JOURNAL OF THE CAMEROON ACADEMY OF SCIENCES Vol. 2 No.3 (2002)

Aeromagnetic study of the Mamfe basalts of southwestern Cameroon

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ABSTRACT

A study is made of the aeromagnetic field over two major basalts flows in the Mamfe Basin as an aid to the location of primary mineralisations. The methods applied are those of spectral and 2½-dimensional inversion of the residual magnetic field. Spectral analysis was used to determine the depth of the basement complex beneath the basalt flows. This method gave depths of 1.81km for the area in the East of the basin, and 2.00km for the location in the West. Magnetic inversion gave model shapes of the basalt layer along 7 profiles chosen in the study areas. From these it was found that the basalt conduits can be reliably located, and the areas favourable for drilling for primary materializations were found to be:

(1) Longitudes 9.24°E to 9.28°E; Latitudes 5.62°N to 5.635°N
(2) Longitudes 8.78°E to 8.84°E; Latitudes 5.88°N to 5.92°N.

Key words:

RÉSUMÉ

Une étude a été faite du champ aeromagnétique au-dessus de deux écoulements basaltiques au Bassin de Mamfe afin de repérer des minéralisations primaires. Les méthodes utilisées sont l'analyse spectrale et l'inversion du champ magnétique résiduel. L'analyse spectrale a permit le calcule des profondeurs du socle dans les deux régions. La valeur de 1,81 km a été trouvée pour la zone Est et celle de 2,00 km pour la zone de l'Ouest. L'inversion magnétique a donné les formes modèles des couches basaltiques le long 7 profils choisis. Ces modèles nous ont permis de repérer les conduits basaltiques, les endroits propices à la prospection pour les minéralisations primaires. Ces derniers sont :

(1) De longitude 9.24°E à 9.28°E ; de latitude 5.62°N à 5.635°N
(2) De longitude 8.78°E à 8.84°E ; de latitude 5.88°N à 5.92 °N

Mots clés:

INTRODUCTION

The Mamfe basin is a largely sedimentary basin that lies astride the border between southeastern Nigeria and southwestern Cameroon (Fig 1). It extends from Latitudes 5°30'N to 6°00'N and longitude 8°15'E to 9°45'E.

Ever since the time of German colonization more than 100 years ago, this area has been known to harbour much valuable mineral deposit (Wilson, 1928; le Fur, 1965, 1966; Dumort, 1968; Vogt, 1966; Letterman, 1967;Eben, 1984). One consistent problem noted by these prospectors has been the low concentrations of the materializations so far encountered. Thus it appears clear that the areas of primary materializations have not yet been located. Basalt flows have been known to cover up areas of economic materialization (Curtis and Jain, 1975; Negi et al, 1983). Thus one way of solving the problem of locating primary mineralizations in this area would be to drill through the basalts located in this largely sedimentary basin. This drilling can economically be carried out in those parts of basalt flows which are not thick.

In the study presented in this paper the aeromagnetic field over the two major basalt flows have been investigated to determine the thicknesses of the basalts in the Mamfe Basin. The basalt flows are: that of Ayundep-Osing in the East (Latitude 5.50°N to 5.80°N and Longitudes 9.10°E to 9.40°E) and that of Ikom in the west of the Basin (Latitudes 5.75°N to 6.00°N and Longitude 8.65°E to 8.95°E); the town of Mamfe is located at 9.30° E, 5.75°N. (Fig. 2). The method applied for the thickness determinations is the two-dimensional inversion of the residual magnetic field following procedures outlined by Won & Bevis (1987) and Talwani & Heirtzler (1963). Spectral analysis of the residual magnetic field carried out to determine

