International Journal of Geosciences, 2024, 15, 1-11
https://www.scirp.org/journal/ijg
ISSN Online: 2156-8367
ISSN Print: 2156-8359

Applying Source Parameter Imaging (SPI) to Aeromagnetic Data to Estimate Depth to Magnetic Sources in the Mamfe Sedimentary Basin

Eric N. Ndikum[1,2*], Charles T. Tabod[3,4]

[1]Department of Physics, HTTC Bambili, The University of Bamenda, Bamenda, Cameroon
[2]Department of Fundamental Sciences, Higher Technical Teacher Training College (HTTTC), Bamenda, Cameroon
[3]Department of Physics, University of Yaoundé 1, Yaoundé, Cameroon
[4]Department of Physics, Faculty of Science, The University of Bamenda, Bamenda, Cameroon
Email: *ndikumeric@yahoo.com

How to cite this paper: Ndikum, E.N. and Tabod, C.T. (2024) Applying Source Parameter Imaging (SPI) to Aeromagnetic Data to Estimate Depth to Magnetic Sources in the Mamfe Sedimentary Basin. *International Journal of Geosciences*, **15**, 1-11.
https://doi.org/10.4236/ijg.2024.151001

Received: December 6, 2023
Accepted: January 23, 2024
Published: January 26, 2024

Abstract

Aeromagnetic data over the Mamfe Basin have been processed. A regional magnetic gridded dataset was obtained from the Total Magnetic Intensity (TMI) data grid using a 3 × 3 convolution (Hanning) filter to remove regional trends. Major similarities in magnetic field orientation and intensities were observed at identical locations on both the regional and TMI data grids. From the regional and TMI gridded datasets, the residual dataset was generated which represents the very shallow geological features of the basin. Processing this residual data grid using the Source Parameter Imaging (SPI) for magnetic depth suggests that the estimated depths to magnetic sources in the basin range from about 271 m to 3552 m. The highest depths are located in two main locations somewhere around the central portion of the study area which correspond to the area with positive magnetic susceptibilities, as well as the areas extending outwards across the eastern boundary of the study area. Shallow magnetic depths are prominent towards the NW portion of the basin and also correspond to areas of negative magnetic susceptibilities. The basin generally exhibits a variation in depth of magnetic sources with high, average and shallow depths. The presence of intrusive igneous rocks was also observed in this basin. This characteristic is a pointer to the existence of geologic resources of interest for exploration in the basin.

Keywords

Mamfe Basin, Aeromagnetic Data, Source Parameter Imaging (SPI), Depth to Magnetic Sources

1. Introduction

Magnetic anomalies resulting from the magnetic properties of rocks beneath the surface of the earth constitute the basis of magnetic method which is used to study the local geology of localities across the earth. When rocks which differ in magnetic properties are located next to each other, there is contrast in magnetization which is the source of the magnetic anomalies.

The Mamfe Sedimentary basin which is about 130 km in length and 60 km in width (**Figure 1**) is known to be the smallest of the three side rifts associated with the Benue trough of West-Central Africa; it extends from the lower Benue trough in Nigeria into Southwestern Cameroon where it narrows and terminates under the Cameroon Volcanic Line (CVL) [1]. A limited amount of geophysical studies are known to have been carried out in this basin in recent times; among which is the work of [2] who did a study of the aeromagnetic field over two major basalt flows in the Mamfe basin as an aid to the location of Primary mineralizations using spectral analysis and 2.5D inversion methods. The depth of the basement complex beneath the basalt flows was determined through spectral analysis to range from 1.81 km to 2.00 km from the east to the west of the basin respectively. Magnetic inversion along 7 profiles in the study area yielded model shapes of the basalt layers which indicated that the basalt conduits can be reliably located. This study also highlighted areas favourable for drilling for primary materializations. Gravity data was used by [3] to lay the foundation for an investigation of the details of the sedimentary basin of Mamfe and the analysis of the tectonic corridor with N-S regional direction which is observed towards the

