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Precise Edge detection of gravity anomalies by Tilt angle filters

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Abstract

Measurements of the tilt angle of potential fields can be a useful aid to their interpretation. There are several varieties of the methods in use, such as tilt angle, and the derivative of tilt angle. Tilt angle filters are used for exact edge detection of the rectangular bodies artificially by writing a MATLAB code. The gravity effects of these models are computed by standard algorithms. The edges of these complex rectangular bodies are determined appropriately by tilt angle. It is also applied on real gravity data. The residual gravity anomalies are used as the real data. Tilt angles are used to determine the edges of these residual anomalies. The results are compared with the results from the analytic signal method which is a classical edge detection method. This shows the better performance of the tilt angle filter method.

Key words: Edge detection, Gravity anomalies, Tilt angle filters

تعیین دقیق گوشه‌های آنومالی گرانی با استفاده از روش فیلتر زاویه تیلت

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چکیده

اندازه‌گیری‌های زاویه تیلت میدان پتانسیل می‌تواند کمک بسیار مهمی در تفسیر داده‌های گرانی باشد. علاوه بر زاویه تیلت گرادیان زاویه تیلت را هم می‌توان مورد استفاده قرار داد. از این روش برای تعیین دقیق گوشه‌های بی‌هنجاری استفاده می‌شود. از این روش برای تعیین گوشه‌های اجسام مکعبی شکل و با استفاده از برنامه نوشته شده در محیط مطلب (Matlab) استفاده شده است. از این روش برای تعیین گوشه‌های بی‌هنجاری داده‌های واقعی استفاده شده است. در این ارتباط از داده‌ای بی‌هنجاری باقی گرانی به‌منزلهٔ داده‌های واقعی استفاده شده است. نتایج استفاده از این روش با نتایج حاصل از روش سیگنال تحلیلی مقایسه می‌شود. نتایج نشان می‌دهد که روش زاویه تیلت در آشکارسازی گوشه‌های بی‌هنجاری بهتر عمل می‌کند.

واژه‌های کلیدی: تعیین گوشه، بی‌هنجاری گرانی، فیلترهای زاویه تیلت

1 INTRODUCTION

Gravity methods are widely used for mineral resources and engineering targets. Edge detection of gravity anomalies is one of the most important steps in the interpretation.

One of the most popular methods for edge detection is analytic signal firstly defined by

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Nabighian (1974) and then improved by Roset et al. (1992) and Hsu et al. (1996) where higher order derivatives of potential-field anomalies are applied. However this method shows some restrictions over the sharp anomalies (Ardestani et al., 2007).

Filters based on the local phase of potential fields (Cooper and Cowan, 2006) describes a new and efficient way for precise edge detection of gravity anomalies.

2 TILT ANGLE FILTERS

An alternative approach to the conventional phase filter is the tilt angle which is defined by Miller and Singh (1994) as follows,

$$T = \tan^{-1}\left(\frac{\partial f / \partial z}{\sqrt{\left((\partial f / \partial x)^2 + (\partial f / \partial y)^2\right)}}\right) \quad (1)$$

where f, refers to the magnetic or the gravity data. The tilt angle is positive when over the source, passes through zero when over, or near the edge where the vertical derivative is zero and the horizontal derivative is a maximum and is negative outside the source region. The tilt angle has a range of -90 to 90 degree and is much simpler to interpret than the analytic signal phase angle.

Veruzco et al. (2004) suggested using the total horizontal derivative (THDR) of the tilt angle,

$$THDR = \sqrt{\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial y}\right)^2} \quad (2)$$

Pilkington and Keating (2004) show the reliability and stability of the method for edge detection of magnetic anomalies.

This filter was applied for synthetic and real gravity data by Cooper and Cowan (2006).

The analytic signal filter is defined as follows (Nabighian, 1974),

$$|AS| = \sqrt{(\partial f / \partial x)^2 + (\partial f / \partial y)^2 + (\partial f / \partial z)^2} \quad (3)$$

3 APPLICATION TO SYNTHETIC MODELS

Some rectangular models located in different depths are used to evaluate the efficiency of the method. The borders of these four rectangular prisms are shown in figure 1 and the depths of the top and bottom surfaces are presented in Table 1:

The gravity effect of the rectangular prisms is computed by the Plouff (1976) method and is shown in figure 1.

