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Characterization of Groundwater Potential Zones of Lassa and Environs, Northeast Nigeria

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Abstract
Analysis of high resolution aeromagnetic data was carried out to evaluate the groundwater potential zones of Lassa and environs northeastern Nigeria. The total magnetic intensity data covering the area were processed and filtered using the Polynomial fitting method and Spectral analysis. The polynomial fitting was used for regional residual separation to obtain the residual map which was later subjected to spectral analysis to computed depth to magnetic sources. The total magnetic intensity value varies from -193.775nT to 240.799nT and the residual magnetic intensity map varies from -166.740nT to 132.322nT respectively. The computed depth to magnetic sources indicates two source depth, the shallow and the deeper sources. The shallowmagnetic sources range from 0.23km to 0.62km and deeper magnetic sources from 0.55km to1.39km.The findings of the sudy revealed that the area is characterized in to low and high groundwater potential zones.
Key Word*: Lassa and Environs, Aeromagnetic Data, Polynomial Fitting, Spectral Analysis, Groundwater Potential Zones*

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I. Introduction

The study area lies between latitudes 10°30'N to 11°00'N and longitudes 13°00'E to 13°30'E (Fig. 1), in the northeastern basement complex of Nigeria[1].The high resolution aeromagnetic data over the area provide information over the geological patterns at depth which overburden regolith lie on. Groundwater in basement areas occurs in overburden regolith, fractures and weathered basement rocks.

However the geophysical and geological investigation work published in the area include hydrological study of Shani and Duhu carried out by [2] and[3] for the defunct northeastern state, hydrological studies of Duhu area by [4]and analysis of aeromagnetic data over Garkida and environs, northeastern Nigeria by [5].

The study was carried out using two-dimensional spectral analysis of high resolution aeromagnetic data to determined depth to magnetic sources which was used in characterizing groundwater potential zones of the area. The result of this study will contribute to the understanding of groundwater and non-groundwater potential zones for easy sitting of hand-dug wells and boreholes.

The geology of the study area [6] (Fig.2) is made up of the Pan-African Older Granitoids which consists of three phasesThey are distinguished as basic and intermediate plutonic rocks fine grain granites and syn-tectonic granites. These rocks vary considerably in structure, texture and mineralogy. The older granites are rich in potash which usually occur as microcline rocks phenocrysts. The basic and intermediate plutonic rocks include smallirregular bodies of gabbro, quartz-diorite and granodiorite. The fine grained graniteswere intruded prior to the syn-tectonic granites, are a group of minor, discordant intrusions of small extent and alluvial[7].

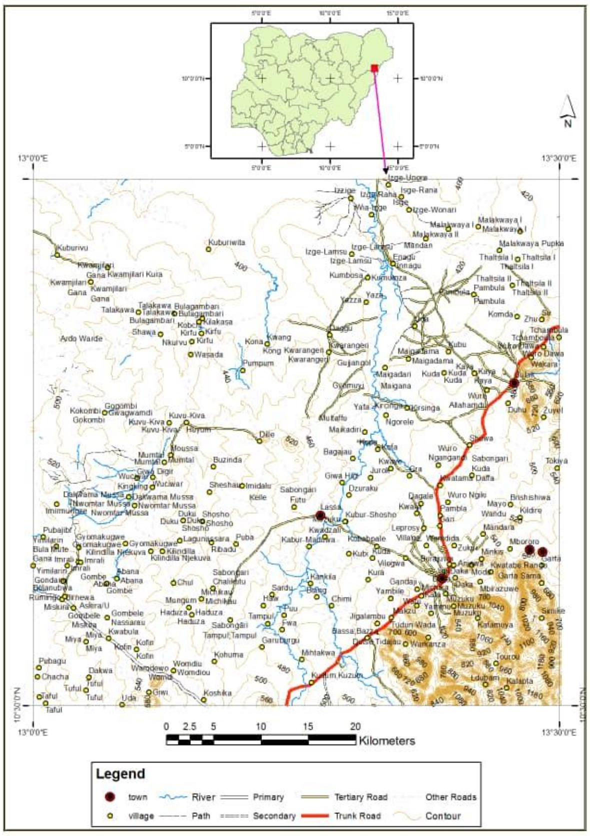

Figure 1: Topographic Map of The Stud Area (After Digital Elevation Model 2006)

