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Spectral Analysis of Higher Resolution Aeromagnetic Data over Some Part of Kwara State, Nigeria.

[1*]Wahaab, F. A., [1]Lawal, S. K., [1]Adebayo, L. L.
[1]Department of Physics and Material Science,
Kwara State University, Malete, Nigeria.

***Abstract* - An aeromagnetic study of part of Kwara State, Nigeria (bounded by longitude $4^0$30'- $5^0$30' E and latitude 8^0 - $8^0$30' N) has been carried out using the Spectral analysis method to establish its main shallow crustal structural form, particularly depth to magnetic basement. Spectral analysis method was chosen because of its ability to filter almost all the noise present from the data and still ensuring no information is lost in the interpretation process by overlapping data. In this research, the Radially Averaged Power Spectrum of the aeromagnetic data was achieved using the Fast Fourier Transform for estimating the depth to top of magnetic basement (source). Analysis of results obtained from the Radially Averaged Power Spectral indicates two depth sources; the depth to deeper source which ranges from 0.8772 to 1.8231 km, while the shallow sources range from 0.1755 to 0.6323 km. The depth to source in the area is relatively shallow, the maximum depth (1.8231 km) could be found at the south-western part of the study area while the minimum depth of about 0.8772 km could be found roughly at the central part of the total intensity map. The basement depth invariably represents the average sedimentary thickness (1.3049 km) of the study area, that is, the depth to the underlying basement complex rocks. The lithology of the basement structure was modelled in contour and 3D surface map.**

Keyword: Aeromagnetic data, depths to basement, Spectral Analysis, deeper and shallow sources

1. INTRODUCTION

The city is situated in the transitional zone between the forest and savanna region of Nigeria. The geology of Kwara consists of Pre-Cambrian basement complex with an elevation that varies from 273m to 333m in the West having an isolated hill (Sobi hills) of about 394m above sea level and 200m to 364m in the East. (Oyegun R., 1985) further asserted that a large part of Kwara State is laid by sedimentary rock, which contains both primary and secondary laterites and alluvial deposits.

Geologically, the study area longitude $4^0$30' – $5^0$30' E and latitude $8^0$00' – $8^0$30' N (part of Kwara State) lies in the Precambrian Basement complex of southwestern Nigeria and is underlain by rock of metamorphic and igneous type. However, migmatite predominantly underlies the area and characterized by weathered regolith which vary in thickness from place to place. The hydrologic setting of the area studied is typical of what is obtained in other Basement complex area where the availability of water is a function of the presence of thick-little clay overburden material and presence of water filled joints, fracture or faults within the fresh Basement rocks. The humid tropical climate of Kwara State has particularly encouraged relatively deep weathering of the near surface rocks to produce porous and permeable material that allows groundwater accumulation as shallow aquifer which is recharged principally through infiltration of rainwater (Ajibade I.T, 2008).

The major advantage of Spectral analysis method is its ability to filter almost all the noise from the data whilst still making sure no information is lost in the process of interpretation by overlapping data. Such techniques of spectral analysis provide rapid depth estimates from regularly-spaced digital field data; no geomagnetic or diurnal corrections are necessary as these remove only low-wavenumber components and do not affect the depth estimates which are controlled by the high-wavenumber components of the observed field (Spector, et al., 1970). The maximum depth that can be probed in this research work is about 2.39km given by

$$D = \frac{L}{2\pi}$$

according to (Shuey R.T., et al., 1977), where L is window length (15km in this case).

(Anakwuba E.K, et al., 2011) interpreted the aeromagnetic data over Maiduguri-Dikwa Depression using Fourier transform to deduce the magnetic source depth (both shallower and deeper) and also to delineate the fracture condition of the study area. (Gunn P., 1998) has reported on the location of prospective areas for hydrocarbon deposits in Australia by aeromagnetic surveying, although it is probable that this application is only possible in quite specific environments.

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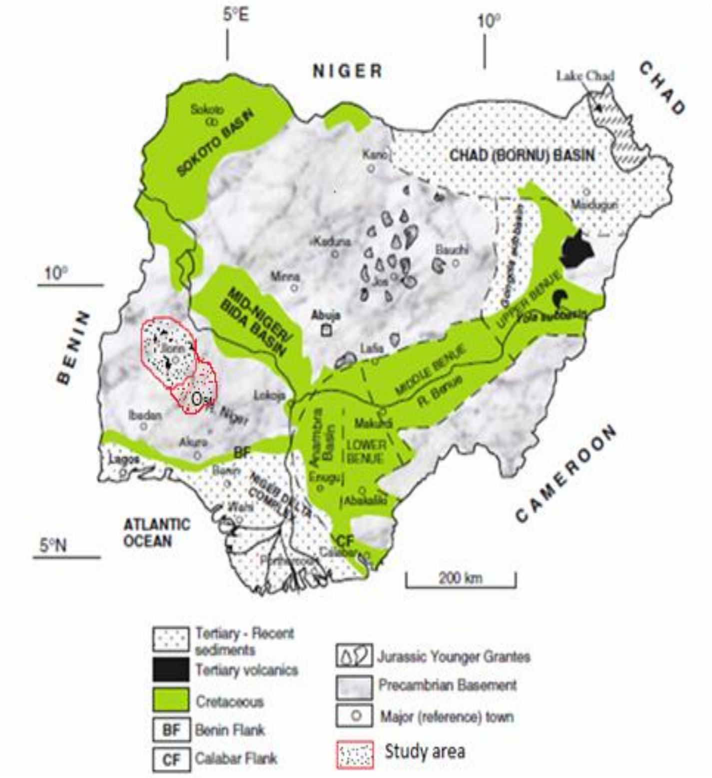

Figure 1 Geological map of Nigeria showing the study area (after Obaje, N. G. (2007).

