MAGNETIC ANOMALY TRENDS AND SPACING PATTERNS IN PARTS OFTHE LOWER BENUE TROUGH, NIGERIA.

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Abstract

A composite aeromagnetic (large and small) map of the Lower Benue Trough, Nigeria, covering an area of about 18,150 km^2 was processed based on the magnetic elements method. A plot of frequency and azimuth of the resulting data were produced. The magnetic trend patterns due to the magnetic anomalies in the study area were seen mostly as sharp and asymmetric trending in the north-northwest to south-southeast direction while the minor arms trend in the east-west direction. The large portion of the map indicates a north-south trending for zone one and north-northeast to south-southwest trend for zones two and three. The entire small portion of the map has a north-south trend. The few observed broad peaks are attributed to recurrent renewals of shifting stress. The magnetic spacing observed between adjacent parallel anomalies was varying and the spacing interval of about 0.15 km is periodic, while semi-periodic spacing lies between 4.5 and 6.0 km for the entire composite map. These trends indicate short to intermediate to long wave components in terms of dispersion of magnetic materials. The magnetic spacing of 2.4 to 3.4 km for the small portion is an indication of deep seated igneous bodies or magnetite bearing formation. Similarly, the large portion with magnetic spacing of 0.45 to 2.5 km indicates anomalies from complex structure at medium depth of burial that are the characteristics of the Lower Benue Trough. The polar plots show shoulder trends which are indicative of the depressed trends that are the offshoot of stresses initiated in the course of development of the main trends.

***Keywords:** Aeromagnetic studies, magnetic anomalies, Tectonic province, magnetic trends, Azimuth and Lower Benue trough.*

Introduction

Aeromagnetic studies of the area in question have not received much attention in recent times. Most of the studies (Ofoegbu, 1985 and 1986; Ajakaiye *et al*, 1986 and Ofoegbu *et al*, 1989) in the Benue Trough have not been extended into the present study area (Fig. 1). The study area occupies about 18,150 square kilometers extending into the Anambra Basin, Lower Benue Trough and the northern extreme of the Niger Delta. The area lies within 6° N to 7° 30' N and 7° E to 8° E (Fig. 1).

Magnetic anomalies are often associated with fractures resulting from either deposition / emplacement of magnetic ore bodies which are controlled by pre-existing fracture systems or by the dislocation of Formations of susceptibility / magnetization contrast (Hall, 1964). Earlier work by Affleck (1963) had suggested that magnetic provinces defined from magnetic data interpretation reflect tectonic provinces. These provinces can be derived from the magnetic trend

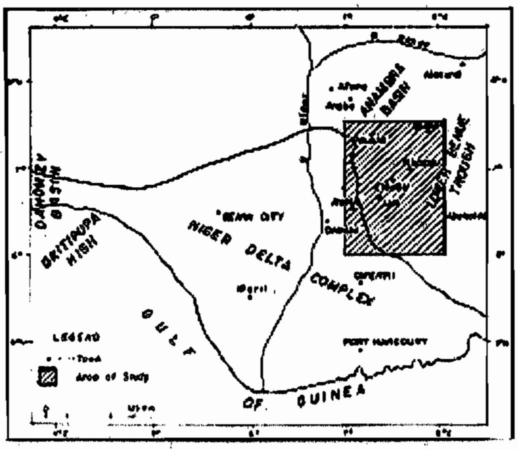

Fig. 1: Map of the study area

patterns of aeromagnetic maps. This implies that the observed magnetic features are expressions of the fracture patterns within an area (Fuller, 1964).Magnetic trend has been able to reveal the reactivation of old rift trends and similar patterns due to shallow source magnetic anomalies which are interpreted as evidence of extensive late Cenozoic volcanism (Behrendt *et al.*, 1996). Similarly, magnetic patterns have been found very essential for the mapping of magnetic units in the Precambrian and Paleozoic basement particularly where there are large susceptibility contrasts (Jorgensen, 2002). Several other significant uses of magnetic trending have been demonstrated by several authors which include Affleck, 1963; Glenn *et al.*, 2000; Phillips, 2001; and Gettings, 2002. Particularly for the Benue Trough, Affleck (1963) was able to show that observed magnetic trends and spacing patterns were attributable to tectonic features. Furthermore, Wright (1976) and Kleinkopf (1995) observed that most of the intrusive in the Middle and Lower Benue Trough manifest as sills, dykes, plugs, or bosses of a few kilometers in diameter.

