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Magnetic Depth Estimation for Dyke-Like Bodies by Using Fraser Filter – A New Scheme

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ABSTRACT

Depth estimation for dyke like bodies has been investigated through using Fraser filter. The procedure consists of applying Fraser filter to magnetic profiles data due to dyke-like sources. Three ways of calculation are followed to estimate the depths of these bodies and good results with low percentage errors are achieved. Firstly, defining the width of the profile at two third of maximum amplitude of the residual filtered out data gives directly the depth to the top of the body. Secondly, plotting filtered data values at various levels of amplitudes against distances between points of these levels at the two lines of maximum slopes of the residual profile give a straight slope line. A projection line from the amplitude axis at two third value of maximum amplitude to the slope line read directly at distance axis the depth to the top of the body. Thirdly, the zero crossover distance defined on the plot of filtered data against distance divided by two gives directly the depth to the top of the body.Low percentage errors are found by applying the three ways, although there are small variations between them, most values are too low. This method of depth estimation is also applied to published field example and the result is too good. The procedure is simply applied and it gives a reliable and accepted depth values compared with actual depth values of the dyke-like bodies. The present procedure can be considered as a new scheme for depth estimation of magnetic sources if one considers the low percentage errors and the success of the results particularly in mid latitudes.

Introduction

The depth to a magnetic source is a piece of information of great value in geological/geophysical interpretation of subsurface structure. Much of the literature on magnetic potential field data is directed at estimation of the depth of a source. Several methods have been developed to estimate the magnetic depth. The number keeps growing with continual development of new algorithms (1).

The relative amplitude of a given anomaly has shown to be a function of the earth's field direction, the configuration of the source and the remnant magnetization. The maximum amplitude of an anomaly is largely a function of the depth and the contrast in the mass of magnetite and to a lesser extent, the configuration of the source.

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Peters slope half–slope method (2) is one of the earliest magnetic estimate techniques. The depth to the top of the body is proportional to the horizontal distance between two parallel lines that pass through the maximum and minimum of an anomaly and have a slope equal to one half the maximum horizontal gradient of the anomaly. This method has improved by Bean ratio method (3) by introducing a regional slope thus removing the effect of a local regional field.

A semi automatic technique has been proposed by Naudy (4). The method work through a folding technique (i.e. split the field curve into symmetrical and antisymmetrical components) it first locates anomaly center and then estimates depths by matching the symmetric component to responses to a given vertically magnetized, two dimensional model. Werner method was originally designed to solve the dipping thin dyke problem (5). The symmetrical curve for horizontal and vertical gradients of the magnetic field of dyke-like models is used to deduce the various parameters of the model(6). This simplified geometry leads to linearization of a complex, non linear, magnetic inverse problem. The solution of a linear system can be then used to estimate the horizontal position, depth, product of susceptibility and thickness of the dyke and dipping angle of the dyke.

Atchuta et.al. (7) and Roest and Verhoef (8) have used the anomaly width at half the amplitude to derive the depth. Atchuta et.al. used the characteristics of the analytical signal which he referred to as complex gradient to solve the effect of overlapping edges. They give relationships that can be used to estimate the depths for geometric bodies.

There are several depth rules that can be used to determine a body depth (9,10,11). The depth estimates derived from any of the techniques described are seldom more accurate than 10 percent of the actual depths and sometimes as poor as 50 percent (12). By theory, most of the estimates are maximum estimate so that the real source will actually be at a shallower depth.

Although the published methods on depth estimation have treated the various geometric shapes as magnetic sources are many, looking for simple and reliable methods is continuing. Therefore, in the present paper the profile shape of filtered magnetic data due to dyke-like bodies obtained through adopting Fraser filter procedure on synthetic magnetic profiles of these bodies (13) is investigated to determine the depth to magnetic sources.

Magnetic Profiles for Dyke-Like Bodies

Magnetic profiles due to thick dykes with various depths, widths and different inclination angles of magnetic field are calculated (Fig. 1). Other parameters are kept constant. Calculations are based on a ready used computer program issued by Geophysical Software Solution Pty. Ltd 2002-2005. The magnetic source parameters for magnetic profiles are exhibited in figure (1). The inclination angles used are 10,40,45 and 70 degree which are representing a good range of latitudes.

The magnetic profiles have various amplitudes and different positions of zero value above the source center. These are digitized at an equal distance interval in order to be used in calculating the filtered output by adopting Fraser filter (13).

Application of Fraser Filter

Fraser filter technique used in the present work interprets the magnetic profiles to estimate the depth of magnetic sources as dyke-like bodies. These dykes have variable depths, inclination angles and some have variable widths. The following steps are applied to treat the magnetic data to determine the depths of these models. These consist: a) digitization of magnetic profile at equal distance interval; b) filtered out the digitized data by using Fraser filter (13); c) the filtered output consists of the sum of the magnetic data at two consecutive magnetic values (T3+T4) subtracted from two consecutive magnetic values before (T1+T2) (i.e. (T3+T4)-(T1+T2)). The first calculated value for the output should be plotted at a mid point between T2 and T3.

