Interpretation of High-Resolution Aeromagnetic Data Over Parts of the Upper Benue Trough, Nigeria Using Source Parameter Imaging and Magnetic Modelling

Nwobodo Anthonia Ndidi[1]; Uduma Ifeanyi Awa[1]; Abonyi Collins Ekene[1]; Abangwu Uchenna Johnson[2*]; Ugwuanyi Maximus Chukwuma[3]; OjobeaguAustin Okechukwu[4]

[1]Department of Industrial Physics, Enugu State University of Science and Technology, Enugu, Nigeria
[2]Department of Physics and Astronomy, University of Nigeria Nsukka
[3]Federal University of Allied Health Sciences, Enugu State
[4]Department of Industrial and Medical Physics, David Umahi Federal University of Health Sciences, Uburu Ebonyi State Nigeria

Corresponding Author: Abangwu Uchenna Johnson[2*]

Publication Date: 2026/06/10

Abstract: Aeromagnetic data from the Lau and Dong regions of Nigeria's Upper Benue Trough were examined in order to assess prospective mineralization zones, estimate sedimentary thickness, and assess hydrocarbon potential. Using polynomial fitting, the residual anomaly field was obtained by subtracting the regional anomaly from the total magnetic intensity field (TMI). A variety of magnetic anomalies are visible in the residual intensity and total magnetic intensity fields, indicating that the research area is magnetically diverse. The sedimentary thickness, which varied from roughly 316.5 to 3716.0 m, was estimated using the Source Parameter Imaging (SPI) approach. Susceptibility values ranged from 0.0001 to 0.5275 units, with corresponding depths ranging from 152 to 2578 m, according to forward and inverse magnetic modelling. Sandstone, gabbro, gneiss, marble, granite, limestone, and shale are among the lithologies that may be present, according to the modelling results and magnetic signatures. These lithological units indicate an environment that is conducive to the accumulation of minerals and could facilitate a number of industrial uses. Additionally, the greatest sedimentary thickness of 3716.0 m indicates favorable circumstances for the production and deposit of hydrocarbons in the region.

Keywords: *Aeromagnetic; SPI; Sedimentary Thickness; Forward and Inverse Modelling.*

How to Cite: Nwobodo Anthonia Ndidi; Uduma Ifeanyi Awa; Abonyi Collins Ekene; Abangwu Uchenna Johnson; Ugwuanyi Maximus Chukwuma; Ojobeagu Austin Okechukwu. (2026) Interpretation of High-Resolution Aeromagnetic Data Over Parts of the Upper Benue Trough, Nigeria Using Source Parameter Imaging and Magnetic Modelling. *International Journal of Innovative Science and Research Technology*, 11(4), 5078-5087. https://doi.org/10.38124/ijisrt/26apr1089

I. INTRODUCTION

Airborne magnetic surveys are especially important because they provide quick, economical, and continuous coverage of geological terrains, enabling the detection of variations in the Earth's magnetic field that reflect differences in rock composition, structure, and depth. Magnetic methods continue to be one of the most effective geophysical instruments for exploring subsurface structures across wide areas, especially in zones with limited surface exposure [11].

Aeromagnetic data are commonly interpreted using both qualitative and quantitative methods. Finding patterns, trends, and unusual signals that highlight important geological features including faults, intrusions, folds, and lithological boundaries is the focus of qualitative interpretation. On the other hand, quantitative interpretation involves quantifying the causal bodies' depth, geometry, and physical characteristics through analytical and numerical methods such forward and inverse modeling and depth estimation algorithms [5, 10]. Whenever integrated, these approaches greatly improve the dependability of subsurface interpretations and reduce ambiguity in geological inference.

The Upper Benue Trough in Nigeria is a structurally complex sedimentary basin that has attracted geophysical interest due to its known mineral concentrations and growing hydrocarbon potential [1, 2, 4]. Precise sedimentary thickness estimation is especially important since it helps to understand the subsurface conditions associated with hydrocarbon systems, whilst identifying intrusive and basement structures helps to understand mineralization pathways and structural controls.

This study examines high resolution aeromagnetic data from the Lau and Dong sectors of the Upper Benue Trough to determine subsurface structure and sedimentary thickness. Source Parameter Imaging (SPI) is utilized to quantify the depth of magnetic sources, while forward and inverse magnetic modeling (FIM) are used to constrain the geometry and magnetic susceptibilities of the causative bodies. By combining these methodologies, the study intends to improve understanding of the area's geological framework and assess its potential for hydrocarbon accumulation and solid mineral development.

➢ *Location and Geology of the Study*

The research sites are situated in the Upper Benue Trough and have geographic coordinates of latitude 9.0°–9.5°N and longitude 11.0°–12.0°E. Their area is roughly 6050 km^2. The Upper Benue Trough is part of Nigeria's Benue Trough and consists of the Yola Basin (Yola Arm), which trends east-west, the Gongola Basin (Gongola Arm), which trends north-south, and the Lau Basin (Main Arm), which trends northeast-southwest. Figure 1 is Geology map of the study area [8]. The Continental Bima Sandstone, which rests unevenly on the rolling Precambrian Basement, marks the start of the Cretaceous sequence [3, 8, 14].

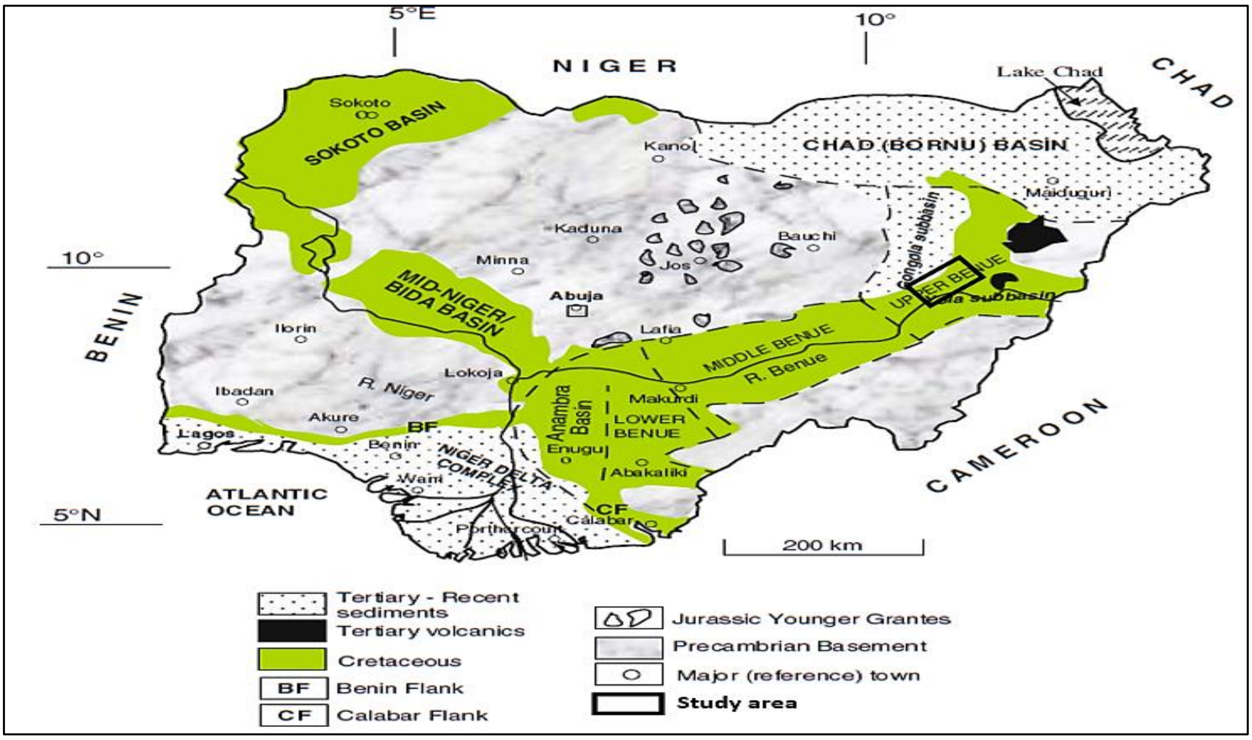


Fig 1 The Research Area's Geology Map [8]

II. MATERIALS AND METHODS

➢ *Materials*

Two high-resolution aeromagnetic digitized data sheets, Sheet 194 (Lau) and Sheet 195 (Dong), comprised the data used in this investigation. The Nigerian Geological Survey Agency (NGSA) was the source of the information.