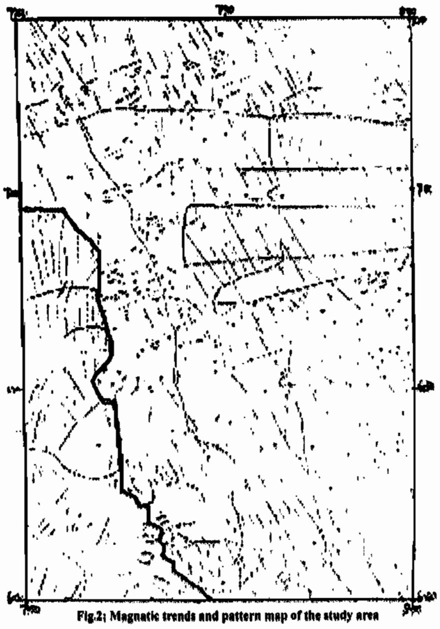

Fig.2: Magnetic trends and pattern map of the study area

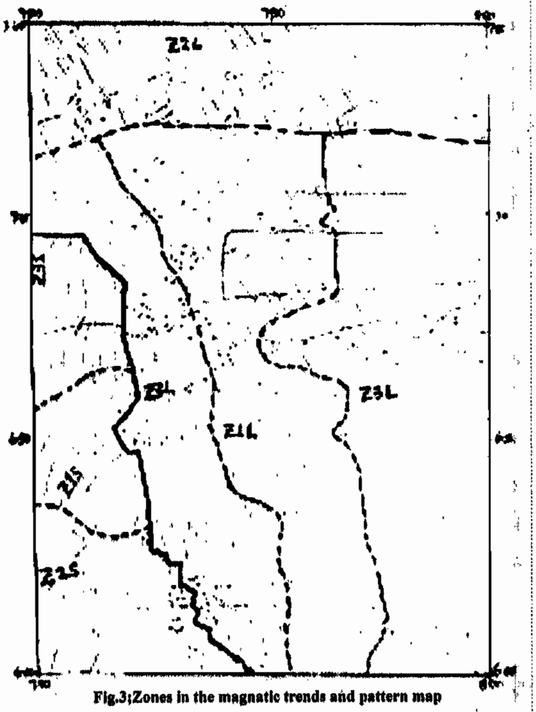

Fig.3:Zones in the magnatic trends and pattern map

The geology of the Benue Trough, including that of the Lower Benue Trough, has been discussed by several authors, for example Simpson, 1955; Cratchley and Jones, 1965; Uzuakpunwa, 1974; Ofodile and Reyment, 1976; and Adighije, 1981 (Fig. 2).

Sedimentation in the area started in the Albian with the deposition of the Asu River

Group and culminated in the deposition of the Nsukka Formation in the late Maestrichtian to early Paleocene. Other geologic sequences overlying the Asu River Group include the Ezeaku Shales / Makurdi and Ajali Sandstones whose deposition commenced in the upper Cenomanian. These are overlain by the Agwu Formation, Nkporo Shales / Otobi Sandstones in the Campanian. The Nkporo Shales are unconformably overlain by the Mamu Formation.

In the present study a composite aeromagnetic map acquired at two different terrain clearances of 150.0 m for the large portion and 750.0 m for the small portion is analyzed graphically and analytically to locate alignments along definite axes which form magnetic trend and spacing patterns. Magnetic signals are delineated into magnetic zoning units according to their amplitudes. The observed magnetic and spacing patterns will then be interpreted in terms of the tectonics and geology of the Lower Benue Trough.