Depth Estimation Procedure

The total magnetic anomaly profiles with the filtered output data for each profile is plotted against distance (Figs.2a,3a,4a,5a). A background trending line is drawn for the filtered profile. Then, the difference between the background line and the filtered profile values is calculated. The difference values, representing residual values, are re-plotted against distances that define the zero level and organize the anomaly shape (Figs.2b,3b,4b,5b). The maximum amplitude of each residual profile value is defined and divided by three in order to delineate the two third value of the maximum amplitude of the residual data. Best maximum slopes at two sides of the residual anomaly are defined. The distance between the intersection points at the two third amplitude value with the straight slope lines represents the depth to the top of the body or the magnetic source. Here, the distance at the two third amplitude of maximum value should be carefully defined because any slight change may produce a large error in depth estimates which is depending on the distance scale.

A second procedure can be followed to determine the depth. This includes measuring distances between the two slope lines at various amplitude levels.

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Re-plot these amplitude values against measured distances, the outcome will be a straight line Figs.(2c,3c,4c,5c). Then, a horizontal line from the two third maximum amplitude value, defined at amplitude axis, projected on the slope line. The vertical projection on distance axis from the intersection point read directly the depth value and it gives estimated depth to the top of the body. It is important to notice here that sources with same depths have similar slope values and those sources having various inclination angles and width have various slope angles.

A more rapid , simple and direct way to estimate source depth is by measuring directly the zero level crossover distance (C.O.) from the plot of filtered data against distance(as shown in Figs.2a,3a,4a,5a). Divided this distance by two will give an estimated depth to the top of the body.

Depth Estimation Results

Sixteen cases of magnetic anomaly profiles due to dyke-like bodies having various depths and inclination angles are treated in the present study in addition to field example case. The above three ways of depth estimation are applied to these profiles shown in mentioned figures above and the estimated depths are compared to the actual values. The percent errors on depth estimation are calculated and presented on Figure (6). The outcome from the application of Fraser filter to magnetic data is very encouraged. This due to the simple of the procedure followed in calculation and application and also to the good results obtained. Judgment on the results is depending on the percent errors accompanied depth estimation (Fig.6) where most values are too low compared to published depth estimation methods.

The effect of increasing width of source body with fixed depth is also investigated in the present paper. The shape of residual curves of the filtered data due to these dykes is shown in Figure (7). The width and amplitude of these curves are increased with increasing width of the dyke body. The estimated depths by the present procedure of calculation from these curves show the increasing of percent error with increasing width (Fig. 6c).

The depths estimated from defining the width of the filtered anomaly at the two third of maximum amplitude of the filtered data give a percent errors ranging between 0.5-13% and mostly of low values except few cases as shown in Figure (6). The depth estimated by plotting slope line is giving approximately the same value. The zero crossover procedure shows a percent errors some how larger than the other two ways of calculation but still mostly of low values less than 10%. Around inclination angle 40 degree the errors are more acceptable and consistent. As one goes to inclinations near the equator and the pole, the percent error values gradually increased. However, the whole percentage values are within an accepted range if one considers the complicated nature of the magnetic potential field and the easy application of this procedure to perform. Also, the percentage errors are so small if they are compared with the results of other methods of depth estimation to magnetic sources.

Field Example

Magnetic field example over the Pima copper mine in Arizona (Fig.8) that has been analyzed by (14) and reinterpreted by (15) through using displacement of the maximum and minimum by upward continuation is treated here by the present procedure of depth estimation. The total magnetic values are used in the present case to calculate the filtered data. The steps mentioned above about depth estimation are followed. The depth value is found to be 65.5m compared to value of 69.8m and 73m given by Gay and Kara et.al. The actual depth of the ore body obtained by drilling was 64m (14) which highlights the applicable of the present procedure. They used the vertical component in their calculation while in the present estimation the total magnetic field due to the ore body is used.

Conclusions, Discussion and Recommendation

The outcome from the application of Fraser filter to treat magnetic profiles and estimate depth to magnetic sources is very successful and reliable due to the low percentage errors arose for model studies. Dykes are so common in nature as geologic structures that creat magnetic anomalies. Therefore, the present procedure of depth estimation is providing a simple procedure with low percent errors that can be used for magnetic interpretation. This reflects the impression about the success of the present procedure in depth estimation.

Although the present models give smooth and isolated magnetic anomalies which making the selection of background line is so easy, particularly at mid latitudes. Certain difficulties should be considered in defining the background line in cases of high and low inclination angles due to the shape of the magnetic anomalies accompanied these angles. Choosing the best line will define the proper value at two third of maximum amplitude position. The low percentage errors and the result from field example highlight the importance of the present scheme for depth estimation. Therefore, Fraser filter technique can be recommended to be applied to magnetic profiles for depth interpretation, which help in interpreting magnetic anomalies.