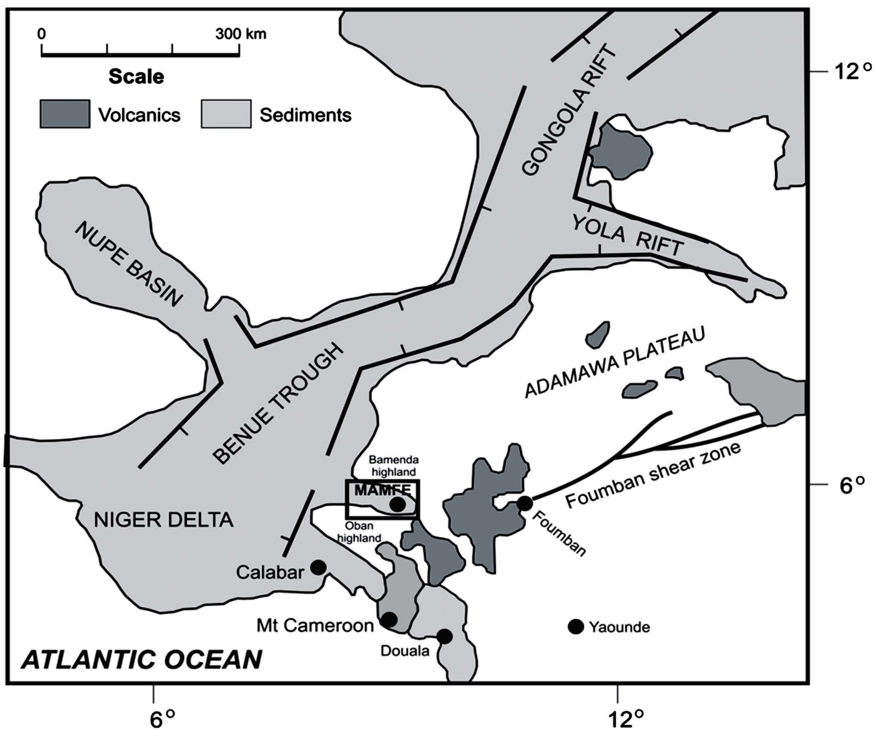

Figure 1. Location map of the Mamfe sedimentary basin ([8] in [1]).

eastern edge of the basin. The results of three gravity surveys were used by [1] to generate residual anomalies which suggested two NE-SW gravity lows attributed to sedimentray infill about the localities of Ekok and Agbokem and about Mukonyong, Mamfe and Bachuo Akangbe. Reduction to the pole (RTP), upward continuation, horizontal gradient of the total magnetic intensity and analytic signal and euler's deconvolution were used by [4] on aeromagnetic data from the Mamfe Sedimentary Basin (MSB) and a part of the East of Nigeria to suggest a structural map of the study area which presents the fault system of the zone. They also highlighted the positions of intrusions of igneous bodies that can help in an orientation for a geophysical investigation. The study also justifies the complexity of the tectonics of the region and reveals geological structures that previous methods could not identify.

A third order polynomial filtering of Bouguer gravity data from the Mamfe sedimentary basin was performed by [5] to estimate the depths of the sediment/basement interfaces along two profiles above the Mamfe sedimentary basin to be equal to 1900 and 5073 m, respectively. Geophysical studies using ETOPO1-corrected high resolution satellite-based EGM2008 gravity data was done by [6] to define the surface extent, depth to basement and shape of the Mamfe basin. They deduced from residual maps that gravity highs in the basin correspond to metamorphic and igneous rocks while gravity lows were matched with cretaceous sediments. From results of 2D modeling, they showed that the Mamfe basin has an average length of 77.6 km, an average width of 29.2 km, an average depth to basement of 5 km and overall U-shape basement. The impact of the opening of the South Atlantic on the tectonics of the Mamfe, Douala, and Rio Del Rey basins was studied by [7] through a geodynamic approach which relied first of all on qualitative and quantitative analysis of an anomaly map and secondly on 2D geological models. The study sought to show that the South Atlantic has similarly impacted the structure of the three basins concerned while the oceanic crust was shown to be thinner than the continental crust through spectral analysis in this study area.

These studies which highlight a number of geophysical features located in the Mamfe sedimentary basin, have nevertheless provided very limited information on the depth to magnetic sources around this basin. This has enhanced the need, in this study, to employ the Source Parameter Imaging (SPI) technique to estimate the depths to magnetic sources in the Mamfe sedimentary basin.

2. Geologic and Tectonic Settings

The Mamfe basin is a non-intracratonic producer basin having a surface area of about 2400 km^2 [4]. It has an altitude range of about 90 m to 300 m and lies between latitudes 5˚30 and 6˚00N and longitudes 8˚50 and 9˚40E (**Figure 2**). It is filled with cretaceous sediments and to the west it opens to the Ikom-Mamfe Embayment while to the north it has as border the granite-gneissic Obudu Massifs [6]. The Oban Massif constitutes a separation between this basin and the