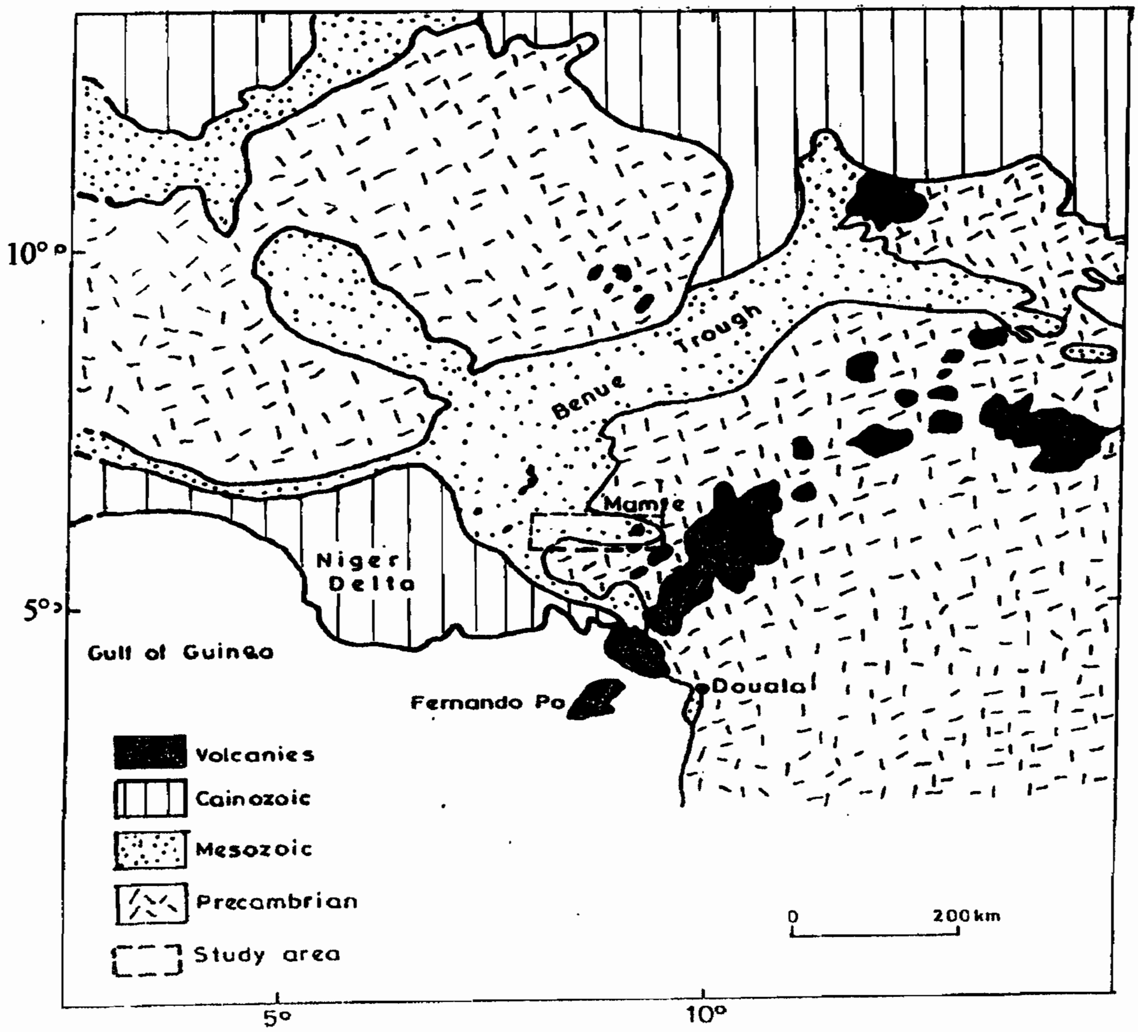

Fig. 1: Generalised Geological Map of Gulf of Guinea Region showing the study area.

