



A Short Note: A Computer Program in FORTRAN for Interpreting the Magnetic Anomalies Over Tabular Bodies

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Abstract: A computer program in FORTRAN language is written to interpret the source parameters for the magnetic anomalies over tabular bodies. Sheet, dike and vertical step models are used in this program. The program is written for the magnetic interpretation method published in Exploration Geophysics, (2009). The method is based on the characteristic positions of the magnetic anomaly profile for determining the origin, depth, width and magnetization angle of the causative source. Geometrical procedure for determining the source parameters is given in the published paper. In this paper, the interpretation procedure is automated for calculating characteristic positions and the computer program is written in FORTRAN for the method. The accuracy of the program is tested on synthetic models and the error percentage is within reasonable limits.

Key words: Computer program, dike, sheet, vertical step, characteristic positions, magnetic anomaly

I. Introduction

Numerous techniques for interpreting magnetic anomalies are available in literature. Rules of thumb may be considered as the earliest techniques of quantitative interpretation [1]; [2]. Theoretical anomaly curves were generated over different geological models for interpreting the observed magnetic anomalies [3],[4]; [5]; [6]. The curve matching is time consuming and requires an album of curves.

Another approach of interpretation is with the use of characteristic curves in which the variation of certain characteristic distances and amplitudes of the anomaly are studied in relation to the parameters of the source. Based on this principle, methods of interpretation for magnetic anomalies have been suggested. Although it is not possible to discuss the bulk of references here, notable among them can be mentioned as follows: [7],[8],[9],[10],[11],[12],[13],[14],[15],[16],[17],[18],[19]. In a review paper, [16] critically examined the interpretation methods that were published prior to 1971 and presented several new charts of characteristic curves for manual interpretation of magnetic profiles due to dikes. Reference [20] also made a comparative study of the various interpretation methods, both manual and computer oriented, that had been published up to 1971 and commended the direct interpretational methods of Koulomzine et al., (1970) [15] for their analytical correctness, speed and independence of any previous knowledge or assumption of the zero datum level. Reference [21] adapted Koulomzine et al., method to the case of a two-dimensional block, faulted at right angles to the ground surface. Reference [22] proposed a method of interpreting magnetic anomalies over tabular bodies based on certain characteristic positions for determining the source parameters irrespective of the knowledge of origin and datum.

With the availability of digital computers, suitable algorithms for automatic interpretation have been evolved by [23], [24],[25], [26], [27],[28], Rao [29], [30], [31] etc., for calculating model parameters from magnetic anomalies. As the methods for interpreting magnetic anomalies are numerous, the use of computer based methods is always preferred by professional geophysicists, since the computers are handy for all. Keeping in view the ease of the method of Subrahmanyam and Prakasa rao (2009) [22], it has been automated with a computer code by Subrahmanyam in this paper.

II. Methodology

In this technique the origin and base line can be determined from the conjugate pairs of points. The advantage of the method is that there is no limitation in the choice of number of conjugate pairs. Once the origin and datum are determined, and then the source parameters such as depth, width and magnetization angle (θ) of Sheet, dike and Fault can be determined from the symmetric and antisymmetric components of anomaly profile. The values determined from symmetric and antisymmetric components would agree. This agreement is a check on the accuracy of interpreted results.

This interpretation technique involves location of characteristic points, determination of origin by the method of circles, determination of datum and then separation of anomaly profile into its symmetric and antisymmetric

components for determining depth and width for dike bodies and depths to top and bottom, in case of fault geometrics. A computer code has been written for the entire process and the program was tested on theoretical anomalies over dike, Fault and Sheet. Real Field data over Sheet, dike and Fault were interpreted with this program.

The input to the program is magnetic anomalies and code of the assumed model. The output is the origin, datum, magnetization angle and geometric dimensions of the model. Computer code: The Program is written in FORTRAN language and compiled with FTN95 Compiler.

Stepwise procedure of the program:

All the characteristic positions of the anomaly profile are computed using interpolation techniques.

