GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES VOL. 7, NO. 1 JANUARY 2001: 111-116
 ISSN 1118-0579

ALTERNATIVE MODELS FOR THE INTERPRETATION OF AEROMAGNETIC DATA IN AREAS AROUND THE MAGNETIC EQUATOR

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(Received 27 April, 2000; Revision accepted 20 June, 2000)

ABSTRACT

Four interpretational models are recognized in areas around the magnetic equator They are point pole, line of poles, point dipole and line of dipoles. Point pole models are recognized by adjacent circular contours of magnetic high and low, while line of poles models are identified by elliptical contours of magnetic high and low adjacent to each other. When magnetic contours are simply circular or nearly circular the source is approximated as point dipole and contours of line of dipole model are always elliptical in shape. A decision between dipolar and monopolar model is made using the shape of magnetic signature. When a magnetic signature has completely dominant low, the correct model will be a dipole. While a magnetic high flanked by low is approximated as point pole/line of pole (monopole). Magnetic signature that does not assume any of these shapes is a pointer to remanent magnetization. The four interpretational models have close relationship with half-width of magnetic anomalies and are therefore valuable for depth determination. The four interpretational models have been employed to analyse aeromagnetic data from crystalline basement and sedimentary areas of Nigeria.

KEY WORDS: Equator, Model, Dipole, Remanent, Anomaly.

INTRODUCTION

In areas around zero latitude (magnetic equator), the geomagnetic field is horizontal. The angle of inclination (i) of the earth's field is no more than 15° (Telford et al, 1976). Figure 1 shows the relationship between the horizontal field, H with the vertical (Z) and total field (T). H has two components X and Y. The inclination in magnetic equator is considered negative because the north-seeking end of magnetic needle points upward. H is always positive, whatever its direction (Jacobs, 1967). The general expression for the magnetic potential, V at a point is given by

$$V = -\frac{M\cos\theta}{r^2}$$

M is the magnetic moment, θ the co-latitude and r the radius of the earth. The magnetic component H, is given by

$$H = \frac{1}{r}\frac{\partial V}{\partial \theta} = \frac{M\, Sin\theta}{r^3}$$

$$Y = 0$$

The maximum value of H on the earth's surface, $H_o = \frac{M}{r^3}$ and this is about 30,000nT. In spherical harmonics (Garland, 1979) Components of H (X Northward, and Y eastward) are obtained by differentiation as

$$X = \frac{1}{a}\frac{\partial u}{\partial \theta} = \sum\left[E_l\left(\frac{r}{a}\right)^l + I_l\left(\frac{a}{r}\right)^{l+1}\right]\frac{\partial P_l(\cos\theta)}{\partial \theta}$$

Where u is total potential on the earth's surface, θ the co-latitude, E_l and I_l are amplitude factors or coefficients which specifies the contribution of the external and internal sources to the lth harmonic term, a, radius of the earth assumed to be a sphere, r, the radius vector and P_l is the desired legendre polynomials.

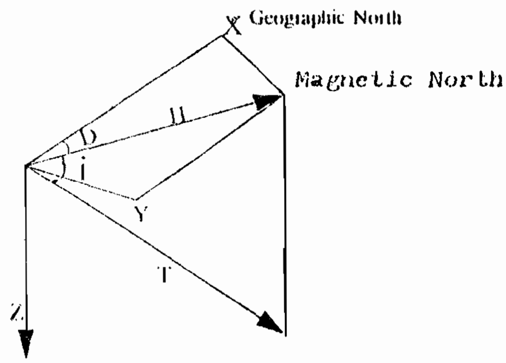

Fig 1 Elements of the Geomagnetic field and their relationship

In this paper, the interpretational models in magnetic equator considered are point pole (monopole), line of poles (line of monopole), point dipole and line of dipoles. These are well documented by Smellie (1973), Telford et al (1976) and Odia (1990). This study is important because it will equip geomagnetisians with the necessary fundamental approximations needed for interpreting magnetic data in equatorial belt.