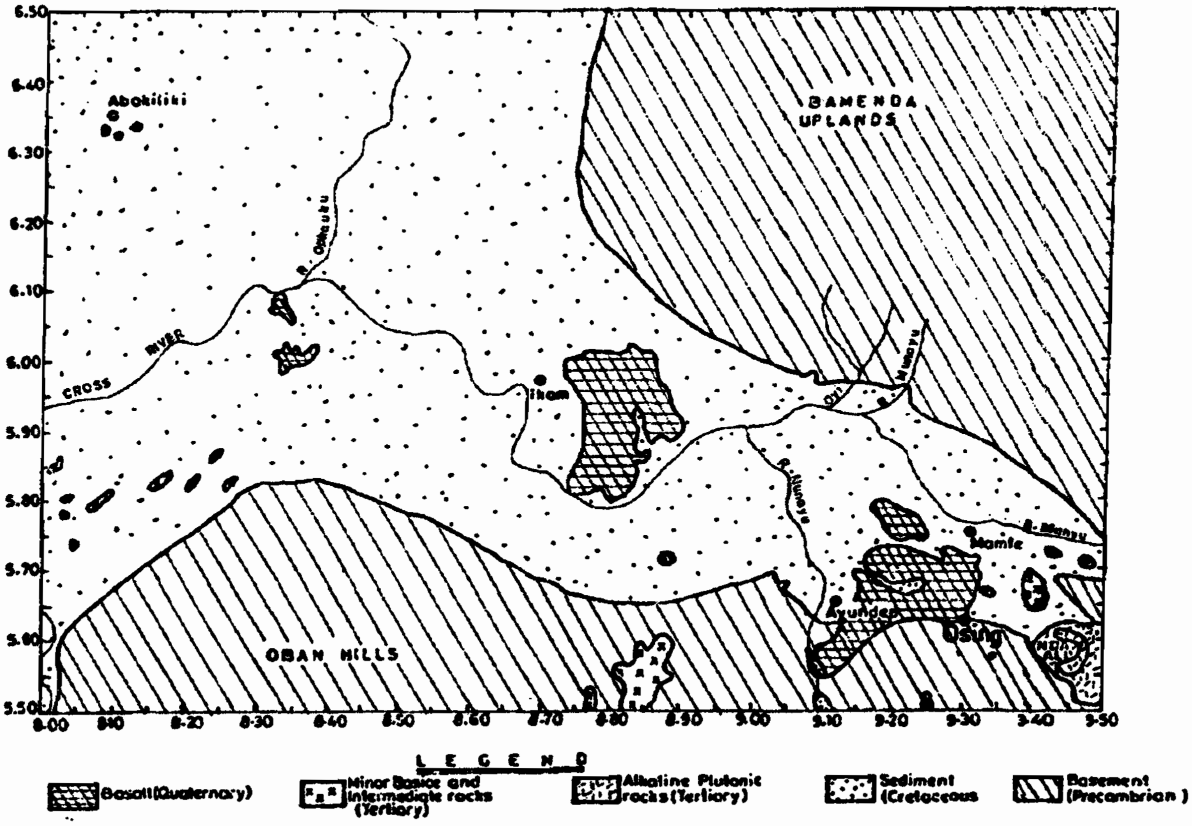

Fig. 2: Detailed Geological Map of study area

depth to the basement complex in these areas. The analysis is based on the method developed by Spector & Grant (1970), with modification made by Fedi et al. (1997).

THE METHODS APPLIED

Spectral Analysis

The two-dimensional Fourier transform pair may be written as (Bath, 1974; Oppenheim & Schafer, 1975):

$$G(u,v)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}g(x,y)e^{-j(ux+vy)}dxdy \qquad 1\text{ (a)}$$

and

$$g(x,y)=\frac{1}{4\pi^2}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}G(u,v)e^{j(ux+vy)}dudv \qquad 1\text{(b)}$$

where u and v are the angular frequencies in the x and y directions respectively.

$G(u,v)$ when broken up into real and imaginary parts is given by

$$G(u,v)=P(u,v)+jQ(u,v) \qquad (2)$$

The energy density spectrum, or simply the energy spectrum is

$$E(u,v)=|G(u,v)|^2=(P^2+Q^2) \qquad (3)$$

Residual total magnetic fields are used to obtain the two dimensional Fourier Transform from which the spectrum is extracted. Next, the frequency intervals are subdivided into sub-intervals, which lie with in one unit of frequency range. The average spectrum of all the partial waves falling with in this frequency range is calculated and the resulting values together constitute the radial spectrum of the anomalous field. A plot of the logarithm of (energy corrected by an exponential factor of exp(-0.29) versus frequency consists of linear segments each of which groups points due to anomalies caused by bodies occurring within a particular depth (Spector & Grant, 1970; Fedi et al. 1997).

Magnetic Inversion

Magnetic inversion involves the determination of a model that is assumed to generate an observed magnetic anomaly. The parameters in this case are body shape, location and the magnetic susceptibility of bodies. A set of parameters is first assumed and used to generate a calculated field that is then compared with the observed field.

