The crystalline basement was reactivated during the Pan-African event. The end of Pan-African tectonic event is marked by a conjugate fracture system of strike-slip faults with consistent trend of movement, which are in the NNE-SSW and the NW-SE trending system. Both sets crosscut all the main Pan-African structures, including older N-S trending shear zones.

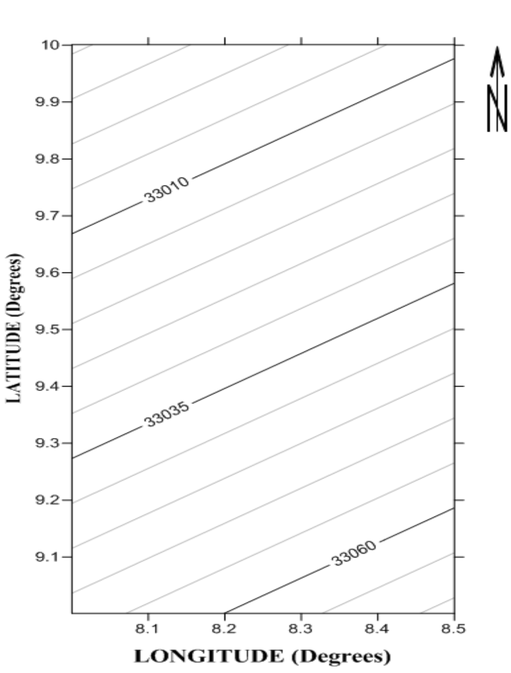

Figure 1: Regional Field Map of study area.

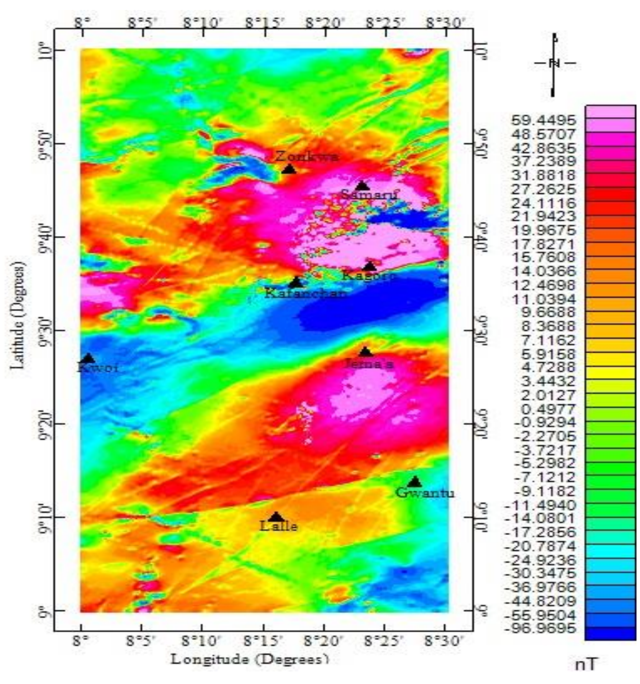

Figure 2: Residual Magnetic Intensity Map of study area

Data Acquisition and Processing

High resolution aeromagnetic data of Kafanchan (Sheet 167) and Jema'a (Sheet 188) covering the study area were obtained from the Nigerian Geological Survey Agency (NGSA) and combined using Surfer 13 software. The data was acquired on a scale of 1:100,000 in half-degree sheets and were collected at a flight altitude of 80 m along NE-SW flight lines spaced approximately 500 m and tie line spacing of 2 km. The effect of deep seated structures (regional magnetic field) was separated from the residual anomaly (the desired component) using the least square method. In the least squares method, the regional uses a polynomial surface to expose the residual features as deviation from the observed field. The separation of a data into two component is done by fitting a trend (plane) surface, which may be defined as a linear function of the geographic coordinates of a set of observations (in this case, total magnetic field data) so constructed that the squared deviations from the trend are minimized. Figures 1 and 2 are respectively the regional magnetic intensity contour map and the gridded residual magnetic intensity map of the study area.

Various interpretation techniques were used in this study to qualitative and quantitatively describe the basement structures within the study area. They include Second vertical derivative (SVD), analytic signal and the Werner deconvolution techniques.