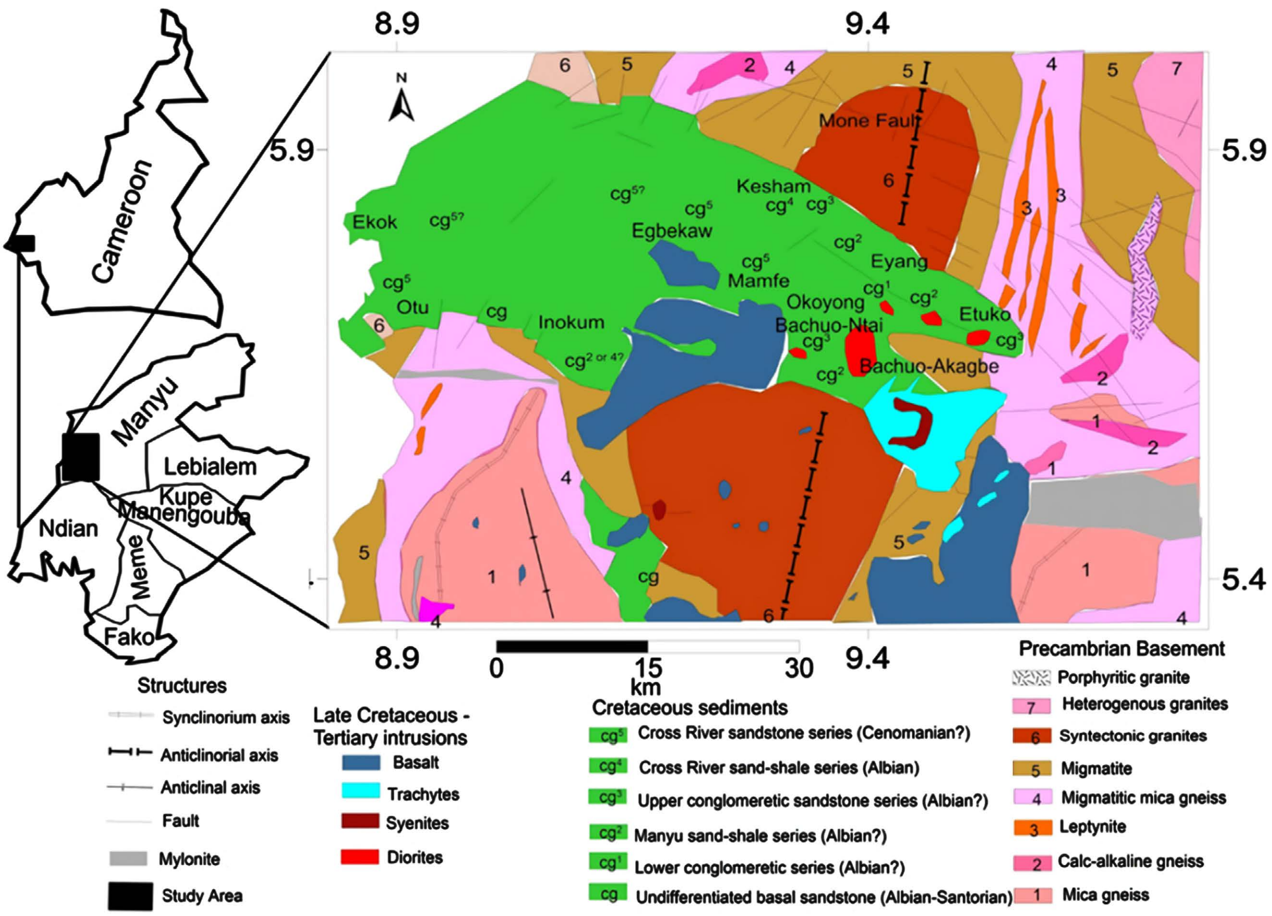

Figure 2. Geologic map of Mamfe basin [12].

Rio-Del-Rey basin to the south while its NE border is the Bamenda highlands in the Cameroon Volcanic Line (CVL). This basin is known to be host to a number of minerals like sapphire, lignite, zinc and lead as well as important oil fields; while it is also made up of horst and grabens [4]. Two main phases characterize the principal tectonic activities of the basin, namely: the extension phase characterized by the formation of many faults which are mostly observed on the Manyu [9] and the compression phase which is characterized through the anticline and syncline pattern of the basin and a late formation of some faults and breaks ([10] & [11]).

3. Data and Method

3.1. Data

The Aeromagnetic data consisting of a grid of 610 data points used in this study is the ASCII grid of the magnetic total intensity EMAG2 (Version 2.0), obtained at 4 km above the WGS84 ellipsoid which was constituted without directional gridding giving it a much sparser coverage which presents more closely the actual measurements. This data set contains gridded global magnetic data, compiled from satellite, marine, aeromagnetic and ground magnetic surveys.

3.2. Method

The data was processed using the Oasis montaj version 7. The regional field of the data over the study area was extracted from the Total Magnetic Intensity (TMI) data grid using a 3 × 3 convolution (Hanning) filter to remove regional trends. The residual dataset was generated through regional-residual separation which represents the very shallow geological features of the basin. The residual anomaly data were done processed for source parameter imaging (SPI) to determine the depth to magnetic sources in the region.

The Source Parameter Imagaing (SPI) method is a method that can be used to determine source parameters from either a profile or gridded magnetic data. It assumes either a 2-D sloping contact or a 2-D dipping thin-sheet model and is based on the complex analytic signal [13]. It is quick, easy and powerful in calculating the depth of magnetic sources with an accuracy that has been shown to be ±20% in tests carried out on real data sets with drill hole control ([14] [15] in [16]). It is also advantageous because the interference of anomaly features is reducible since the method used the second-order derivatives. The SPI method also yields solutions grids which show the edge locations, depths, dip, and susceptibility contrasts; where the estimation of the depth is independent of the magnetic inclination, declination, dip, strike and any remanent magnetization [13]. For any magnetic field T, the local wavenumber (K) will be given by:

$$K = \frac{\frac{\partial^2 T}{\partial x \partial z}\frac{\delta T}{\delta x} + \frac{\partial^2 T}{\partial y \partial z}\frac{\delta T}{\delta y} + \frac{\partial^2 T}{\partial^2 z}\frac{\delta T}{\delta z}}{\left(\frac{\delta T}{\delta x}\right)^2 + \left(\frac{\delta T}{\delta y}\right)^2 + \left(\frac{\delta T}{\delta z}\right)^2} \quad (1)$$

The maxima of K for a dipping contact is located directly over the isolated contact edges and are independent of the magnetic inclination, declination, dip, strike and any remanent magnetization. Consequently, the depth (d) is estimated at the source edge from the reciprocal of the local wave number by using:

$$d_{(x=0)} = 1/K_{max} \quad (2)$$

where K_{max} is the peak value of the local number K over the step source [15].