➢ *Method*

Gridding, source parameter imaging, and forward and inverse modelling are methods used in the analysis of magnetic data.

➢ *Gridding of the Digitized Data*

The process of gridding aeromagnetic data entails interpolating the data into cells with equal spacing in order to create a map. The data was gridded using the Oasis Montaj software's minimal curvature gridding algorithm to create the research area's total magnetic intensity (TMI) map.

➢ *Source Parameter Imaging (SPI)*

The SPI approach determines magnetic depth by extending a complex analytical signal [7, 13]. It uses the link between source depth and local wave number to estimate the depth of a region [13].

➢ *Forward and Inverse Modelling (FIM)*

The FIM technique entails producing quantitative estimates of the depth and magnitude of anomalous sources [9]. The Potent Q tool from the Oasis Montaj package was used for FIM. Profiles of the area's residual grid were taken at various places and simulated. The susceptibility is determined by how well the observed field matches the estimated field.

III. RESULTS

- *Total Magnetic Intensity (TMI) Anomaly Map*

Fig 2 depicts the TMI map, which runs from -32.9 to 131.0 nT. The TMI map indicates that the region is magnetically varied, with a wide range of abnormalities observable. The Lau area with strong positive anomalies (pink colour) are most likely intrusions of igneous matter with a higher concentration of magnetic susceptibility. The southern part of Dong area with large magnetic lows (blue colour), are most likely low in magnetic concentration, making them less susceptible.

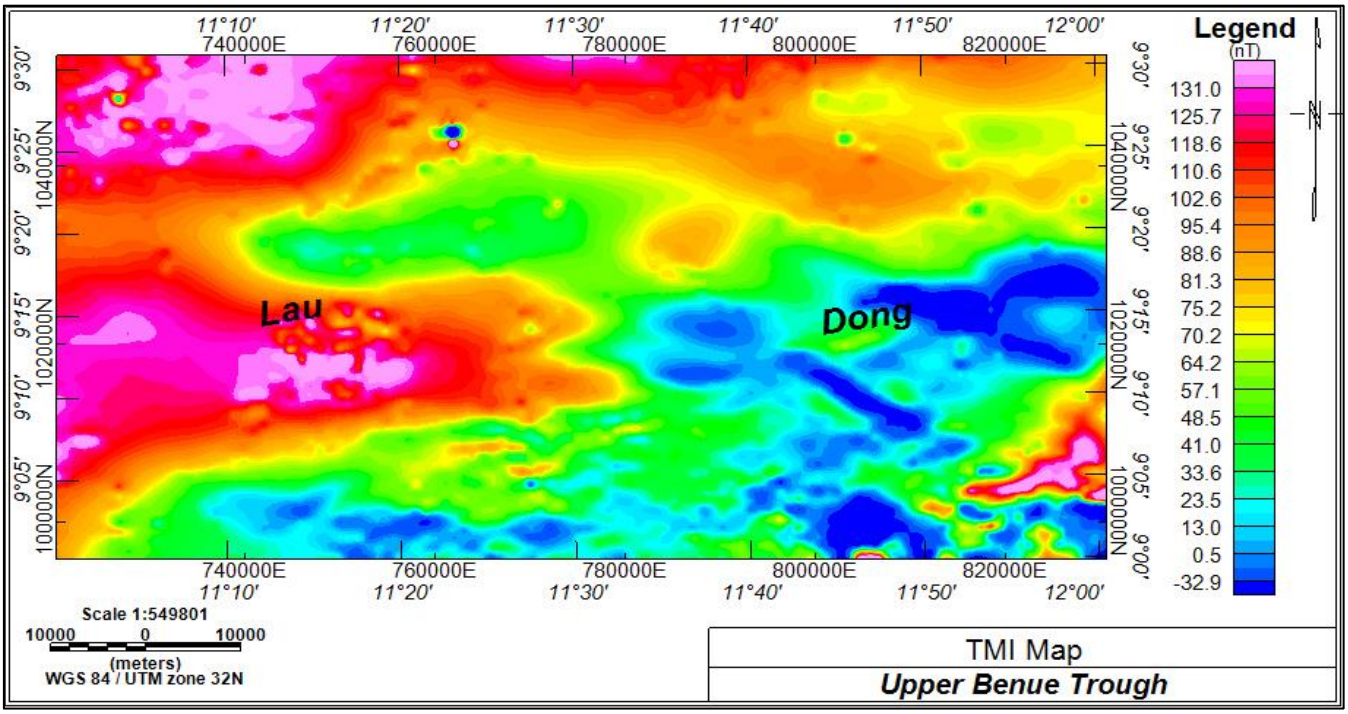


Fig 2 Total Magnetic Intensity (TMI) Map

- *Residual Magnetic Anomaly Map*

The area revealed positive and negative residual anomalies ranging from -97.5 to 61.2 nT (Fig 3), which may be the result of the joint influence of zones of basic intrusive bodies observed in the basement complex or sedimentary basin. A higher concentration of magnetically sensitive minerals, such as igneous intrusions, is most likely connected to the Lau area with notable positive anomalies (pink color).

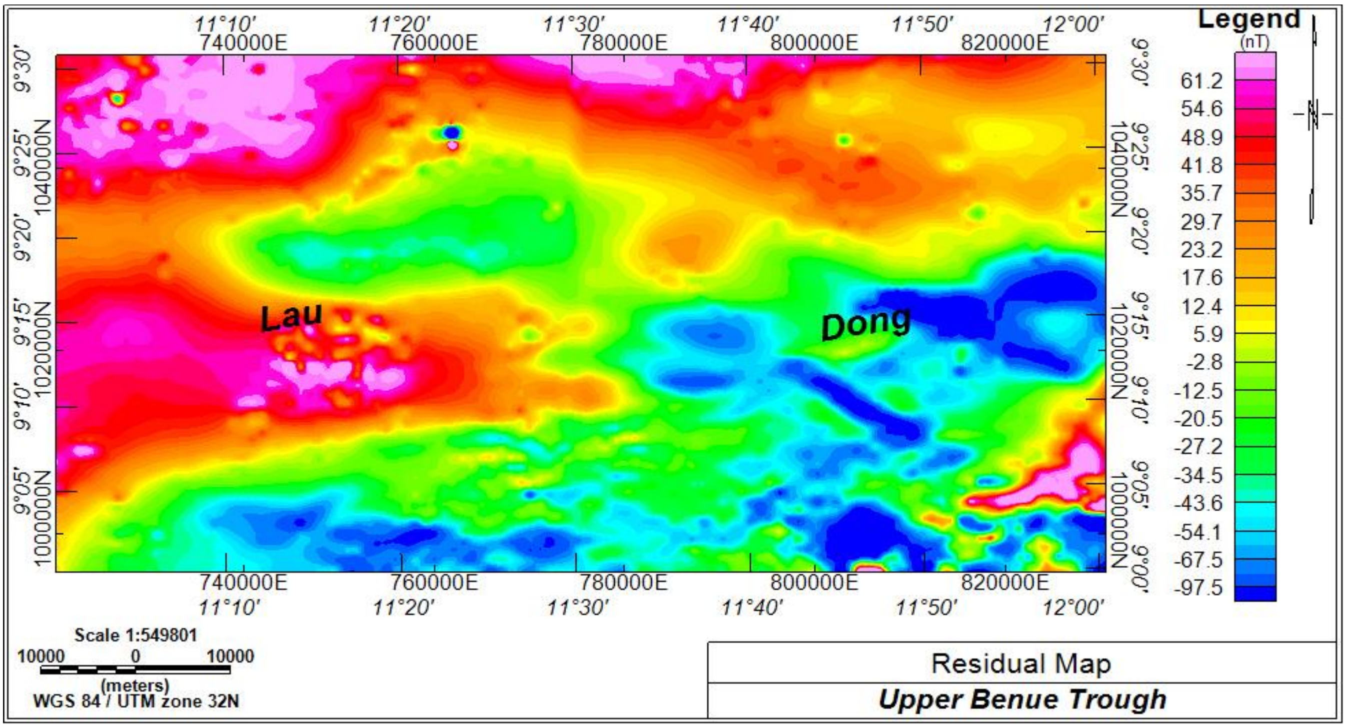


Fig 3 Residual Magnetic Anomaly Map

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/26apr1089

- *Source Parameter Imaging (SPI) Map*

The range of the SPI map is -316.5 to -3716.0 m (Fig. 4). The depths of magnetic bodies are represented by the negative depth numbers on the SPI legend. places with modest depths are represented by the color pink, whilst places with large depths are represented by the color blue.

