NEW INSIGHT INTO THE GEOLOGY OF THE CHAD BASIN

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Abstract

Many properties of the solid earth have been shown to exhibit fractal behaviour. The scaling exponent which is usually used in the characterization of fractals is used here for geological mapping. This was first done using theoretical data and then real data from an area of known geology. Results obtained were used to predict the basement geology of part of the Chad basin, north-east of Nigeria. Application on the Chad basin reveal the existence of intrusions into a basement that is overlain with a highly magnetic layer such as basalt flow, which corresponds to scaling exponent values ranging between -3.85 to -3.11..

Keywords: *Fractal, Chad, susceptibility, spectra, scaling exponent*

1.0 Introduction

Until recent years, no appropriate mathematical tools existed to analyze the heterogeneity of real objects. Today the theory of fractals allows for qualitative description of the heterogeneity of real geological formations. Fractals are usually analyzed using spectral techniques because the scaling law such as the power law dependence are preserved by Fourier transforms (Voss,1988). The spectral slope (known as scaling exponent) is a measure of the scaling behavior of the distribution. Pilkington and Todoeschuck (1993) derived scaling exponents from susceptibility logs of Ontario and found a sufficient difference between the values for sedimentary and igneous sections. In their work it was discovered that the scaling exponents ranges from -1.32 to -1.96 for sedimentary and from -2.08 to -2.72 for igneous rocks. Lawal *et al.* (2005) made detail analysis on the use of scaling exponent for geophysical mapping using both theoretical and real data. Application to real data was done on three different areas of known geology; the Mamfe basin, the Gongola basin and the Younger Granite province. The results obtained showed good correlation between the geologic maps and the fractal maps for each area, and it was also observed that the scaling exponents representing basement rock generally have values between -2.0 and -3.0. In this work the technique is applied to the Chad Basin of north eastern Nigeria of which the basement geology is not known (that is, in terms of rock composition).

2.0 The Technique

Fractal geological mapping is first done by computing the Fourier transform of the data and then squaring the Fourier amplitudes to obtain the power spectra. The power spectra is plotted as log of power against log of frequency and the slope of the graph which represents the scaling exponent is determined. This operation is performed on a small data window which is moved around systematically until the entire area is covered, and the scaling exponent computed is plotted and contoured to produce the fractal map.

Figure 1 shows the field produced by two sources in the form of three-dimensional vertical prism uniformly magnetized in the direction of the geomagnetic field and assuming an ambient field of 33,000 gamma. The geomagnetic field inclination and declination are 2° and 4° respectively and the data generated by the field was calculated on a 160 by 208 regular grid at 1.0 km interval. The bigger source is 50 km wide along the x-direction (assumed parallel to the north-south direction), 50 km wide (y-direction) and 12 km thick (z-direction) while the smaller source has a dimension of 30 km by 30 km along the x and y-directions respectively, and is of the same thickness and susceptibility contrast as the bigger source. The tops of both sources are located 4 km below the plain of measurement and the magnetic susceptibility is 0.011 S.I. unit. Using a data window of 32 km by 32 km, the power spectrum was calculated, plotted on a log-log graph, and a line of best-fit was used to obtain a value of the scaling exponent. This was done continuously each time by moving the data window one grid unit until the entire area of the map was covered. The results of the scaling exponent computed at each window were plotted and contoured and the result is shown in Figure 2. Different kinds of shading have been used so as to differentiate susceptibility contrasts and it can be seen that the two sources were successfully resolved and mapped with the contour line approximating the boundary of each source.