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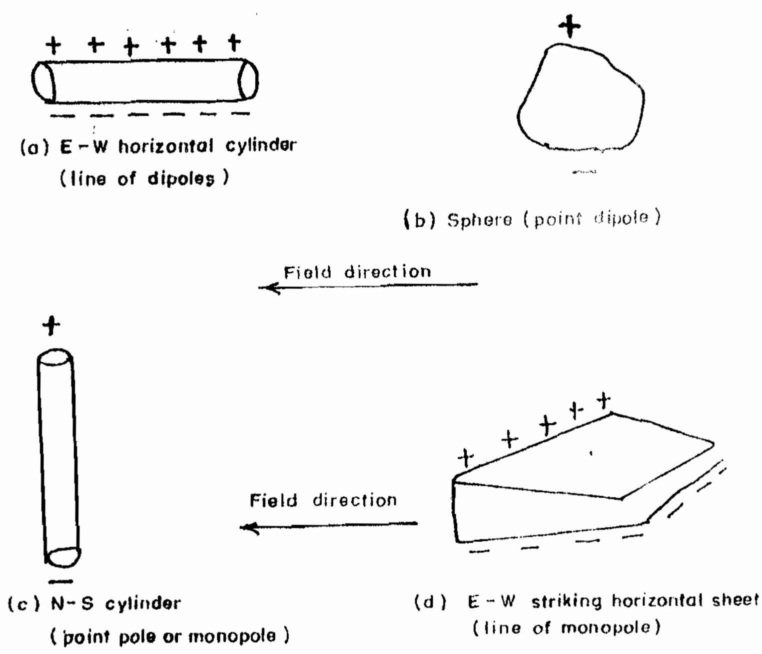


Fig. 2 Dipoles, monopoles and their equivalent line or sheet distributions in horizontal field.

THE CONCEPT OF MONOPOLE AND DIPOLE IN MAGNETIC EQUATOR

Whether a model is approximated as a monopole or dipole and its equivalent line of pole or line of dipole depends on the dimension of the magnetic source and the inclination of the geomagnetic field. Thus, narrow vertical source in horizontal field will yield a point pole as shown in figure 2c, for example, a vertical dyke. Whereas a spherically shaped source will be approximated as a point dipole (figure 2b). A magnetic source which lies in horizontal direction and very long compared to the depth to its top can be modelled as line of dipole (fig. 2a). The line of monopole (fig. 2d) can be pictured as a sill.

CHARACTERISTICS OF THE FOUR MODELS

Generally, in equatorial belt, the magneti signatures from anomalous sources are either magnetic low (dipole, figure 3a) or a high flanke by a low (monopoles, fig. 3b). Any magneti signature, which does not assume either of thes two shapes in equatorial belt, will be a pointer t remanence magnetization.

In magnetic maps where the contours ar nearly circular, they are normally from point dipolar sources (fig. 4c). However, circula contours of magnetic highs and lows adjacent t one another are due to point pole sources (fig 4a). In cases where the observed contours ar elongated, their respective magnetic sources ma be modelled as either line of monopole or line c dipole (fig. 4b and 4d).

APPLICATIONS

A relationship exists between the hal width of any anomaly and the four models. Whe this relationship is established it can be ver useful for determining depth to a magneti source. The half-width in magnetic equator fc dipolar model is the horizontal distance betwee the principal minimum of the anomaly and th point where the value is exactly one half th minimum value (Fig. 5a). For monopolar mode the half-width rule being the horizontal distanc between the points of maximum (or minimum and zero anomaly (fig. 5b).

To estimate depth to a magnetic sourc the four models and the half-width rule ar employed according to the following steps.

(1) An anomaly is recognized in magnetic map. If the contours ar elongated, then it can b approximated as either a line c monopole or line of dipole. If it i circular or nearly circular, then it i modelled as a point pole or poir dipole.