Method of Analysis

The magnetic anomalies on the composite aeromagnetic map are observed to align themselves along definite axes forming trend patterns which are traced out to produce the magnetic trend and pattern map of Fig. 3. The composite map was initially gridded into squares of 33.0 km on a side, with each square defining the elements. The elements in each square (which are the solid strike lines in Figs. 2 and 3) were counted and their directions measured as azimuths. The number of elements in each 20^0 of azimuth was then determined. As a means of rationalizing the elements contributing to the 20^0 classes, the numbers were converted to frequencies by taking percentage of the number of elements in each 20^0 class interval over the total number of elements. The results were smoothened by the use of a simple fine point average computer programme (Ngwueke, 1997). The entire composite map was thereafter grouped into three zones of magnetic trends and patterns having first, second and third order highs and lows. Zone one was identified as predominantly first order lows and highs; zone two is characterized by a combination of first and second order lows and highs, while zone three contains first, second and third order lows and highs. For the large portion, the first order highs and lows have amplitudes of 400 gammas and above, the second order comprise highs and lows with amplitudes of 150 to 400 gammas, while the third order lows and highs have amplitudes between 0 and 150 gammas. Similarly for the small portion of the map,

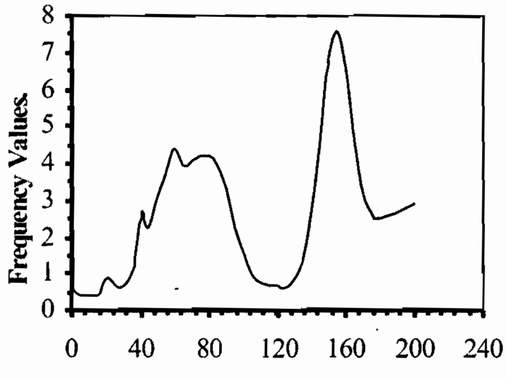

Fig. 4(a): Plot of frequency values of magnetic elements for large map.

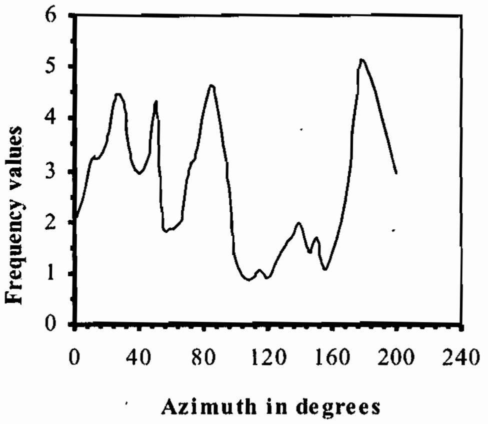

Fig. 4(b): Plot of frequency values of magnetic elements for small map.

The first order lows and highs comprise amplitudes of 150 to 500 gammas, second order lows and highs have amplitudes between 100 and 150 gammas, while the third order lows and highs have amplitudes from 0 to 100 gammas (Fig. 3).

Graphs of the frequencies of magnetic elements and magnetic zone elements against azimuth for each portion were plotted (Figs. 4a and 4b) and (Fig. 5a and 5b) respectively.

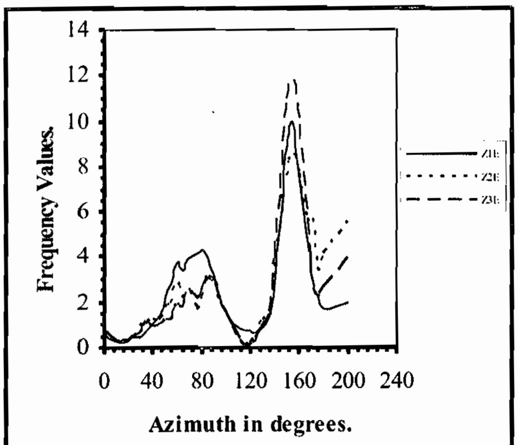

Fig. 5(a): Plot of frequency values of magnetic zone elements for large map.

The distances between elements or adjacent parallel anomaly trends were determined and the spacing which is the number of samples or trending with the same distance computed.

The most frequent spacing intervals were subsequently determined. Histograms of the magnetic zone elements and trends for both large and small portions were plotted (Figs. 6a and 6b). Finally polar plots for both portions were constructed in order to determine the predominant trend (Figs. 7(a), (b) and (c)) and Figs. 8(a), (b) and (c).