- 1) Reads the code of model, and magnetic anomalies.
- 2) Calculate Horizontal Derivatives of the magnetic anomalies.
- 3) Determines the abscissa values of zero derivative positions which correspond to maximum and minimum on magnetic anomaly profile.
- 4) Computes maximum and minimum anomaly values on the magnetic anomaly profile corresponding to the abscissa values (zero derivative positions) determined in the above step. Maximum and minimum anomaly values form a conjugate pair (figure 1).
- 5) Subtracts a specified value from maximum and minimum anomaly positions. The pair of anomaly values obtained thus by subtraction, form another conjugate pair (figure 1). The positions of these conjugate values on the abscissa are determined from the interpolation technique. Two or more such conjugate pair positions are determined.
- 6) With the co-ordinates of the conjugate pairs and following the property of right angles and circles, the origin is determined. Reference [22] shows the relevant mathematical description and graphical procedure is shown in figure 1.
- 7) The datum is shifted using the expression

$$\Delta F (M) + \Delta F (m) = \Delta F (O) = \Delta F (a) + \Delta F (b)$$

Where $\Delta F (M)$, $\Delta F (m)$ are the maximum and minimum anomaly positions. $\Delta F (a)$ and $\Delta F (b)$ are characteristic conjugate positions on the anomaly profile and A and B are their corresponding positions on the abscissa.
- 8) After origin and datum are located, the anomaly curve is separated into symmetric and antisymmetric components.
- 9) The characteristic positions S(r) & S(s) on the symmetric component and A (Max) & A (half-max) on the antisymmetric component and their corresponding position on the X- axis obtained (figure 2). S(r) & S (s) positions should be chosen following the criteria that $2[S (O) - S(r)] = [S (O) - S(s)]$ where S (O) is the symmetric component anomaly at origin. Any number of such S(s) pairs can chosen satisfying the above criteria.
- 10) Then from the relations between the characteristic distances of symmetric & Antisymmetric anomaly curves (equations are given in Ref.[22]), the source parameters such as depth, width and magnetization angle, the top & bottom depths of the fault are determined.

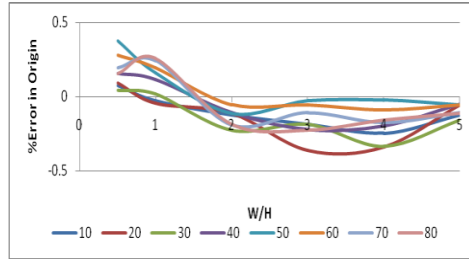
The origin and datum are located irrespective of the assumption of the geometry of the tabular source. A number is assigned to the model. Model codes 1, 2, 3 are assigned to sheet, dike and fault respectively. The program reads the mode number and goes to the particular block of the program for determining the source parameters. The computer program is attached as a separate file with file name "MAG-ANO-INT-PROF.F".

Input To Program:

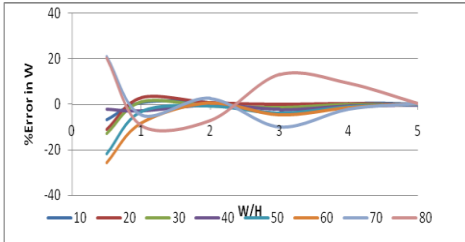
- 1ST LINE: N (NUMBER OF POINTS), M (MODEL NUMBER)
- 2ND LINE: 0.00001 (ACCURACY OF THE CHARACTERISTIC POINTS TO BE DETERMINED)
- 3RD LINE: XZ1, XZ2, XZ3, XZ4 (FIRST 3 VALUES ARE SOME ARBITRARY ANOMALY TO BE SUBTRACTED FROM MAXIMUM, MINIMUM ANOMALIES; XZ4 IS THE ANOMALY TO BE SUBTRACTED FROM MAXIMUM OF SYMMETRIC COMPONENT)
- 4TH LINE: DISTANCE, MAGNETIC ANOMALY (ONE PAIR FOR EACH ROW) ONWARDS

III. Discussion

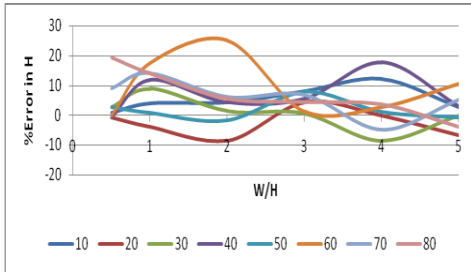
The program has been tested on a number of synthetic examples over sheet, dike and vertical fault for different combination of source parameters. The percentage error charts in the interpreted parameters are shown in figure 3 (sheet), figure 4 (dike) and figure 5 (vertical fault). The percent of error in all cases is within reasonable limits less than 20% and the percent error in the case of origin is less than 0.5% for all the models. This shows the accuracy of the method in the location of source which is more important. But in some cases for the large