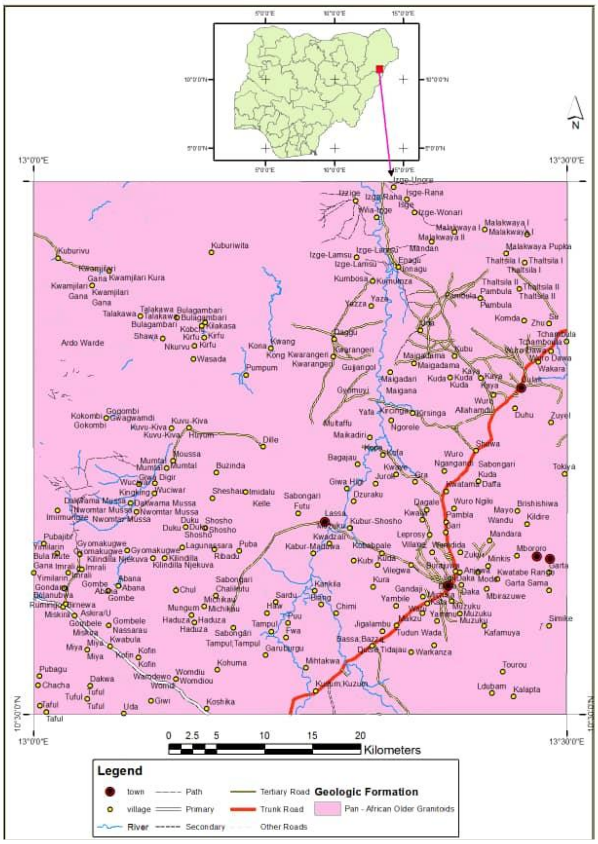

Figure 2: Geologic Mapof the Stud Area (After Nigeria Geological Survey Agency 2006)

II. Material And Methods

Data Acquisition

The high resolution aeromagnetic data that was used for this work,were obtained from the Nigerian geological Survey Agency (NGSA), on a scale of 1:100000. The Nigerian geological survey agency carried out a nationwide airborne aeromagnetic survey in2009 with aim of diversifying the country's economy from mono product economy to other sector. Regional high resolution aeromagnetic data, were acquired in Nigeria by Fugro airborne survey limited for the NGSA between 204 and 2009. The acquisition, processing, compilation of the new data were jointly financed by the federal government of Nigeria and the World Bank as part of the sustainable management for mineral resource project. The aeromagnetic data was acquired using 3X Scintrex CS3 Cesium Vapour Magnetometer,were carried out by means of fixed-wing aircrafts flown at mean terrain clearance at 80m with 500m line spacing and nominal tie line spacing of 2km.

Data Processing and Enhancement

Regional-residual separation

The Polynomial fitting method was used in regional-residual separation to obtain the residual map. In polynomial fitting the regional is matched with mathematical Polynomial of low order to expose the residual features as random errors, and the treatment is based on statistical theory. The observed data are used to compute, usually by least square method, the mathematically described surface given the closet fit to the magnetic field that can be obtained within a specified degree of detail. This surface is considered to be the regional field and the residual is the difference between the magnetic field values thus determined [8]. The simplest approach is to fit a polynomial of first order to the magnetic data over a large area as possible around the zone of interest and to subtract the polynomial surface from the observed surface. If the regional field were a simple inclined plane it will be a first order surface. Thus

$$Z = Ax + By + C1 \qquad 1$$

The next stage of complexity is the representation of a second order polynomial where,

$$Z = Ax^2 + By^2 + CxyDx + Ey + F3. \qquad 2$$

The next stage of complexity is another representation of a third order polynomial, etc.

The residual magnetic field of the study area was produced by subtracting the regional field from the total magnetic field using the Polynomial fitting method. The computer program aero-super map was used to generate the coordinates of the total intensity field data values. This super data file, for all the magnetic values was used for production of composite aeromagnetic map of the study area using Oasis Montaj software version 7.0.1. The program was used to derive the residual magnetic values by subtracting values of regional field from the total magnetic field values to produce the residual magnetic map and the regional map.