2. METHODOLOGY

The analysis was achieved based on the mathematical model, Fast Fourier Transform for the Spectral analysis, this process is discussed below.

2.1 Statistical Spectral Interpretation

The Energy Spectral Analysis method applied to magnetic grid data allows calculation of an average depth to ensembles of the causative bodies. From the slope of the linear segment of the spectrum graph, the depth is calculated. Depth is a function of the decay of the spectrum function within a corresponding frequency interval. A plot of the logarithm of the radially averaged energy spectrum versus the radial frequency from gridded magnetic data shows the decay of this function which indicates depth to the modelled prism (K. A. Salako & Udensi, 2013)

The Fourier transform of the potential field due to a prismatic body has a broad spectrum whose peak location is a function of the depth to the top and bottom surfaces and whose amplitude is determined by its density or magnetization. The peak wave number (ω^i) can be related to the geometry of the body with the following expression:

$$\omega^i = \frac{Hn({}^{h_b}/_{h_t})}{h_b - h_t}$$

ω^i is the peak wave number in radian/ground – unit, h_t is the depth to the top and h_b is the depth to the bottom (K. A. Salako & Udensi, 2013).

$$f(\omega) = e^{h\omega}$$

Where ω is the angular wave number in radians/ground – unit and h is the depth to the top of the prism. For a prism with top and bottom surface, the spectrum is:

$$f(\omega) = e^{-h_t w} - e^{-h_b w}$$

Where h_t and h_b are the depths to the top and bottom surface respectively. As the prism bottom moves closer to the observation point at surface, the peak moves to a higher wave number. When looking at the spectrum, it is important to note that the amplitude of a deep prism does not exceed the amplitude of the same prism at shallow depth at any wavenumber. The effect of increasing the depth is to shift the peak to lower wavenumbers. The sources can only be distinguished if the deep sources have greater amplitude or if the shallow sources have less depth extent. When considering a line that is long enough to include many sources, the log spectrum of this data can be used to determine the depth to the top of a statistical ensemble of sources using the relationship.

$$Log\ E(k) = 4\pi hk$$

Where, *h* is the depth in ground – units and *k* is the wavenumber in cycles / ground – unit. The depth of an 'ensemble' of source can be determined by measuring the slope of the energy (power) spectrum and dividing by 4π. A typical energy spectrum for magnetic data may exhibit three parts – a deep source component, a shallow source component and a noise component (K. A. Salako & Udensi, 2013).

Multiple linear segments (slopes) on the spectrum correspond to separate depth ensembles. The spectrum consists of three parts; the highest wavenumber signal (corresponding to noise signal), the low frequency and the high frequency signals. The spectrum graph depicts the 1st slope, the steepest, which corresponds to deeper bodies dominating the low frequency zone. The 2nd slope indicates the average depth to the shallower sources.

2.2 Depth Estimation

The general mathematical basis for the application of power spectrum analysis to aeromagnetic map interpretation has been developed by Spector and Grant (Spector, et al., 1970). They studied the relationship between the power spectrum of aeromagnetic anomalies and the average depth of source bodies using some statistical assumption. This provides a foundation for anomaly source parameter estimation of depth to magnetic sources (Lawal T. O. et al, 2015). The plot of log power spectrum against the radial wave number gives results of different spectrum segments. The slope obtained from the above plot indicates the average depth to the source bodies (Lawal T. O. et al, 2015).

2.2.1 *Depth Estimation from Spectral Analysis of Higher Resolution Aeromagnetic Data*

Aeromagnetic data covering the study area (Part of Kwara State bounded by longitude $4^0 30^{'}$ – $5^0 30^{'}$ and latitude 8^0-$8^0 30'$) collected by Fugro Airborne Surveys within 07/12/06 - 31/05/07, with magnetic data recording interval of 0.1 seconds or less (~7m) and Sensor Mean Terrain Clearance of 80 meters was acquired from the Nigeria Geological Survey Agency. The component of the field measured was the total magnetic field. Since most of the data was collected between 2005 and 2009; hence an IGRF 2005 model was used for the calculation of declination and inclination. The total magnetic field intensity value Z was stripped of 33,000nT for ease of processing. A simple arithmetic addition of 33,000nT to each value of Z therefore gives you the Z-Total (NGSA). The study area is covered by two aeromagnetic map of total-field intensity in sheet 222 and 223 on a scale of 1:100,000. The data used were gridded into 21 overlapping windows using Oasis montaj. In this study, Fast Fourier Transform (FFT) filter was used to calculate the depth. The data was transformed from space domain to frequency domain using FFT. A Matlab program was developed to separate the high and low frequency signal zones and to calculate their slopes.

The database of the study area was gridded and then used to contour the total intensity map. Fig 2 and Fig 3 below are the contoured magnetic map of the study area and the gridded total magnetic intensity map of the study area respectively.

3. RESULTS AND DISCUSSION

The total magnetic field data was used to determine the depth to magnetic sources within Ilorin using statistical spectral analysis. Some of the power spectrum blocks of the plot of logarithm of spectral power (energies) against wavenumbers (frequencies) obtained for the area are shown in Fig 4 below.

Two linear segments were drawn from the graph, the spectral data of each window (block) was exported to excel. The data was later imported into Matlab and used to plot the logarithm of the radially averaged power spectrum against the wavenumber for each of the twenty-one window (some of the blocks are shown below, Fig 5) from which the slope of the two linear segments (deeper and shallow) was obtained.