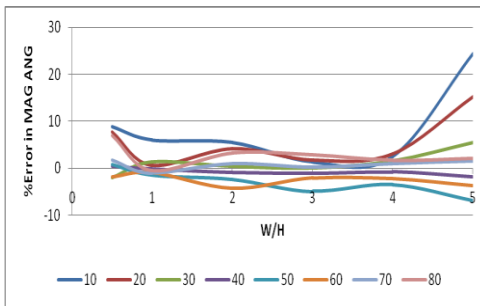
(a)



(b)

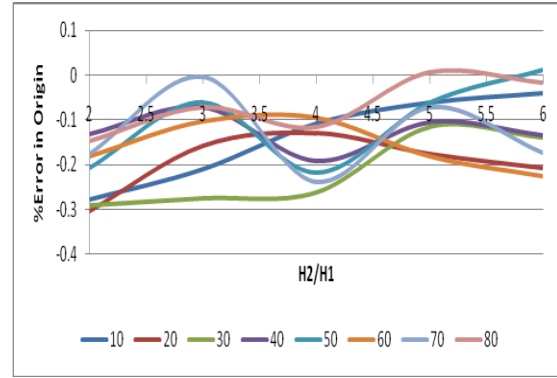


(c)

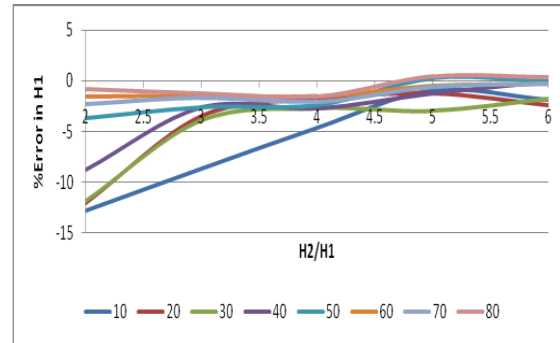


(d)

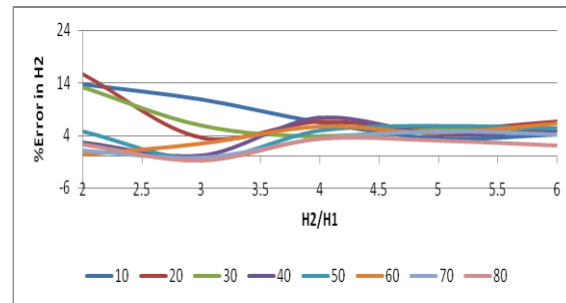
Fig. 4. Percent error analysis charts for varying directions of amagnetisation angles. The legend for magnetisation angles is given at the bottom of each figure (a) Percent error in origin against w/H (half width/Depth) for different magnetisation angles. (b) Percent error in w (half width) against w/H for different magnetisation angles. (c) Percent error in depth (H) against w/H for different magnetisation angles. (d) Percent error in magnetisation angle (MAG ANG) against w/H for different magnetisation angles.



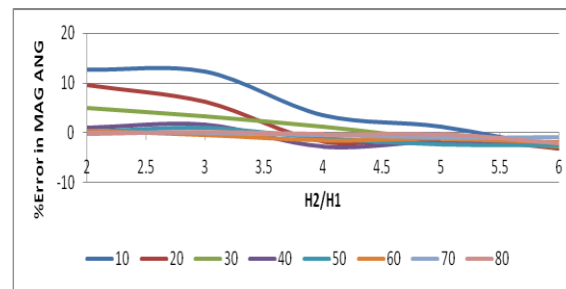
(a)



(b)



(c)



(d)

Fig.5. Percent analysis charts for vertical step model for varying direction of magnetisation angles. (a) Percent error in origin against H2/H1(depth to bottom/depth to top) for different magnetisation angles. (b) Percent error in depth to top(H1) against H2/H1 for different magnetisation angles. (c) Percent error in depth to bottom (H2) against H2/H1 for different magnetisation angles. (d) Percent error in magnetisation angle(MAG ANG) against H2/H1 for different magnetisation angles.