Spectral analysis

Determination of depths to buried magnetic rocks is among the principal applications of an aeromagnetic data. The depths are commonly computed from measurement made on the widths and slopes of an individual anomaly of the aeromagnetic profiles. The statistical approach has been found to yield good estimates of mean depth to basement underlying a sedimentary basin [9]. [10] developed a depth determination method which matches two dimensional power spectral calculated from gridded total magnetic intensity field data with corresponding spectral obtained from a theoretical model. For the purpose of analyzing aeromagnetic data, the ground is assumed to consist of a number of independent ensembles of rectangular, vertical sided parallelepiped, and each is ensemble characterized by a joint frequency distribution for the depth (h) and length (b) and depth extent (t).

In this research, the characteristics of the residual magnetic field were studied using statistical spectral methods. This is done by first transforming the data from space to the frequency domain and then analyzing their frequency characteristics. In the general case, the radial spectrum may be conveniently approximated by straight line segments, the slopes of which relate to depths of the possible layers. The residual total magnetic field intensity values are used to obtain the two dimensional Fourier Transform, from which the spectrum is to be extracted from the residual values $T(X, Y)$ consisting of M rows and N columns in $X - Y$. The evaluation is done using an algorithm that is a two dimensional extension of the fast Fourier transform [11]. Next, the frequency intervals are subdivided into sub-intervals, which lie within one unit of frequency range. The average spectrum of the partial values together constitutes the radial spectrum of the anomalous field.

If z is the mean depth of the layer, the depth factor for this ensemble of anomalies is exp (-2zk). Thus the logarithmic plot of the radial spectrum would give a straight line whose slope is -2z.

The mean depth of the burial ensemble is thus given as

$$Z = -\frac{m}{2} \qquad 3.4$$

Where (m) is the slope of the best fitting straight line.

Equation (3) can be applied directly if the frequency unit is in radian per kilometer. If however, the frequency unit is in circle per kilometer, the corresponding relationship can be expressed as

$$Z = -\frac{m}{4\pi} \qquad 3.5$$

In this study the aeromagnetic data set were divided into a block of 5' x 5' which is 9.17 x 9.17kmof 6 x 6 data points totaling 36 blocks covering an area of 84.1km^2. Each block was subjected to Fast Fourier transformation (FFT) to compute the power spectrum of the magnetic data using Oasis montajand math lab software.

III. Result

Table 1 shows the summary of the deeper magnetic sources depths (D_1) and shallow magnetic source depths (D_2). The values of D_1ranges from 0.55km to 1.29km, while the values of D_2ranges from 0.23km to 0.62km respectively.

Figure 3 showsthe total magnetic intensity (TMI) map of the study area. The map was subdivided into low magnetic intensity area having dark-blue-light-blue-green colour with values range of -193.775nT to 16.939nT, medium magnetic intensity with yellow-orange colour having values with the range of 29.719nT to 95.421nT and high magnetic intensity with red-pink colour having values range of 101.597nT to 240.799nT.

Figure 4 shows the residual magnetic intensity (RMI) map of the study area. The map was also divided into low residual magnetic intensity values that vary from -166.740nT to 5.957nT with dark-blue-light-blue-green colour, medium with yellow-orange colour having values range of 9.244nT to 29.159nT and high residual magnetic intensity with red to pink colour having range of values from 32.521nT to 132.322nT.

Figure 5 shows the graph of logarithm of spectral energies plotted against obtained frequencies for the various blocks The depth of the deeper magnetic sources (D_1) of the distribution from the slope of the first longest wave length and the depth to the shallow magnetic sources (D_2) of that distribution from the slope of the second longest wave length segment was calculated. Most of the graphs of the blocks have first and second segments of wave lengths having both D_1 and D_2 with others having only first wave length segment D_1.

Figure 6 shows a map of contoured values of $D_1$of the study area. High overburden thickness were observed in the western extreme and southeastern part of the map with other areas having moderate overburden thickness.