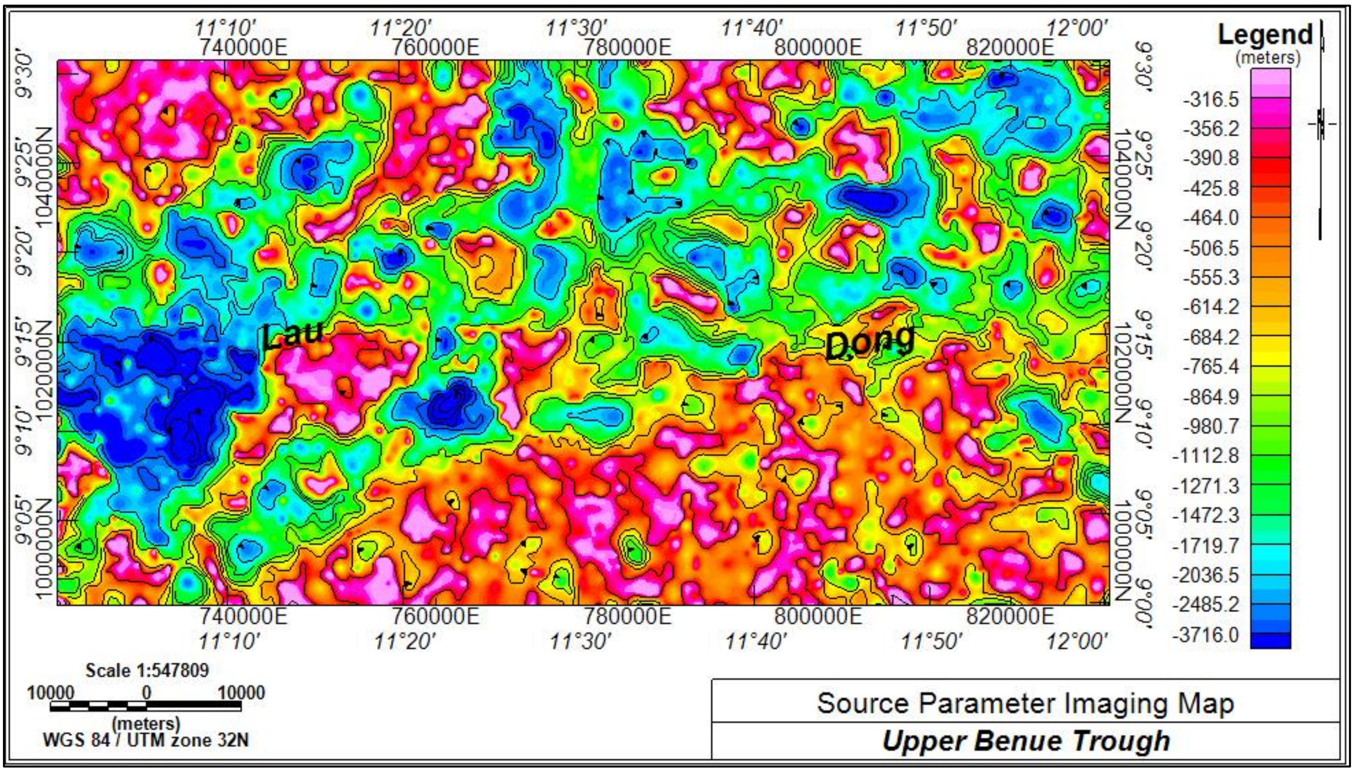


Fig 4 SPI Map

- *Forward and Inverse Modelling (FIM)*

On the residual grid (Fig 5), eight profiles were chosen and modelled. In Figure 6(a–h), the red curves show estimated field values, whereas the blue curves show observed field values. The results of the FIM are shown in Table 1.