Results and discussion

The Second Vertical Derivative: The second vertical derivative (SVD) of potential field data helps to outline the edges of anomalous bodies and provides a finer representation of shallow anomalies. From the second vertical derivative data, the zero contours on the calculated surface can be obtained. The zero contours have special geological significance. It coincides with mineralized boundaries and fault zones. These inflections commonly trend sub-parallel to lithological or mineralized boundaries and fault zone. Visual inspection of the SVD map of the study area (Figure 3) shows the dominant trend of faults around the study area to be NE-SW. The zero contours of the second vertical derivatives were obtained using Surfer software and this is shown in Figure 4. The red lines indicate the zeros of the contour that delineate the spatial locations of the magnetic source edges which in effect outline anomalous areas.

Although no fault is observed within the vicinity of Kwoi town as observed in Figure 3, some linear structures (possibly faults) are however observed North-East of the town. These faults could possibly be the location or source of the epicenter that caused the 2016 earth tremor around Kwoi town and its environs.

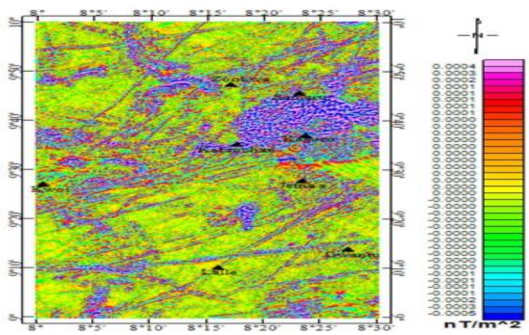

Figure 3: SVD map of the Study Area

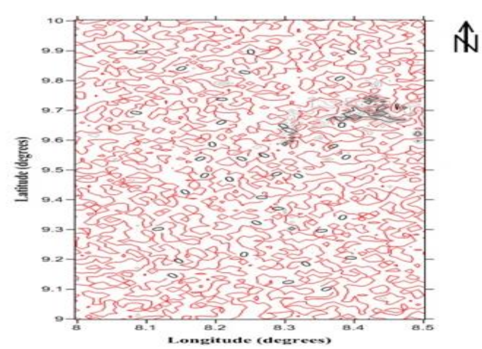

Figure 4: Zero contour of SVD map of the Study Area.

The Analytic Signal Technique: Analytic signal is an interesting interpretation technique because they define source positions regardless of any remenant magnetization in the sources [8] hence it's independent of the direction of magnetization. Maxima (ridges and peaks) in the calculated analytic signal of a potential field anomaly map locate the anomalous source body edges and corners. Result of analytic signal filtering technique, applied on the residual magnetic field data, is presented in Figure 5. Areas with variable magnetic contrast were delineated with the amplitude of analytic signal varying from 0.002 nT/m to 0.1766 nT/m. The analytic signal map further reveals that zones of suspected faults have high magnetization. Other areas with high magnetization, particularly around the eastern portion, could be due to the presence of rock outcrops with high magnetizable materials.

In order to correlate the mapped lineaments or faults within the study area, the Second Vertical derivative zero contour map Figure 4 was overlaid on the analytic signal map and the result was used to infer possible faults zones and mineralized boundaries (in black lines) within the study area Figure 6.

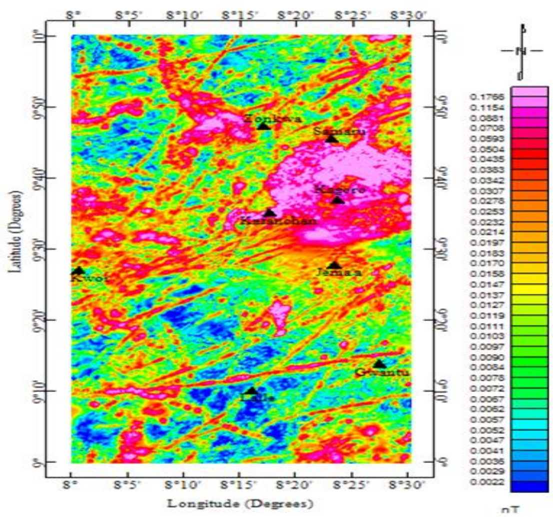

Figure 5: Analytic Signal map.