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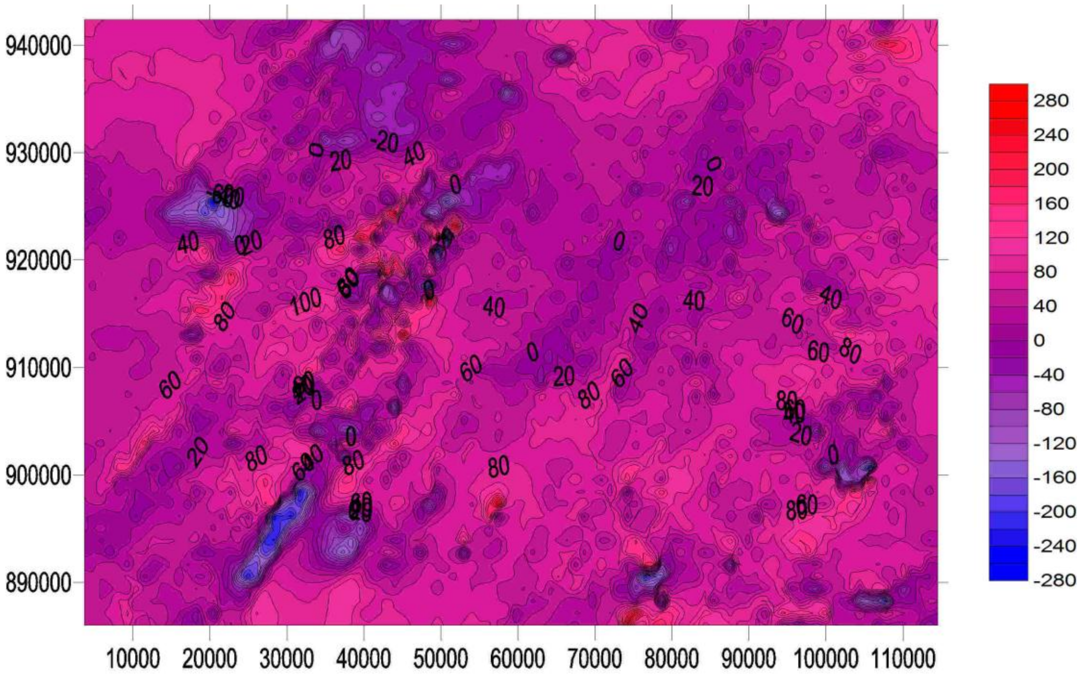

