A COMPARATIVE STUDY ON EDGE DETECTION METHODS FOR NORTHWEST OF IRAN

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Abstract: The paper presents applying the edge detection methods on NW Iran. Iran is located in the Alpine Himalayan collision zone and is one of the areas where significant tectonic activities occur between the Caucasus and the Zagros Thrust Zone in the north. The area containing important areas of the Alpine-Himalayan orogenesis zone is controlled by a number of active and inactive faults. In order to determine the boundaries of these structures, the magnetic map of the region was constructed and edge detection methods (analytical signal, total horizontal derivative method and tilt angle derivative) were applied to the potential field data. With the interpretation of the magnetic data, the depth of deep sources caused to regional anomalies was found to be approximately 12.71 km whereas the depth of shallow sources was calculated as 1.25 km. In addition to these, when taking into consideration geological background of the NW Iran, the main tectonic elements especially located in the eastern part of the study area are in good agreement with the constructed maps.
Keywords: Analytic signal, tilt, radially average power spectrum

Introduction

Edge detection methods using potential field data play an important role in the interpretation of aeromagnetic data. For this purpose, many methods (analytic signal (AS), tilt derivative, horizontal derivative of tilt (THDR), theta map method, vertical and horizontal derivatives of potential field data, normalized standard deviation method etc.) have been developed by the researches. Nabighian (1972, 1974, 1984) developed the AS method for determining the location of the 2D sources. To define the boundaries of magnetic sources, Cordell and Grauch (1982, 1985) purposed the three steps procedure. The new technique using curve-fitting approach was proved by Blakely and Simpson (1986). Miller and Singh (1994) also generalized the tilt derivative method whereas the total horizontal derivative of the tilt angle for this aim was suggested by Verduzco et al. (2004).

This paper aims to define the boundaries of structures of NW Iran using aeromagnetic data. The investigated areas are situated between the longitude of 44-49° and the latitude of 35-39°. It has important tectonic elements due to collision of the Afro-Arabian continent and Iranian microcontinent (Jahangiri, 2007). Therefore, the determining the boundaries of these structures is great of importance. In this study, the derivatives techniques (i.e., AS, Tilt, THDR) known as edge detection methods have been applied to reduce to pole (RTP) aeromagnetic data that has been built using Geosoft® Oasis Montaj™ software and the results of the study and geological-tectonic structures of the area was correlated with each other.

Geo-tectonic Settings

Iran is located in the Alpine Himalayan collision zone where is an active seismic zone between the Caucasus in the north and the Zagros Overthrust Zone in the south. The tectonic activity of the area mainly related to Tabriz Fault Zone (TFZ) (Fig.1). Many studies have been conducted on the tectonic-geological structure of this region (Stocklin and Nabavi, 1973; Nabavi, 1976; Alavi, 1994; Emami et al., 1993; Saber et al., 2013, Ranjitekantapeh et. al., 2017). These studies have showed that the area has complex tectonic activities associated with both the N–S compressive (E–W thrusts and folds) and E–W extensional (N–S faults) structures (Rebai et al. 1993; Baron et al. 2013; Afshar et al. 2017). The one of the significant region is the Sabalan area located in the northwest part of Mt. Sabalan and it takes place in a very complex compressional tectonic zone, on the NE moving South Caspian sub-plate, near the junction of the Eurasian, Iranian, and Arabian plates (Bromley et al., 2000). Sabalan geothermal field and Sabalan volcano have important role for the region and three main directions of faulting have been recorded: NE, NW and N-S. The area is characterized by late Miocene and Quaternary, trachyandesitic and trachytic to dacitic lavas with massive ignimbrites pyroclastic flows (Shahbazi Shiran 2013; Afshar et al., 2017). The composition of igneous rock complexes is also located in the east of the study area ranges from andesite, trachyandesite to dacite and these rocks are called as cenozoic volcanics.