Figure 7 shows the result of D_2 which was contoured to obtain the contoured map of the shallow magnetic source depths of the study area which are crucial to groundwater exploration. Careful observation of the map indicate high potential zones of groundwater exploration extending from the southwest to the northeast and from the north to northeast due to considerable thickness of the weathered basement range from 0.46km to 0.6km , indicated by the blue colour. While other areas are considered to have low groundwater potential due to low thickness of weathered basement range from 0.20km to 0.44km and therefore referred to as low groundwater potential zones.

Table 1: Summary of magnetic source depth D_1 (Deeper magnetic source depth), D_2 (Shallow magnetic source depth) obtained from the study area.

Block	D_1	D_2
1	0.96	0.47
2	0.64	
3	0.68	
4	0.57	
5	0.58	
6	0.65	
7	0.92	0.47
8	0.61	
9	1.29	0.51
10	0.73	0.42
11	0.83	0.39
12	0.66	
13	0.91	0.51
14	0.71	
15	0.77	0.48
16	1.00	0.52
17	0.70	0.43
18	0.69	
19	0.63	
20	1.00	0.45
21	1.03	0.43

22	1.07	0.43
23	1.05	0.53
24	1.06	0.56
25	0.61	
26	1.23	0.43
27	1.09	0.47
28	1.18	0.50
29	1.19	0.49
30	1.08	0.47
31	0.62	
32	0.73	
33	1.15	0.47
34	1.28	0.62
35	0.55	
36	0.56	0.23