The analytic signal of the gravity effects computed through equation (3) is presented in figure 2.

The results of using tilt angle (equation (1)) and THDR (equation (2)) filters are shown in figures 3 and 4 respectively. As it is clear from the figures the edge detection is highly improved in comparison wich the analytic signal and the tilt angle filter maps.

Table 1. Top and Bottom depth of the models.

No	Top (m)	Bottom (m)	Contrast Density gr/cm^3
1	10	15	1
2	5	10	1
3	20	30	1
4	30	40	1

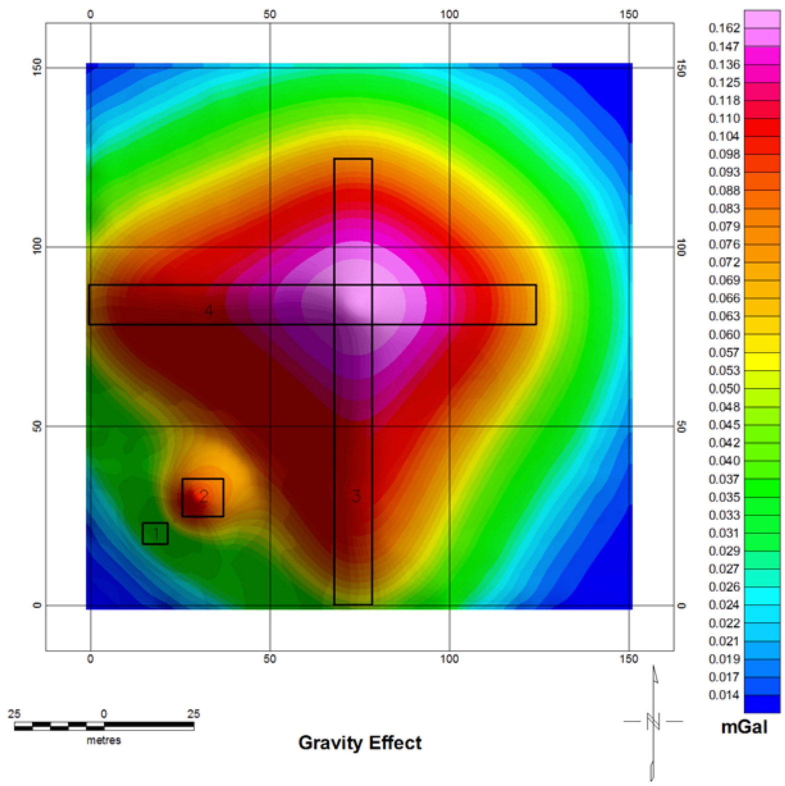

Figure 1. Gravity effects (Synthetic data) of rectangular models (mGal).