Discussion of Results

The magnetic elements for the large portion of the map (Fig. 4a) show two well-defined peaks which include one broad peak at N72°E and a sharp one at N27°W.

However, for the small portion the magnetic elements show four peaks having almost equal occurrence or frequency (Fig. 4b). These peaks are all sharp and are located at N26°E; N48°E; N82°E and N4°W. Short wavelength anomalies show broad or sharp peaks and well-defined trendings unlike the medium and longer wavelength anomalies of deep seated intrusive bodies of asthenospheric origin which produce broad and indeterminate trendings (Ofoegbu, 1986).

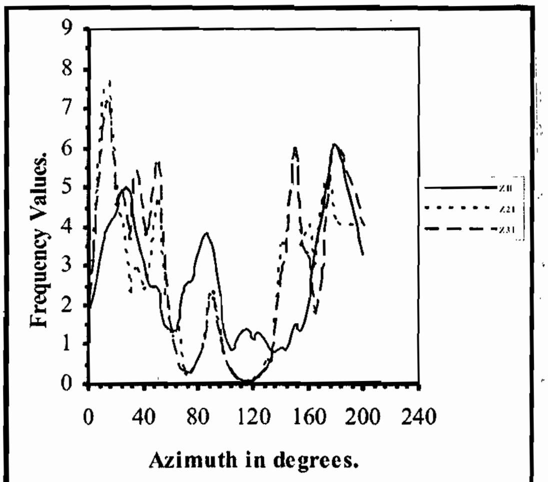

Fig. 5(b): Plot of frequency values of magnetic zone elements for small map.

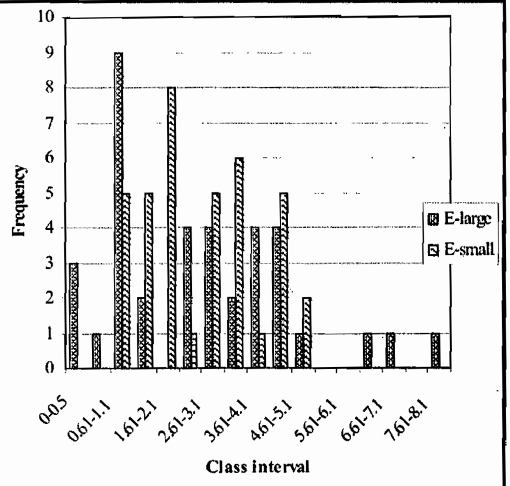

Fig. 6(a): Histogram of magnetic elements for large and small maps.

The study area is known for the existence of intrusives which extend from Isiagu in the Lower Benue Trough to Zurak in the Upper Benue Trough. These intrusives take the form of sills, dykes or bosses and plugs. Fig. 5(a) shows the occurrences of magnetic elements in the large portion of the map for the zones. Zones 1, 2 and 3 have two prominent peaks (one broad and sharp) that are symmetrical and both located around N72°E and N27°W, respectively. Zone 3 has the highest frequency for the sharp peak while Zone 1 has the highest frequency for the broad peak. Fig. 5(b) shows occurrence of elements in the small portion of the map for the zones, with small portion of the map for the zones, with Zone 1 being characterized by two prominent peaks (one broad and sharp) located at N78°E, N88°E and S2°W respectively. The broad peaks are asymmetrical and could be attributed to successive renewals of shifting stresses, where these stresses could be large or small and in different directions (Affleck, 1963 and Hall, 1964). The trimodal neighbouring peaks could also be the result of overlapping complex formations (Krutikhovskaya *et al.*, 1973). Zone two has five sharp peaks. The first and the fourth peaks have the highest percent of occurrence. The peaks are located at N18°E, N50°E, E90°W, N30°W and N4°W respectively.