(2) If a meridional profile is taken acros an anomaly and a magnetic high i flanked by a magnetic low the mode

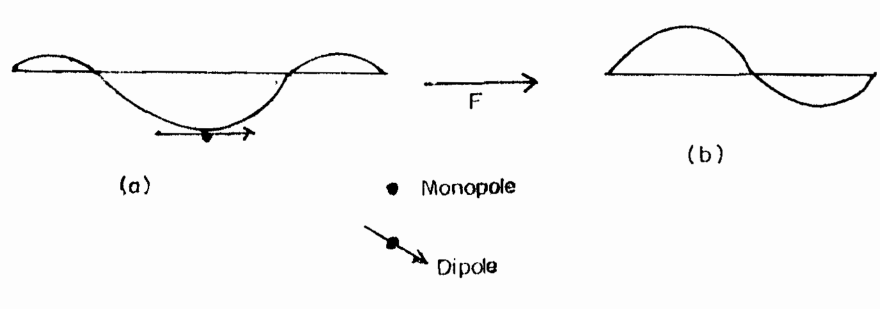


Fig. 3 Sketch of monopole and dipole for horizontal field

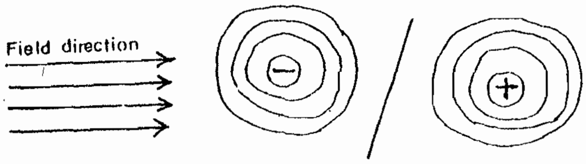


Fig. 4a : Point pole model contours

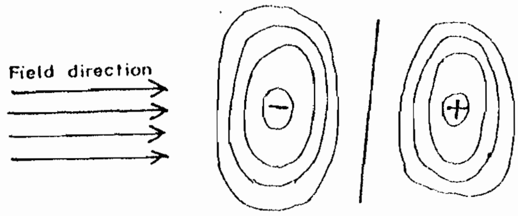


Fig. 4b . Line of monopole model contours

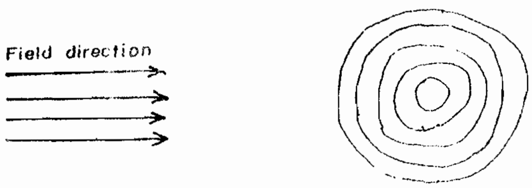


Fig. 4c Point dipole model contours

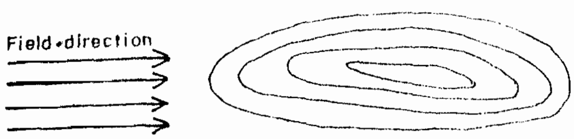


Fig. 4d Line of dipole model contours

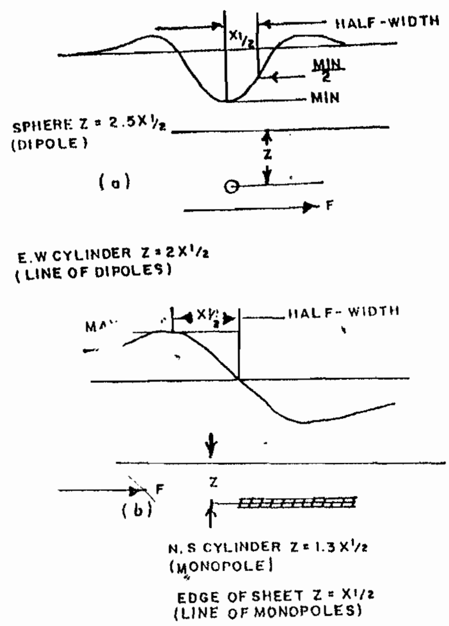


FIGURE 5 [HALF-WIDTH RULES – HORIZONTAL FIELD (EQUATORIAL). After Breiner, 1973]