4. Results

The Total Magnetic Intensity (TMI) for the area under study was plotted on a grid (**Figure 3**) using Oasis montaj version 7.

This TMI map is characterized by a variation in magnetic susceptibility from very low towards the eastern portion of the map and progressively through averagely high values around the center to very positive values towards the western portion of the study area. This progressive variation suggests a transition in magnetic behavior across the entire study area. The magnetic fields are oriented principally SW-NE and almost N-S especially in the center portion where the contours are mostly elongated; while toward the NW and SE portions some E-W orientations are observed. Also, some circular orientations are also seen around the upper western portion and the center portions of the map.

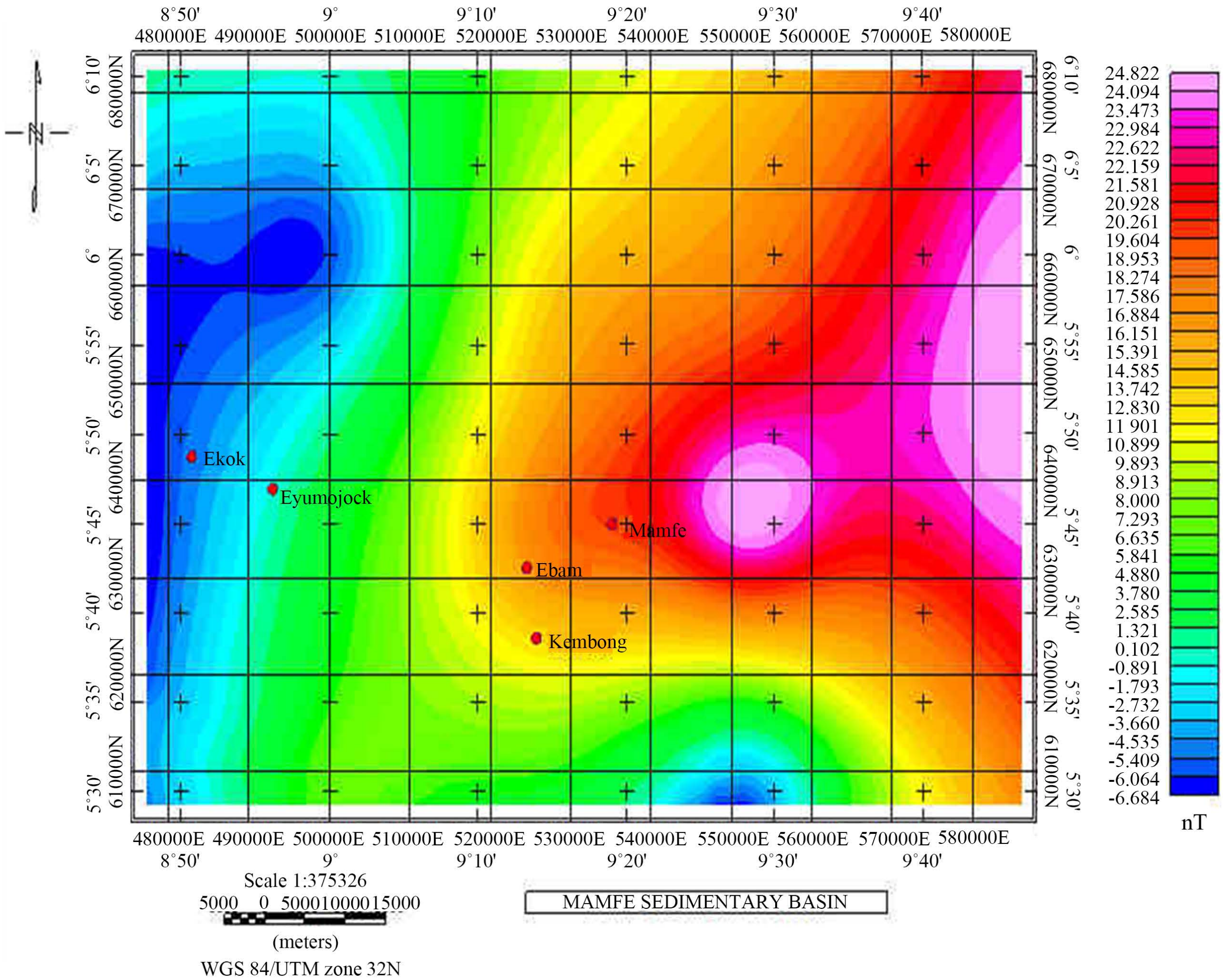

Figure 3. Plot of Total Magnetic Intensity (TMI) over study area.