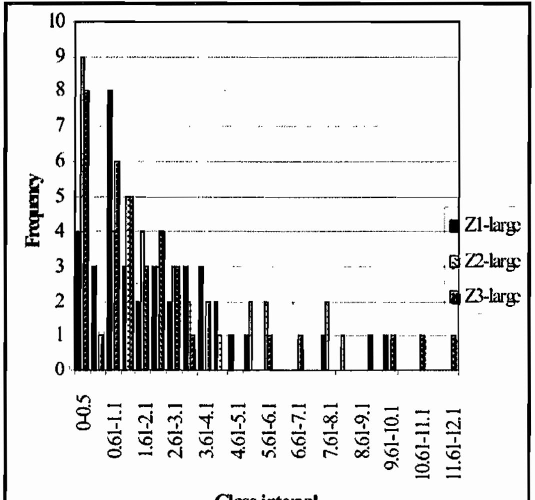

Fig. 6(b)(i): Histogram of magnetic zone elements for large map.

Under similar considerations we observe that zone three has six possible sharp peaks which are located at N18°E, N38°E, N50°E, E90°W, N30°W and S3°W respectively.

The magnetic trend distributions for the large map show clusters with frequency range of 1 to 10 percent and a prominent occurrence at the class range of 1.1 (Fig. 6(a)). Zones one, two and three are skewly distributed towards

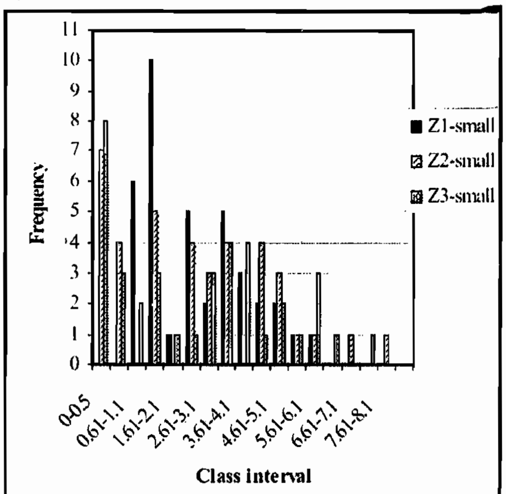

Fig. 6(b)(ii): Histogram of magnetic zone elements for small map.

the 6.1 (see Fig. 6(b)(i)) class interval and oddly distributed as the class range increases.

These are indications that the magnetic trend directions are within the class intervals of 0.5 to 4.6. For the small portion their magnetic trends are quite distinct from that of the large portion. The trends of 5 percent occurrence are predominant at the class ranges of 1.1, 1.6, 3.3 and 4.6. However, an eight percent occurrence shows at the azimuthal class range of 2.1 (Fig. 6(b)(ii)). Zone 1 appears to be a skewed distribution of the magnetic trend having the highest occurrences at 20° to 40° azimuths. Zones 2 and 3 show uniform distribution of magnetic trends in all direction or in various class ranges. These trends and patterns are due to tectonic evolution of the Benue Trough (Ofoegbu *et al.*, 1989) which involved the upwelling of mantle plume that resulted to some degree of thinning of the lithosphere and the development of initial lines of weakness marginal to the plume. Consequently, intrusive igneous materials were emplaced in the crust followed by more extensive stretching and thinning which ended in rifting (Ofoegbu *et al.*, 1989).

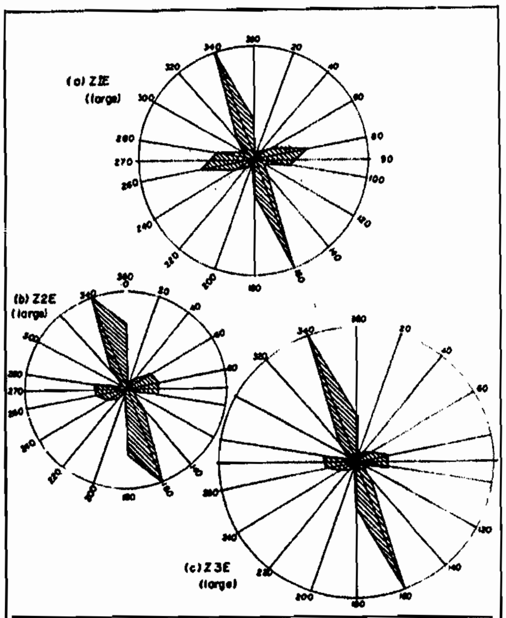

Fig. 7: Polar plot (Rose diagram) of the magnetic zone elements for the large map.