Figure 2 Total magnetic intensity of the study area

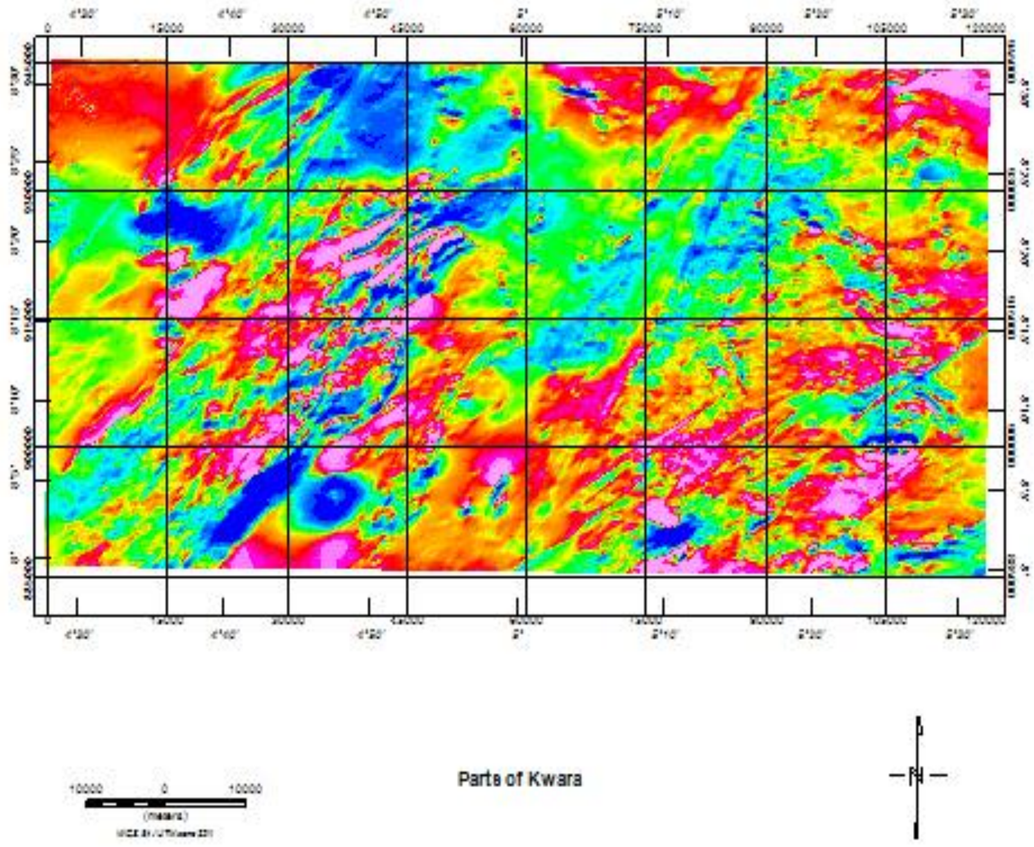

Figure 3 Gridded total magnetic intensity map of the study area

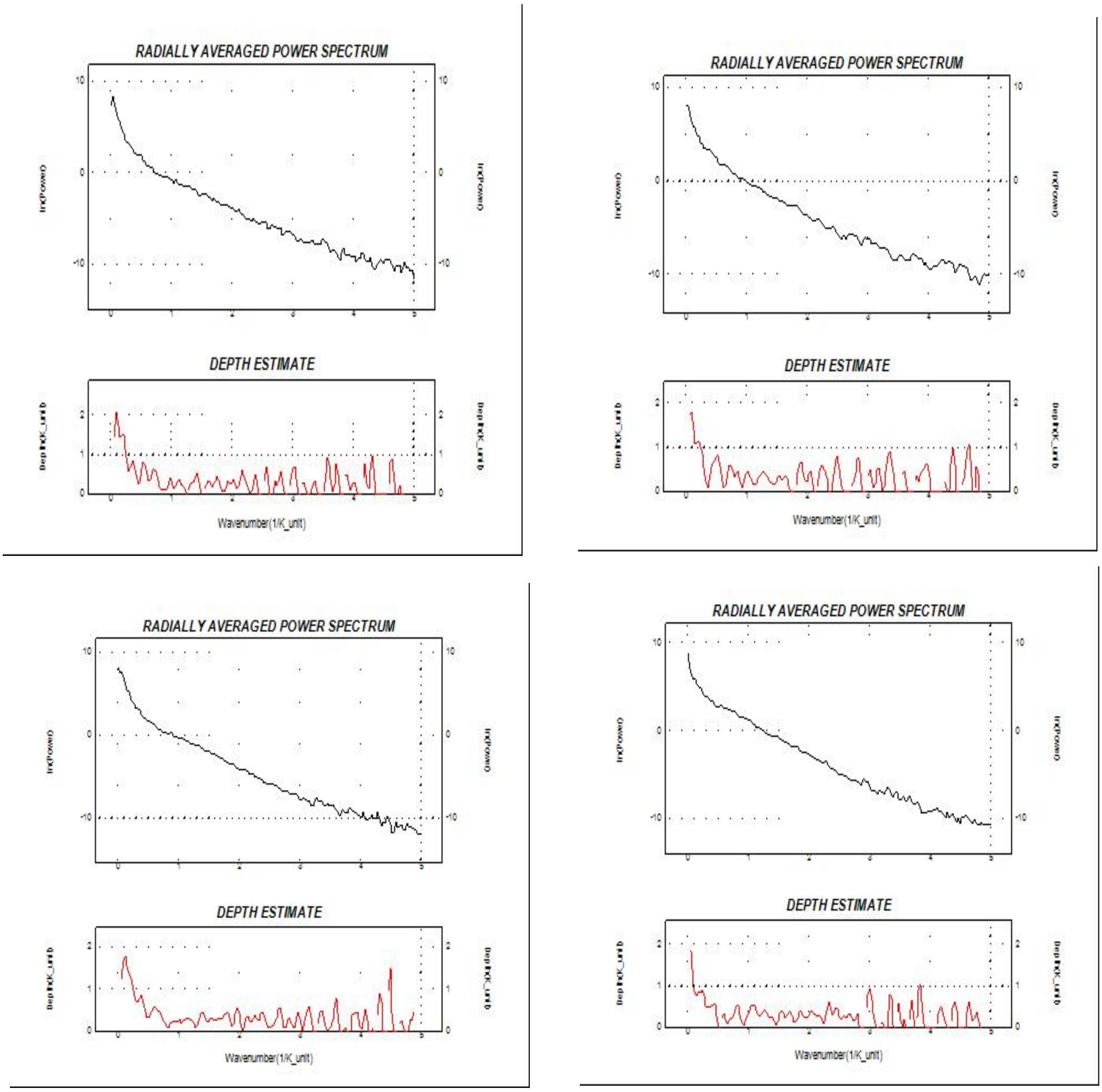

Figure 4 Power Spectral Plot Of Selected Blocks

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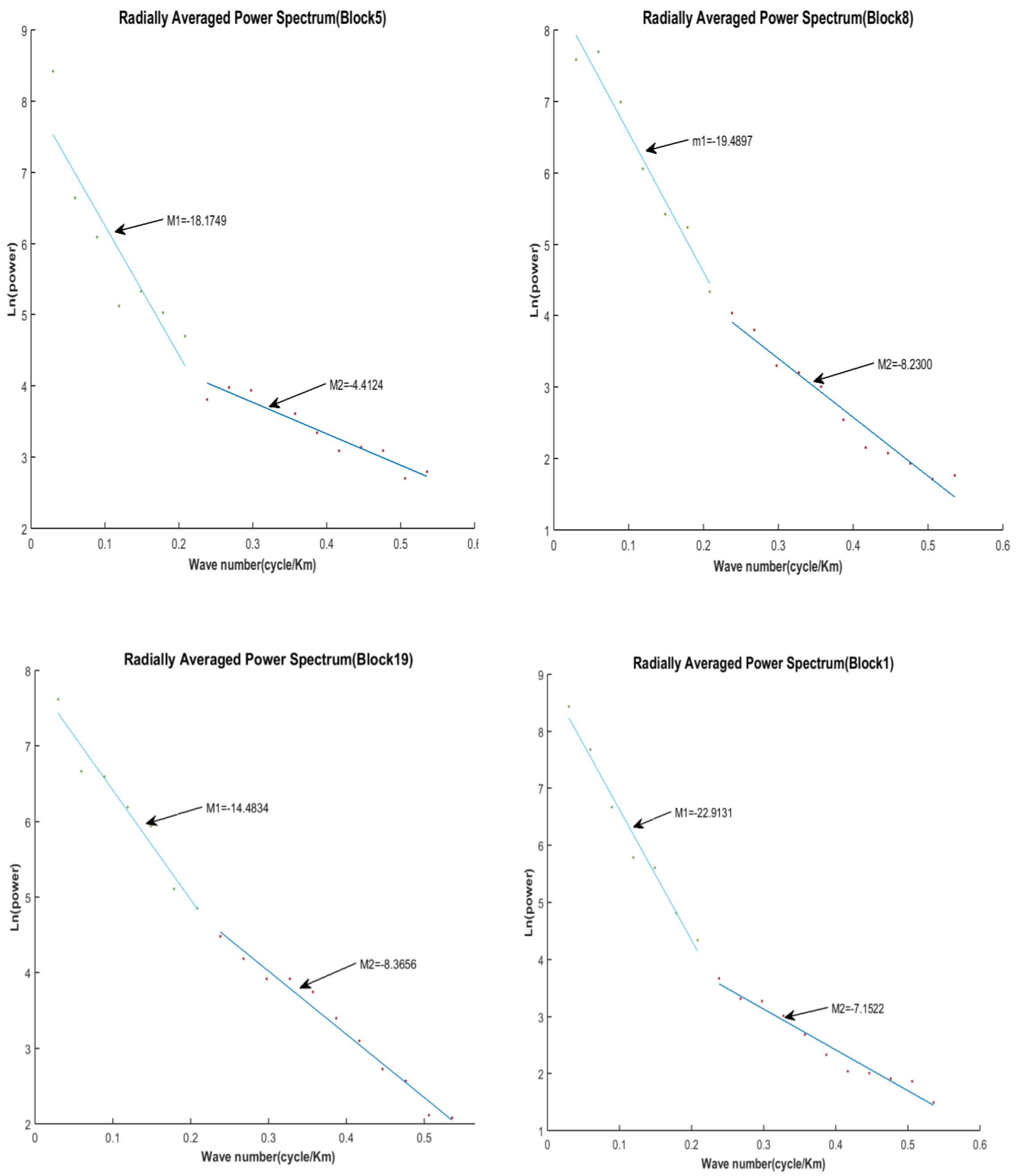

