Application of Logistic function technique for structural mapping: Application to the gravimetric data of Ougarta Mountains

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Abstract— The Ougarta Mountains are located at the extreme West of the Algerian Sahara in the Algerian Moroccan border; this area includes various Precambrian to post Paleozoic geological and litho-structural units. It correspond to the limit between the West African Craton (WAC) and the pan-African domain, , Gravity data derived from GRACE mission combining terrestrial marine and satellite data were used to understanding the subsurface geology; the edge of anomalous bodies provides important information in structural and mining studies, the present paper compares the effectiveness of various used techniques for edge detection such as Analytic signal, Tilt angle, Theta angle, Tilt angle of the horizontal gradient , modified Theta angle, Normalized Tilt angle and the Logistic function of the total horizontal gradient , the cited techniques are tested on a synthetic model and also to the real gravity data of the Ougarta area

***Key-Words*— Theta map, Logistic function, Synthetic model, Ougarta**

I. INTRODUCTION

High resolution geophysical data are of paramount importance understanding the deep structure and dynamics of the crust, edge detection techniques in potential field data are essential tools in geologic interpretation based generally on vertical and horizontal derivatives of the total field, most used is Analytic signal Amplitude (AS) introduced by [1], called also the total gradient, in a planar grid the maxima values of the AS are used to identify lateral boundaries. The method perform poorly enhancing shallow and deep anomalies because it cannot balance the amplitude of different anomalies[2],[3], Pham et al [4],Miller and Singh [5], proposed the tilt angle method based on balancing the amplitudes edges by normalized derivatives of the potential field. Defined as arctangent of the ratio of the vertical derivative to the total horizontal derivative of the potential field.

Chen et al [6], introduced the Modified theta map (MTM) defined as the arc cosines of the ratio of second order derivatives in x,y direction of the potential field data to second order derivatives in the three directions, Chen et al [6], have proved that MTM bring false edges and will lead to false interpretation

A newest technique is proposed by [4], using the Ratio of vertical and total horizontal derivatives of the total horizontal gradient and the logistic function (LTHG)

The logistic function produces sinusoidal curves to make small and large amplitude visible simultaneously.

The present article aims testing the newest techniques in gravimetric data filtering to disclose the edges of deep and shallow structure, implemented on synthetic gravity data and on real data of the Ougarta Mountains in the Algerian Moroccan limits.

II. Methods

The following procedure is used to test the effectiveness of the geophysical filters on synthetic data.

A. Analytic signal

The AS is introduced by [1], preferably called the total gradient in interpretation of gravimetric and magnetic data, the analytic signal amplitude is defined as:

$$|AS| = \sqrt{(\frac{\delta f}{\delta x})^2 + (\frac{\delta f}{\delta y})^2 + (\frac{\delta f}{\delta z})^2} \quad (1)$$

Where $\frac{\delta f}{\delta x}, \frac{\delta f}{\delta y}, \frac{\delta f}{\delta z}$ are the first derivatives of the total gravimetric field in *x*,*y* and *z* directions

B. The Tilt Angle

Miller and singh [5], define the TA as

$$TA = \left[a\tan((\partial f / \partial z) / \sqrt{(\partial f / \partial x)^2 + (\partial f / \partial y)^2 }) \right]. \quad (2)$$

C. Modified theta map

The method is proposed by [6], and is considered as a modified version of the theta map

$$MTM = \cos^{-1}\left(\sqrt{f_{zx}^2 + f_{zy}^2} / \sqrt{f_{zx}^2 + f_{zy}^2 + (f_z / h * p)^2} \right) \quad (3)$$

Where $f_{zx}, f_{zy}, \frac{\delta f}{\delta z}$ are the first derivatives of the vertical derivatives of the total field in *x* and *y* directions, *h* represent the grid spacing and *p* is a constant vary from 0.05-5 in this work *p=0.05*

D. LTHG

The method is proposed by [4], based on the ratio of the first vertical derivatives and the total horizontal derivatives of the total horizontal gradient and the logistic function referred as the logistic of the horizontal gradient

$$LTHG = \left[1 + \exp\left(-\frac{\delta THG}{\delta z} / \sqrt{(\frac{\delta THG}{\delta x})^2 + (\frac{\delta THG}{\delta y})^2} \right) \right]^{-\alpha} \quad (4)$$

The total horizontal gradient is defined as:

$$THG(x,y) = \sqrt{(\frac{\delta f}{\delta x})^2 + (\frac{\delta f}{\delta y})^2} \quad (5)$$

α is positive constant , test results on synthetic data shows that α =2-10 more details can be fined in [4].