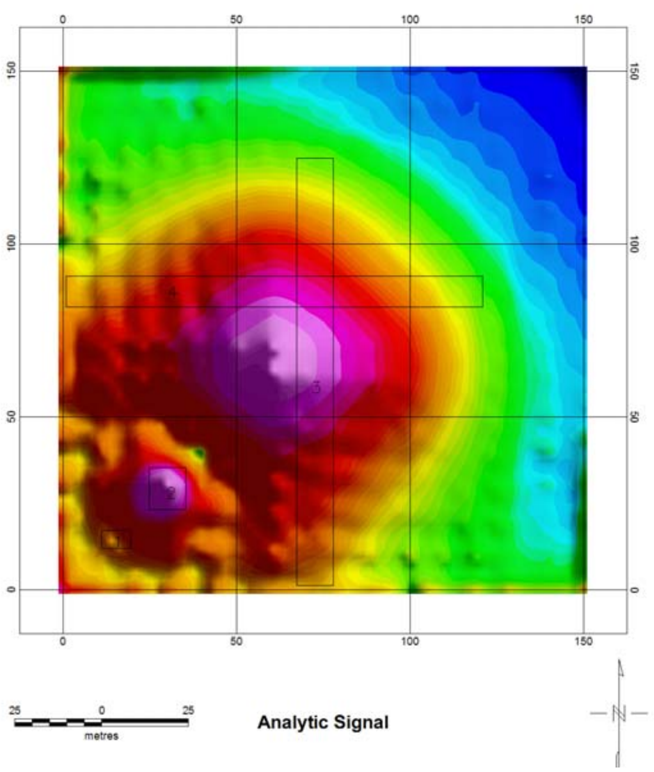

Figure 2. Analytic signal of Synthetic data (mGal/m).

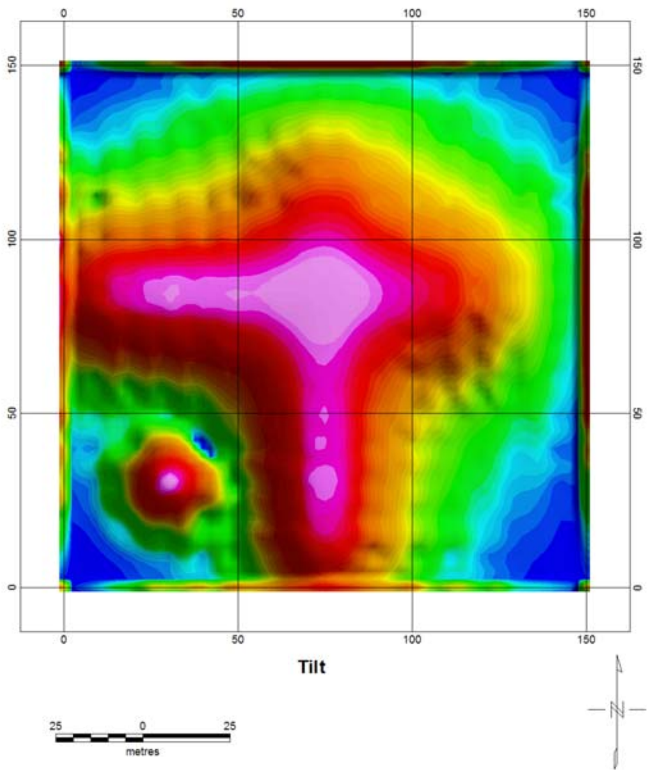

Figure 3. Tilt angles of synthetic data.

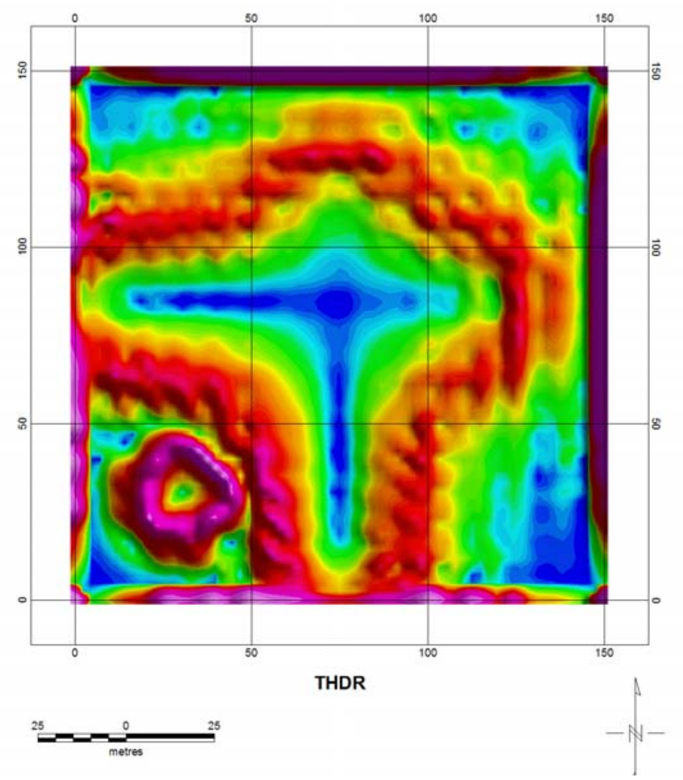

Figure 4. THDR of tilt angles of synthetic data.