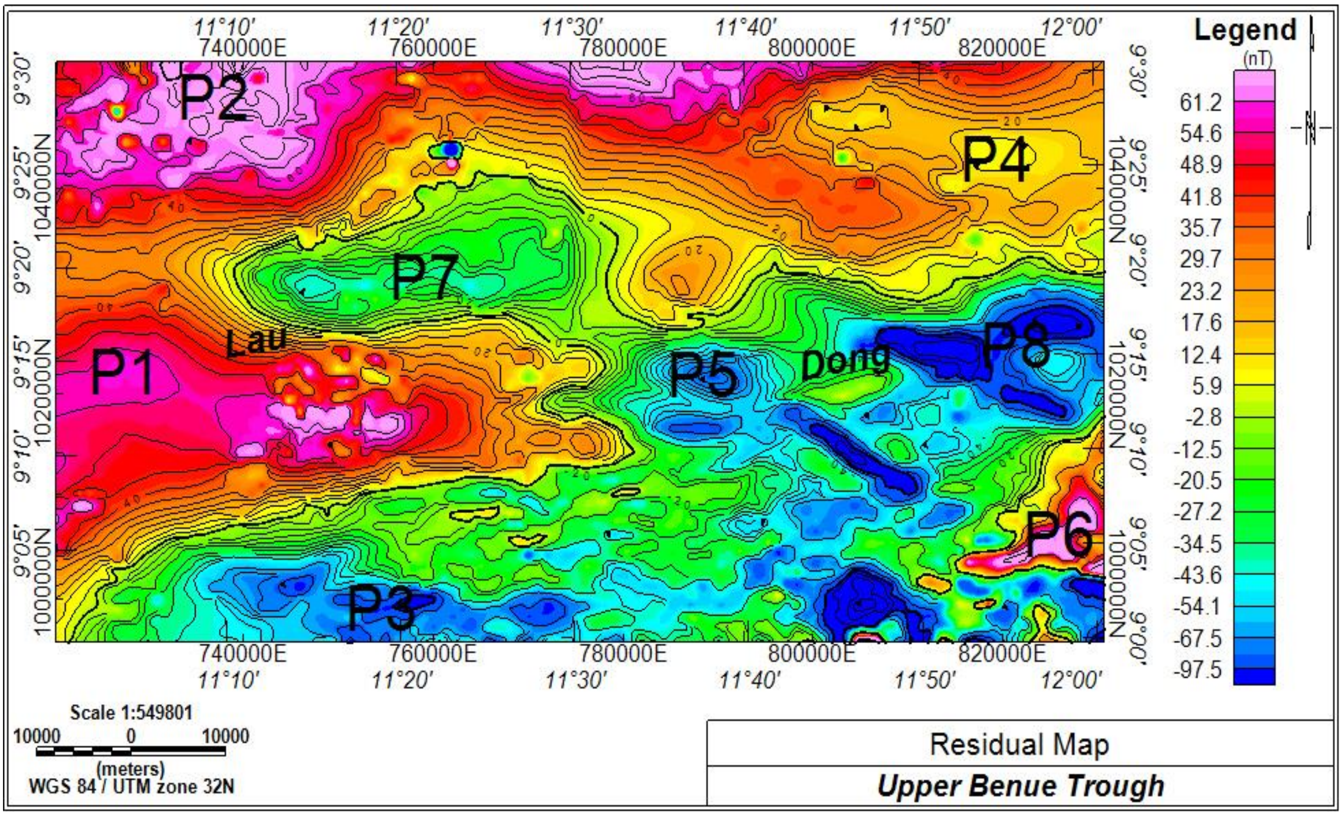
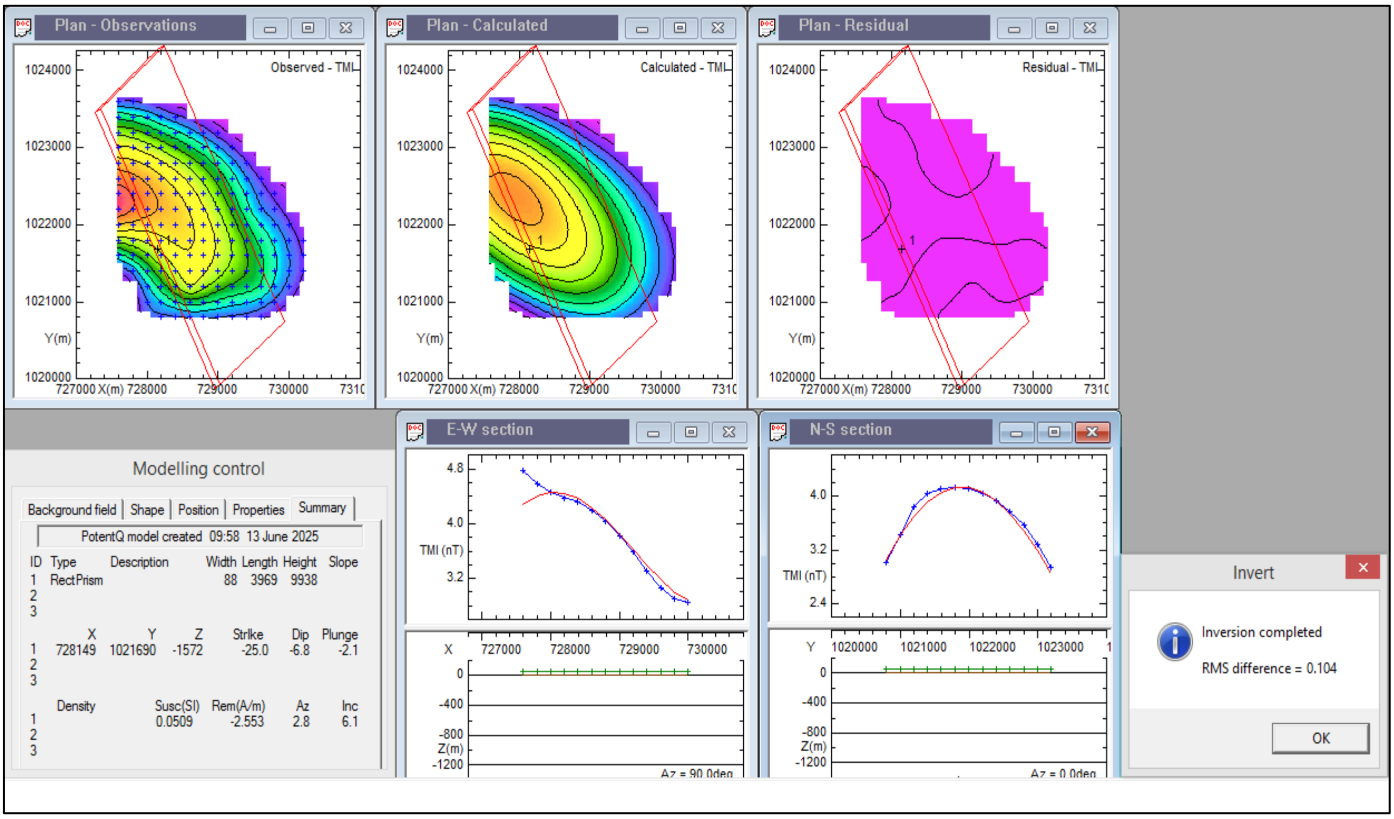


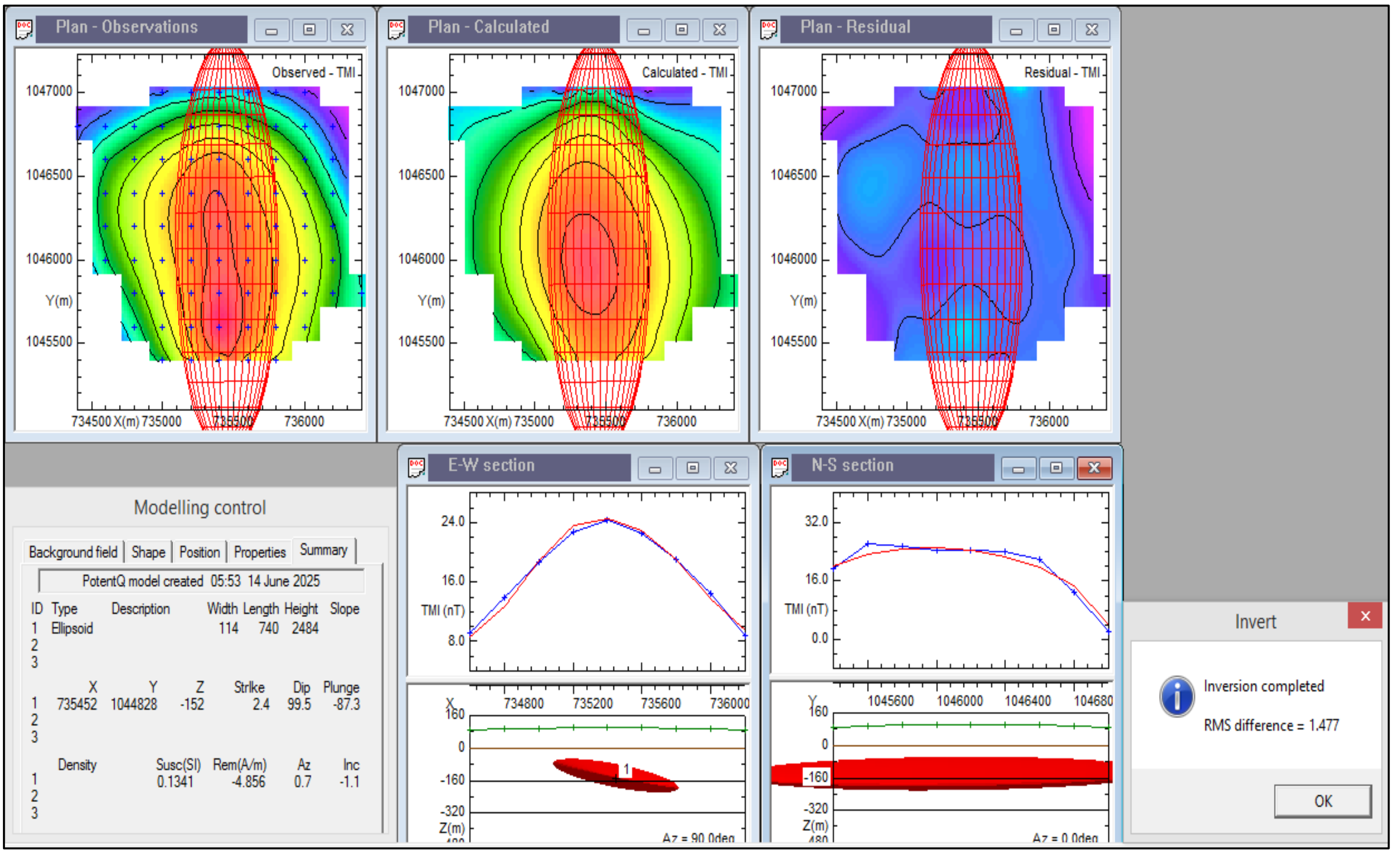
Fig 5 Magnetic Residual Contour Map



```
Modelling control
Background field | Shape | Position | Properties | Summary
PotentQ model created  09:58  13 June 2025
ID  Type        Description       Width  Length  Height   Slope
1   RectPrism                        88    3969    9938
2
3
           X        Y       Z        Strike    Dip   Plunge
1     728149  1021690   -1572         -25.0   -6.8     -2.1
2
3
      Density          Susc(SI)  Rem(A/m)      Az      Inc
1                      0.0509      -2.553     2.8      6.1
2
3
```

```
Inversion completed
RMS difference = 0.104
```