A great similarity exists between the entire large portion and its three zones. Similarly, the polar plots (Rose diagrams) for the large portion and its zones show magnetic trend directions in the NNW SSE with shoulder trends mostly in the east-west direction (Figs. 7a, b, c). The shoulder trends are depressed trends and are considered as the offshoot of stress(es) initiated in the course of development of the major trends. These may also be attributed to older fundamental lineaments of the basement that have been healed or rotated away from their true directions. Polar plots for the small portion show magnetic trend direction in the north south with broad shoulder trends in the east- west and northeast southwest directions (Figs. 8a, b, c). Zones 2 and 3 display similar magnetic trend directions with nondefinite sharp shoulder trends, unlike Zone 1 that has a north south direction. This area is associated with deeper structures that are due to tensional forces in which the folding has been largely controlled by faults in the underlying basement (Wright, 1981).

The magnetic trend map for the large portion exhibits an average magnetic spacing of about 1.68 km. Zone 1 has an average spacing of 1.66 km, with zone 2 having an average spacing of 1.32 km, while zone 3 has two average spacings of 1.38 km and 2.85 km which could be the result of complex structures buried at shallow and medium depths. For the small map an average magnetic spacing of 1.93 km was obtained. Zone 1 has an average magnetic spacing of 3.4km which is considered wide and could be the result of deep seated intrusive igneous rocks or magnetite sedimentary rocks (Kleinkopf, 1995 and Cook *et al.*, 2003). An average magnetic spacing of 2.4 km was estimated for zone 2, while zone 3 has an average of 2.5 km.

In this study it is noted that the most prevalent magnetic spacing is about 0.15 km which is not a function of magnetic tectonic provincial boundaries. It has been observed that the Lower Benue Trough is associated with complex features, several intrusives and some lineament trends (Ofoegbu, 1985 and Okeke, 1992).

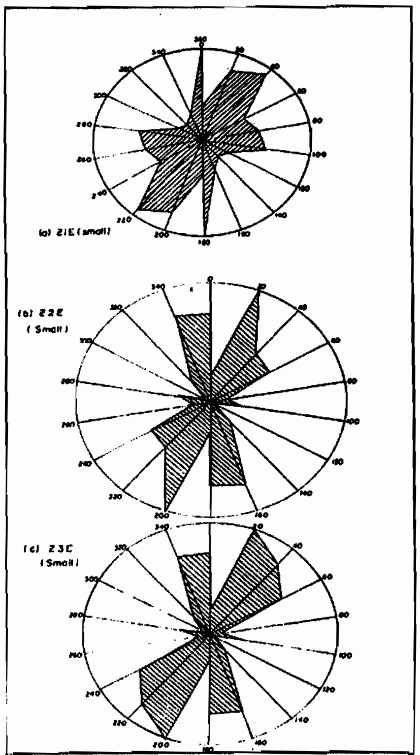

Fig. 8: Polar plot (Rose diagram) of the magnetic zone elements for the small map.

Conclusions

Magnetic trend patterns of the study area were observed to be dominant in the northwest and generally recessive in the southwestern directions. In the east-west and the northeastern areas, sharp and asymmetric peaks were observed. These could be attributed to fracturing within a uniform medium in response to tensional stresses assumed to be constant in direction. The observed broad peaks could be associated with successive renewals of shifting tensional stresses. The observed magnetic spacing between adjacent parallel anomalies is not constant but fluctuating with the commonest spacing being about 0.15 km. The large portion of the magnetic trend map contains harmonic and sub-harmonic spacings which are between 0.45 km and 3.3 km. These values indicate two wave components of short and intermediate nature during the emplacement or deposition of magnetic minerals. The small portion of the map features short, intermediate and long wave components having periodic and sub-periodic spacings of 0.9 km to 6.0 km. The polar plots show shoulder trends which are indicative of the depressed trends that are the offshoot of stresses initiated in the course of development of the main trends. These could be older fundamental lineaments in the basement that have been healed or rotated away from their true position.

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