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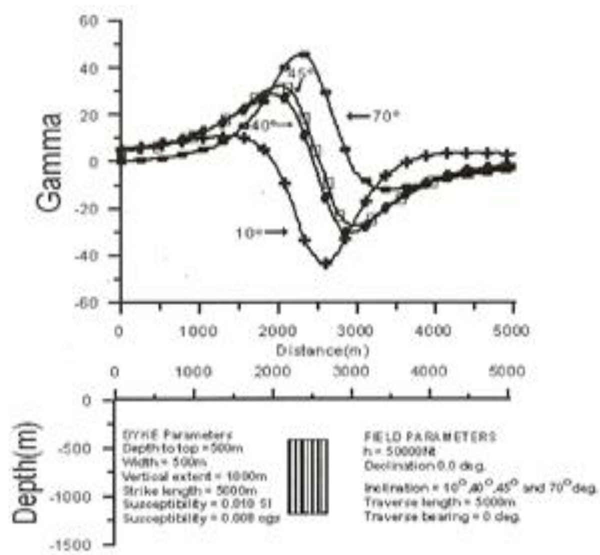

Fig.(1) Total magnetic anomaly profile for dyke-like body with inclination angles 10,40,45,and 70 degrees.

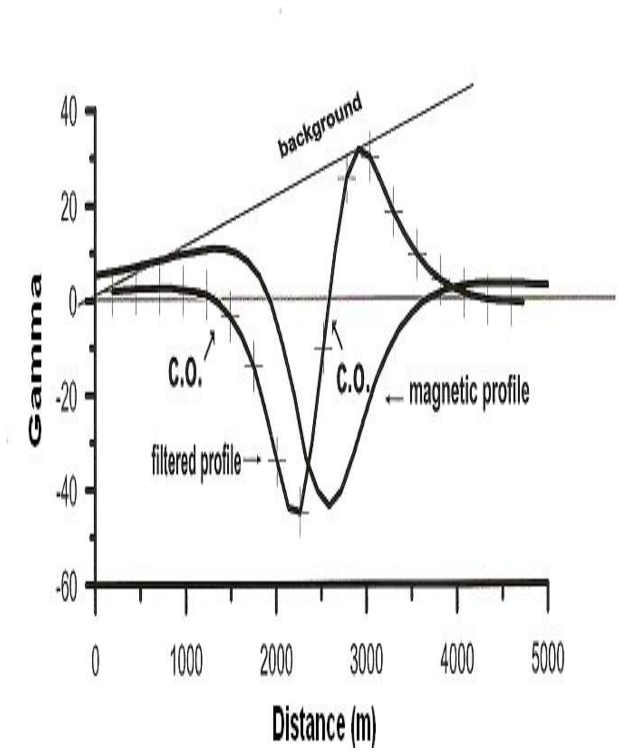

Fig.(2a) Magnetic anomaly profile for dyke-like body (depth 500, width 500, inclination angle 10^o) with its filtered profile using Fraser filter.

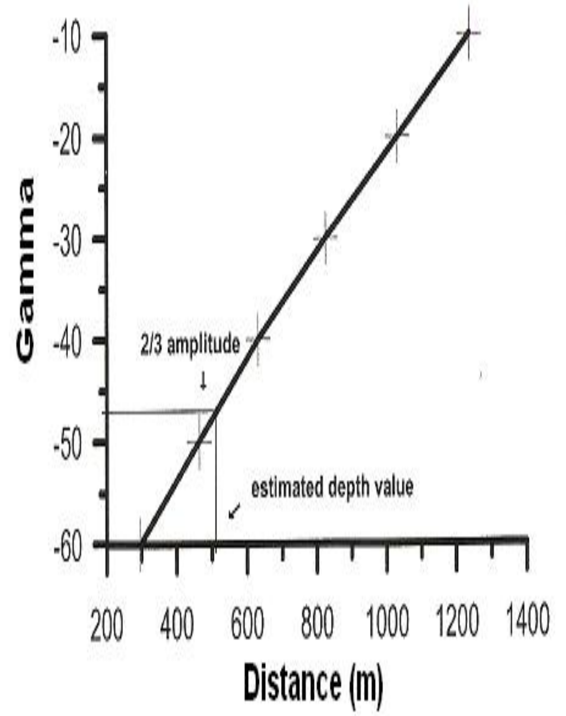

Fig.(2c) Depth estimation of dyke-like body from the relation of various amplitudes against distances between two straight lines of filtered profile.