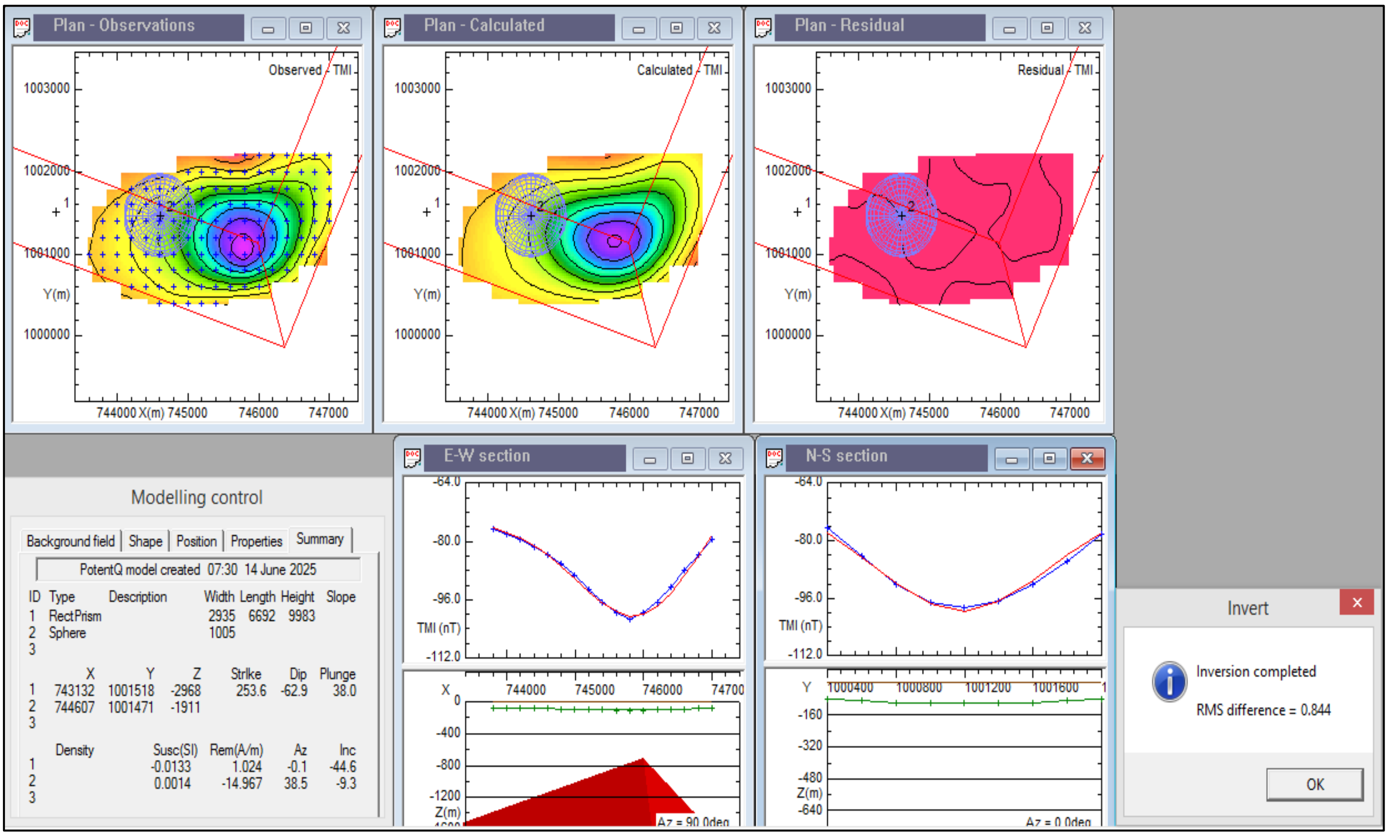
Fig 6 (a) Magnetic Residual Contour Profile 1 (P1) Modelled



```
Modelling control
Background field | Shape | Position | Properties | Summary
PotentQ model created  05:53  14 June 2025
ID  Type        Description       Width  Length  Height   Slope
1   Ellipsoid                       114     740    2484
2
3
           X        Y       Z        Strike    Dip   Plunge
1     735452  1044828    -152           2.4   99.5    -87.3
2
3
      Density          Susc(SI)  Rem(A/m)      Az      Inc
1                      0.1341      -4.856     0.7     -1.1
2
3
```

```
Inversion completed
RMS difference = 1.477
```

Fig 6 (b) Magnetic Residual Contour Profile 2 (P2) Modelled



Modelling control

Background field | Shape | Position | Properties | Summary

PotentQ model created 07:30 14 June 2025

ID	Type	Description	Width	Length	Height	Slope
1	RectPrism		2935	6692	9983	
2	Sphere		1005			
3						

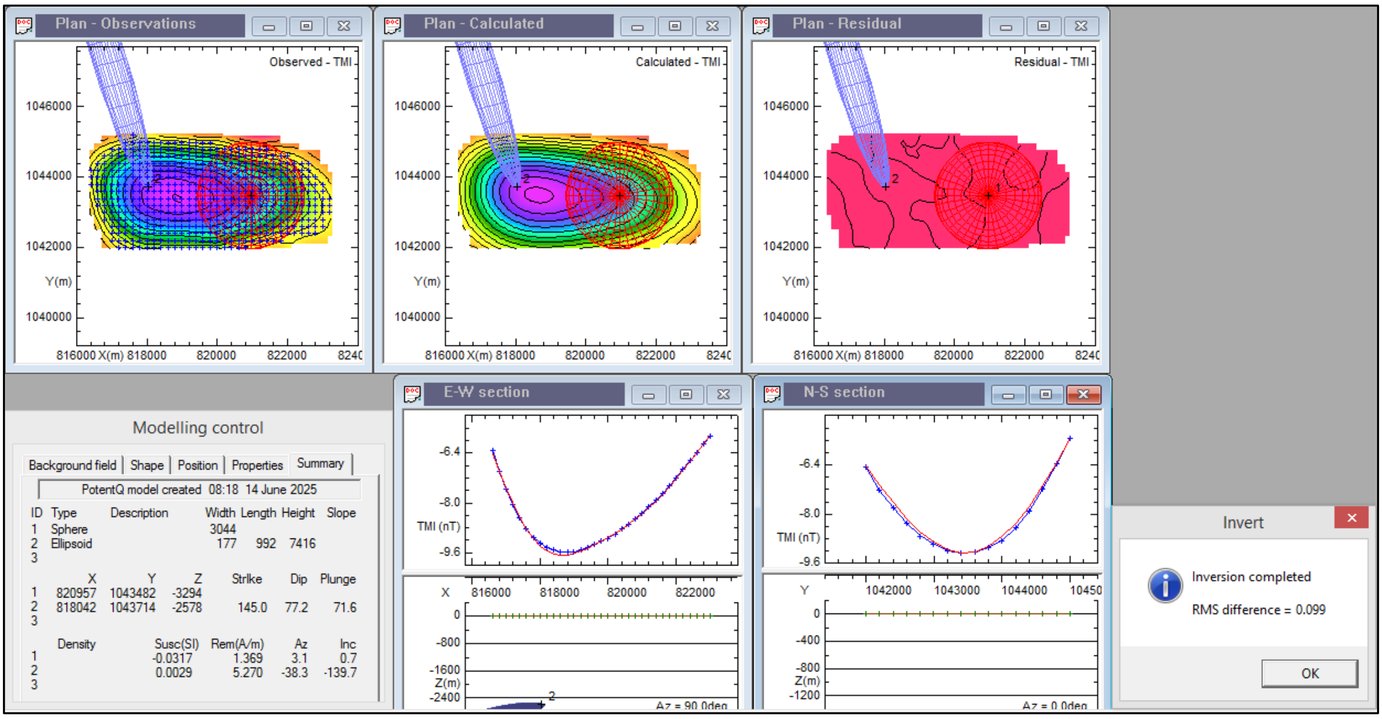
	X	Y	Z	Strike	Dip	Plunge
1	743132	1001518	-2968	253.6	-62.9	38.0
2	744607	1001471	-1911			
3						