Gridding the TMI using a 3 × 3 convolution (Hanning) filter resulted to a regional magnetic field (**Figure 4**) of the study area. Major similarities in magnetic field orientations, progressive variation from east to west in magnetic fields and positions of intensities were observed at identical locations on both the Regional and TMI data grids. This suggests a major signature of the regional field on the overall TMI field of the region of study.

Using the TMI and the regional field, the residual dataset was generated through regional-residual separation by subtracting the residual field from the TMI using grid mathematics and plotted as a grid file (**Figure 5**).

The residual field of the study area presents a more uneven variation in magnetic susceptibility across the entire study area with a considerable difference in the intensity of susceptibility values compared to those of the TMI and regional fields. Principal locations low magnetic susceptibilities are noticed to the NW and SE portions of the study area which suggest very poor magnetic rock materials. Also, two main locations with peak magnetic susceptibilities are located towards the center of the study area around Ebam and to the right of Mamfe;

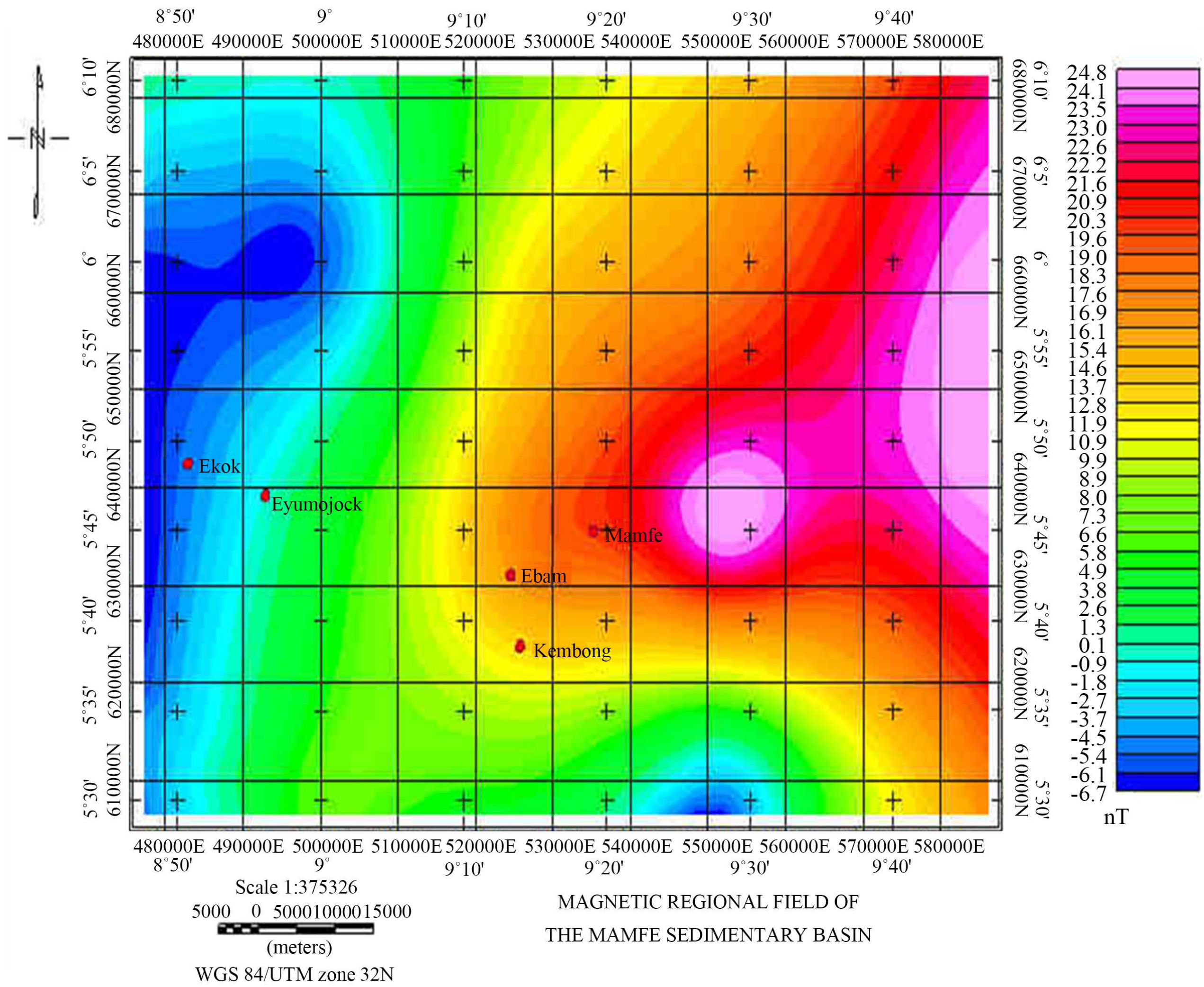

Figure 4. Regional Anomaly field over study area.

while another relatively high susceptibility is observed around the SW portion of the study area. These locations of peak magnetic susceptibilities are indicative of the presence of rocks with very high magnetic properties. There is a relative gentle transition between the locations of magnetic highs towards the central and SW portions of the study area and those of magnetic lows to the NW and SE portions.