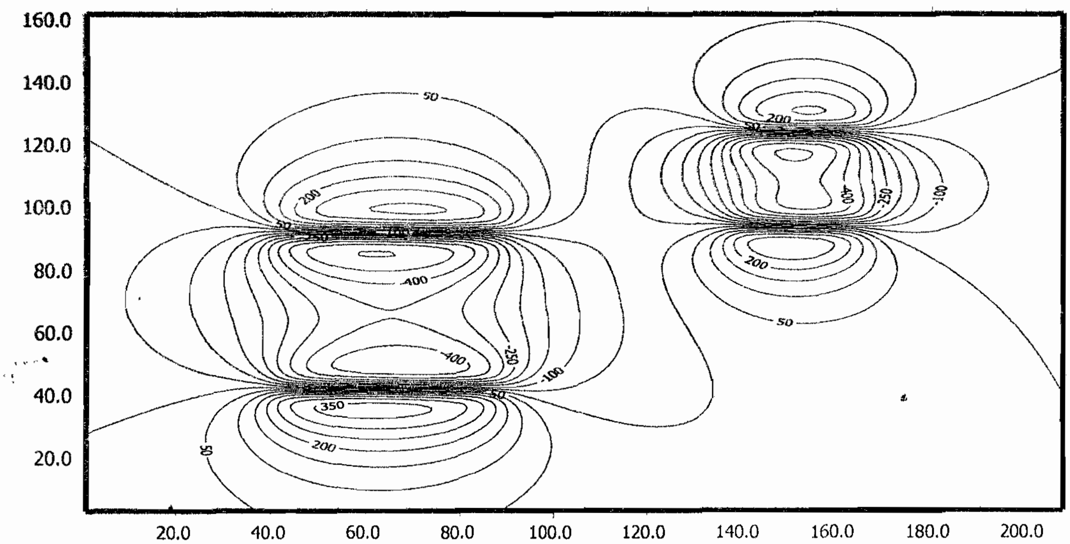

Fig. 1: Field generated by two sources. Contour interval is 50 nT.

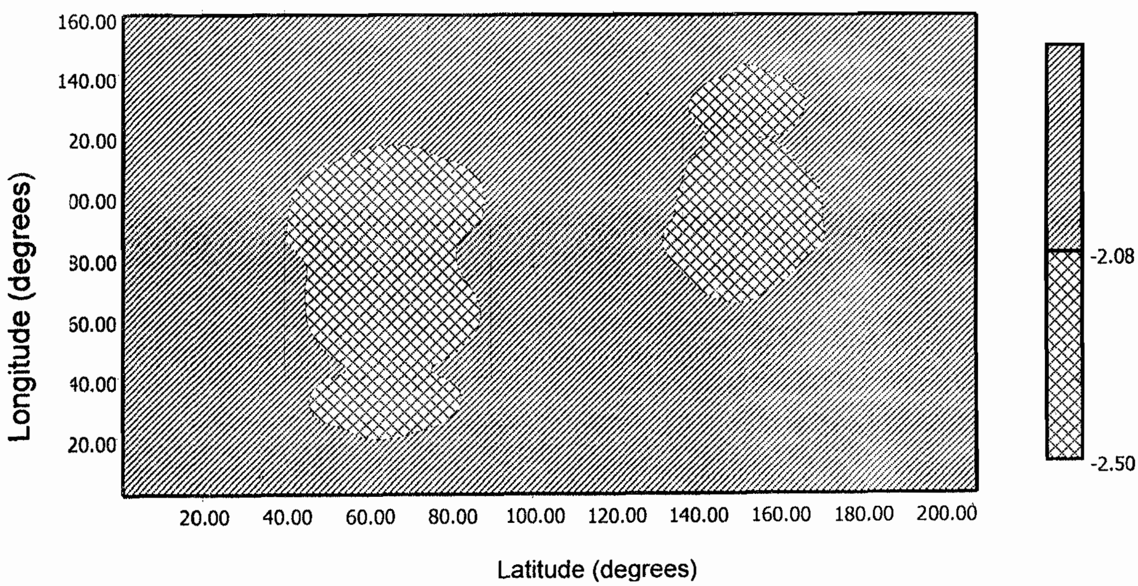

Fig. 2: Contour map showing variation of scaling exponents.

3.0 Application to the Chad Basin North East of Nigeria

The Nigerian sector of the Chad basin is a plain which slopes gently towards Lake Chad. It is devoid of rock outcrops and is covered by superficial deposits of sand and clay. It is a large sedimentary basin which occupies the northeastern corner of Nigeria (Figure 3). The Chad basin exhibit platform sedimentation in a geotectonic setting related to rifting, and sedimentation is believed to have started during the Albian (Carter *et al*, 1963). Knowledge of Chad basin is deduced primarily from lithologic information obtained from water boreholes (Avbovbo *et al.*, 1986). The area of study lies between geographic latitudes $12^0 00^1$ N and $13^0 30^1$ N and longitude $11^0 30^1$ E and $13^0 30^1$ E. It is covered by aeromagnetic map sheets 021 to 024, 042 to 045 and 064 to 067, and has an area of approximately 37,000 km^2.The maps were digitized along flight lines and the data obtained were interpolated onto a regular grid at 1.0 km intervals. A regional-residual operation was performed on the data by fitting a first order polynomial, and the residual map of the area is shown in Figure 4.