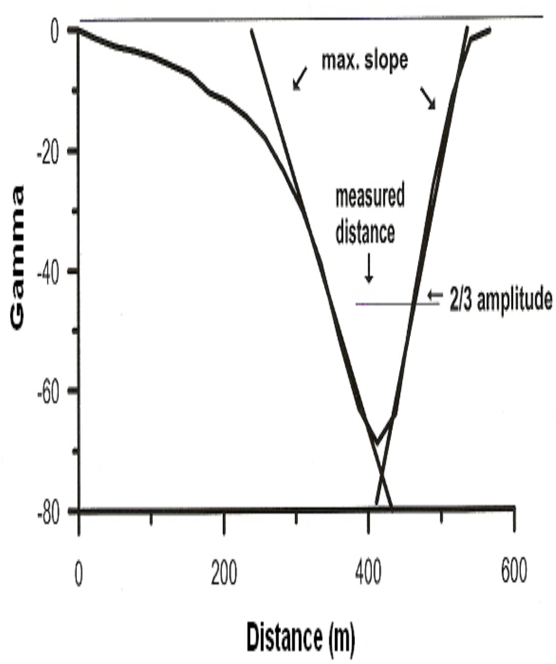

Fig.(2b) Residual curve obtained by subtracting Fraser filter values from background for the above magnetic profile.

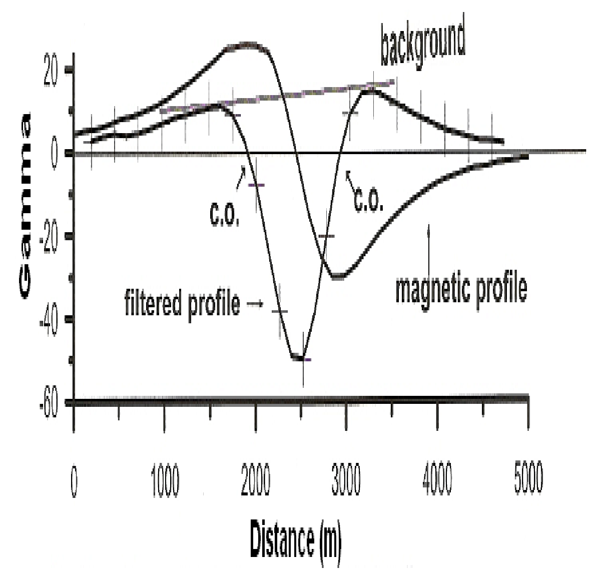

Fig.(3a) Magnetic anomaly profile for dyke-like body (depth 500, width 500, inclination angle 40o) with its filtered profile using Fraser filter.

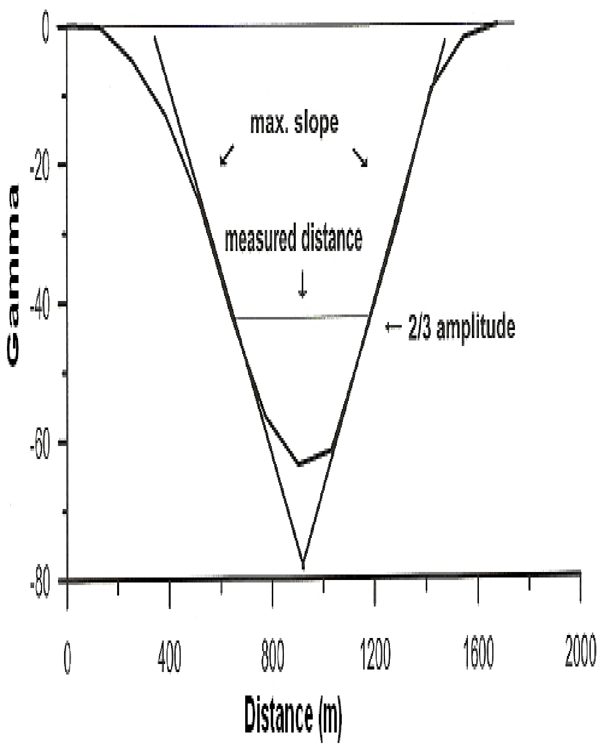

Fig.(3b) Residual curve obtained by subtracting Fraser filter values from background for the above magnetic profile.