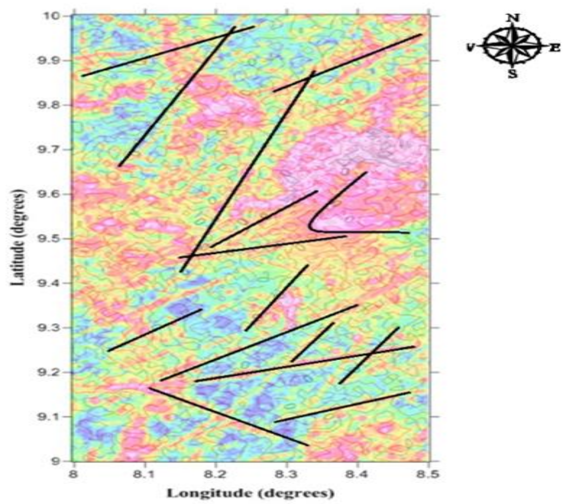

Figure 6: Overlay of SVD zero contours on the Analytic Signal Map

***Werner Deconvolution Technique*:** The Werner deconvolution method is a 2-Dimensional depth estimation technique which assumes source bodies to be either dikes or contacts with infinite depth extent [9]. It uses least square approach to solve for the source body parameters in a series of moving windows along the profile [10]. Solutions derived from the total field profile are designated dike solutions and solutions derived from the horizontal gradient are designated contact solutions. Apart from its usage in estimating depth to magnetic source, Werner deconvolution can also be used in locating horizontal location, dip and magnetic susceptibility of earth materials.

The Werner deconvolution function was applied to the RMI data. Five profiles (AA', BB', CC', DD' and EE') were selected perpendicular to the strike of the geologic structure generating the field of interest (Figure 7). Profile BB' was taken to cut across Kwoi town for possible delineation of the fault that caused the 2016 earth tremor within the locality. A better set of solution was obtained by using a residual cut-off value to 0 nT and X cut-off value to 20 on the depth to basement extension on the Oasis Montaj software.
Depth to magnetic source was calculated using the Werner deconvolution technique. Five profiles; AA' (≈ 36 km long), BB' (≈ 60 km long), CC' (≈ 80 km long), DD' (≈ 74 km long) and EE' (≈ 120 km long) were digitized perpendicular to the strike of suspected fault lines using Surfer 13 software. The depth estimate to magnetic source, for both contact and dike models, range from 113 m to 1,800 m along profile AA', 270

m to 1600 m along profile BB', 250 m to 2,400 m along profile CC', 330 m to 2,100 m along profile DD' and 150 m to 1,400 m along profile EE'. The Werner depth solution also revealed that Kwoi town is not underlain by any major fault. However, the possible epicenter of the 2016 earth tremor around the town and its environs may lie along faults passing through profile CC', Northeast of Kwoi town. Also, areas with high magnetization were delineated on the Werner plots, particularly along profile DD' (denoted *X*) and profile EE' (denoted X_1 and X_2), with depth values ranging between 500 m to 1,000 m. These highly magnetic materials picked on the Werner plots is suspected to be associated to Nickel deposit discovered in parts of the area. The Werner profiles plots are shown in Figures 8, 9, 10, 11 and 12.