4 APPLICATION TO REAL GRAVITY DATA

The three local phase angle filters are applied to a gravity data set provided by the Gravity section of the Institute of Geophysics. This data set to highlight the gravity signatures of Karst zones in an area considered for excavating a water tunnel in the Sabzkoh area located in the Zagros mountains, Chahar mahal and Bakhtiyari Province. The residual anomaly map is shown in figure 5. Inspection of the map shows some negative anomalies representing the Karst zones.

Figure 6 shows the analytic signal map of the residual anomalies of figure 5. figure 7 and figure 8 show the tilt angle and THDR maps respectively.

The maximum of analytic signals are shown in figure 6 (pink color) which have wide margins (red color). Therefore to distinguish the exact location of the edges is difficult in this figure (figure 6). The areas of maximum values of analytic signals are detected by minimum values of Tilt angles in figure 7 (dark blue color).

The maximum of THDR's are also shown in pink in figure 8. The areas of minimum values of tilt angles and maximums values of THDR have narrow margins in comparison to maximum values of analytic signals in figure 6. So we can conclude that the edges of the anomalies are much better resolved by tilt angle and THDR filters than by the analytic signal method.

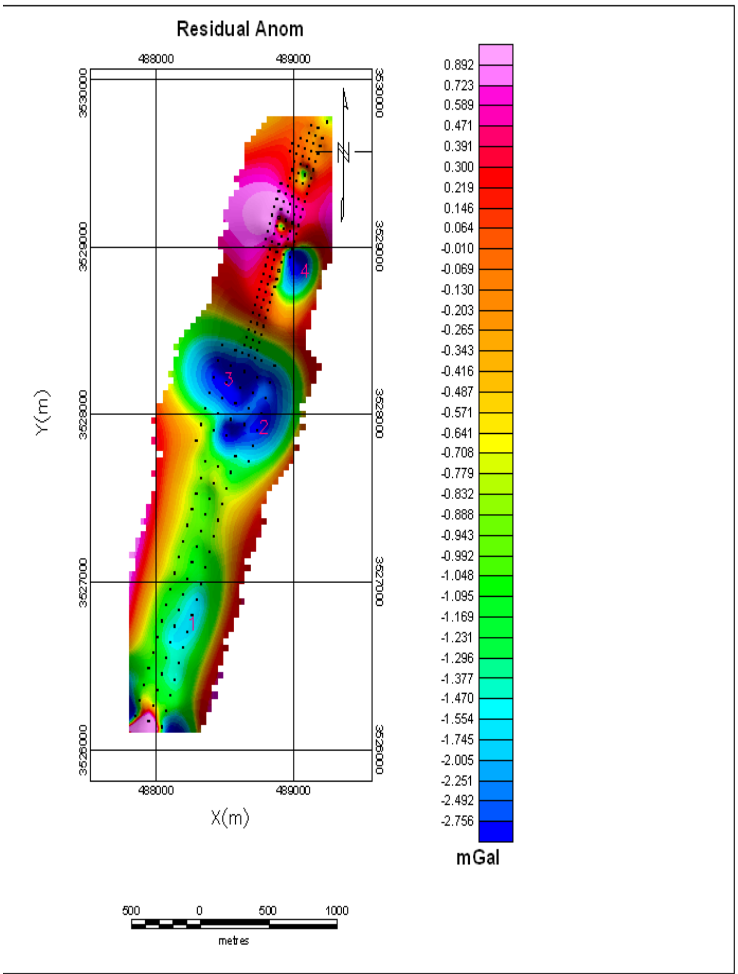

Figure 5. Residual anomalies (mGal) of Karst zones in Chahar mahal Bakhtiari Province.