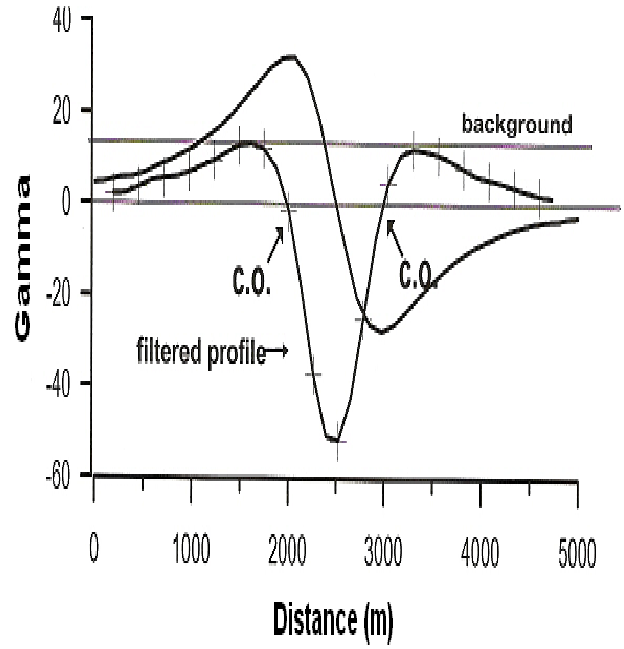

Fig.(4a) Magnetic anomaly profile for dyke-like body (depth 500, width 500, inclination angle 45o) with its filtered profile using Fraser filter.

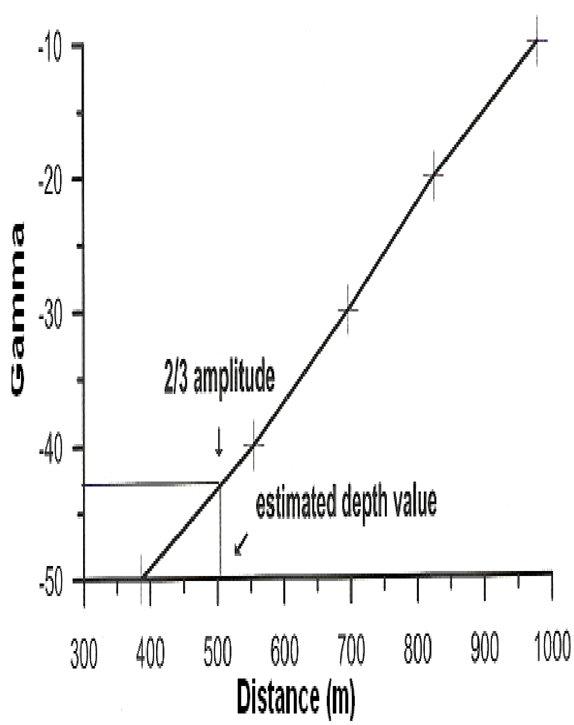

Fig.(3c) Depth estimation of dyke-like body from the relation of various amplitudes against distances between two straight lines of filtered profile.

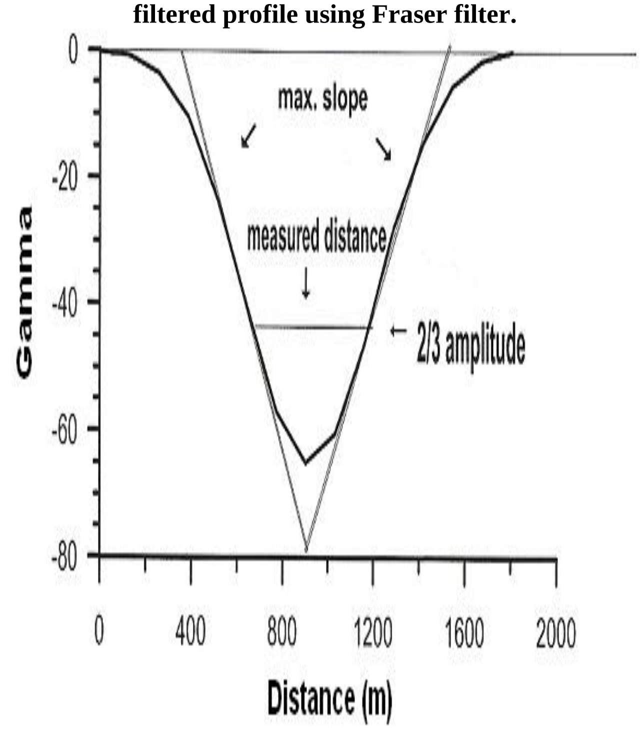

Fig.(4b) Residual curve obtained by subtracting Fraser filter values from background for the above magnetic profile.