III. Application to synthetic model

In this section effectiveness of the new methods is tested using two synthetic examples: the first one involving two dykes and prisms with top depth of -1 Km for prism1 and dyke2,-2 Km for Dyke 4 and -3 Km for prism 3 (Fig 1a), The geometric characteristics and the contrast density of the first model are exposed in Table 1.

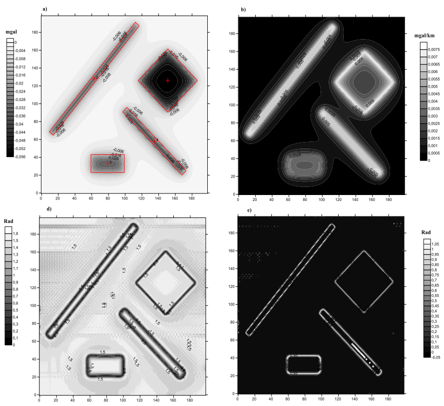

Fig.1. First Case a)Residual anomaly, b) analytic signal magnitude, c) tilt angle, d) Modified theta map, e) LTHG

we consider that all bodies contain positive residual density (the contrast density for the bodies 1 and 3 is 0.3 g/cm^3, the density contrast for the body 2 is 0.25 g/cm^3 and for the body 4 the contrast is 0.4 g/cm^3), the gravity anomaly obtained for this model is shown in Fig 1a. The gravimetric signal is calculated using 200×200 observation points with grid spacing of 0.25 Km.

In the second model (Fig.2) is same as the first one but with a random Gaussian noise of 5% of the gravity data amplitude.

Table 1 Parameters of the intersect dyke model

Parameters	Prism 1	Dyke 2	Prism 3	Dyke 4
Lounger (Km)	50	160	20	100
Width (Km)	50	6	40	7
Top (km)	1	1	3	2
Bottom (km)	6	9	7	7
Density (g/cm^3)	0.3	0.25	0.3	0.4
Strike°	-45	-50	-90	-45
Dip°	0	0	0	0
Plunge°	0	0	0	0
X center	151	63	79	136
Y center	126	128	33	58

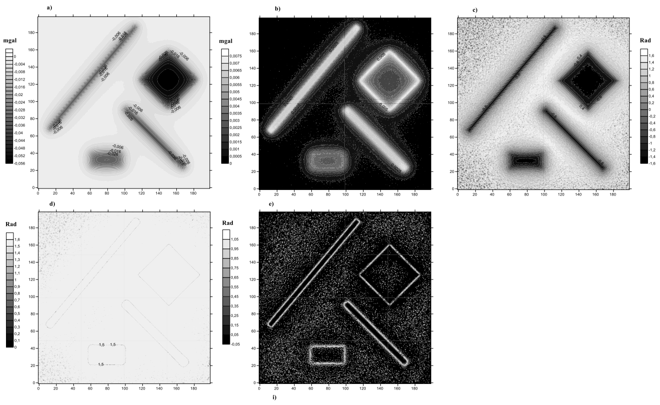

Fig.2. Second case Noisy data a)Residual anomaly, b) analytic signal magnitude, c) tilt angle, d) Modified theta map, e) LTHG

Based on the gravity anomaly the first case, we used AS, TA, MTM and LTHG techniques to perform edge detection, we can see that the analytic signal results are poor for deep sources the edges of the Prism 3 and 4 are not clear.

The Tilt angle is not an edge detection filter, the method equalize the signal amplitude and the peaks of data are superimposed over the center of the body, as shown in the MTM result it can be seen that the technique produced better resolution on the edges of deep bodies than the other methods [4],, the application of MTM present one disadvantage that the deep bodies are seem bigger in size than they are (Fig.1.c ,prism 3 and dyke 4)

The LTHG method produced best results than MTM, comparing results it can be seen that the method delineate clearly the edges of the bodies and gives high resolution of the edges.

The second case is tested applying a 5% random noise to the gravimetric data of the first model, the figure 2b shows that the AS is dominated by large amplitude responses from shallow sources (Prism1,Dyke2) but small amplitude responses are from deeper sources (Prism3,Dyke4).

The figure 2c shows the sharpened responses of the inter and outer edges of the sources could be difficult to localize or could not be produced by the TA [4], the use of MTM gives poor results delineating the edges of both shallow and deep bodies, the LTHG is more successful than the other methods delineating the edges of deep and shallow sources, the method is less sensitive to noise and produced higher resolution at the edges due to the use of THG derivatives.