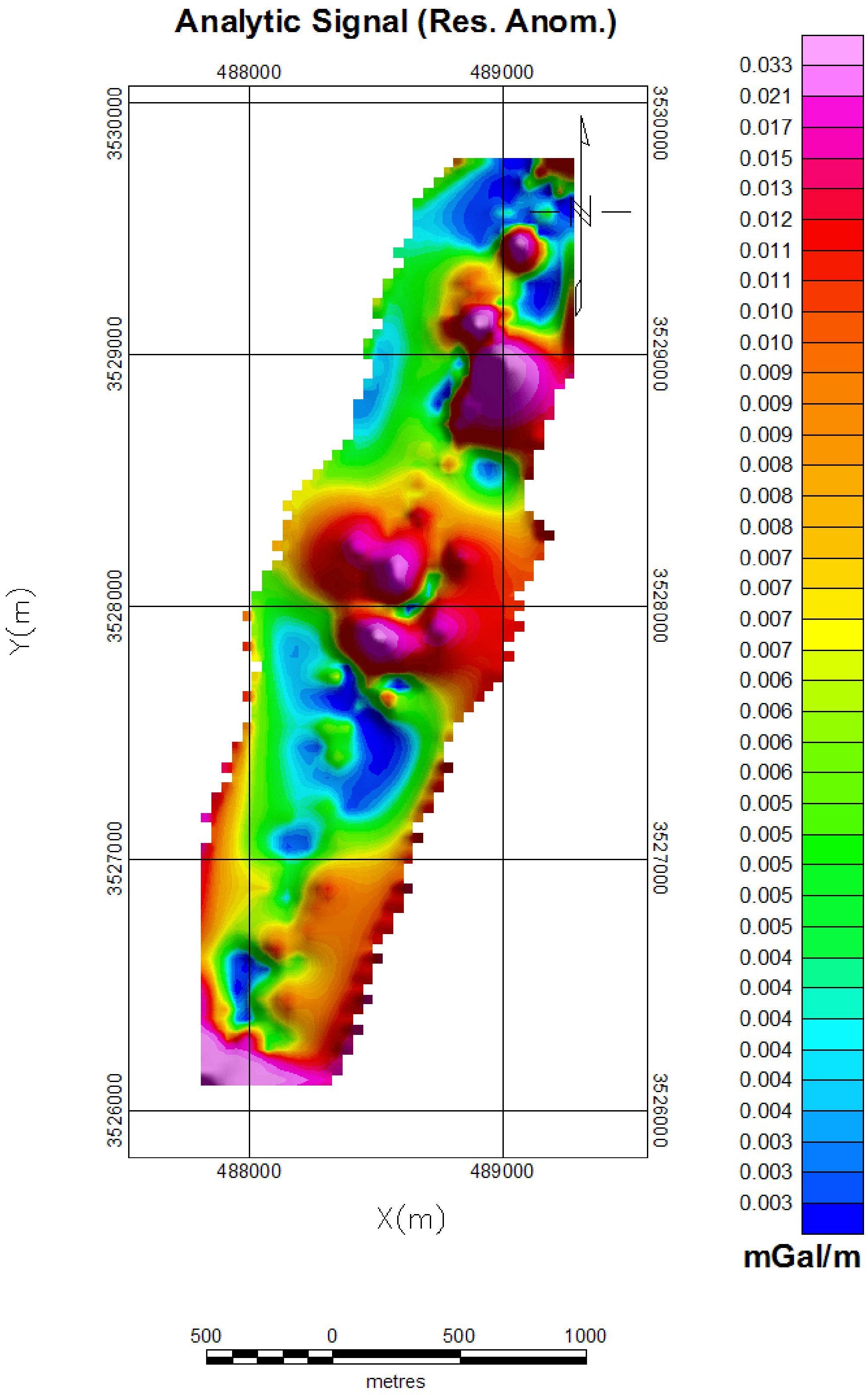

Figure 6. Analytic signal of residual anomalies (mGal/m) of Figure 5.