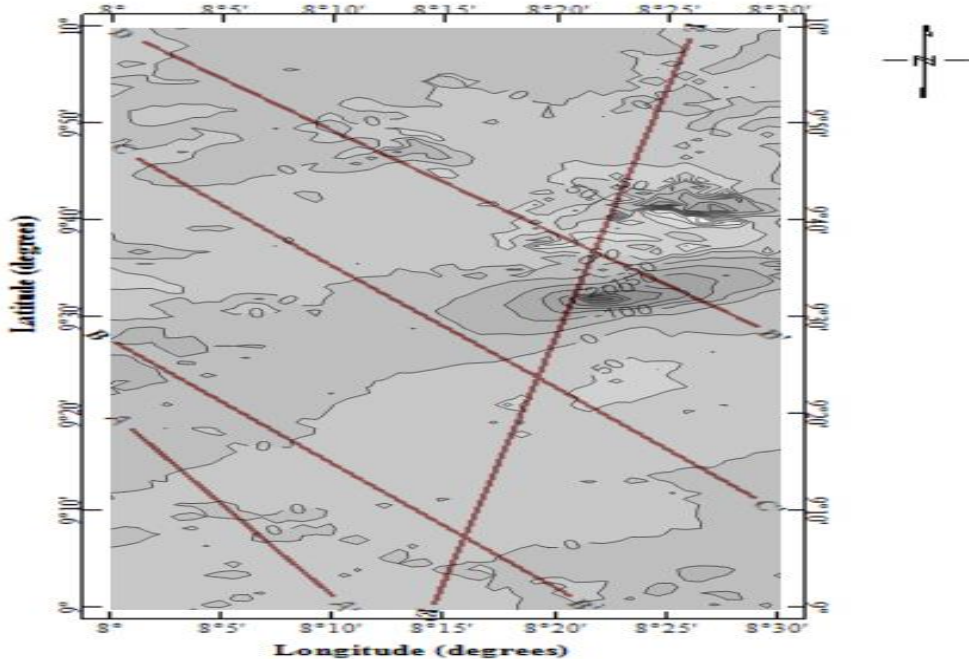

Figure 7: Residual Aeromagnetic Contour Map with selected profiles; AA', BB', CC', DD' and EE'.

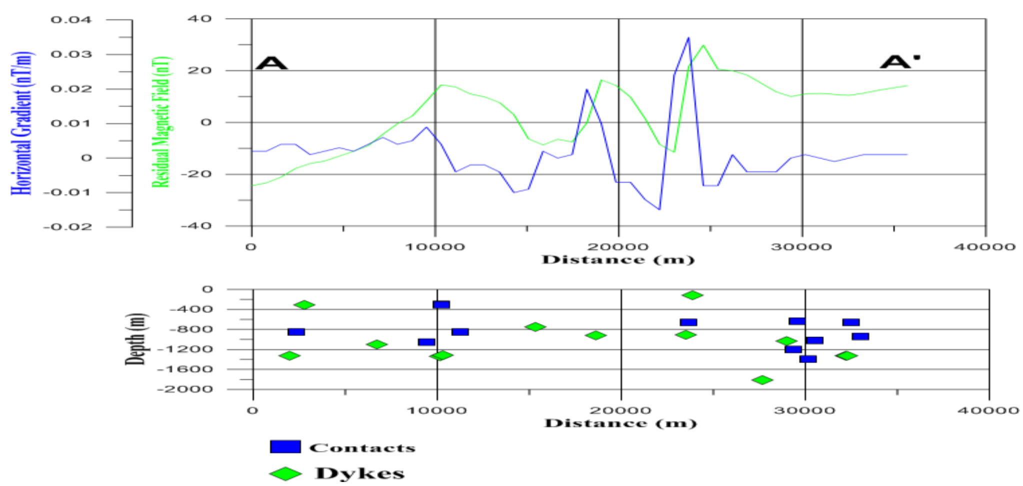

Figure 8: Werner Depth Solution along Profile AA'.