	Density	Susc(SI)	Rem(A/m)	Az	Inc
1		-0.0133	1.024	-0.1	-44.6
2		0.0014	-14.967	38.5	-9.3
3					

Inversion completed

RMS difference = 0.844

Fig 6 (c) Magnetic Residual Contour Profile 3 (P3) Modelled



Modelling control

Background field | Shape | Position | Properties | Summary

PotentQ model created 08:18 14 June 2025

ID	Type	Description	Width	Length	Height	Slope
1	Sphere		3044			
2	Ellipsoid		177	992	7416	
3						

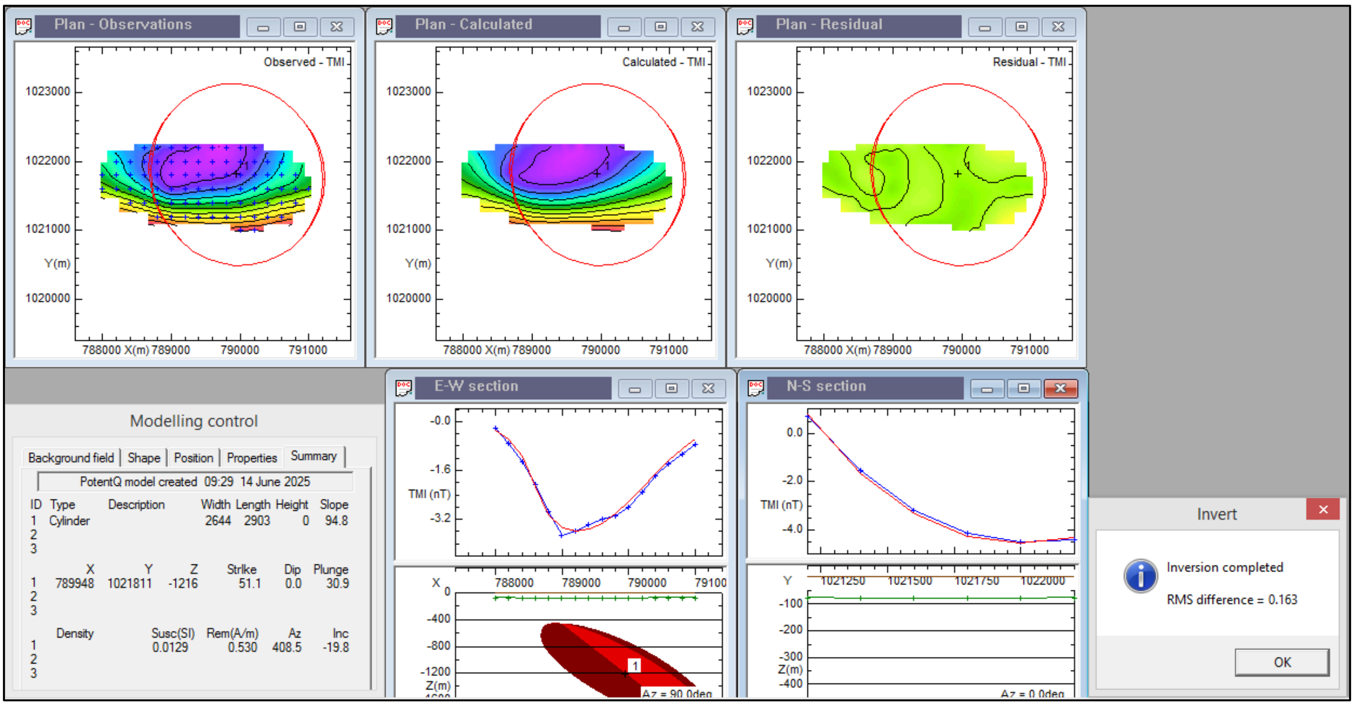
	X	Y	Z	Strike	Dip	Plunge
1	820957	1043482	-3294			
2	818042	1043714	-2578	145.0	77.2	71.6
3						

	Density	Susc(SI)	Rem(A/m)	Az	Inc
1		-0.0317	1.369	3.1	0.7
2		0.0029	5.270	-38.3	-139.7
3					

Inversion completed

RMS difference = 0.099

Fig 6 (d) Magnetic Residual Contour Profile 4 (P4) Modelled

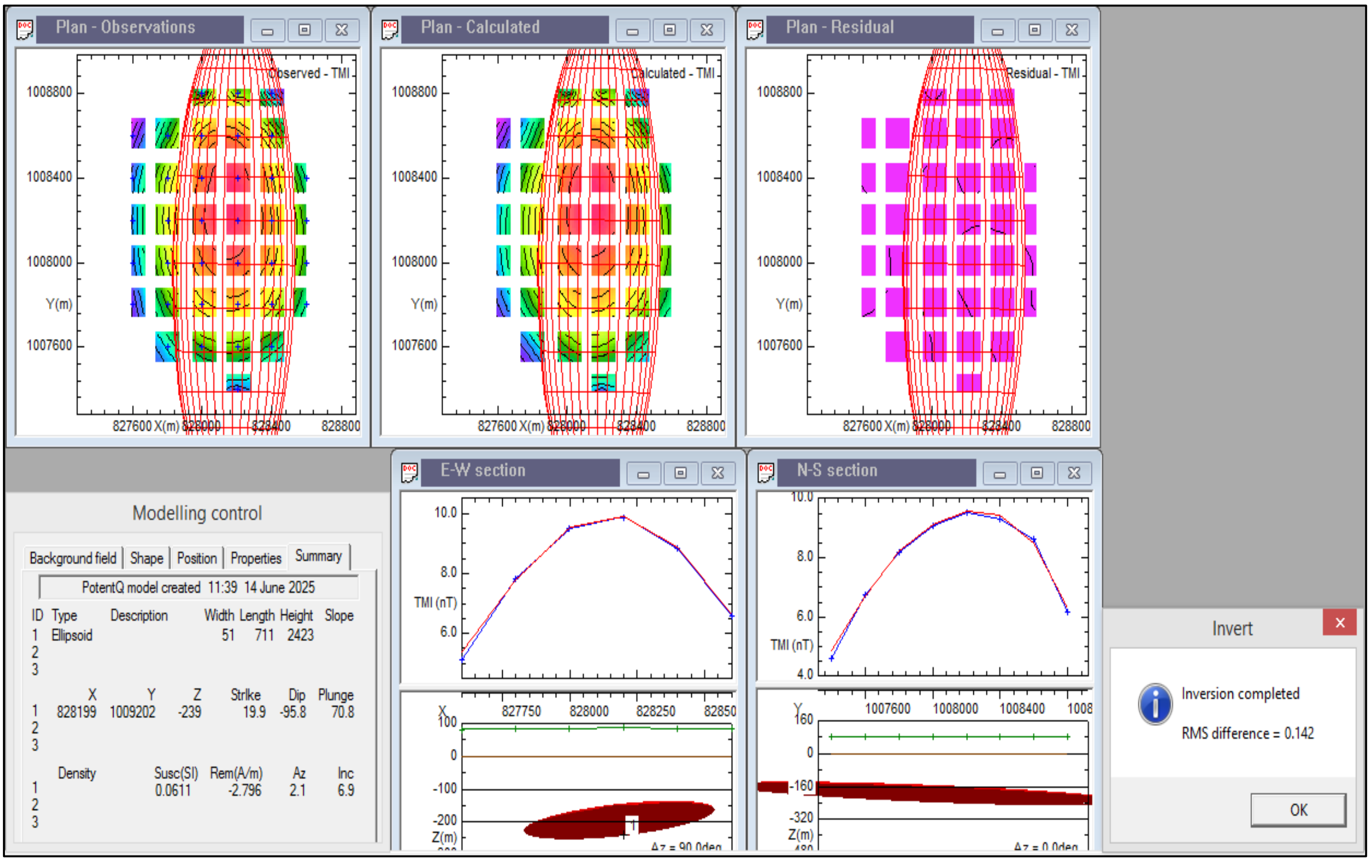


```
PotentQ model created  09:29  14 June 2025
ID  Type       Description     Width  Length  Height   Slope
1   Cylinder                   2644    2903       0     94.8
2
3
         X          Y        Z       Strike    Dip   Plunge
1   789948    1021811    -1216         51.1    0.0     30.9
2
3
     Density           Susc(SI)   Rem(A/m)       Az      Inc
1                        0.0129      0.530    408.5    -19.8
2
3
```