Figure 5 Plot of Ln(power) against wavenumber of some selected blocks

The slope obtained was used to calculate the depth to causative body as

$$D_1 = -\frac{m_1}{4\pi} \qquad D_2 = -\frac{m_2}{4\pi}$$

Where m_1 = slope of the deeper source, m_2 = slope of shallow source

D_1 = depth to deeper source, D_2 = depth to shallow source

The maximum depth that can be probed in this research work is about 2.39k given by

$$D = \frac{L}{2\pi}$$

in relation to (R.T. Shuey, et al., 1977), where L is window length (15km in this case).

Table 1 below shows the estimated magnetic sources for both the shallow source (D2) and deeper sources (D1).

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Table 1 Result of depth estimate from spectral analysis of aeromagnetic data of the study area.

BLOCK	LONGITUDE(m)	LATITUDE(m)	SLOPE(M1)	SLOPE(M2)	DEEPER(Km)	SHALLOW(Km)
1	15003.10327	930259.88690	-22.91310	-7.15220	1.82313	0.56908
2	29890.76948	930163.83750	-18.79780	-6.09480	1.49569	0.48495
3	44874.48515	930163.83750	-13.40470	-5.46850	1.06657	0.43511
4	59858.20082	930163.83750	-14.49680	-5.51500	1.15347	0.43881
5	74841.91649	930259.88700	-18.17490	-4.41240	1.44613	0.35108
6	89825.63217	930067.78800	-19.77210	-4.29880	1.57321	0.34204
7	103848.85325	929971.73860	-17.89910	-4.56460	1.42418	0.36319
8	14907.05381	915084.07230	-19.48970	-8.23000	1.55074	0.65484
9	29890.76948	915084.07230	-14.94800	-5.65770	1.18937	0.45017
10	44874.48515	915084.07230	-11.02440	-5.24000	0.87718	0.41693
11	59858.20082	915084.07230	-11.53130	-5.81470	0.91751	0.46266
12	74841.91649	915084.07230	-19.41140	-4.42480	1.54451	0.35207
13	89729.58271	915180.12180	-14.70140	-2.20590	1.16975	0.17552
14	103752.80379	915084.07230	-16.80100	-2.29500	1.33681	0.18261
15	15003.10327	900676.65350	-15.36410	-7.94710	1.22248	0.63233
16	29890.76948	900388.50510	-18.70850	-6.23960	1.48858	0.49647
17	44874.48515	900676.65350	-18.24000	-5.94200	1.45130	0.47279
18	59858.20082	900196.40610	-14.17820	-6.22790	1.12812	0.49554
19	74745.86703	900196.40610	-14.48340	-8.36560	1.15240	0.66563
20	89921.68163	900100.35670	-14.89280	-6.14390	1.18498	0.48885
21	103752.80380	900100.35670	-15.16370	-4.51290	1.20653	0.35908

The primary sources that account for the first layer depth derived from the statistical spectral analysis are the basement (magnetic) rocks that intrude the sedimentary formation.

The first layer magnetic source's depth as estimated using FFT ranges from 0.1826 to 0.6656 km, while the range of the second (deeper) magnetic source depth is from 0.8772 to 1.8231 km. The maximum depth of 1.8231 km could be found at the south-western part while the minimum depth of about 0.8772 km could be found roughly at the central part of the total intensity map. Contour and surface maps of the shallow sources in the study area were given in figure 6 and 7.

The second layer depth may be attributed to magnetic rocks that are emplaced into the basement underlying the sedimentary cover. Also, intra-basement features such as fractures could equally contribute to sources that accounted for the second layer depth.

The second layer depth invariably represents the average sedimentary thickness (1.3049km) of the study area, that is, the depth to the underlying basement complex rocks.