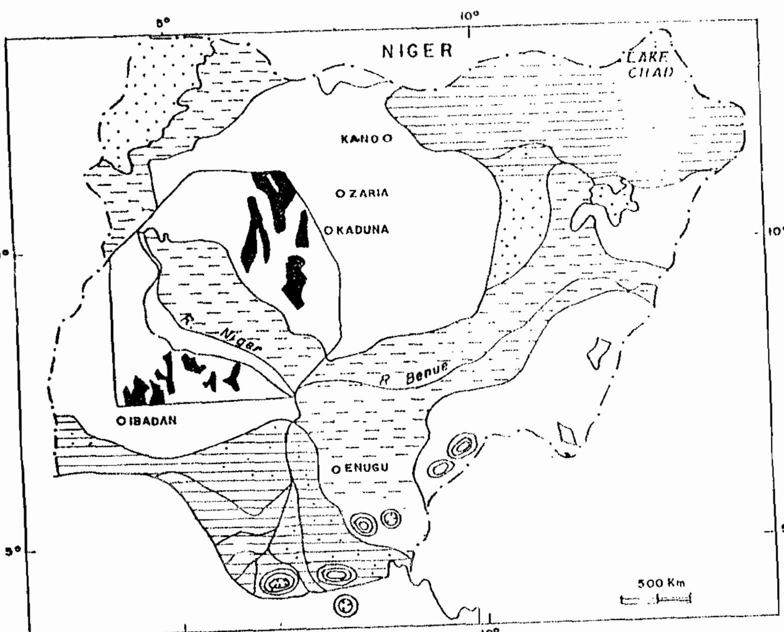
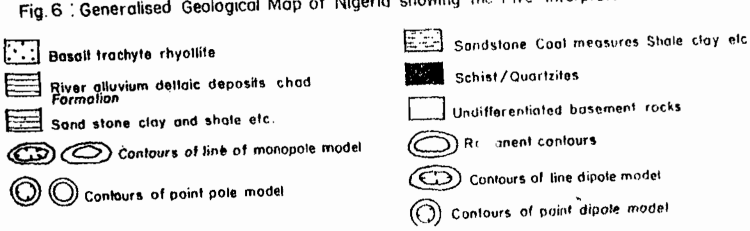


Fig. 6 : Generalised Geological Map of Nigeria showing the Five Interpretational Models



is a monopole (point pole), while an anomaly with a completely dominant low is a dipole.

(3) For depth estimates, the above criteria are used and whichever case is applicable is employed in conjunction with the half-width of the anomaly.

FIELD EXAMPLES

The four interpretational models are used to analyse some airborne magnetic anomalies from basement and sedimentary terrains in Nigeria. Four of the field examples were evaluated assuming normal induction in the earth's magnetic field and the fifth owing to remanent magnetization (magnetization in the absence of external magnetic field [Dalan and Banerjee, 1998].). The case histories in examples one to five are shown in the generalized geological map of Nigeria (fig 6).

EXAMPLES 1

The magnetic anomaly over Obudu Precambrian massif is shown in figure 7a. The contours from the anomalous source are elliptical and adjacent to each other. A meridional profile (line A A') taken across the airborne magnetic anomaly produced a magnetic high flanked by low (fig. 7b). Therefore, it is modelled as a line of monopole. The depth estimate is 1km, and

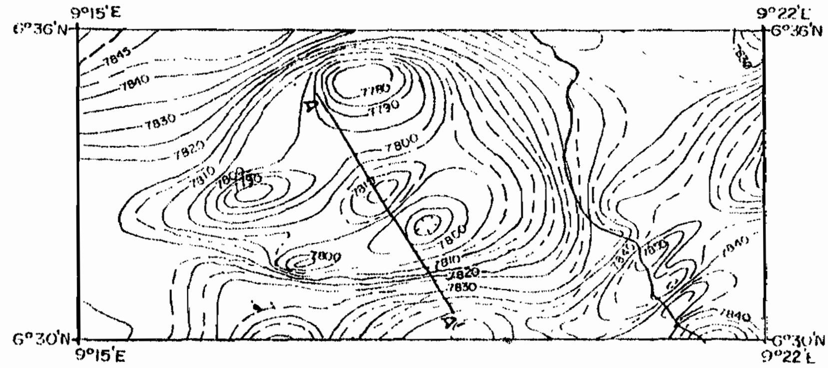


Fig.7a Aeromagnetic anomaly over Obudu Precambrian Massifs, Southeastern Nigeria Contours are in nanoTesla.

agrees closely with that value obtained by Iliya and Bassey (1993) from the same area. The inclination of the earth's magnetic field (i) in this area is – 4.33°.

