Int. j. adv. multidisc. res. stud. 2024; 4(6):1091-1094

Received: 29-10-2024
Accepted: 09-12-2024

International Journal of Advanced Multidisciplinary Research and Studies

ISSN: 2583-049X

Determination of Depth to Magnetic Sources using Source Parameter Imaging (SPI) of High-Resolution Aeromagnetic Data of Esie, North central Nigeria: An Investigation tool for Geothermal Exploration

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Abstract
The High-Resolution Aeromagnetic data of Ilorin (sheet 223) and Osi (sheet 224) of Esie, North central Nigeria was analyzed using source parameter imaging (SPI). The aim of the analyses was to determine the depth to magnetic sources which is based on the total magnetic intensity (TMI) map of the study area and to ascertain whether the study area has a good geothermal potential. The area under study is situated between latitudes 8.0833 $^{\circ}N$ and longitudes 4.7333 $^{\circ}E$ and it covers an area of 43 km ^{2} .The results of the analysis indicate that the deepest and the shallowest magnetic sources are about 1250 m and 20 m respectively. The deepest magnetic sources represent the magnetic basement and the shallow magnetic sources represent sedimentary layer. A significant variation is observed in the sedimentary thickness and this is shown to be dipping almost parts of the study area, thereby gives the basement a rugged topography. The interpreted SPI showed that the study area is a shallow depth to basement sedimentary basin area. Hence, further exploration of geothermal potential is recommended.

Keywords: Aeromagnetic Data, Source Parameter Imaging, Sedimentary, Basement, Geothermal

1. Introduction

Nigeria is currently tackling continuous problem of power supply and this has affected her in terms of productivity and her inability to compete economical, political, socially, and technologically with other nations of the world. Nigeria much dependant on oil and natural gas has constituted much hindrance towards the harnessing of other sources of energy which can contribute enormously to the economic, social, political and technological growth of the nation. In other to generate constant electricity, other sources of power such as renewable energy which are emerging in the rise of climate change and the depletion of the ozone layer should be examined (Sedara and Joshua, 2013; Olusola, 2014, Ikechukwu *et al*., 2015) [15, 14, 7]. The surface manifestation of geothermal energy in the study area. The essence of geophysical surveys is to ensure the plausibility of the occurrence of suspected deposit and secondly to ascertain where there is sufficient evidence, that the occurrence is an economic deposit and viable for Geothermal exploitation.

Geothermal energy is a form of heat which flows out from the earth's interior from the decaying of natural occurring radioactive isotopes. It is a form of renewable source of energy and environmental friendly because it emits little or no greenhouse gas. Parameters such as depth to top, depth to centroid and depth to the basement are factors to be considered when prospecting for geothermal energy (Bertani, 2010) [3].

Source Parameter Imaging (SPI) technique has been widely used in the recent years for estimation of depth to magnetic sources. The Source Parameter Imaging (SPI) technique is a quick, easy, and powerful method for calculating the depth of magnetic sources. Its accuracy is similar to the accuracy of the Euler deconvolution which has been shown to be +/- 20 % in tests on real data sets with drill whole control (Thurston and Smith, 1997) [6]. However, SPI has the advantage of producing more complete set of coherent solution points and it is easier to use. The Source Parameter Imaging (SPI) of aeromagnetic fields over an area would differentiate and characterize regions of sedimentary thickening from those of uplifted or shallow basement and also determine the depths to the magnetic sources (Odidi *et al*, 2022) [12]. Results obtained from SPI of aeromagnetic map could be used to suggest whether or not a study area would have good potential for oil and gas or other mineral deposits (Obaje and Yusuf, 2013). Therefore, the aim of this study is to analyse the aeromagnetic data of Esie and environs to determine the depth to magnetic layers with a view of finding certain geothermal parameters within the basement complex.

2. The Study Area

The study area, Esie, located between latitude 8.2121 °N and Longitude 4.8975 °E, in the southwest of Ilorin, the capital of Kwara State Nigeria. It falls within category of hard rock terrain where there is presence of distinct features from porous and permeability products. The rocks are agents of erosion because they are weak when depositing (Olawepo *et al*, 2013) [13]. The area is dominated by rocks such as granite, pegmatite, gabbro, gneiss, amphibolites and migmatite (Bamigboye and Adekeye, 2011) [2]. The Geological map of the study area is as shown in Fig 1.