The contour map and 3D surface map below (Fig 8 and 9) are that of the second layer depth representing the depth to magnetic basement rock. This depth approximation correlates previous works and geology of the study area (Part of Kwara State, Nigeria bounded by longitude $4^0 30^{'}$- $5^0 30^{'}$ E and latitude 8^0 - $8^0 30^{'}$ N) which is a basement complex, the depth to magnetic source is expected to be shallow in the study area.

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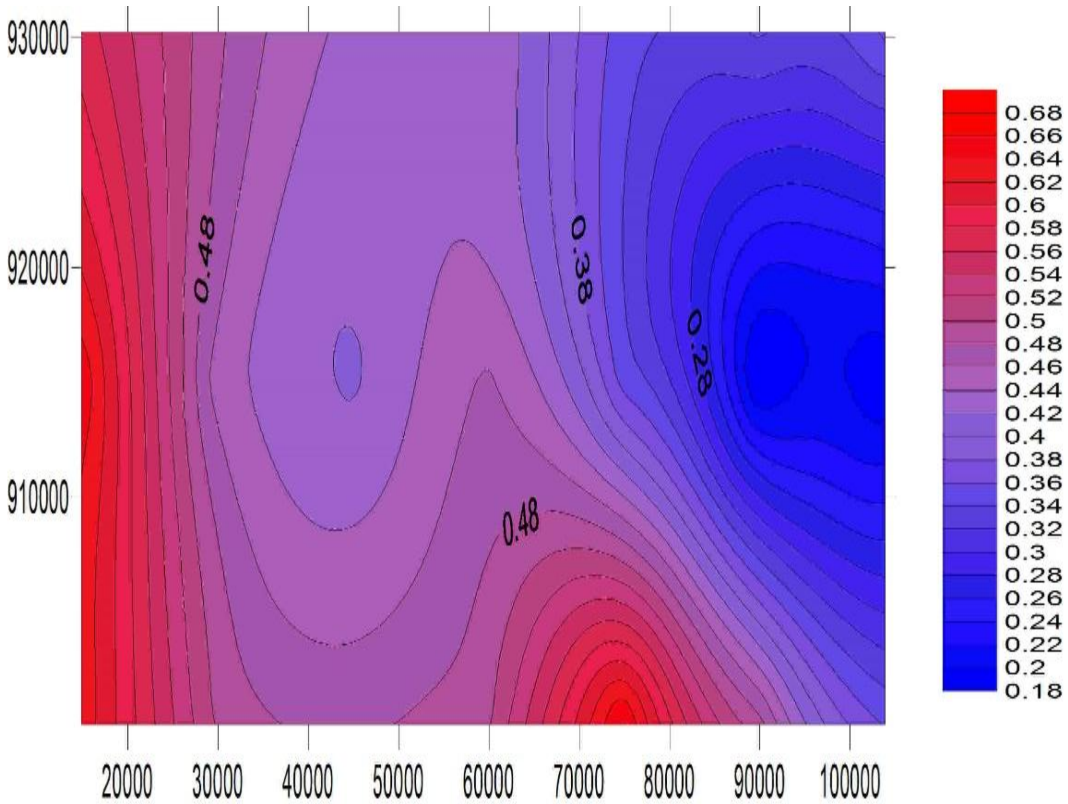