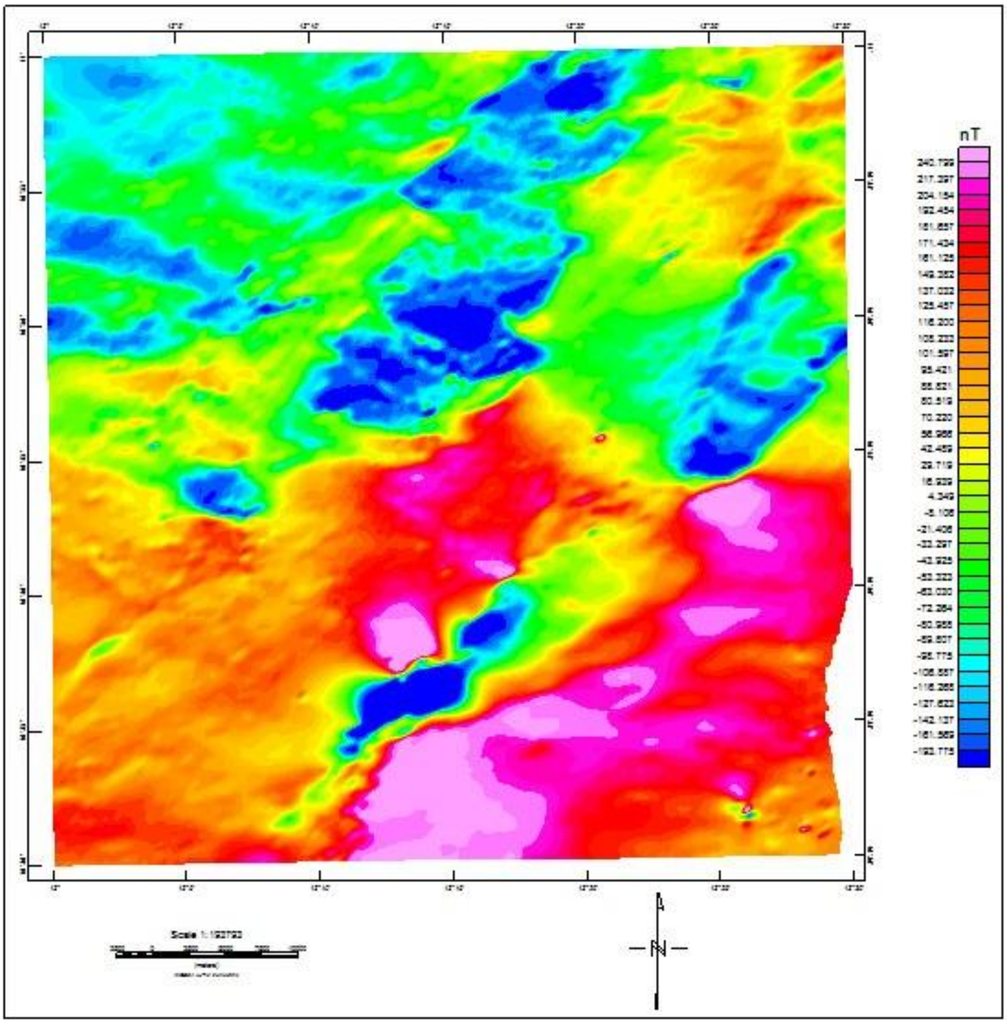

Figure 3: Total Magnetic Intensity (TMI) Map of the Study Area.