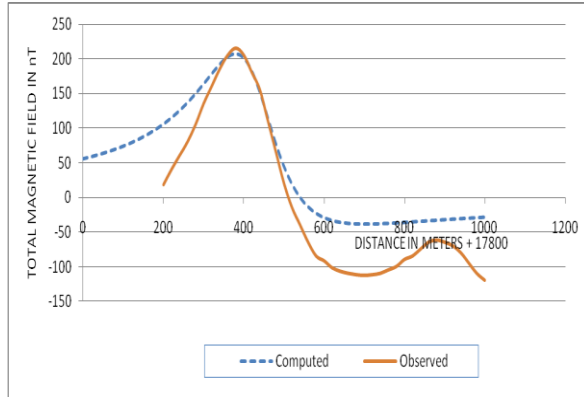


Fig.6. Total magnetic field profile (continuous line) of aeromagnetic data of Abitibi sub province of northeastern Ontario, Canada (Keating and Pilkington, 2004, Profile L-81921 of Figure 5a [32]). Dashed line is the computed profile interpreted with sheet model. Interpreted results are shown in Table 1.

Table 1: Interpreted results of total magnetic field profile of aeromagnetic data of Abitibi sub province of northeastern Ontario, Canada (Keating and Pilkington, 2004, Profile L-81921 of Figure 5a). This profile is shown in figure 6 and is interpreted with sheet model.

Method	Depth to the top of source from magnetic sensor in meters (height of sensor from ground surface is 72meters)	Location of the source in meters + 17800	Magnetization angle in degrees	C _F size parameter
Present Program	116.2	430	-46.5	28478.0
Keating and Pilkington, 2004	139	450	-	
Drilled results of nearby borehole from the magnetic anomaly profile	Depth to the source: 41m from ground surface	-	-	

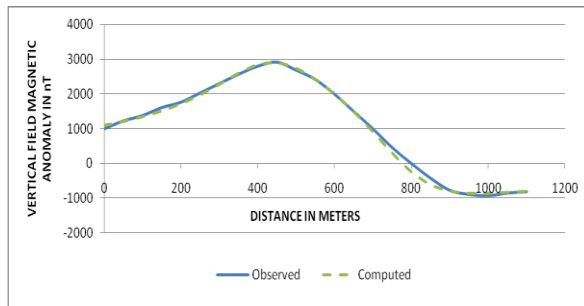


Fig.7. Vertical magnetic anomaly profile (continuous line) in Marcona district Peru. (Taken from Gay, 1963, fig.11). Dashed line is the computed profile interpreted with dike model. Interpreted results are shown in Table 2.

Table 2: Interpreted results of vertical magnetic anomaly profile in Marcona district Peru. (Taken from Gay, 1963, fig.11[3]). The profile is shown in figure 7 and is interpreted with dike model.

Method	Half width (W) in meters	Depth to top(h) in meters	Magnetisation angle (θ_F) in degrees	Origin in meters	Datum shift in nT	Size parameter (C _F)
Present Program	198.4	144	-52.0	596	-	1777
Parker Gay (1963)	186.0	124.0	-50.0	-	-	-
Koulomzine et al., (1970)	206.0	126.7	-50.1	-	-	-

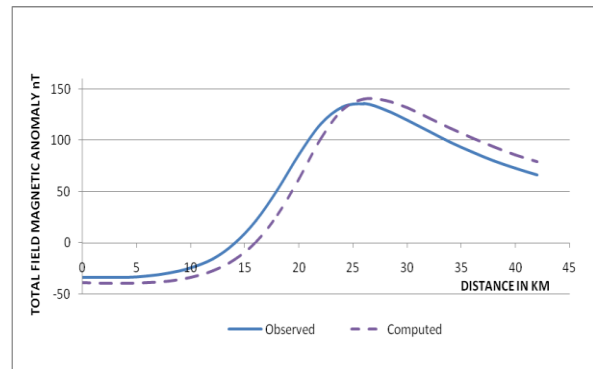


Fig.8. Total field magnetic anomaly profile (continuous line) in Western margin of Perth basin, Australia (Taken from Qureshi & Nalaye 1978, Fig.5). Dashed line is the computed profile interpreted with vertical step model. Interpreted results are shown in Table 3.

Table 3: Interpreted results of total field magnetic anomaly profile in Western margin of Perth basin, Australia (Taken from Qureshi & Nalaye 1978, Fig.5 [21]). The profile is shown in figure 8 and is interpreted with vertical fault model.

Method	Depth to top(h) in meters	Depth to bottom(H) in meters	Arbitrary Magnetisation angle (θ_F) in degrees	Origin in meters	Size parameter (C _F)
Present Program	5.2	16.3	327	22.0	166
Qureshi & Nalaye (1978)	6.8	15.5	-	-	-

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