IV. Application to Ougarta gravimetric data

The Ougarta Mountains were located at 200 Km of Bechar district, oriented to NW-SE direction and subdivided into two bundles folds. The actual deformations of the Ougarta are induced by the combined effects of several tectonic constraints and rifting-subduction process during Precambrian, Paleozoic and post Paleozoic phases. The structural trends are marked by NW-SE trending faults witch controlled the Paleozoic basins dynamics.

The Ougarta is boarded by two major accidents the Saoura gravimetric anomaly (SGA) in the NE and the Anti -Atlas Major fault (AAMF) in the SW, characterizing a suture zone between the West African Craton (WAC) and the Panafrican domain.

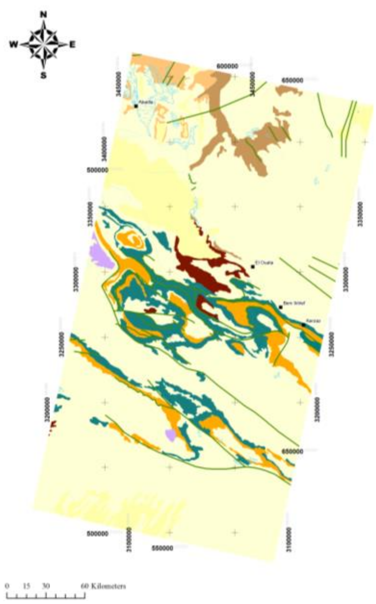

Fig.3. Simplified geologic map of the study area

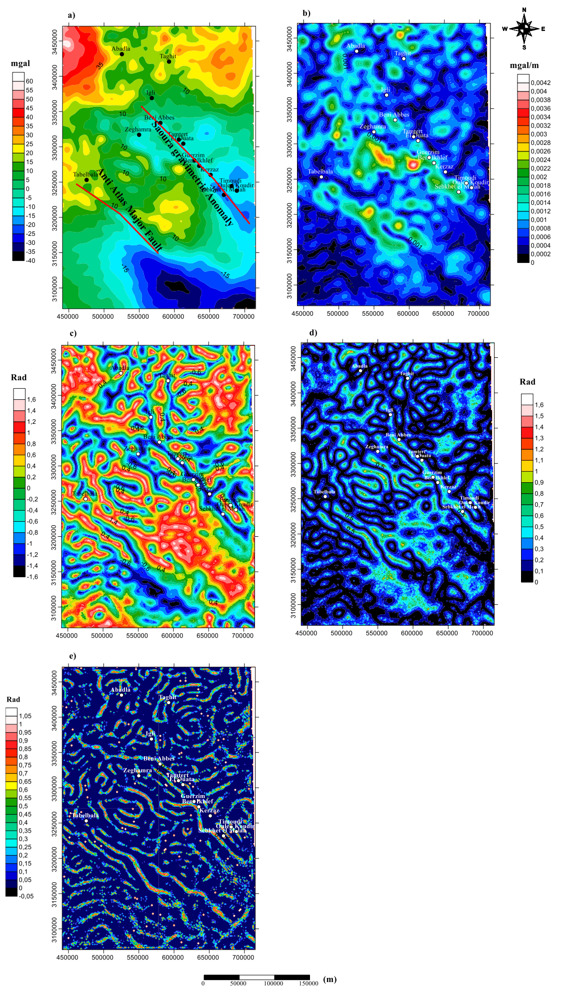

Fig.4. Application to Real data of the study area a) Residual anomaly, b) analytic signal magnitude, c) tilt angle, d) MTM, e) LTHG

The figure 4.a shows the Bouguer anomaly map from Ougarta area, calculated using polynomial surface fitting algorithm, the data is collected from Topex gravity database, the figures 4b-e displays the results of AS, TA, MTM and LTHG these results allow us to highlight new gravimetric anomalies and provide evidence for the determination of existing faults. The LTHG generate more subtle geologic features improving the qualitative and quantitative interpretation of the study area, the method show a dominant North West-South East and East-West structural trending

V. Conclusion

The present work is a comparative study of Edge detection methods for the enhancement of potential field data, the used techniques are tested on synthetic and real data from western Algeria provinces.

For the synthetic model the LTHG produced anomalies positioned close over the edges of source bodies, the method is less dependent of the sources depth.

For the gravity data of the Ougarta Mountains South Eastern Algerian Sahara the generated edge map is consistent with the geologic features of the study area, the LTHG is compared to other common used methods it produces high resolution edge for the used datasets and an improved geologic interpretation in term of major and minor faults.

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