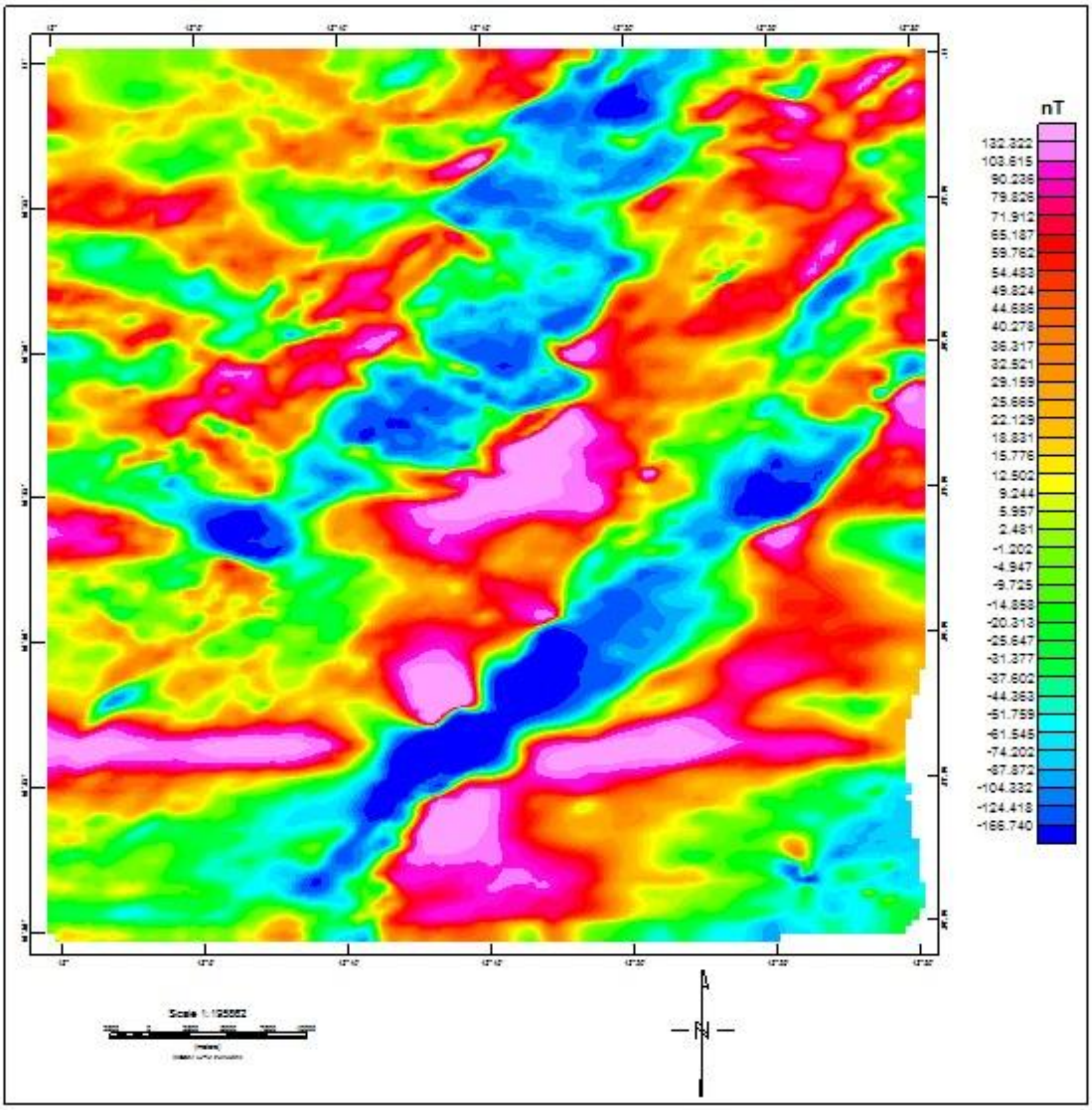

Figure 4: Residual Magnetic Intensity (RMI) Map of the Study Area.

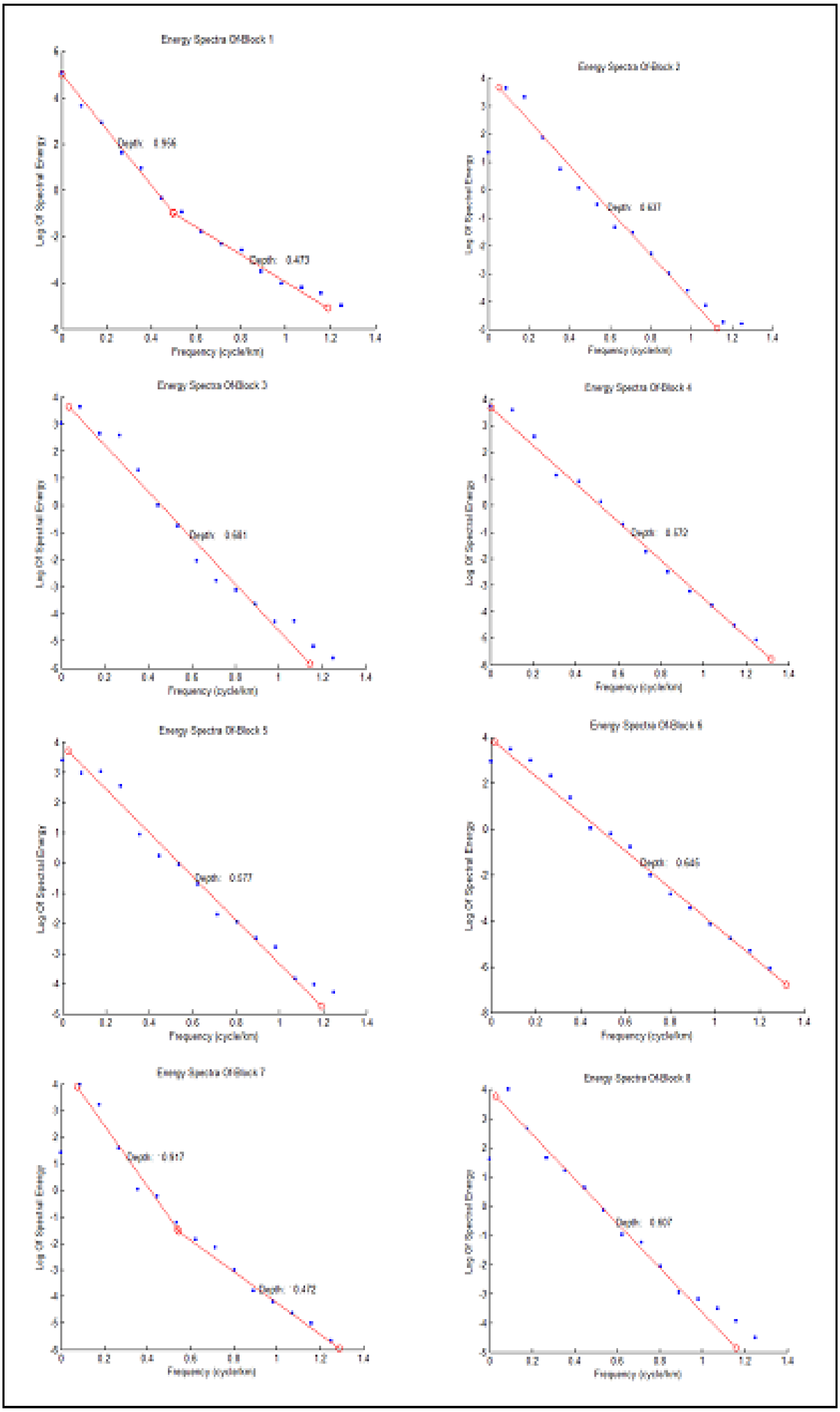

Figure 5: Example of Graphs Spectral Blocks of the of the Study Area.