The calculated field used here is that for the generation of magnetic anomalies caused by structures of arbitrary shape (Talwani & Heirtzler, 1964; Won and Bevis, 1987). The magnetic anomaly ?H due to an n-sided polygon is given by

$$\Delta H = \Delta H_z \sin I + \Delta H_x \sin \beta \cos I \qquad (4)$$

where I = geomagnetic inclination

β = strike of the prism measured anticlockwise from magnetic North to the negative y-axis.

Also the quantities ΔH_z and ΔH_x are given by

$$\Delta H_z = 2kH_e\left(\sin I \frac{\partial Z}{\partial z} + \sin \beta \cos I \frac{\partial Z}{\partial x}\right) \qquad (5)$$

and

$$\Delta H_x = 2kH_e\left(\sin I \frac{\partial X}{\partial z} + \sin \beta \cos I \frac{\partial X}{\partial x}\right) \qquad (6)$$

where k = magnetic susceptibility of the prism

He = ambient earth magnetic field strength

The geometric factors Z and x are given for consecutive vertices (x_1, y_1) and (x_2, y_2) of the polygon (Fig. 3) by

$$Z = A\left[(\theta_1 - \theta_2) + B \ln \frac{r_2}{r_1}\right] \qquad (7)$$

and

$$X = A\left[-(\theta_1 - \theta_2)B + \ln \frac{r_2}{r_1}\right] \qquad (8)$$

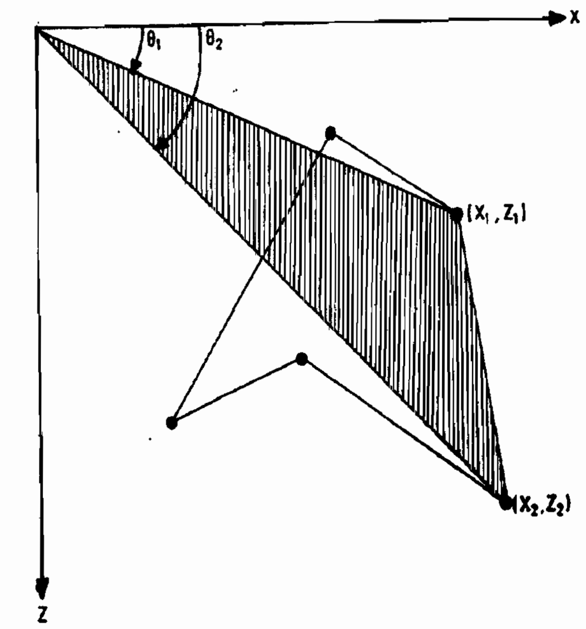

Fig. 3: Geometric conventions used for expression of Magnetic anomaly

where

$$A = \frac{(x_2 - x_1)(x_1 z_2 - x_2 z_1)}{(x_2 - x_1)^2 + (z_2 - z_1)^2}$$

$$B = \frac{(z_2 - z_1)}{(x_2 - x_1)}$$

$$r_1^2 = x_1^2 + z_1^2$$

$$r_2^2 = x_2^2 + z_2^2$$

APPLICATION AND RESULTS

The total magnetic field was obtained by digitizing six maps supplied by the Cameroon Ministry of Mines and Power (Sheet Numbers: NB–32-X-1, NB–32-X-2, NB–32-IX-4, NB –32-X-5, NB–32-X-6 and NB–32-IX-8); four maps supplied by the Geological Survey of Nigeria (Sheet Numbers:303,304,314 and 315). Merging of the data sets was done using the method described by Kangkolo & Ojo (1995). The residual magnetic field was subsequently obtained using the method statistics described by Ojo and Kangkolo (1997).

SPECTRAL

The method of spectral analysis was applied to the residual magnetic field in order to determine the depths to the basement complex in each of the two study areas. Figure(4) and Figure (5) shows plots of the logarithm of energy values versus frequency for the