Figure 6: Contour plot of depth to shallow sources

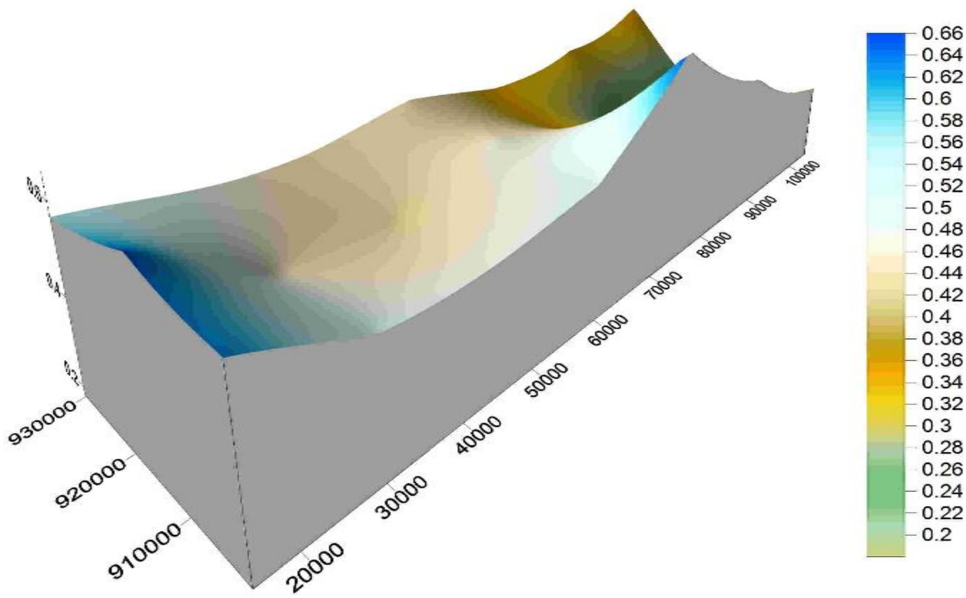

Figure 7: 3D Surface map of depth to shallow sources

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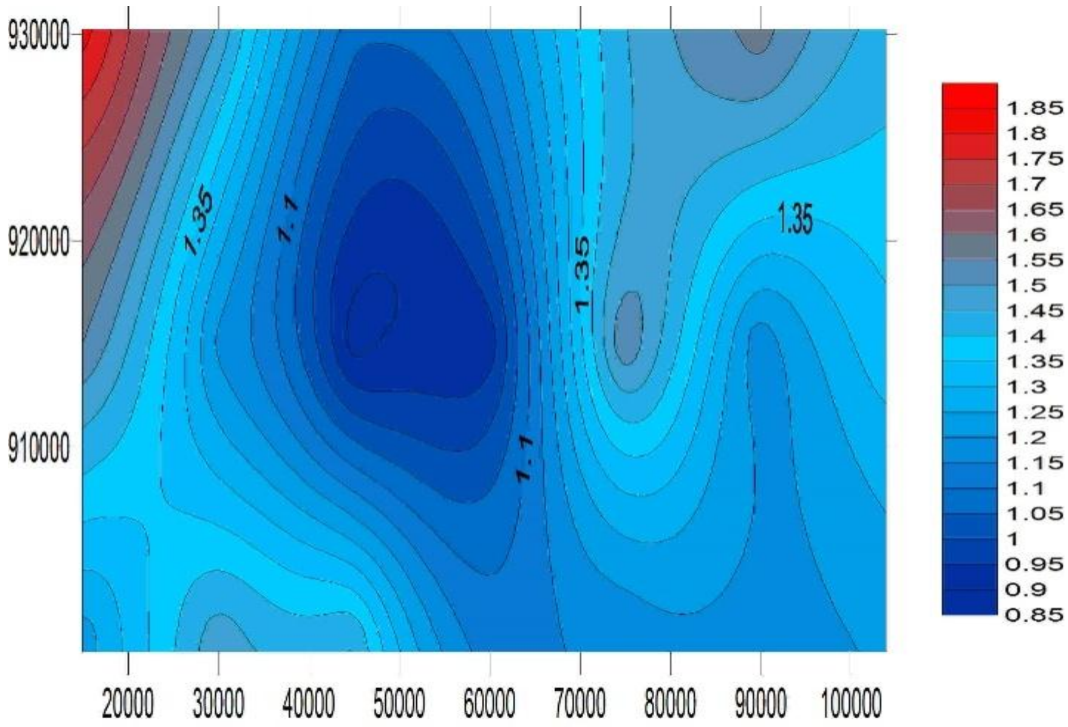

Figure 8: Contour plot of depth to deeper sources

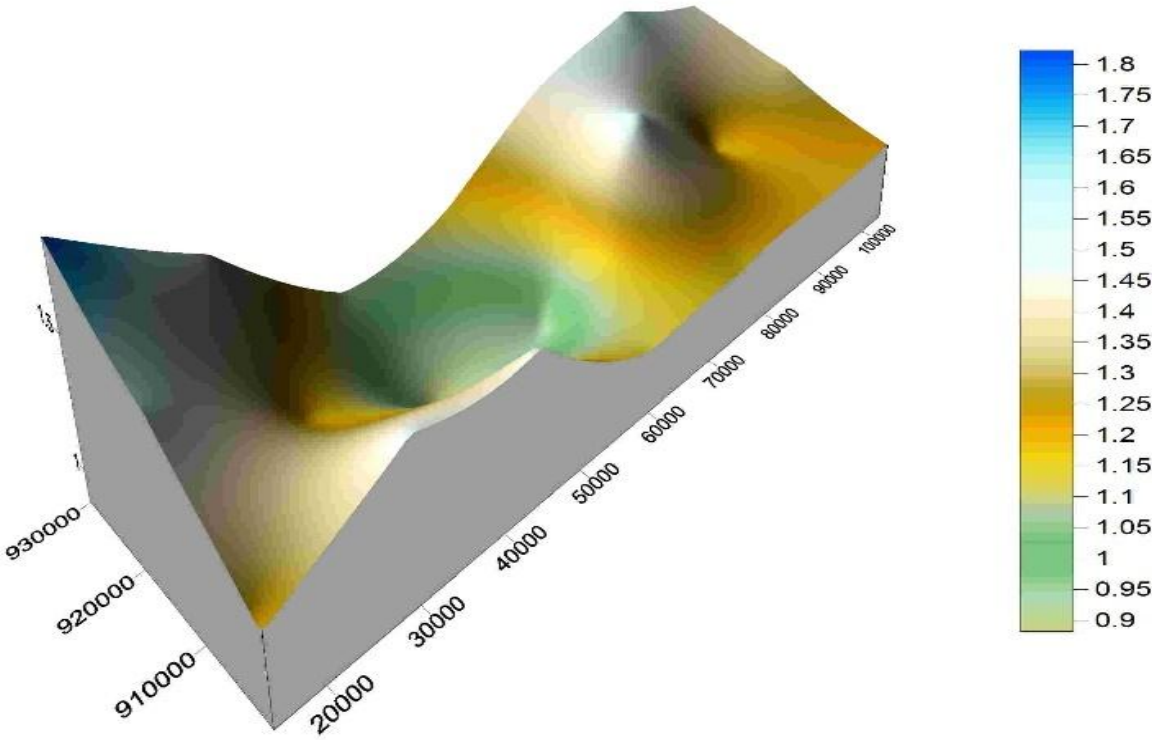

Figure 9: Surface map of depth to deeper sources

4. CONCLUSION

The high resolution aeromagnetic data over part of Kwara State was subjected to quantitative analysis using Fast Fourier Transform method. The procedure involved in this study includes gridding of the magnetic data, production of the frequency domain map, and estimation of depths to magnetic sources. The results reveal two depth source models in the study area. The deeper sources range from 0.8772 to 1.8231km, while the shallower sources range from 0.1755 to 0.6323km. The deeper magnetic sources identified with the crystalline basement, while the shallower magnetic sources could be associated to near surface magnetic sources, which may be magnetic (igneous or metamorphic) rocks that intruded into the sedimentary formations or magnetic bodies (e.g. laterite) within the sedimentary cover.