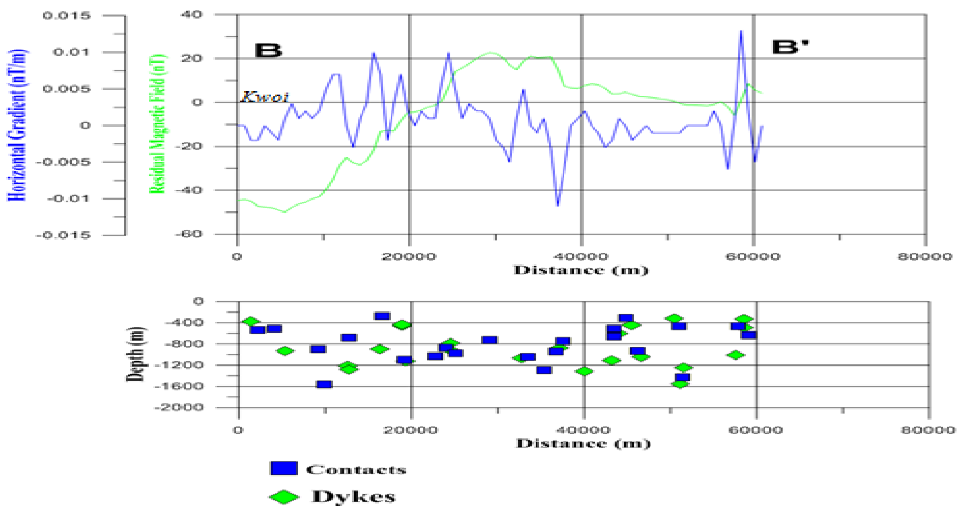

Figure 9: Werner Depth Solution along Profile BB'.

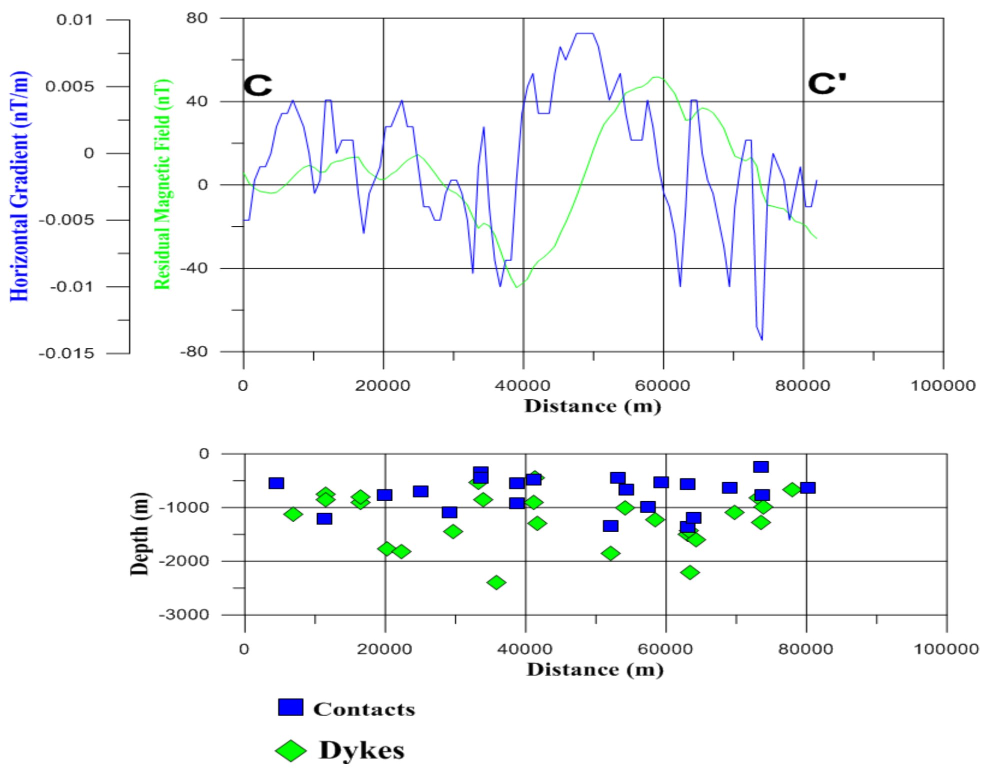

Figure 10: Werner Depth Solution along Profile CC'.