Inversion completed

RMS difference = 0.163

Fig (e) Magnetic Residual Contour Profile 4 (P5) Modelled



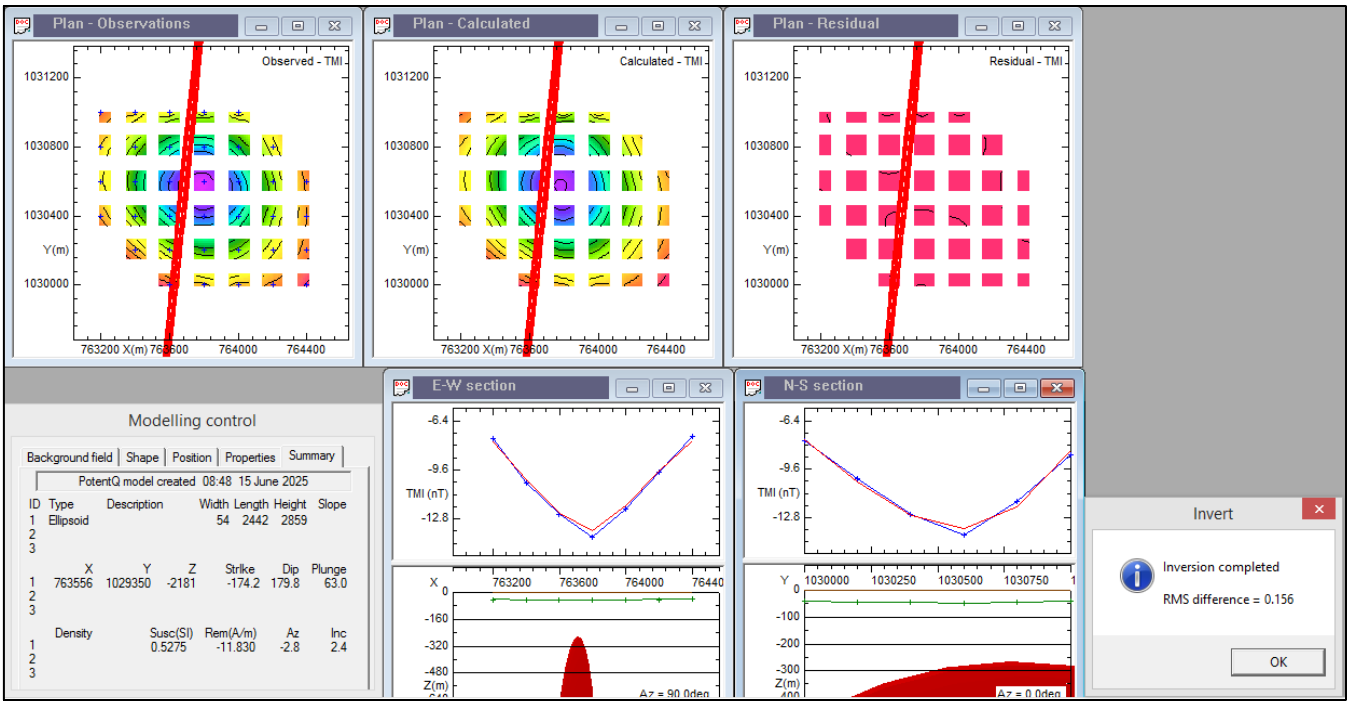
```
PotentQ model created  11:39  14 June 2025
ID  Type       Description     Width  Length  Height   Slope
1   Ellipsoid                     51     711    2423
2
3
         X          Y        Z       Strike    Dip   Plunge
1   828199    1009202     -239         19.9  -95.8     70.8
2
3
     Density           Susc(SI)   Rem(A/m)       Az      Inc
1                        0.0611     -2.796      2.1      6.9
2
3
```

Inversion completed

RMS difference = 0.142

Fig 6 (f) Magnetic Residual Contour Profile 6 (P6) Modelled

ISSN No: -2456-2165
https://doi.org/10.38124/ijisrt/26apr1089



Modelling control

Background field | Shape | Position | Properties | Summary

PotentQ model created 08:48 15 June 2025

ID	Type	Description	Width	Length	Height	Slope
1	Ellipsoid		54	2442	2859	
2						
3						

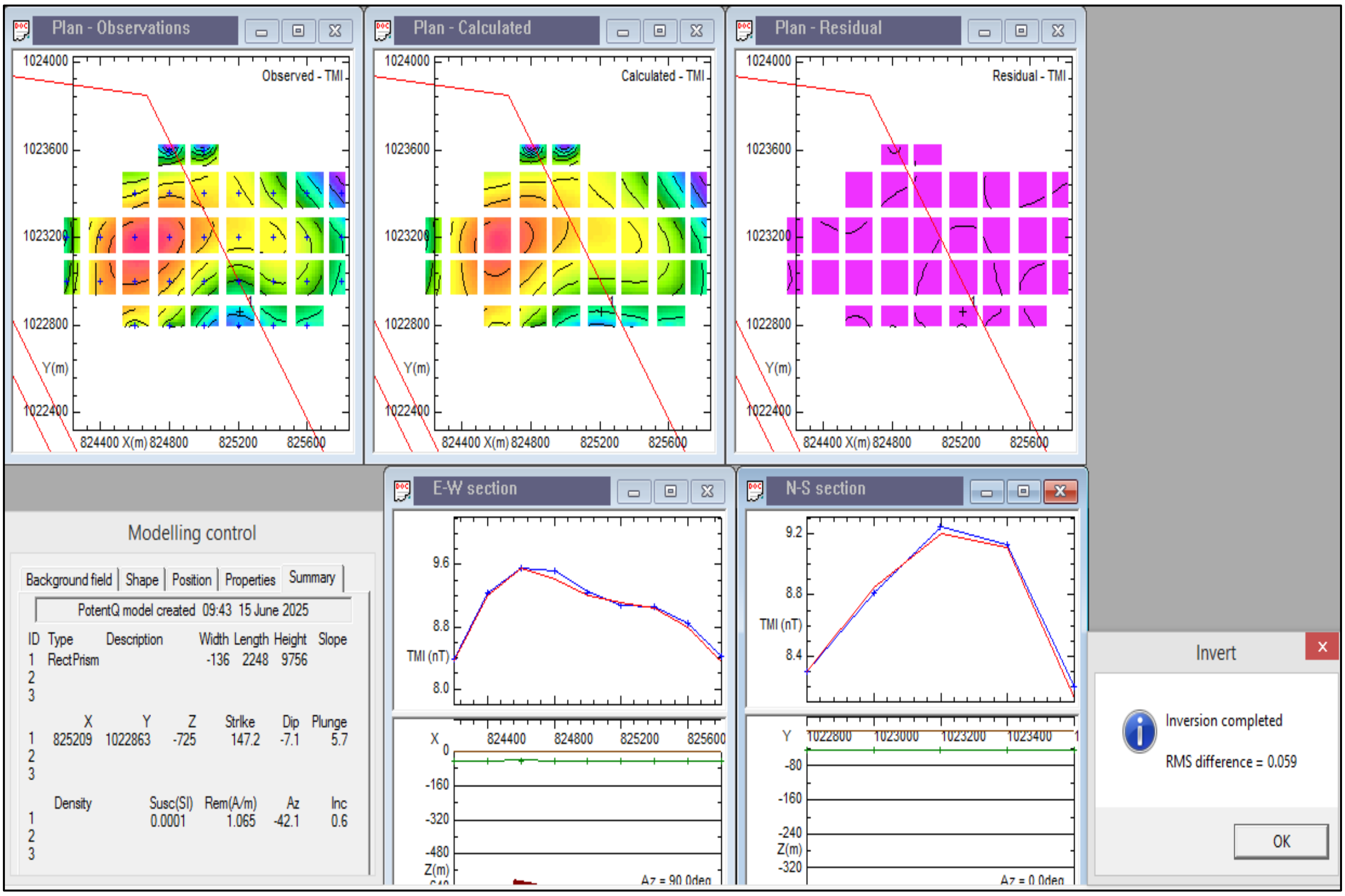
	X	Y	Z	Strike	Dip	Plunge
1	763556	1029350	-2181	-174.2	179.8	63.0
2						
3						