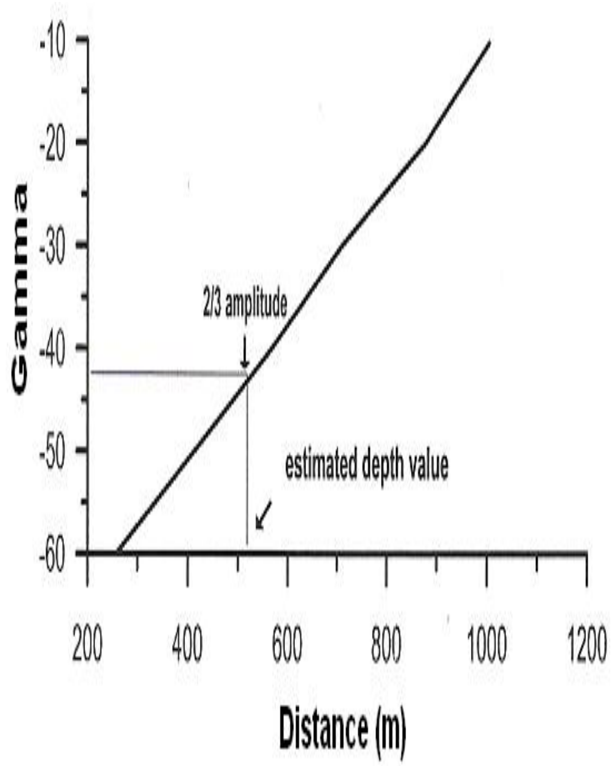

Fig.(4c) Depth estimation of dyke-like body from the relation of various amplitudes against distances between two straight lines of filtered profile.

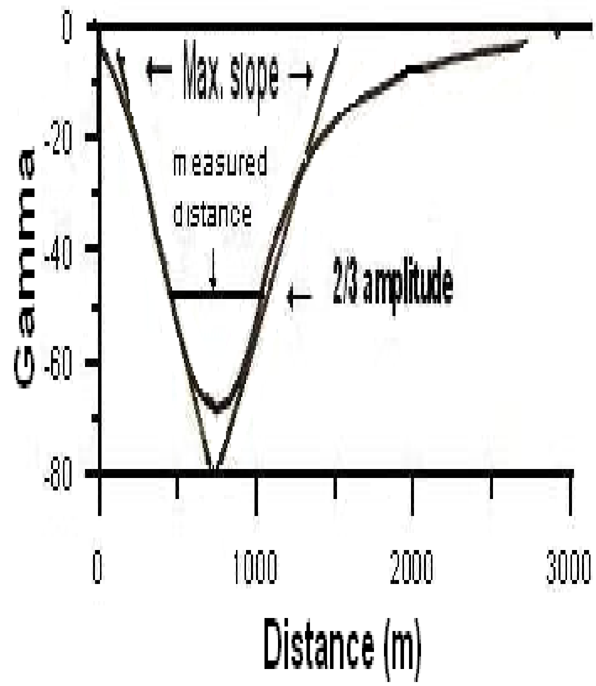

Fig.(5b) Residual curve obtained by subtracting Fraser filter values from background for the above magnetic profile.

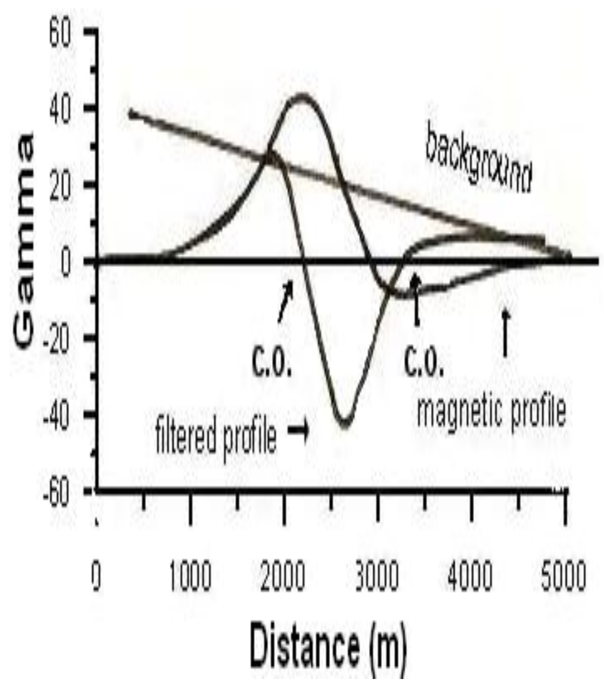

Fig.(5a) Magnetic anomaly profile for dyke-like body (depth 500, width 500, inclination angle 70o) with its filtered profile using Fraser filter.

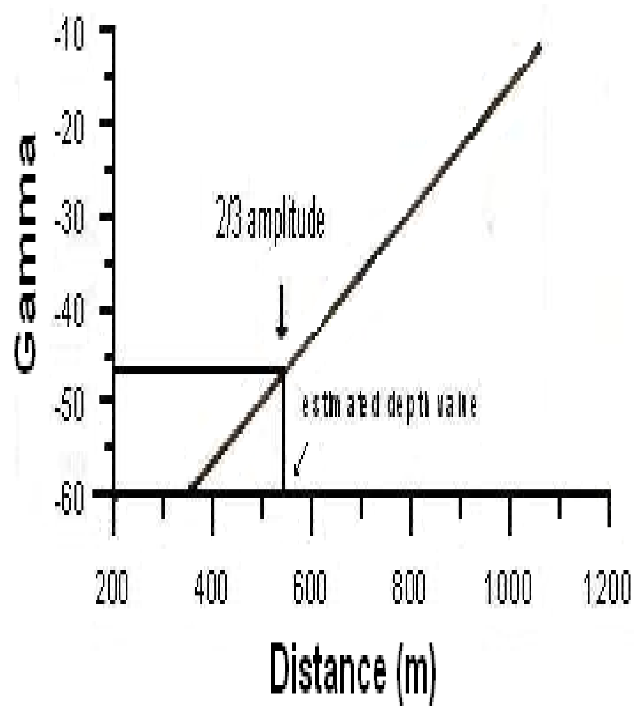

Fig.(5c) Depth estimation of dyke-like body from the relation of various amplitudes against distances between two straight lines of filtered profile.