Processing the residual data grid using the Source Parameter Imaging (SPI) for magnetic depth (**Figure 6**) suggests that the estimated depths to magnetic sources in the basin range from about 271 m to 3552 m.

The highest depths are located in two main locations somewhere around the central portion of the study area which correspond to the area with positive magnetic susceptibilities, as well as the areas extending outwards across the eastern boundary of the study area. Shallow magnetic depths are prominent towards the NW portion of the basin and also correspond to areas of negative magnetic susceptibilities.

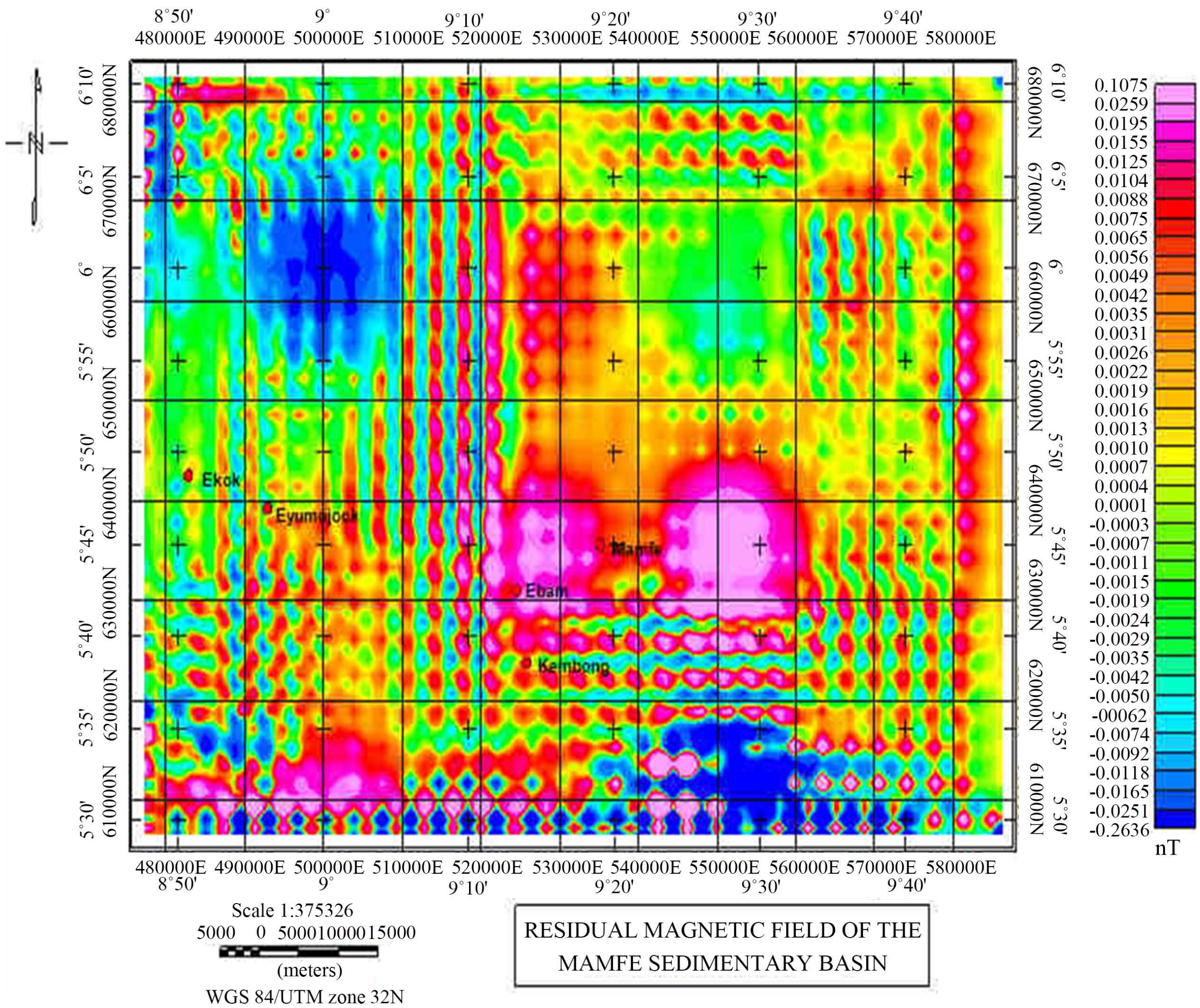

Figure 5. Residual field over study area.

5. Discussions

The orientation of the magnetic fields of the TMI and regional plots in this study area were seen to be principally SW-NE and almost N-S and translate the alignment of magnetic materials in this area. These are similar to the results of [3] which presented tectonic corridor with N-S regional direction observed towards the eastern edge of the basin. The locations of magnetic highs identified towards the center of the study area around Ebam and to the right of Mamfe which correspond with positions of greater depths from SPI results of up to about 3.5 km are suggestive of the presence of highly magnetic rocks like basalt which are in agreement with the study of [2] which suggest the depth of the basement complex beneath the basalt flows through spectral analysis to range from 1.81 km to 2.00 km from the east to the west of the basin respectively. The principal SW-NE orientations are also in agreement with results of [1] who suggested two NE-SW gravity lows attributed to sedimentary infill about the localities of the study area.