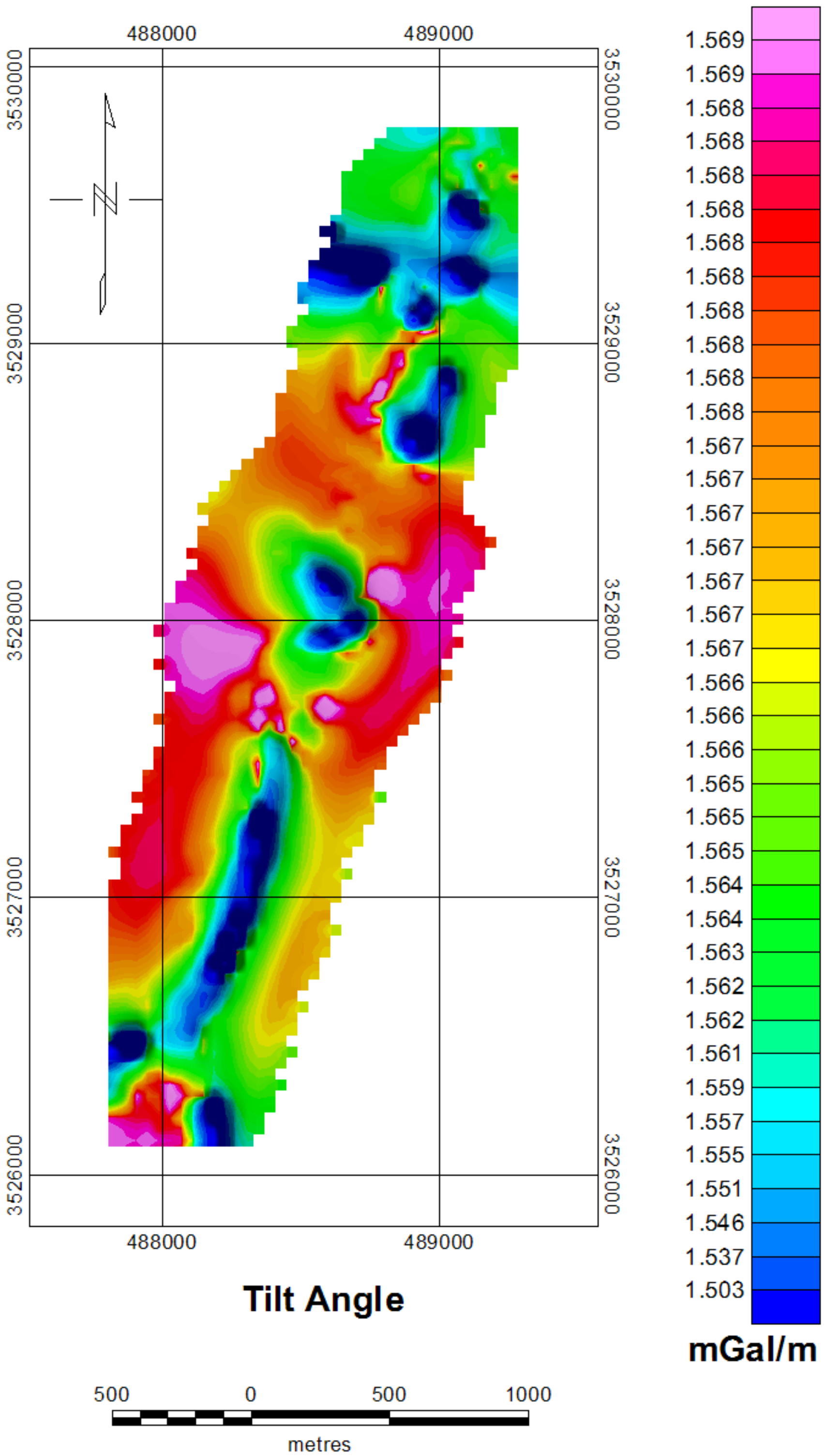

Figure 7. Tilt angles of residual anomalies of Figure 5.