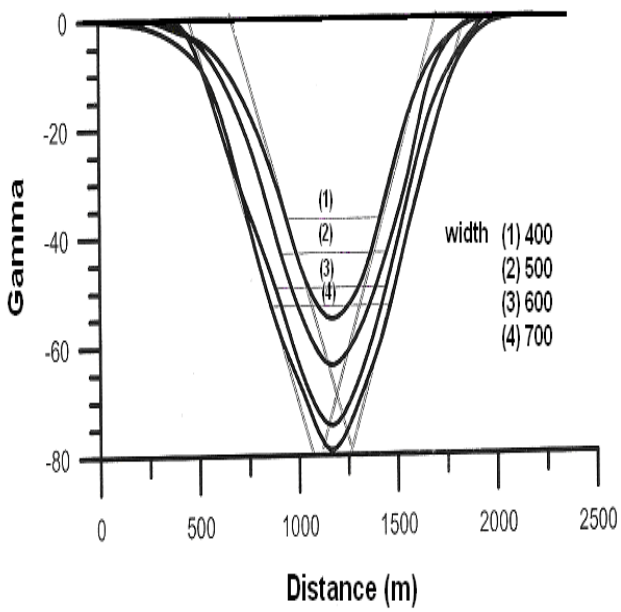

Fig.(6) Residual curve obtained by subtraction Fraser filter values from background for magnetic profile for dyke-like body with same depth of 500m, various widths and with inclination angle 40o.

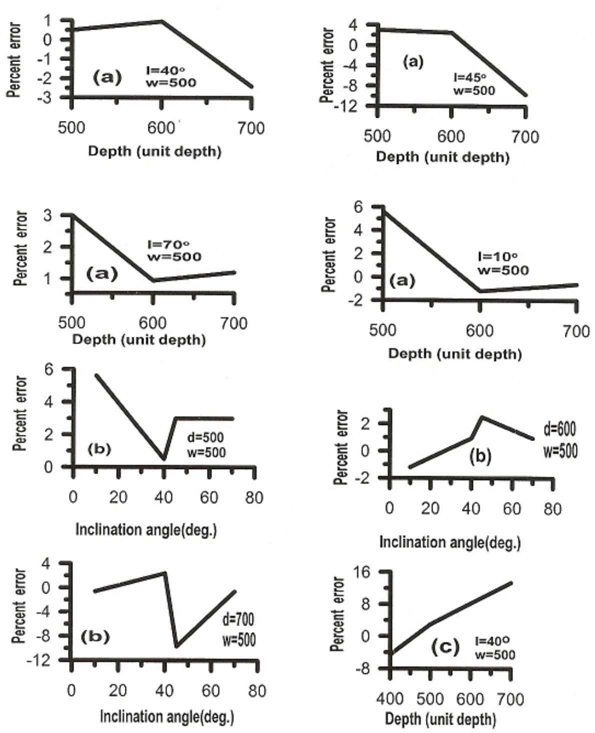

Fig.(7) Percent errors in depth estimation for dyke-like bodies a) same inclination with angle various depths, b) same depths and width with different inclination angles, c) same depth and inclination angle with different widths.

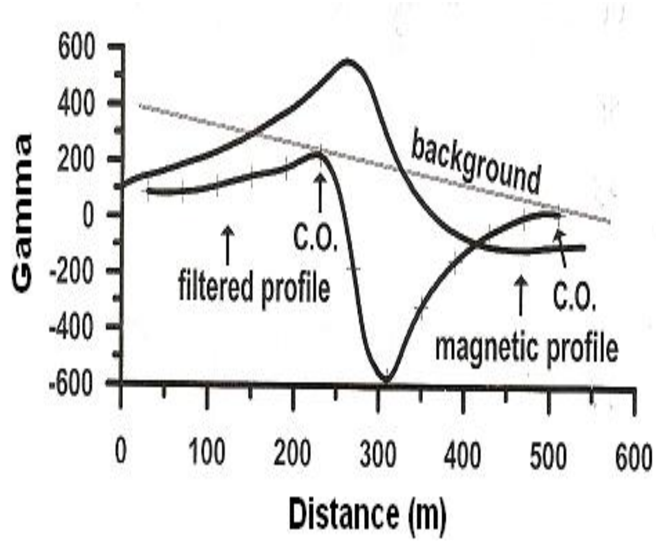

Fig.(8a) Field example of the total magnetic profile and its filtered profile obtained by applying Fraser filter. (magnetic anomaly after Kara et.al. 2003)