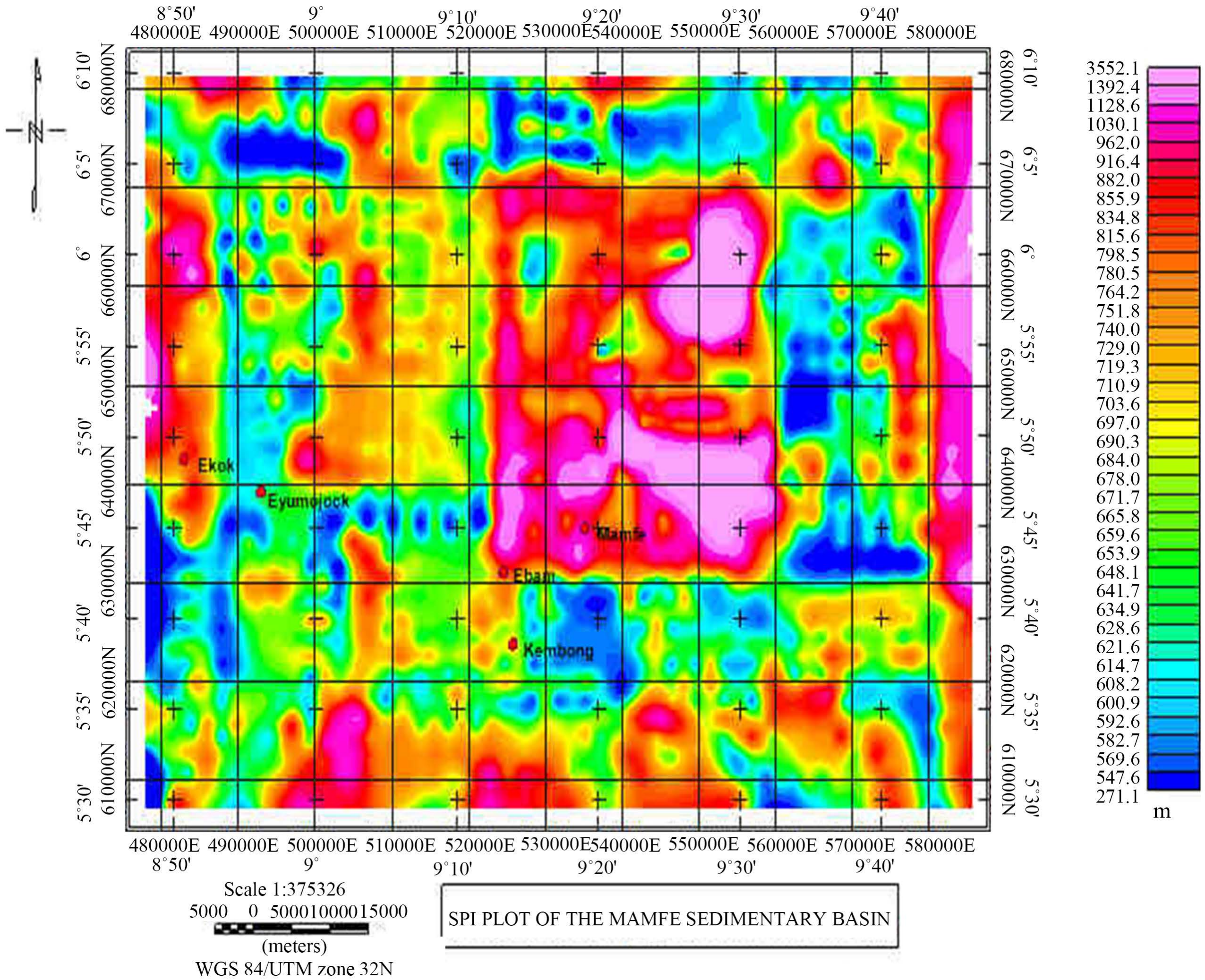

Figure 6. Plot of SPI results over study area.

The presence of the two locations of the highly magnetic materials which are suggestive of igneous rocks like basalt at the depths ranging up about 3.5 km are also in line with the results of [4] who highlighted the intrusions of igneous bodies in the Mamfe sedimentary basin.

6. Conclusion

The study of the Mamfe sedimentary basin using aeromagnetic data by the Source Parameter Imaging (SPI) technique has been carried out. The Total Magnetic Intensity (TMI), the regional magnetic field and the residual magnetic field have also been plotted as gridded maps which suggest signatures of rock behaviors in the study area which are similar to those of other studies carried out in the same study area. Results of the SPI method have highlighted the depth to magnetic sources in this area to range from about 271 m to 3552 m. The presence of intrusive igneous rocks is also observed. The basin generally exhibits a variation in depth of magnetic sources with high, average and shallow depths.

This characteristic is a pointer to the existence of geologic resources of interest for exploration in the basin.