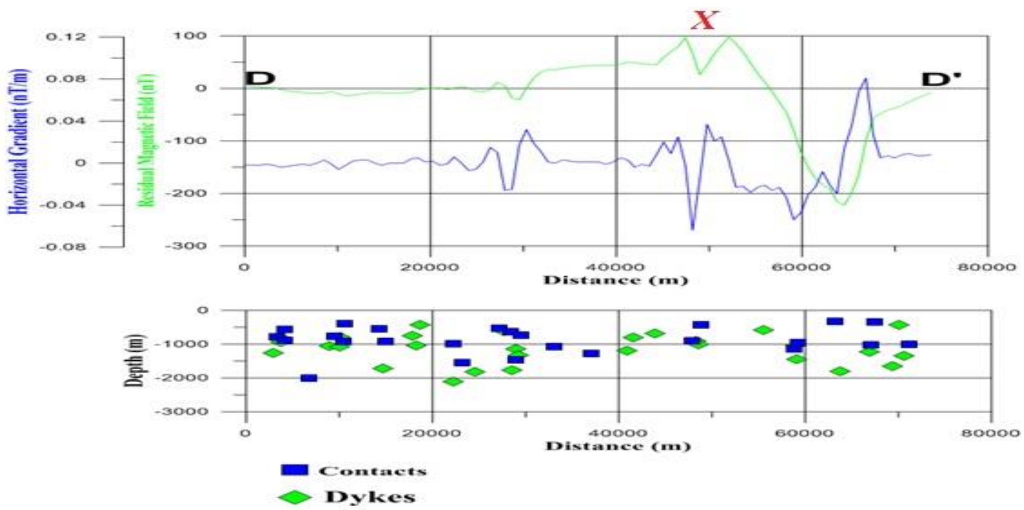

Figure 11: Werner Depth Solution along Profile DD'.

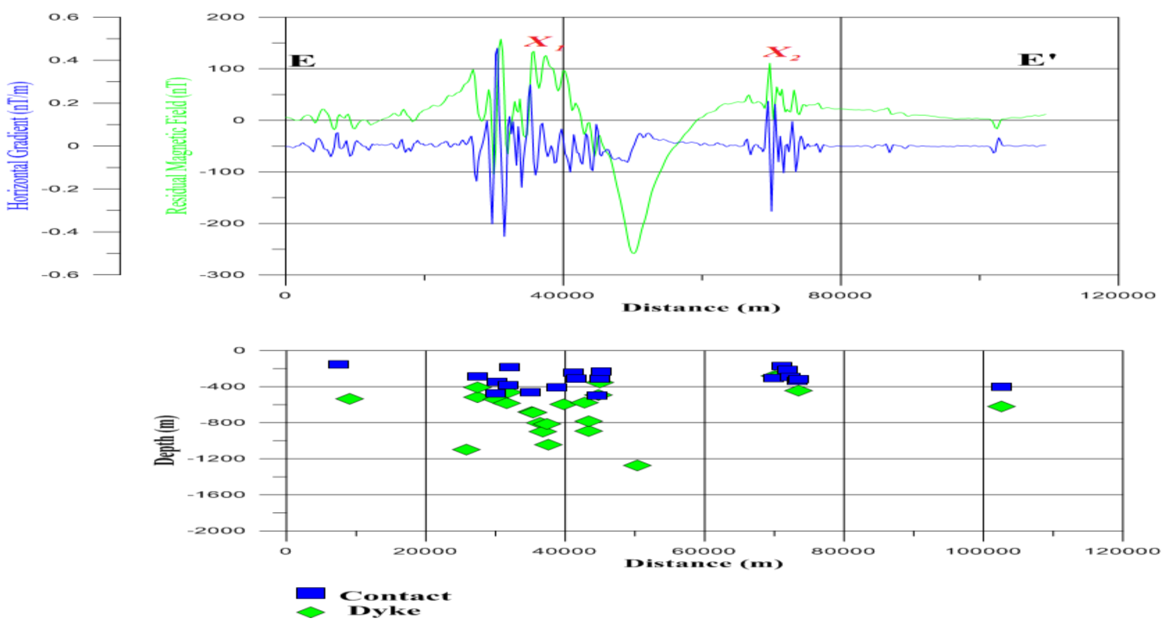

Figure 12: Werner Depth Solution along Profile EE'.

Conclusion

Various qualitative filtering techniques employed in this study reveal the occurrence of several faults, predominantly trending in the NE-SW direction. However, no major structural lineament exists within Kwoi town, hence the epicenter of the 2016 earth tremor could be attributed to faults lying NE of kwoi town.

The Werner depth estimation technique employed reveals a depth to associated dike sources ranging from 100 m to 2,300 m. It can be concluded from the depth estimation techniques that the faults within the area are attributed to shallow magnetic sources ranging in depth from 100 m to 1,000 m predominantly lower than 500 m.

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