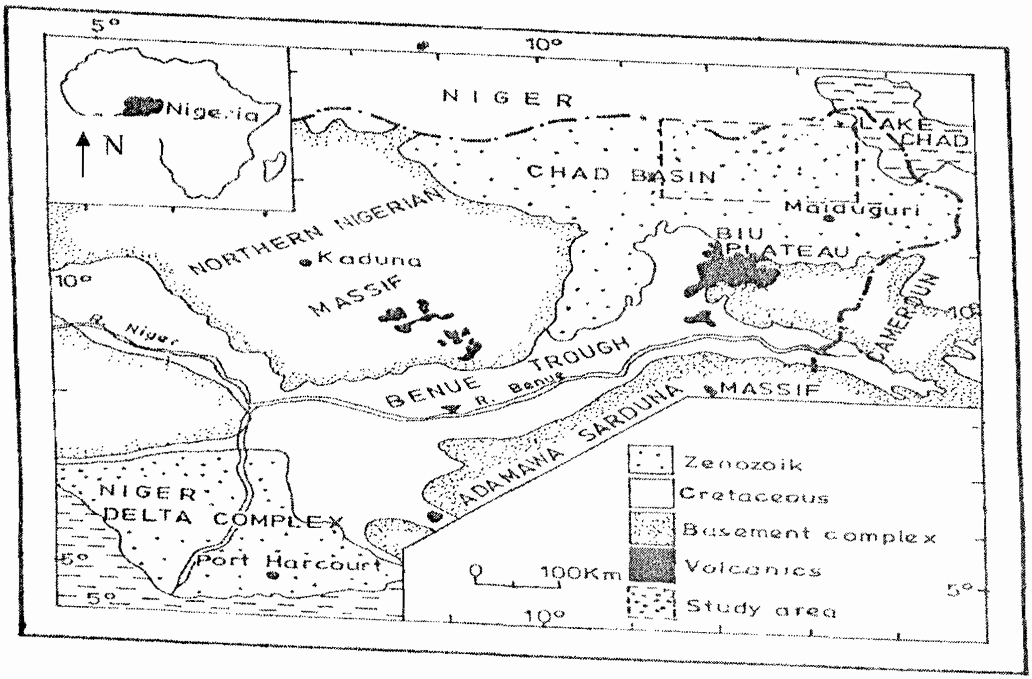

Fig. 3: Geological Map of Nigeria showing the Nigerian sector of the Chad Basin and the location of the study area. (After Whiteman, 1982)

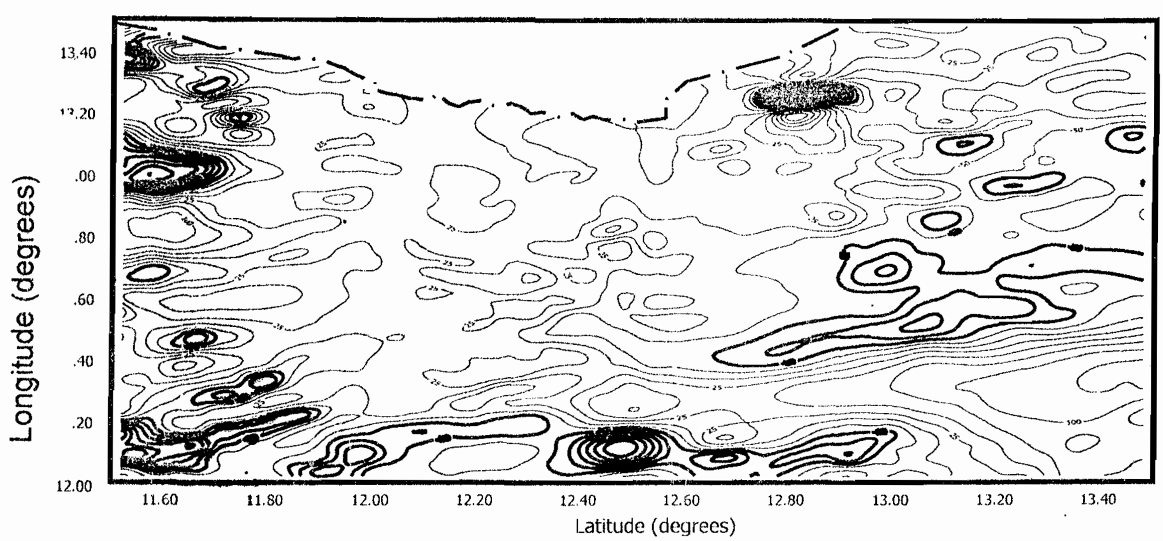

Fig. 4: Residual map of the area of study. Contour interval is 25 nT.