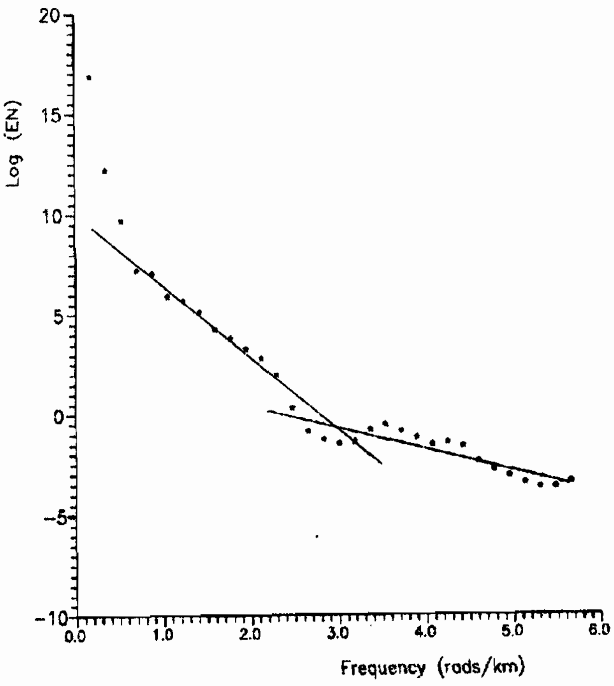

Fig. 4: Energy Spectrum for Ayundep-Osing

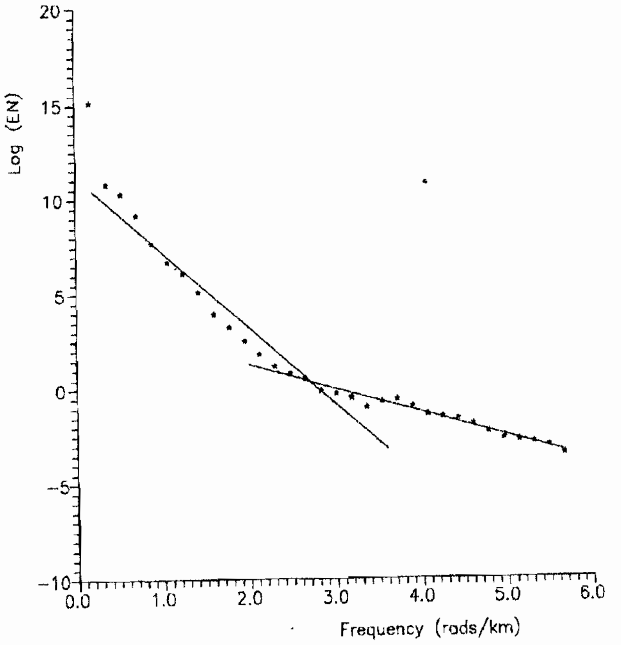

Fig. 5: Energy Spectrum for Ikom

Ayundep-Osing and Ikom areas. Two linear sections stand out in each case. The first group of points are neglected in each case because they arise from deep magnetic sources whose depth determinations would be highly erroneous in view of the limited extent of the areas covered (Naidu, 1970; Pal et al., 1978). If Z is the mean depth to a magnetic layer, the logarithmic plot of the energy spectrum would give a straight line whose slope is –2Z. The mean depth of burial of the ensemble is thus given by

$$Z = -\frac{m}{2} \qquad (9)$$

where m is the slope of the best fitting straight line.

MODELING

Three profiles were taken in the Ayundep-Osing area and four profiles in Ikom area for which magnetic inversion of the residual field was carried out. Before carrying out the modeling the constant regional field was removed from each profile (Rao & Babu. 1991; Kangkolo, 1997). Modeling along each profile was carried out using the 2½-dimensional Interactive Modeling procedure (GM–SYS) developed by the Northwest Geophysical Associates, Inc (1991).

Observed and calculated fields are displayed over the subsurface structures along one of the Ayundep-Osing profiles in Figure 6. The sensor is located at 235m above sea level. Similar ones for the Ikom profiles are shown in Figure 7. The profiles run in the directions from P to Q in each case as shown in Figures 8 and 9.

Basalt thicknesses along these profiles were then calculated from the depths to the top and bottom of the basalt layers. These values were then used to construct contour maps of basalt thicknesses for the two areas. That for the Ayundep-Osing area is shown in Figure 8, and that for the Ikom area is shown in Figure 9.