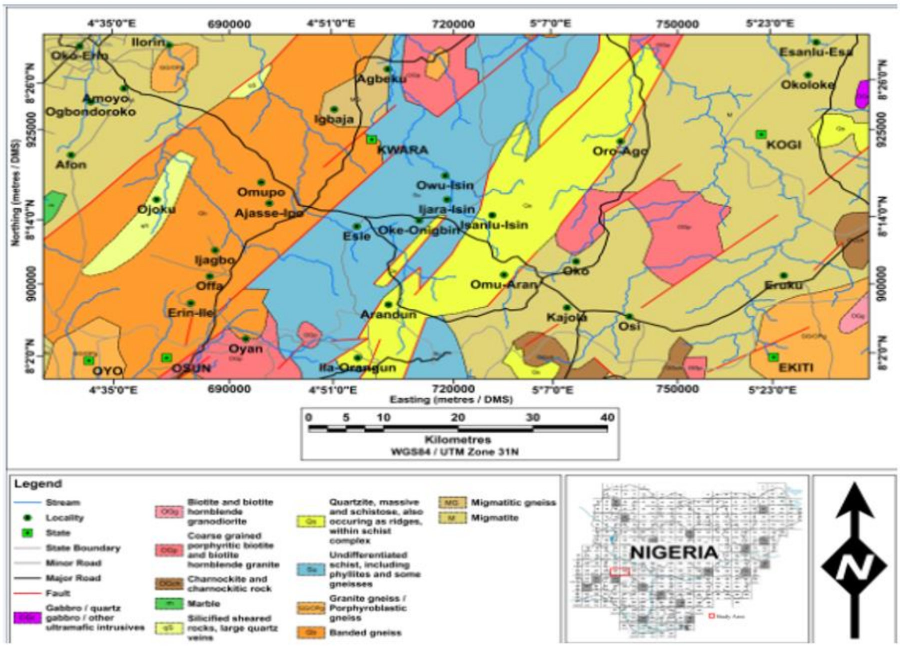

Fig 1: Geological map Esie (Modified after NGSA, 2022)

3. Materials and Methods

The high-resolution aeromagnetic dataset of Ilorin (sheet 223) and Osi (sheet 224) used for this study was obtained from the Nigerian Geological Survey Agency (NGSA). The data set were recorded at a sampling interval of 100m and stored in grid form. The study area is covered by fifty aeromagnetic maps of total-field intensity sheets. The data set were leveled; de-cultured, recorded on profile by profile and were plotted using Oasis Montaj software (version 8.4). Total magnetic field Intensity data of two high resolution aeromagnetic maps namely sheet numbers 223 and 224 on a scale of 1:100,000 covering ½º by ½º sheets were collected. Hence, the magnetic values were plotted at interval of 10 nT and the actual magnetic values were reduced by 25,000 gammas before plotting contour maps (Huntings, 1976). The plotted data comprising longitude, latitude and the total field magnetic values were used to produce the source parameter image (SPI) for interpretation as guided by the local geology of the study area (Thurston and Smith, 1997) [6]. The source parameter imaging method is used to estimate the depth from the local wave number of an analytical signal (Thurston and Smith, 1997) [6]. The analytical signal A1(x, z) is defined by Nabighian (1972) [10] as:

$$Depth = \frac{1}{k_{max}} = \frac{1}{\sqrt{\left(\frac{\partial Tilt}{\partial x}\right)^2 + \left(\frac{\partial Tilt}{\partial y}\right)^2}} \qquad (1)$$

$$Tilt = \tan^{-1}\left(\frac{\frac{\partial T}{\partial Z}}{\sqrt{\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial y}\right)^2}}\right) \qquad (2)$$

$$Tilt = \tan^{-1}\frac{\frac{\partial T}{\partial z}}{HGRAD} \qquad (3)$$

Where **T** =- total magnetic Field

$$\mathbf{HGRAD} = \text{Horizontal Gradient}\ \sqrt{\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial y}\right)^2} \qquad (4)$$

The contacts of thin sheet and horizontal cylinder which are two-dimensional models of infinite strike extent are implicit assumption of the Source parameter Imaging (SPI) method. The modeled bodies are two-dimensional such that there is no interference from nearby bodies. Hence, the depth estimate is reasonable and the structural index and there is no interference from nearby bodies, the depth estimate will be reasonable and the structural index should be constant over the entire area for which the response is anomalous. Estimate will be reasonable and the structural index was relatively constant over the entire area for which the response is anomalous. Also the estimated structural index was reasonable made constant over the entire area for which the response is anomalous.

4. Results and Discussions

4.1 The Total Magnetic Intensity (TMI) and Magnetic Residual Maps

The TMI and residual maps of the study area shown in Fig 2 indicate that the area comprises of high and low magnetic intensity. The high magnetic intensity depicted by pink colouration on Fig 2 ranges from 0 nT to 50 nT, and covers the North-eastern and the central parts of the map. The low magnetic anomalies have values ranging between -25 and -100 nT. The high magnetic residual separation observed on the residual data on Fig 3 has values ranging from -50 nT to 50 nT. Thus, the high magnetic anomaly on the TMI map and residual map could be as a result of presence of dense rock types, such as metamorphic formations thereby suggesting the presence of geothermal reservoirs that could be exploited for geothermal energy generation (Mohammed *et al.,* 2019) [9].