EXAMPLE 2

The airborne magnetic data (Fig.8a) is from basement terrain (Uwet area) in South Eastern Nigeria. The contours from the anomalous source are adjacent and nearly circular. Line BB' gave a magnetic low in the South to magnetic high in the north (fig. 8b). The model is therefore approximated as point pole. The calculated depth to the magnetic source is 1.56km. The inclination (i) of the earth's magnetic field in this area is – 17°

EXAMPLE 3

The aeromagnetic anomaly from Niger Delta basin and adjoining offshore is shown in figure 9a. The contours are elliptical in shape. A meridional profile taken across the magnetic depression appeared as broad low (Fig. 9b). The model is therefore, recognized as a line of dipole. Sedimentary rocks are magnetically transparent; therefore, the information in the aeromagnetic map is from the basement. Therefore,

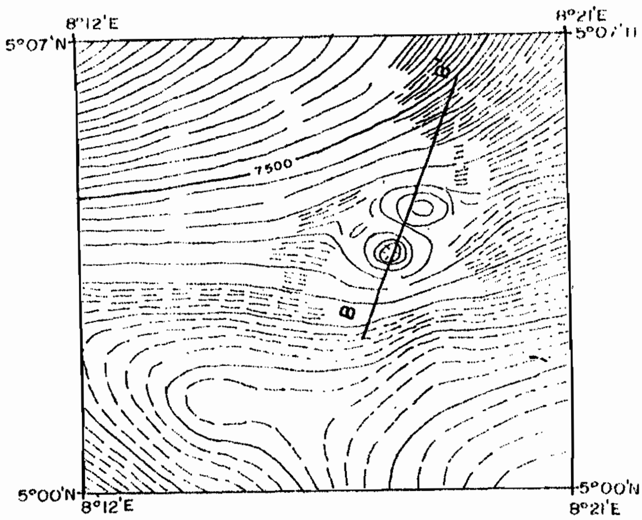


Fig. 8a Airborne magnetic data from basement terrain of Uwet area, Southeastern Nigeria.

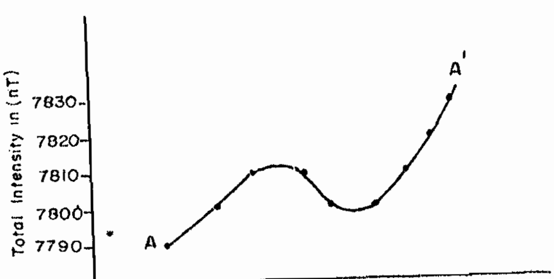


Fig.7b : Magnetic signature from basement terrain in Obudu.

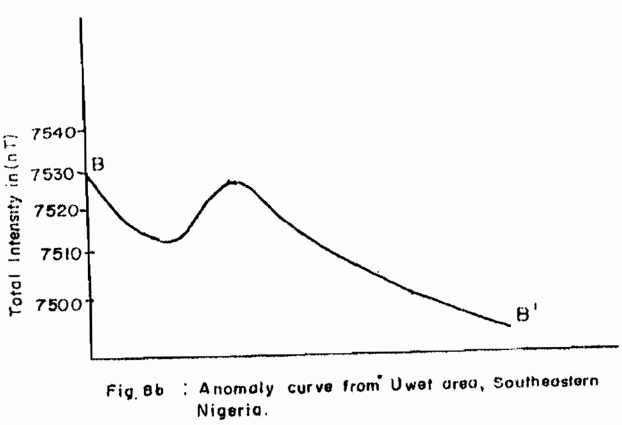


Fig. 8b : Anomaly curve from Uwet area, Southeastern Nigeria.

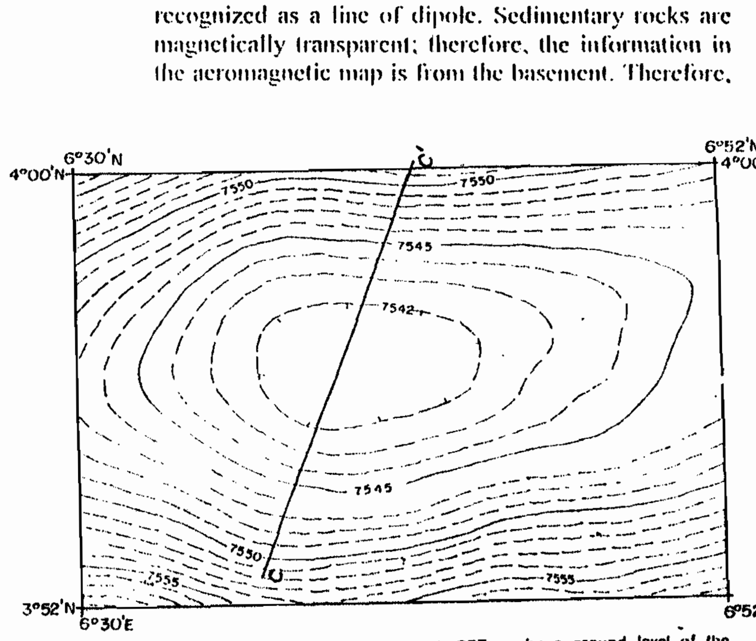


Fig 9a The aeromagnetic anomaly flown at 833m above ground level of the part of Niger Delta Basin, Nigeria