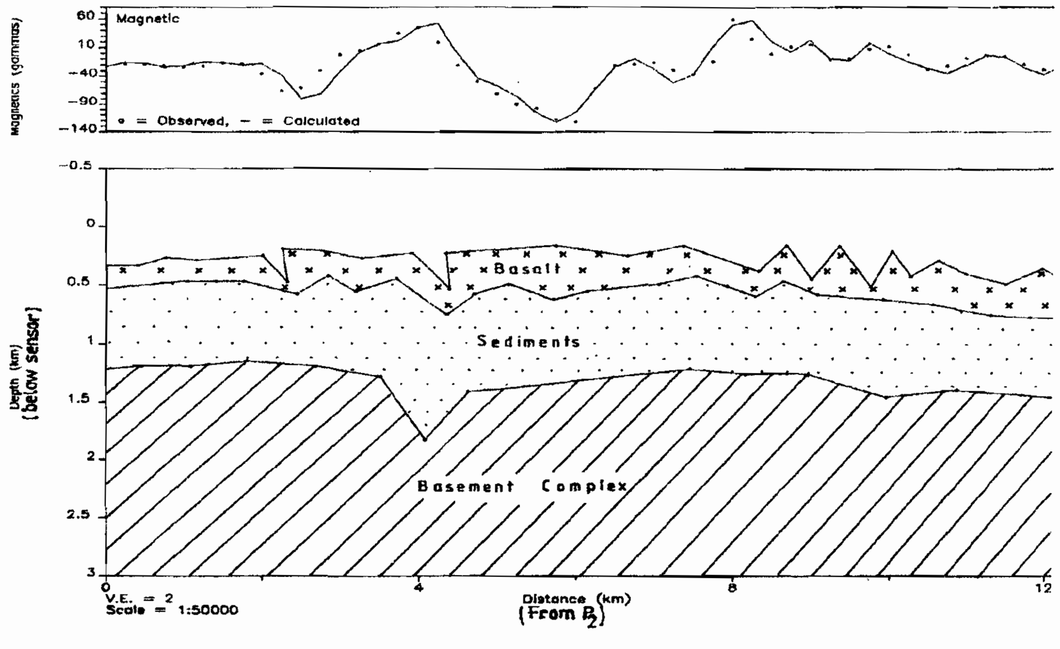

Fig. 6: Ayundep-Osing Basalt (Profile 2)

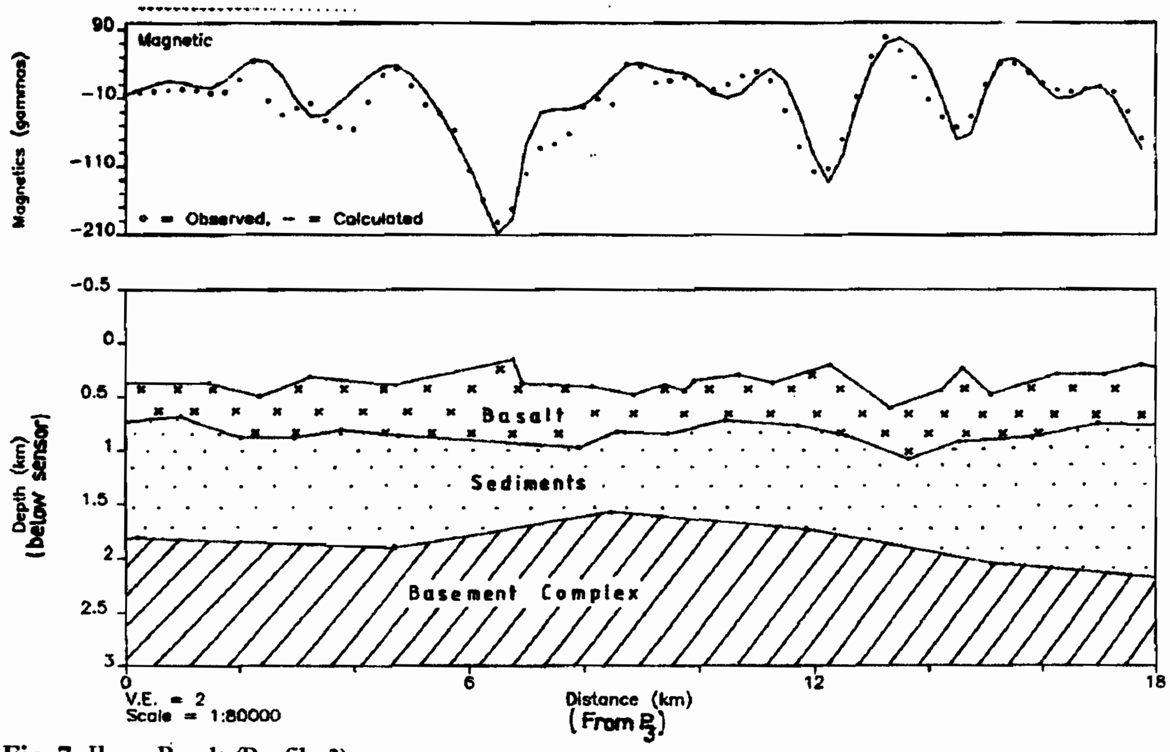

Fig. 7: Ikom Basalt (Profile 3)