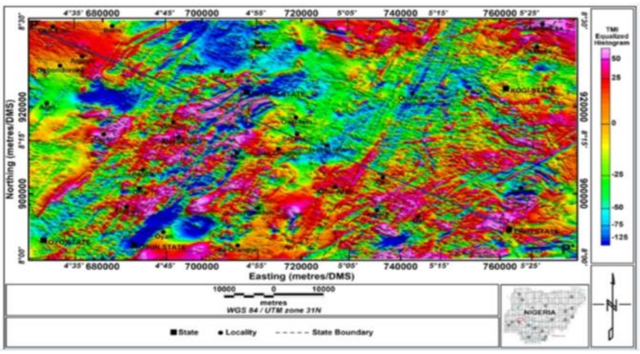

Fig 2: Total Magnetic Intensity (TMI) map of Esie and environs

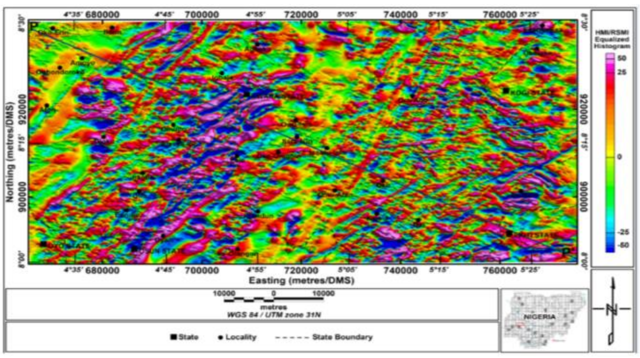

Fig 3: High pass Residual map of Esie and environs

4.2 The Source Parameter imaging (SPI)

The Source Parameter Imaging (SPI) of the study area is shown in Fig 4. The application of SPI method needs the following:

GRD1 Grid of the horizontal derivative in the X-direction
GRD2 Grid of the horizontal derivative in the Y-direction
GRD3 Grid of the first vertical derivative
GRD4 Grid of tilt derivative
GRD5 Grid of local wave number k grid (horizontal gradient of tilt derivative).

Fig 4 is the depth estimates obtained from the source parameter imaging (SPI) map of the study area. It is observed that the highest sedimentary thickness of about 20 m to 250 m which is depicted by blue colouration is experienced in almost all the areas covered by the study area but are mostly found in Eastern parts and the northern parts of the study area. It can be observed from the SPI grid that the shallowest and the deepest depths of the sediments as obtained by the SPI are between the range of 20 m to 250 m and 1000 m to 1250 m respectively. However, relatively higher depths are scattered around Eastern and Western parts of the study area. The results from the SPI methods agreed largely with other published works in the study area. These include; Nur *et al*., (1994) who obtained 1.6 km to 5 km for deeper source around middle Benue, while 60 m to 1.2 km was obtained for shallow magnetic source; Nwogbo (1997) got 2 km to 2.62 km for deeper source and 70 m to 0.63 km for shallow source from spectral analysis of upper Benue trough; Nur *et al*., (1999) [11] stated that, the deeper magnetic sources were at depth of up to 33.28 km, representing the sedimentary cover in the study area and the highest depth to the shallower magnetic source model is 8.30 km and represents intrusive/extrusive bodies within the trough Basin; Nur (2000) obtained depth range of 625 m to 2.219 km for deeper source and an average of 414 m for shallow source at upper Benue trough; Eetta and Udensi (2012) [4] obtained a depth range of 2-8.4 km; Ikumbur *et al*., (2013) [8] obtained a depth range of 2.81-3.24 km; Igwesi and Umego (2013) [5] obtained a depth of 3.03km; Bello *et al*., (2017) obtained a depth of 5 km; Mohammed *et al*., (2019) [9] obtained a depth range of 12.43-33.91 km; Abdullahi *et al 2019* obtained a depth range of 1-9 km.