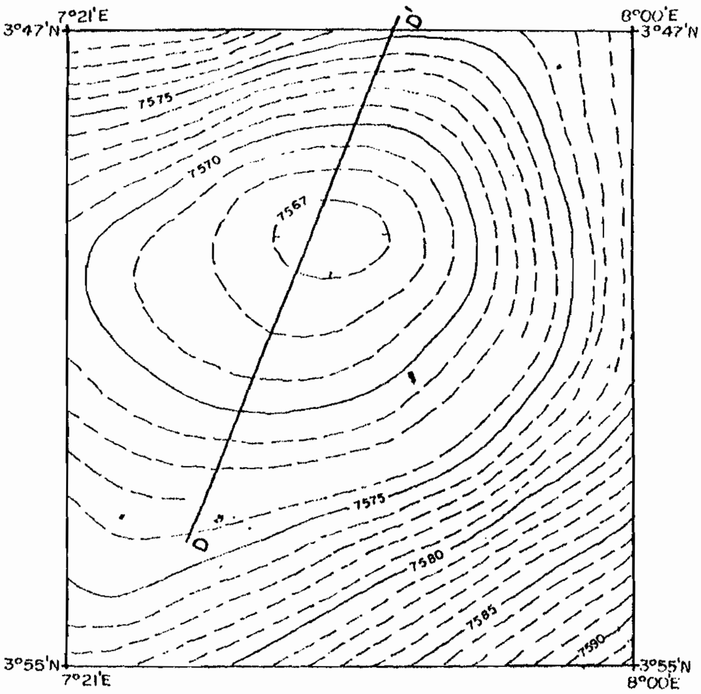


Fig.10a The aeromagnetic anomaly from the Eastern Niger Delta, Nigeria

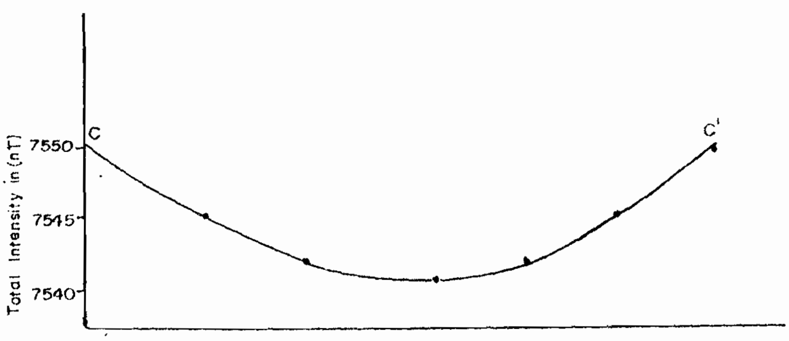


Fig. 9b : Magnetic low from line C-C' in figure 8.

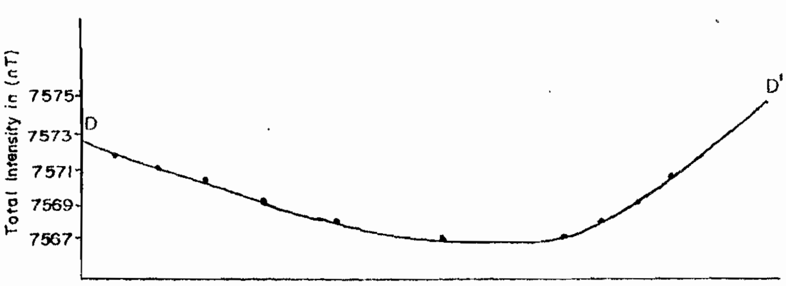


Fig 10b : Magnetic signature from line D-D' in airborne map of Eastern Niger Delta

the most logical approach is to determine depth to basement. The calculated depth, which invariably represents the thickness of the sedimentary sequence, is 8,400m. This depth estimate is not out of place in such a depocentre where the thickness of the sedimentary sequence attains a maximum value of 12,000 metres. ! = - 6°. Avbovbo (1978) reported, 8,535m of sedimentary