Application of the procedure in section 2.0 produces a fractal map shown in Figure 5 with the scaling exponents having values which vary between -1.58 and -4.85. Using the results from the analysis on areas of known geology (Lawal *et al.,* 2005), the dotted region represents Precambrian basement rock, while the cross hatched region with scaling exponents of very low numeric values and the white coloured region with scaling exponents of very high numeric values represents intrusions into the basement. The black coloured region of relatively higher scaling exponents than the grey region probably represents the basement which is overlain with a high magnetic layer such as basalt flow. Similar occurrence of basalt in the northern part of the Chad basin (within Niger Republic) has been reported by Genik (1992). It can also be seen in Figure 5 that the white coloured region at the north-east part of the map, which can be regarded as an intrusion into the basement, correlates very well with the strong negative anomaly in the residual field map (Figure 4). Also the intrusion situated below this anomaly is now more resolved than it was in the residual map. The NE-SW trend of some of the structures in the fractal map is also consistent with the trend of the gravity anomalies obtained by Fairhead and Okereke (1987).

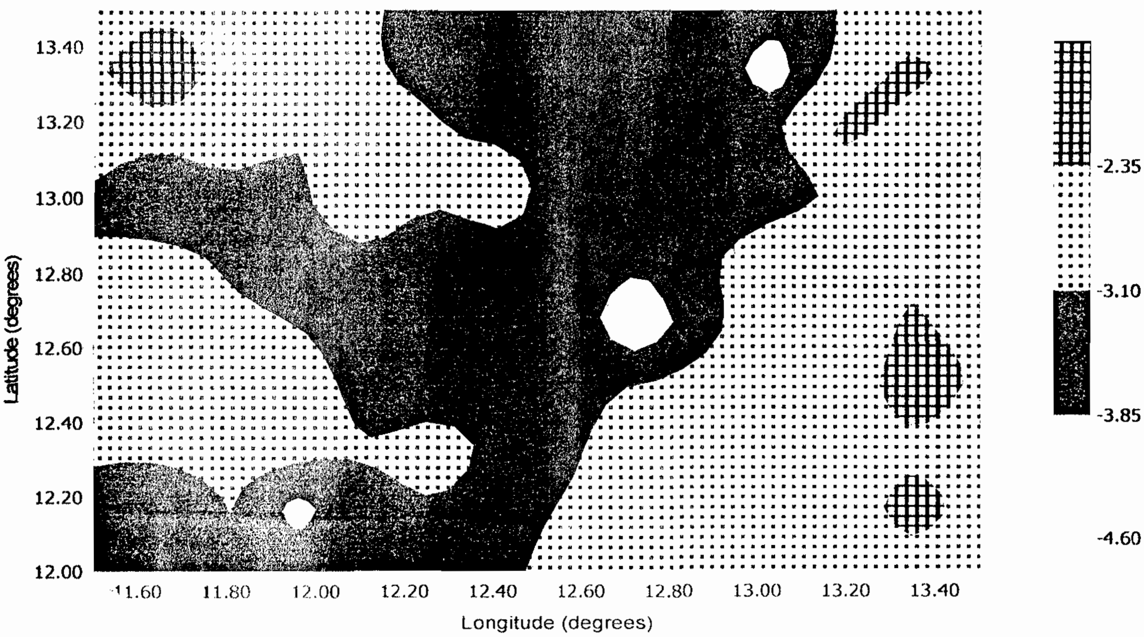

Figure 5: Contoured map showing variation of scaling exponent of the result obtained from the area of study.

4.0 Conclusion

The scaling exponent directly contains information on local geology, and can therefore be used to distinguish between different rock types. This was first demonstrated using synthetic data and then later applied to the Chad basin north east of Nigeria. Following results obtained from an earlier work (Lawal *et al.*, 2005), the values of the scaling exponents derived from the application of this technique on the Chad basin were used to produce a fractal geological map of the basement. The resulting map revealed the presence of intrusions into the basement and also that the basement is overlain by a high magnetic layer which might have resulted from a basalt flow.

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