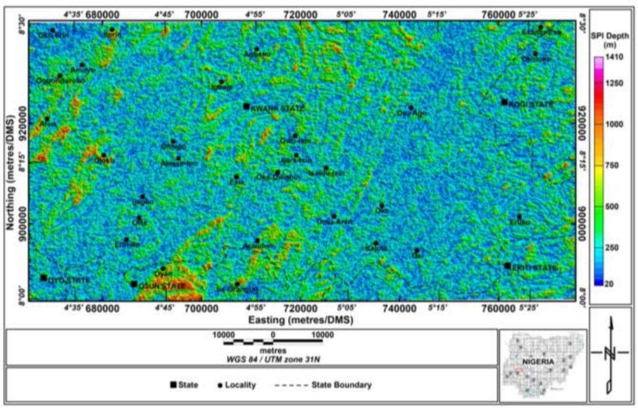

Fig 4: Source parameter Imaging Map of the Study Area

5. Conclusion

The study has successfully estimated the depth to magnetic sources in Esie. The value ranges from 20 m to 1410 m. The highest depth was found in the south, East and parts of North of the study area. However, relatively higher depth scattered at almost all the study area, but were a little concentrated in areas around Southern and eastern parts of the study area. The depth to magnetic basement is shallower mainly in the western and mid north-eastern parts of the study area with magnetic high flanking areas of magnetic low. However, some parts of the south are dotted by shallower depths. The above characteristics of these areas and the location of warm springs at the north-eastern and south-western parts of the study area (Esie warm spring, Opa warm spring and Iyara warm springs respectively), which according to Rowland and Nur (2018) suggests the occurrence of tectonic activities, could be an indication that, there might probably be good sources for geothermal energy. Hence, we recommend further geothermal exploration using other imaging techniques such as seismic and gravity.

6. References

1. Abdullahi M, Kumar R, Singh KU. Magnetic basement depth from high-resolution aeromagnetic data of parts of lower and middle Benue Trough (Nigeria) using scaling spectral method. Journal of African Earth Sciences. 2019; 150:337-345. Doi: https://doi.org/10.1016/j.jafrearsci.2018.11.006.
2. Bamigboye OS, Adekeye JID. Stream sediment survey of Eruku and its environs, Central Nigeria: Implication for Exploration. IJRRAS. 2011; 7(2).
3. Bertani R. Geothermal power generation In the world 2005–2010. Bali, Indonesia 25–29 Flow for Determination of Geothermal Energy Sources in Monguno Area of Northeastern Nigeria Journal of Geography, Environment and Earth Science International. 2010; 20(1):1-8. Article no.JGEESI.47809 ISSN: 2454-7352
4. Eletta BE, Udensi EE. Investigation of the Curie Point Isotherm from the Magnetic Fields of Eastern Sector of Central Nigeria. Geosciences. 2012; 2(4):101-106. Doi: 10.5923/j.geo.20120204.05
5. Igwesi ID, Umego NM. Interpretation of Aeromagnetic Anomalies Over Some Parts of Lower Benue trough Using Spectral Analysis Technique. International Journal of Scientific & Technology Research. 2013; 2(8):153-165. ISSN 2277-8616**.**
6. Thurston JB, Smith RS. Automatic conversion of magnetic data to depth, dip, and susceptibility contrast using the SPITM method. Geophysics. 1997; 62:807-813.
7. Ikechukwu IO, Derick CA, Olusola OB. Exploration and Application of Geothermal Energy in Nigeria. International Journal of Scientific & Engineering Research. 2015; 6(2):726-732.
8. Ikumbur EB, Onwuemesi AG, Anakwuba EK, Chinwuko AI, Usman AO, Okonkwo CC. Spectral Analysis of Aeromagnetic Data over Part of the Southern Bida basin,West-Central Nigeria. International Journal of Fundamental Physical Sciences. 2013; 3(2):27-31.
9. Mohammed A, Adewumi T, Kazeem AS, Abdulwaheed R, Adetona AA, Usman A. Assessment of geothermal potentials in some parts of upper Benue Trough northeast Nigeria using aeromagnetic data. Journal of Geoscience, Engineering, Environment, and Technology, [S.l.]. 2019; 4(1):7-15. ISSN 2541-5794. <https://www.journal.uir.ac.id/index.php/JGEET/article /view/2090>. Date accessed: 22 jan. 2020. doi: https://doi.org/10.25299/jgeet.2019.4.1.2090.
10. Nabighian MN. The analytic signal of two-dimensional magnetic bodies with polygonal cross-section: Its properties and use for automated anomaly interpretation, Geophysics. 1972; 37(3):507-517.
11. Nur A, Ofoegbu CO, Onuoha KM. Estimation of depth to the Curie point isotherm in the Upper Benue Trough, Nigeria. Jour. Mining and Geol. 1999; 35(1):53-60.
12. Odidi IG, mallam A, nasir N. Investigation of geothermal energy potential of parts of central and north-eastern Nigeria using spectral analysis technique, 2022.
13. Olawepo AO, Fatoyinbo AA, Ali I, Lawal TO. Evaluation of Groundwater Potential and Subsurface Lithologies in Unilorin Quarters using Resistivity Method. The African Review of Physics. 2013; 8(45):317-323.
14. Olusola OB. A Review of Solar Chimney Technology: Its' Application to Desert Prone Villages/Regions in Northern Nigeria. International Journal of Scientific & Engineering Research. 2014; 5(12):1210-1216.
15. Sedara SO, Joshua EO. Evaluation of the Existing State of Geothermal Exploration and Development in Nigeria Journal of Advances, Physics Journal of Advances in Physics. 2013; 2(2):118-123.