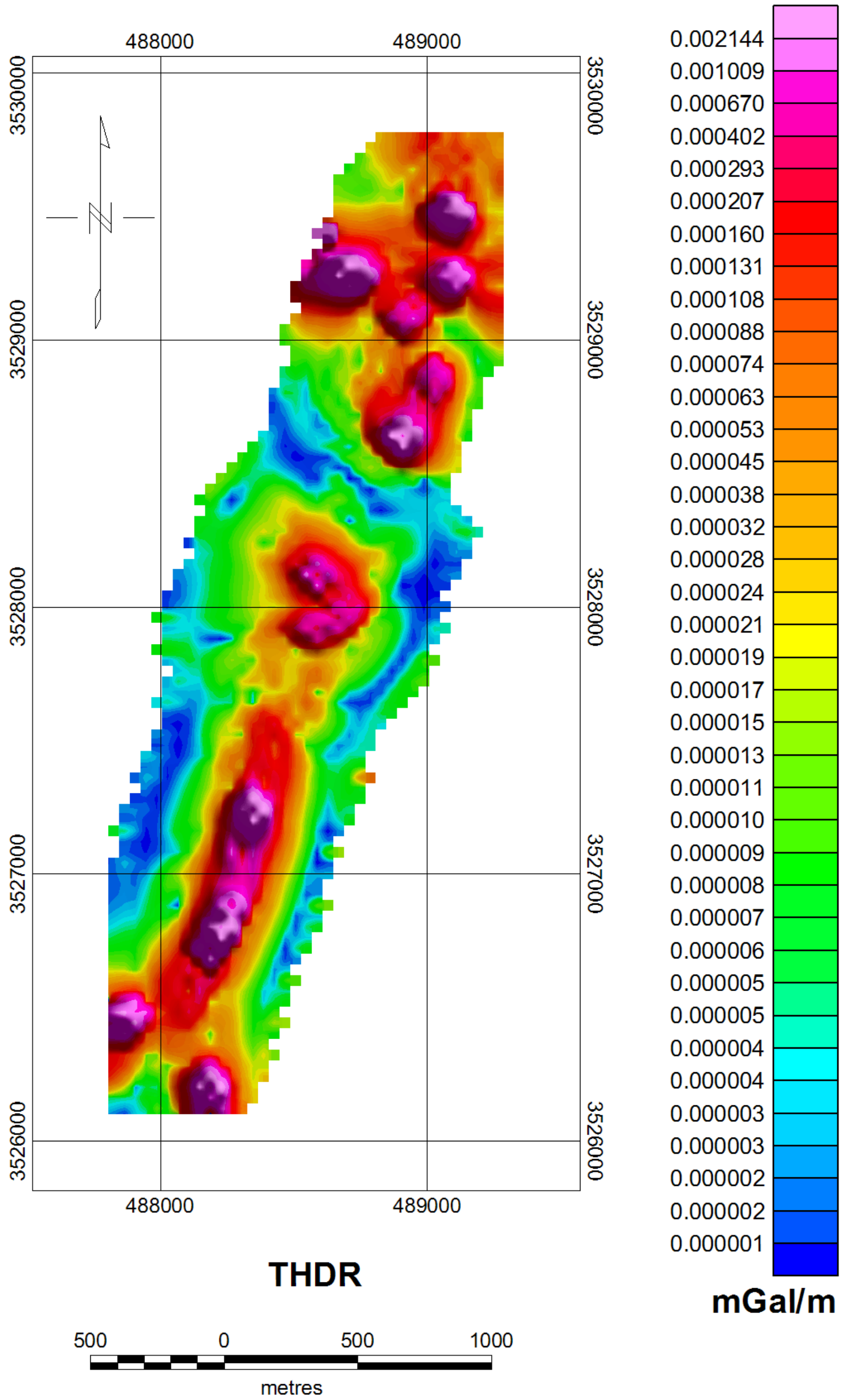

Figure 8. THDR of tilt angles of Figure 5.

5 CONCLUSION

The tilt angle filter provides a powerful and precise tool for edge detection.

An accurate calculation of the derivatives is a basic need for using these methods.

The edge of complex models (rectangular bodies) are detected appropriately which is quite promising in the case of real data where we are faced with complex geological structures. This method can be applied for real data very easily.

The results of the tilt angle filters show narrower margins for minimum and maximum values of tilt and THDR filters respectively than analytic signal results. Therefore the edges of real anomalies are better resolved by tilt angles filters.

In all these methods the gradients should be computed precisely.

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