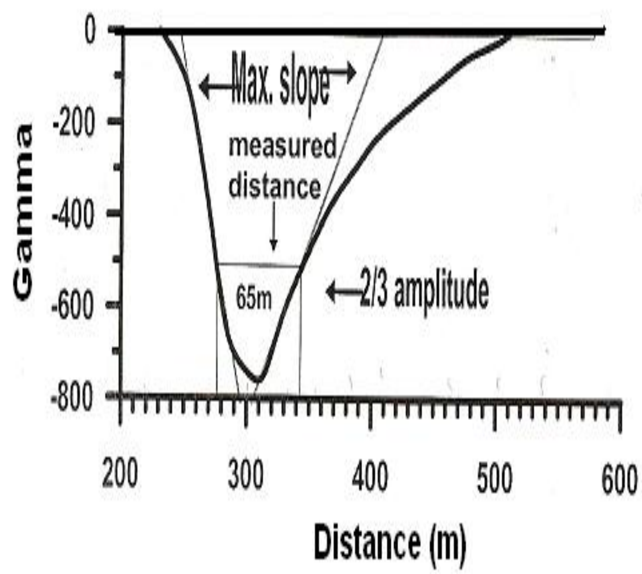

Fig.(8b) Residual curve obtained by subtracting Fraser filter values from background for magnetic field profile.

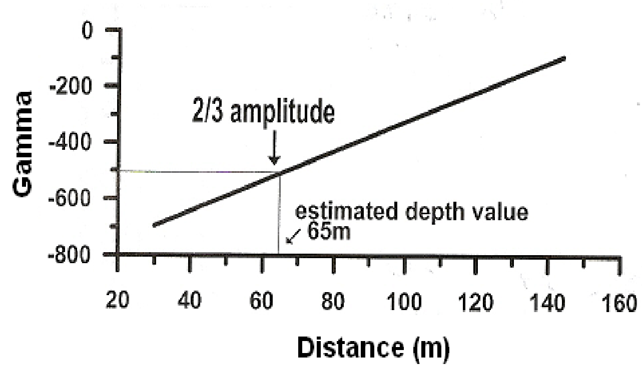

Fig.(8c) Depth estimation of magnetic source body from the relation of various amplitudes against distances between two straight lines of filtered field profile.

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حساب عمق اجسام مغناطيسية تشبه القاطع باستخدام مرشح فريزر– اسلوب جديد

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الخلاصة:

تم البحث في حساب العمق لأجسام تشبه القاطع عن طريق استخدام مرشح فريزر. يشتمل ألأسلوب على تطبيق مرشح فريزر على معلومات لمسارات مغناطيسية تعود الى مصادر تشبه القاطع. اتبعت ثلاث طرق في الحسابات لتقدير الاعماق لهذه الاجسام وقد تم الحصول على نتائج جيدة ونسبة خطا مئوية واطئة. الاولى تمت عن طريق تحديد عرض المسار عند قيمة ثلثي اقصى سعة للمتبقي من المعلومات المرشحة وهذه اعطت مباشرة قيمة العمق الى قمة الجسم . الطريقة الثانية تشمل رسم قيم المعلومات المرشحة عند مستويات مختلفة للسعات مقابل المسافات بين النقاط عند تلك المستويات للخطين الممثلين لاقصى ميل لمنحي المسار المتبقي والتي اعطت ميل لخط مستقيم . وعند اسقاط خط مستقيم من محور السعة عند قيمة ثلثي اقصى سعة للمتبقي على الخط المائل يقرا مباشرة عند محور المسافة قيمة العمق الى قمة الجسم. تتضمن الطريقة الثالثة تحديد نصف المسافة بين نقطتين ناتجة من تقاطع الخط عند قيمة الصفر لمنحني المتبقي لمرتسم المعلومات المرشحة مقابل المسافة لتعطي مباشرة العمق الى قمة الجسم.عند تطبيق الطرق الثلاث اعطت نسب مئوية واطئة بالرغم من وجود بعض الاختلافات بينهما الا ان معظم القيم واطئة جدا. كذلك تم تطبيق الطريقة لحساب العمق على مثال حقلي منشور وكانت النتيجة جيدة جدا. ان هذا الاسلوب بسيط التطبيق ويعطي قيم للاعماق معول عليها ومقبولة مقارنة مع قيم الاعماق الحقيقية لاجسام تشبه القاطع. يمكن اعتبار الاسلوب الحالي على انه اسلوب جديد في حساب اعماق مصادر المغناطيسية اذا اخذ بنظر الاعتبار نسب الاخطاء المئوية الواطئة ونجاح هذه النتائج خصوصا عند خطوط العرض المتوسطة.