	Density	Susc(SI)	Rem(A/m)	Az	Inc
1		0.5275	-11.830	-2.8	2.4
2					
3					

Inversion completed

RMS difference = 0.156

Fig 6 (g) Magnetic Residual Contour Profile 7 (P7) Modelled



Modelling control

Background field | Shape | Position | Properties | Summary

PotentQ model created 09:43 15 June 2025

ID	Type	Description	Width	Length	Height	Slope
1	RectPrism		-136	2248	9756	
2						
3						

	X	Y	Z	Strike	Dip	Plunge
1	825209	1022863	-725	147.2	-7.1	5.7
2						
3						

	Density	Susc(SI)	Rem(A/m)	Az	Inc
1		0.0001	1.065	-42.1	0.6
2					
3					

Inversion completed

RMS difference = 0.059

Fig 6 (h) Magnetic Residual Contour Profile 8 (P8) Modelled

Table 1 Summary of the FIM Results

Model	Model shape	X(m)	Y(m)	Depth to anomalous body (m)	Plunge (deg)	Dip (deg)	Strike (deg)	K-value (SI)	Possible cause of anomaly
P1	Rect. Prism	728149	1021690	1572	-2.1	-6.8	-25.0	0.0509	Granite
P2	Ellipsoid	735452	1044828	152	-87.3	99.5	2.4	0.1341	Diabase
P3	Sphere	744607	1001471	1911	38.0	-62.9	253.6	0.0014	Sandstone
P4	Ellipsoid	818042	1043714	2578	71.6	77.2	145.0	0.0029	Schist
P5	Cylinder	789948	1021811	1216	30.9	0.0	51.1	0.0129	Hamatite
P6	Ellipsoid	828199	1009202	239	70.8	-95.8	19.9	0.0611	Gabbro
P7	Ellipsoid	763556	1029350	2181	63.0	179.8	174.2	0.5275	Magnetite
P8	Rect. Prism	825209	1022863	725	5.7	-7.1	147.2	0.0001	Shale

IV. DISCUSSION

The magnetic intensity map for the studied area shows considerable areas of high positive anomalies, which are most likely caused by igneous intrusions, which are frequently connected with magmatic processes. On the contrary, locations with low magnetic intensity are more likely to be sedimentary deposits. These findings were consistent with those of [11, 12], who found that magnetic surveys are particularly good at differentiating between igneous intrusions and sedimentary layers due to their differential magnetic properties.

The SPI and FIM depth values are comparable with earlier geological studies undertaken in the Upper Benue Trough [1, 6]. Notably, the maximum depth of 3716.0 m determined from the SPI analysis indicates the presence of thick sedimentary layers, implying that the area has a high potential for hydrocarbon accumulation [1, 6].

Additionally, the FIM results provide more information about the subsurface lithology. A wide range of minerals found in rocks, such as granite, diabase, sandstone, schist, hematite, gabbro, magnetite, and shale, were detected by these models. The magnetic susceptibility estimates are consistent with [11, 12]. These results further confirm the reliability of the modeling results by correlating with the general geological features of the Benue Trough as anticipated by [8].

V. CONCLUSION

This study has effectively used a variety of analysis methodologies to analyze the aeromagnetic data in order to estimate the types of mineralization, hydrocarbon potential, and sedimentary thickness in the studied area. The FIM susceptibility values range from 0.0001 to 0.5275, corresponding to depths ranging from 152 to 2578 m, indicating the existence of sandstone, gabbro, gneiss, marble, granite, limestone, and shale in the study area. These potential mineral deposits in the research region may provide raw materials for numerous Nigerian factories and enterprises. The likelihood of hydrocarbon accumulation and exploration is indicated by the highest sedimentary thickness of 3716.0 m.

ACKNOWLEDGMENT

The authors gratefully acknowledge the Nigerian Geological Survey Agency (NGSA) for providing the aeromagnetic data used in this study

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

REFERENCES

[1]. Ajala, S. A., Salako, K. A., Rafiu, A. A., Alahassan, U. D., Adewumi T. and Sanusi, Y. A. (2021). Estimation of Sedimentary Thickness for Hydrocarbon Potential over part of Adamawa Trough, Nigeria using magnetic method. Earth Sciences Pakistan, 5(1): 07-11.

[2]. Alagbe, O. A., and Sunmonu, L. A. (2014). Interpretation of aeromagnetic data from Upper Benue Basin, Nigeria using automated techniques. IOSR Journal of Applied Geology and Geophysics, 2, 22–40.

[3]. Carter, J. D., Barber, W., and Tait, E. A. (1963). The geology of parts of Adamawa, Bauchi and Bornu provinces in northeastern Nigeria. Geological Survey of Nigeria Bulletin.

[4]. Haruna, A. A., Ayanninuola, O. S., Ofoegbu, C. O. and Uko, E. D. (2024). Aeromagnetic Study of Kaltungo-173, Guyok-174, Lau-194 and Dong-195 in Upper Benue Trough Nigeria for Mineralization Potentials. Engineering Heritage Journal, 5(2): 88-96. https://doi.org/10.26480/gwk.02.2024.88.96

[5]. MacLeod, I. N., Jones, K., and Dai, T. F. (1993). 3-D analytic signal in the interpretation of total magnetic field data. Geophysics, 58, 116–127.

[6]. Mohammed, S. C., Ovie, I., and Igbinosa, T. S. (2019). Environmental geochemistry of Igarra marble mining district, Southwestern Nigeria. Journal of Environmental Protection, 10, 722–737.

[7]. Nwosu, O. B. (2014). Determination of Magnetic Basement Depth over Parts of Middle Benue Trough by Source Parameter Imaging (SPI) Technique Using HRAM. International journal of scientific & technology research, 3(1): 262.

[8]. Obaje, N.G. (2009). The Benue Trough. Geology and Mineral Resources of Nigeria. Springer, PP. 221.
[9]. Reeves, C. (2005). Aeromagnetic surveys: Principles, practice and interpretation. Geosoft.
[10]. Reid, A. B., Allsop, J. M., Granser, H., Millett, A. J., and Somerton, I. W. (1990). Magnetic interpretation in three dimensions using Euler deconvolution. Geophysics, 55, 80–91.
[11]. Telford, W. M., Geldart, L. P., and Sheriff, R. E. (1990). Applied geophysics (2nd ed.). Cambridge University Press.
[12]. Thompson, R., and Oldfield, F. (1986). Environmental magnetism. Allen & Unwin.
[13]. Thurston, J. B., & Smith, R. S. (1997). Automatic conversion of magnetic data to depth, dip, and susceptibility contrast using the SPI™ method. Geophysics, 62(3), 807–813.
[14]. Nwobodo, A. N., Uduma, I. A., Nnamani, J. F, and Abangwu U. J. (2025). Natural Radioelement Concentrations and Dose Rate Assessment Using High-Resolution Aeroradiometric Data of Dapchi and Biriri Areas, Upper Benue Trough Nigeria. Radiation Science and Technology, 11 (2), 33 - 42 https://doi.org/10.11648/j.rst.20251102.