The obtained from the spectral analysis of high resolution aeromagnetic data to determine depth to magnetic basement is shallow and this correlates to previous geological work which pointed out that the area is a basement complex.

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REFERENCES

[1] Ajibade, L., Ojelola, A.O. (2004). Effects of automobile mechanics activities of soils in ilorin nigeria. Geo-Studies Forum (An International Journal of Environmental and Policy Issues) 2(1), 18-27.
[2] Ajibade, L.T. (2008). Waste Ergonomics Optimization in Ilorin, Nigeria. Ethiopian Journal of Environmental Studies and Management 1(2), 83-92.
[3] Anakwuba, E.K., Onwumesi, A.G., Chinwuko, A.I., Onuba, N. L. (2011). The interpretation of aeromagnetic anomalies over Maiduguri-Dikwa depression, Chad basin Nigeria: A structural view. Scolars Research Library, Archieves of Applied Science Research, 2(3), 77-93.
[4] Atlas. (1982). Ilorin, Nigeria: Geography department university press.
[5] Churchill, C.O., Ajana, K. O., Kenechukwu, E. A., Ifeanyi, C.A., Emmanuel, I.B., Ojonugwa, U.A. (2012). Aeromagnetic Interpretation over Maiduguri and Environs of Southern Chad Basin,Nigeria, Journal of Earth Sciences and Geotechnical Engineering, 2(3), 77-93.
[6] Clarke, D. (1997). Magnetic petrophysics and magnetic petrology: aids to geological interpretation of magnetic surveys. AGSO Journal of Geology and Geophysics 1(7), 83-103.
[7] David, I., Marius, N. (2013). Interpretation of Aeromagnetic anomalies over some parts of lower Benue trough using spectral analysis technique, International journal of scientific & technology research, 2(8), 53-165.
[8] Gadallah, M.R., Fisher, R. (2009). Exploration Geophysics: Berlin Germany: Springer.
[9] Horsfall, K. (1997). Airborne magnetic and gamma-ray data acquisition. AGSO journal of Geology and Geophysics 3(17), 23-30.
[10] Keary, P., Micheal, B., Hill, I. (2002). An Introduction to Geophysical Exploration (3rd Edition). Willey Blackwell Science.
[11] Lawal, T. O., Nwankwo, L. I., Akoshile, C. O. (2015). Wavelet Analysis of Aeromagnetic Data of Chad Basin, Nigeria. The African Review of physics 10(16).
[12] Lowrie, W. (2007). Fundamentals of Geophysics (2nd edition), Zurich: Swiss Federal University, Switzerland. Cambridge University Press.
[13] Raimi, J., Dewu, B.B.M., Sule, P.(2014). An Interpretation of structures from the aeromagnetic field over a region in the nigerian younger granite province, International journal of geophysics, 5(3), 313-323
[14] Mariitia, N. (2007). The Magnetic Method. Presented at Short Course II on Surface Exploration for Geothermal Resources KenGen Lake Naivasha, Kenya.
[15] Milsom, J., & Asger, E. (2011). Field Geophysics (4th edition), West Sussex, UK. Wiley and Sons Ltd.
[16] Muhibbu-Din, O., Ajibade, L,T. (2011). Study of physiochemical parameter of Effluent Impacted Stream. A Dissertation Submitted to the Department of Zoology, Obafemi Awolowo University, Ile-Ife Nigeria (unpublished).
[17] NGSA. (2016). http://www.ngsa-nig.org/content/airborne-geophysical-data. (Nigeria Geological Survey Agency) Retrieved November 3, 2016, from http://www.ngsa-nig.org: www.ngsa-nig.org
[18] Obaje, N. G. (2007). Geology and Mineral Resources of Nigeria. Dordrecht Heidelberg London New York. Springer.
[19] Olawuyi, A.K. (2015). Lineaments mapping for Hydrogeological study using Aeromagnetic and pseudogravity Data: A case study of Lafiagi, Southwestern nigeria, Zimbabwe journal of Science and Technology, 10(27), 40-53.
[20] Raab, P., Frischnecht, F.C. (1984). Time-domain electromagnetic soundings at Nevada Test Site,. Nevada.: Society of Exploration Geophysicists, 49(7), 981–992.
[21] Rahman, M.A. (1973). Review of the basement geology of south western Nigeria . Geology of Nigeria (2nd edition). Lagos, Nigeria. Elizabethan publishing Company.
[22] Rajaram, M., Anand S.P., Hemant, K., Purucker, M.E. (2009). Curie Isotherm map of India subcontinent from satelite and aeromagnetic data. Earth and Planetetary Science Letters, 281(3-4), 147-158.
[23] Salako, K. A., Udensi, E. E. (2013). Spectral Depth Analysis of Parts of Upper Benue Trough and Borno Basin, North-East Nigeria, Using Aeromagnetic Data. International Journal of Science and Research (IJSR), India. 2(8), 48-55.
[24] Shuey, R.T., Schellinger, D.K., Tripp, A.C., Alley, L. (1977). Curie depth determination from aeromagnetic spectra. Geophysical Journal. 50(1), 75-101.
[25] Spector, A., Grant, F.S. (1970). Statistical models for interpreting aeromagnetic data. Geophysics, 35(2), 293–302.
[26] Sheriff, L. P., Rajaram E. (1991). Geophysics Encyclopedic dictionary of Exploration Geophysics (3rd edition). Society of Exploration Geophysics.
[27] Sheriff, R.E., Geldart, L.P. (1995). Exploration Seismology (2nd Edition).University of Houston. Cambridge University Press.
[28] Telford, W., Geldart, L., Sheriff, R., Keys D. (1976). Applied Geophysics (2nd edition). New York. Cambridge University Press.