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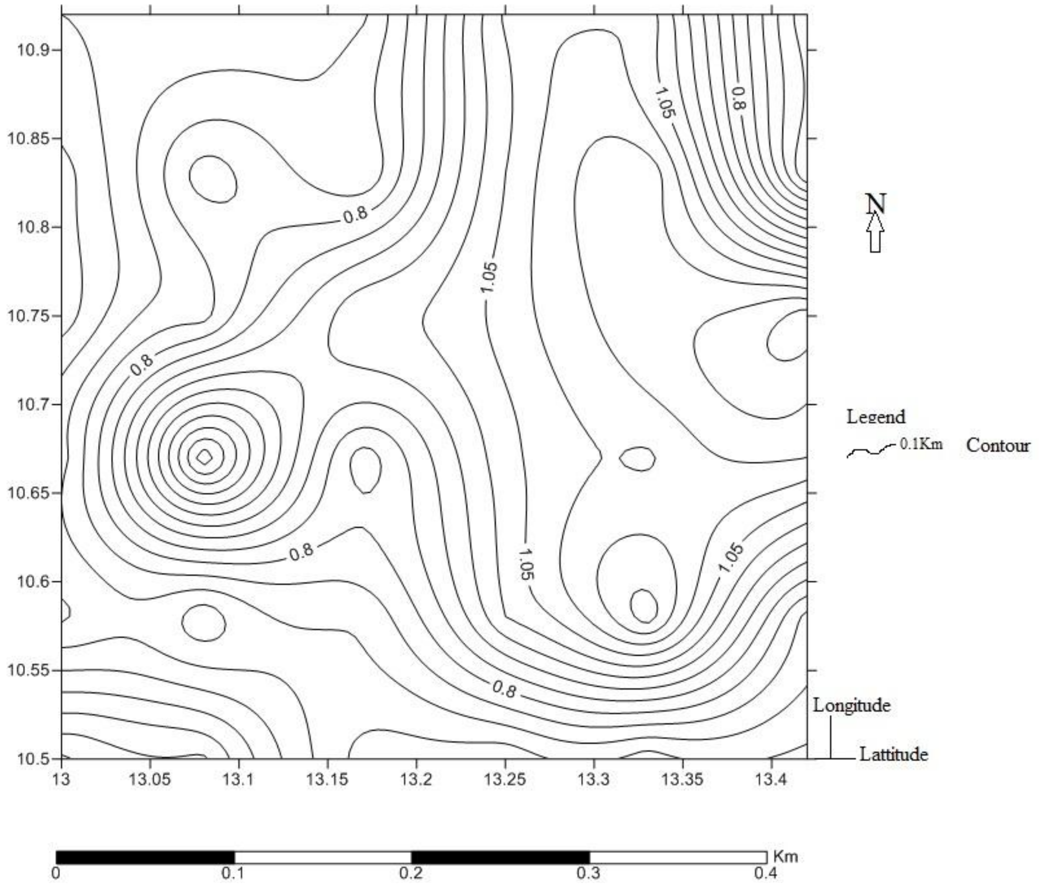

Figure 6: Contoured deeper magnetic source depth (D1) map of the study area (Cont. Int. of 0.1km).