Acknowledgements

We acknowledge the authors of the EMAG2 data and all anonymous reviewers for their inputs into this work.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Ndougsa-Mbarga, T., Manguelle-Dicoum, E., Campos-Enriquez, J.O. and Atangana, Q.Y. (2007) Gravity Anomalies, Sub-Surface Structure and Oil and Gas Migration in the Mamfe, Cameroon-Nigeria, Sedimentary Basin. *Geofísica Internacional*, **46**, 129-139. https://doi.org/10.22201/igeof.00167169p.2007.46.2.22

[2] Kangkolo, R. (2002) Aeromagnetic Study of the Mamfe Basalts of Southwestern Cameroon. *Journal of the Cameroon Academy of Sciences*, **2**, 173-180.

[3] Ndougsa Mbarga, T. (2004) Etude géophysique par méthode gravimétrique dans les structures profondes et superficielles de la région de Mamfé. Université de Yaoundé I, Cameroon, 255 p.

[4] Nzeuga, A.R., Nouayou, R., Enyegue à Nyam, F. and Fairhead, J.D. (2017) The Use of Aeromagnetic Data Interpretation to Characterize the Features in the Mamfe Sedimentary Basin Cameroon and a Part of the East of Nigeria. *International Journal of Science and Research*, **6**, 617-624.

[5] Nguimbous-Kouoh, J.J., Takam-Takougang, E.M., Ndougsa-Mbarga, T. and Manguelle-Dicoum, E. (2018) Polynomial Separation and Gravity Data Modeling with Hyperbolic Density Contrast: Case of Two Profiles along the Mamfe Sedimentary Basin (Cameroon). *Geoinfor Geostat*: *An Overview*, **6**, 2.

[6] Lordon, D., Eugene, A., Mbohlieu, Y., Christopher, A., Yves, S. and Kuisseu, T.S. (2018). Geometrical Characterisation of the Mamfe Basin from the Earth Gravitational Model (EGM 2008). *Earth Science Research*, **7**, 94-105. https://doi.org/10.5539/esr.v7n1p94

[7] Nzeuga, A., Nyam, F., Nouayou, R. and Fairhead, J. (2019) Impact of the South Atlantic Opening on the Origin and the Tectonic of the Mamfe, Douala and Rio Del Rey Sedimentary Basins, Geodynamics Implication. *Open Journal of Earthquake Research*, **8**, 299-312. https://doi.org/10.4236/ojer.2019.84017

[8] Fairhead, J.D., OKEREKE, C.S. and Nnange, J.M. (1991) Crustal Structure of the Mamfe Basin, West Africa, Based on Gravity Data. *Tectonophysics*, **186**, 351-358. https://doi.org/10.1016/0040-1951(91)90368-3

[9] Nouayou, R. (2005) Contribution à l'étude géophysique du bassin sédimentaire de Mamfé par prospections Audio et Hélio Magnétotelluriques. Thèse de Doctorat d'Etat ès Sciences, Université de Yaoundé I, Cameroon, 212 p.

[10] Dumort, J.C. (1968) Notice Explicative sur la Feuille de Douala-Ouest. Carte Géologique de Reconnaissance à l'Echelle 1/50,000. Direction des Mines et de la Géologie du Cameroun. République Fédérale du Cameroun, Yaoundé, 69.

[11] Eyong, T.J. (2003) Litho-Biostratigraphy of the Mamfe Cretaceous Basin, S. W.

Province of Cameroon, West Africa. PhD Thesis, University of Leeds, Leeds, 256 p.

[12] Akoachere, R., Eyong, T., Egbe, S., Wotany, R., Nwude, M. and Yaya, O. (2019) Geogenic Imprint on Groundwater and Its Quality in Parts of the Mamfe Basin, Manyu Division, Cameroon. *Journal of Geoscience and Environment Protection*, **7**, 184-211. https://doi.org/10.4236/gep.2019.75016

[13] Thurston, J.B. and Smith, R.S. (1997) Automatic Conversion of Magnetic Data to Depth, Dip, and Susceptibility Contrast Using the SPI (TM) Method. *Geophysics*, **62**, 807-813. https://doi.org/10.1190/1.1444190

[14] Salako, K.A. (2014) Depth to Basement Determination Using Source Parameter Imaging (SPI) of Aeromagnetic Data: An Application to Upper Benue Trough and Borno Basin, Northeast, Nigeria.

[15] Al-Badani, A.M. and Al-Wathaf, M.Y. (2018) Using the Aeromagnetic Data for Mapping the Basement Depth and Contact Locations, at Southern Part of Tihamah Region, Western Yemen. *Egyptian Journal of Petroleum*, **27**, 485-495. https://doi.org/10.1016/j.ejpe.2017.07.015

[16] Odidi, I., Mallam, A. and Nasir, N. (2020) Depth to Magnetic Sources Determination Using Source Parameter Imaging (Spi) of Aeromagnetic Data of Parts of Central and North-Eastern Nigeria: A Reconnaissance Tool for Geothermal Exploration in the Area. *Science World Journal*, **15**, 19-23.