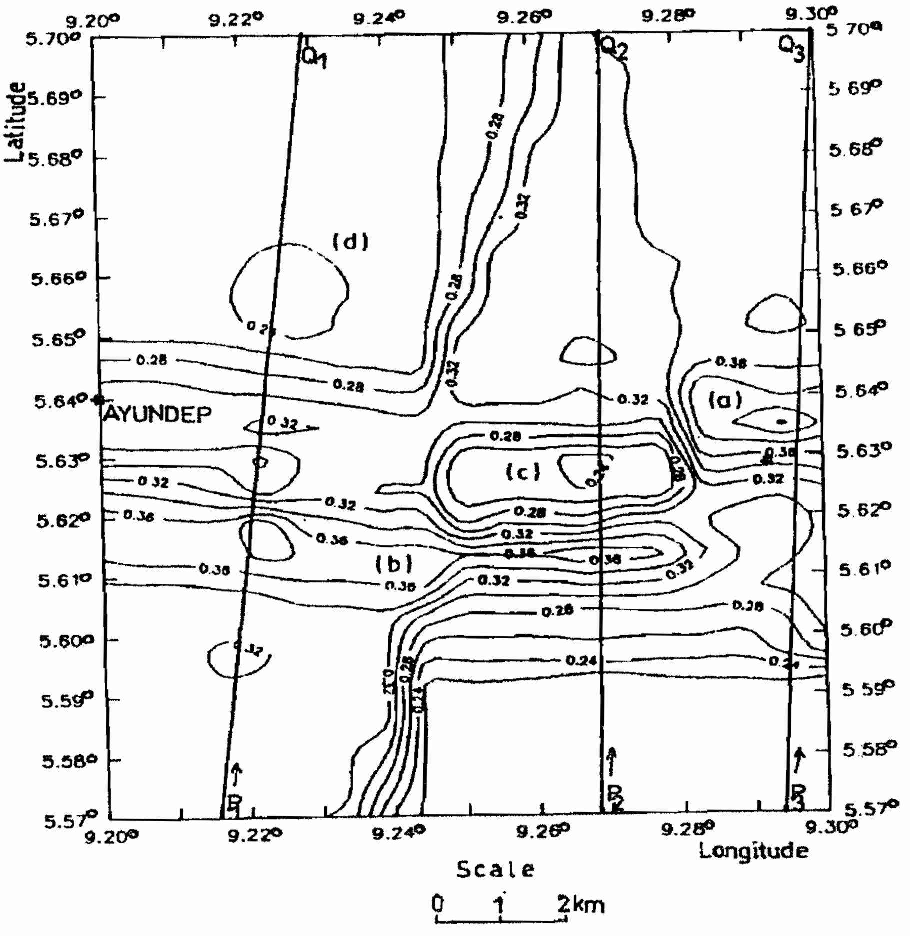

Fig. 8: Basalt thickness for Atundep

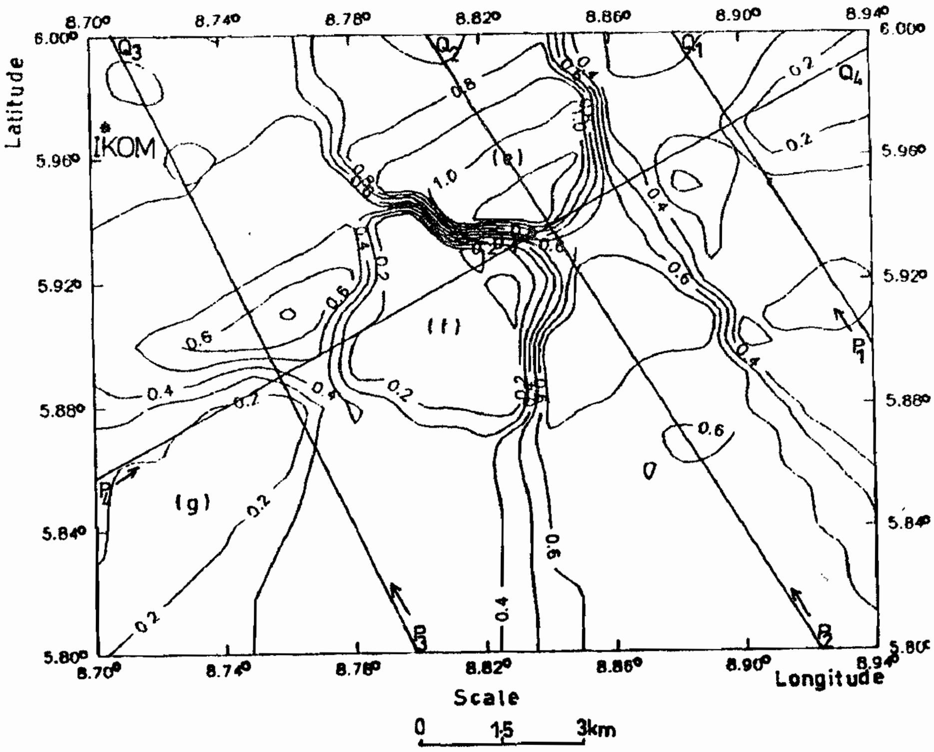

Fig. 9: Basalt thickness for Ikom

DISCUSSION

Spectral analysis of the residual magnetic field gave two magnetic layers. The top layer at an average depth below the sensor of 0.54km at Ayundep-Osing and 0.63km for Ikom. This top layer represents the basaltic layer that outcrops in these areas. The second magnetic layer has a depth below the sensor of 1.81km at Ayundep-Osing and 2.00km at Ikom. This layer can be attributed to magnetic rocks extruded onto the basement surface and to intra-basement features such as faults and fractures. Fairhead et al. (1991) obtained values of between 1km and 3km for the depths long three gravity profiles taken in the Basin. Being profiles, these values may not be close to the average over the area. Also, using spectral analysis of the aeromagnetic data, Ofoegbu and Onuoha (1991) obtained basement depths of range 1.5km to 2.5km for the Abakiliki area that lies immediately to west of the Mamfe Basin. Since sedimentary thickness is expected to increase westwards into the Benue Trough, the depth values obtained in this work appear to be quite logical.

Magnetic Inversion gives for the Ayundep-Osing area the basalt thicknesses illustrated in Figure 8. It can be seen that the thicknesses values lie in the areas:

a) – Longitudes 9.28°E to 9.30°E; Latitudes 5.625°N to 5.645°N