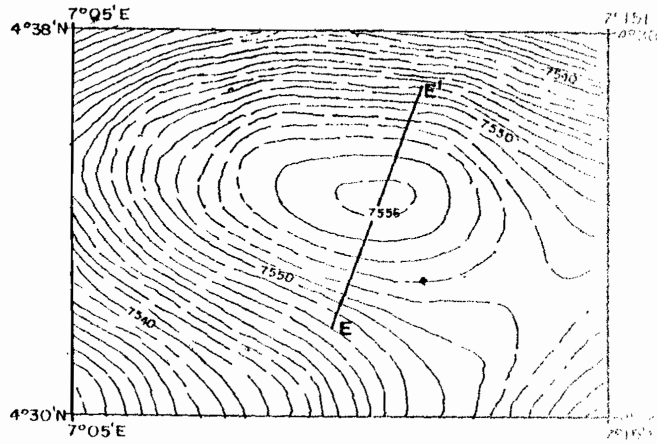


Fig. 11a : Airborne magnetic anomaly from Port Harcourt and environs, Southeastern, Nigeria

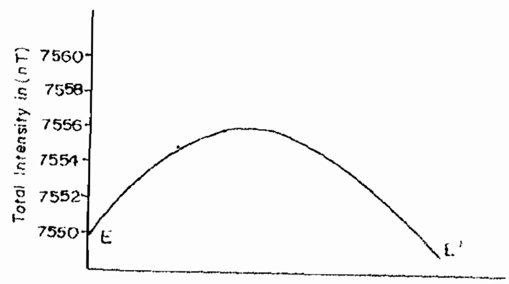


Fig 11b: Anomaly curve indicating remanence in Port Harcourt and environs, Nigeria

section at the approximate depocenter in the Niger Delta basin.

EXAMPLE 4

The contours from the airborne magnetic anomaly in Fig. 10a (Eastern Niger Delta Basin) are nearly circular. Line DD' produced a dominant low (fig. 10b). These characteristics approximate the model as a point dipole. The depth to the basement is 7,400m. i = - 17°.

EXAMPLE 5

Fig. 11a shows the airborne magnetic data from Port Harcourt and environs which lies in a sedimentary terrain. The magnetic high (fig. 11b) from the anomaly is neither a dominant low or a high flanked by low as in magnetic equator. This cannot be approximated by any of the four models. Therefore, a remanence is suspected. Inclination of the earth s magnetic field is = - 17°.

DISCUSSION AND CONCLUSION

Although, the concept of monopole appears fictitious it has been recognized by geomagnetisians in geophysical community as a magnetic body, which is very long with the upper end near the magnetcmeter and the lower end at infinity. In magnetic equator a N – S cylinder is modelled as a point pole. If a meridional profile is taken across such anomalous source, the magnetic anomaly curve will be a high flanked by low. Although, the N – S cylinder is also modelled as point pole in vertical field, the magnetized upper end has a negative pole while in magnetic equator the upper end is positive. In areas around zero latitude an E – w trending horizontal sheet is modelled as a line of poles. In higher latitude (northern hemisphere) and mid-southern latitude magnetic signatures will assume a high and high with very weak low respectively. If such signatures are recognized in any magnetic data in equatorial belt they will be interpreted as remanent magnetization. In fact, if there is a departure from the two types of magnetic signatures in magnetic equator a remanence will be suspected. In low latitude a sphere is approximated as a point dipole just like in higher latitude but the magnetic signatures are dominant low and high for horizontal field and vertical field respectively. Contours of dipolar sources are circular or nearly circular and elliptical for point dipole and line of dipole models respectively. The established relationship between the four models and half - width of anomalies is very useful in determining depth to their centers. It is important to mention that the depth estimates are more amenable to simple forms in magnetic equator and that the approximations are only suitable in areas where the plane of magnetization of the geomagnetic field is horizontal.

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