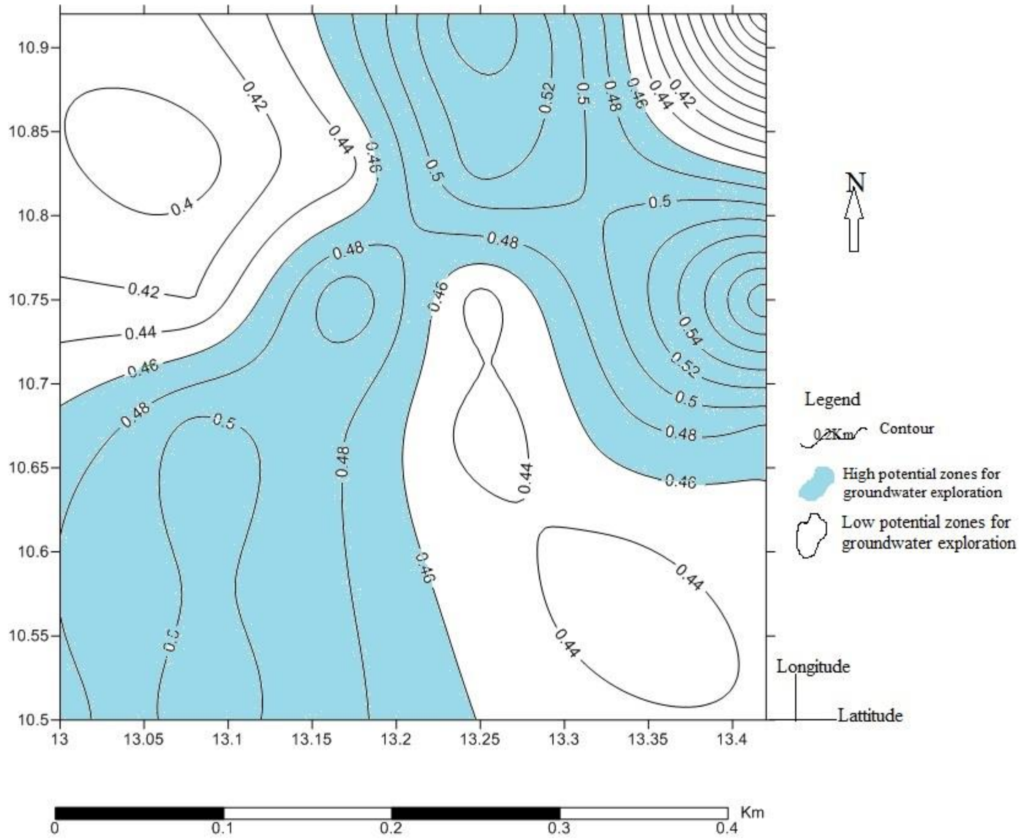

Figure 7: Contoured shallow magnetic source depth (D_2) map of the study area (Cont. Int. of 0.2km).

IV. Discussion

The graph of spectral energy (Fig.5) used to estimate depth to magnetic sources revealed shallow and deeper magnetic source depth. The shallow magnetic source depth range from 0.23km to 0.63km and deeper magnetic sources from 0.55km to 1.29km respectively (Table 1). However these was further contoured to have an overview of the weathered sediment thickness distribution in the area. The contoured deeper magnetic source depth map (Fig.6) indicate areas withthick sedimentary cover in the southeast and southwest.

Also the contoured shallow magnetic source depth (Fig. 7) revealed the distribution of the overburden regolith (weathered basement), which is crucial to groundwater exploration. Based on the distribution of overburden regolith of shallow magnetic sources, the study area is characterized into two zones. Low groundwater potential zones symbolized with white colour zones with overburden regolith of less than or equal to 0.45km. This low groundwater potential zone covers northwestern, southeastern, and extreme end of northeastern part of the study area. These areas could be productive sites for sitting of hand-dug wells and hand pump boreholes.

In addition the high potential groundwater zones extend diagonally from the southwest towards northeast which further extends northwards down to southeast symbolized with blue colour.These area have overburden regolith of 0.46km to 0.60km which is suitable for sitting of boreholes with motorized pumps.

V. Conclusion

The following conclusion can be drawn from the findings of the analysis of aeromagnetic data of Lassa and environs:

1. The study revealed that the area have two magnetic source depths,the shallow and deeper magnetic source.
2. The shallowmagnetic source depth was used to characterize the area into low groundwater potential zones and high groundwater potential zones. Low groundwater potential zone could be used for sitting of hand-dug wells while high groundwater potential zones are potential areas for the sitting of boreholes.

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