b) – Longitudes 9.20°E to 9.28°E; Latitudes 5.605°N to 5.620°N

The thinnest values lie in the areas:

c) – Longitudes 9.24°E to 9.28°E; Latitudes 5.620°N to 5.635°N

d) –Longitudes 9.20°E to 9.25°E; Latitudes 5.645°N to 5.680°N

For the Ikom area (Figure 9) the thickest values lie:

e) – Longitudes 8.77°E to 8.84°E; Latitudes 5.92°N to 5.96°N

and the thinnest values lie:

f) – Longitudes 8.78°E to 8.84°E; Latitudes 5.88°N to 5.92°N

g) –Longitudes 8.70°E to 8.76°E; Latitudes 5.80°N to 5.88°N

The thickest areas can be interpreted as the locations of the conduits through which the basalts were extruded onto the surface. The process of extrusion provided heat sources that would have driven hydrothermal currents leading to the possible deposition of minerals. The thin areas close to these thick ones are therefore favourable locations at which to drill in search of primary materializations. These areas are labelled as (c) and (f) above.

ACKNOWLEDGEMENT

This is an extension of the work I did for the Ph.D. I hereby acknowledge the contributions and help provided me by my supervisors: Prof. S. B. Ojo and Dr M. N. Umego, all of the Department of Physics, Ahmadu Bello University, Zaria, Nigeria. I am also grateful for the facilities made available to me by the Departments of Physics of Ahmadu Bello University, Zaria, Nigeria and the University of Buea.

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Received: 02/08/02
Accepted: 06/11/02