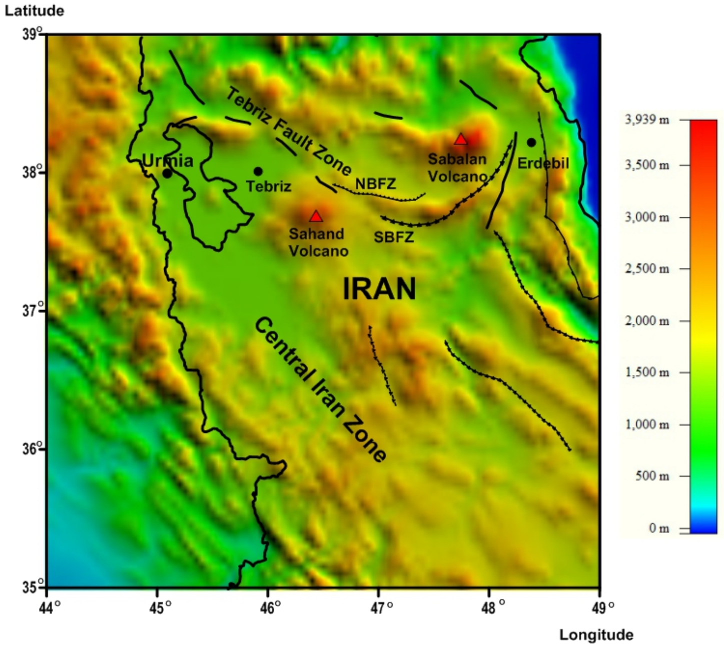

Figure 1. Tectonic map of NW Iran: NBFZ: North Bozkus Fault Zone, SBFZ: South Bozkus Fault Zone

This paper aims to determine the magnetic parameters such as boundaries of important fault structures, volcanos and the depth of the magnetic source in the region. With this purpose, different edge detection methods (analytic signal, tilt angle method, total horizontal derivatives of tilt), which base on the use of potential field derivatives, were applied to the magnetic data obtained from EMAG3.

Methods

The edge - detection methods base on the derivatives of potential field data and they are used to be the filtering process. Prior to applying edge - detection methods, reduce to pole (RTP) correction on magnetic data was performed for eliminating the effects of the earth's magnetic field over source bodies. In this study, edge - detection methods were employed to determine the boundaries of the source bodies for NW of Iran using RTP magnetic data.

1. Analytic Signal

Analytic signal (AS) method enables to define the boundary locations of the causative sources by calculating the horizontal and vertical derivatives of magnetic field anomalies. This method is not much influenced from the ambient magnetic field and source magnetization directions and AS exhibits maxima over magnetization contrasts. Thus, the locations of these maxima specify the outlines of the magnetic sources (Roest et al. 1992; MacLeod et al. 1993). AS formula has been given by Roest et al. (1992) to be:

$$|A(x,y)| = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2 + \left(\frac{\partial f}{\partial z}\right)^2} \qquad (1)$$

where |A (x, y)| is the amplitudes of the analytic signal whereas f is the magnetic anomaly field intensity. ∂_f/∂_x, ∂_f/∂_y and ∂_f/∂_z derivatives of magnetic field, in the *x*, *y* and *z*-direction, respectively.

2. Total horizontal Derivative Method

Total horizontal Derivative Method (TDX) allows to describe sensitively boundaries of structures by using the two orthogonal derivatives of magnetic field. The method is generally utilized as an edge detection filter and it is mathematically expressed as seen in equation 2 (Cordell and Graunch, 1985).

$$\mathbf{TDX} = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2} \qquad (2)$$

The f is magnetic field, ∂_f / ∂_x and ∂_f / ∂_y the two orthogonal derivatives of magnetic field in the *x* and *y*-directions, respectively. It is worth to note that the method gives more effective results on shallower bodies than deeper bodies.

3. Tilt Angle Derivative

The tilt angle is defined (eq. 3) as the arctangent of the ratio of vertical derivative to total horizontal derivative of the magnetic field (f) by Miller and Singh (1994). The method is a useful tool to mapping of shallow basement structure and determining boundaries of the magnetic sources. The tilt angle amplitudes vary between $-\pi/2$ and $+\pi/2$ because of the arctangent trigonometric function. They show positive values over the magnetic body. The negative values of tilt angle amplitudes can be seen near the edge of a vertical source and outside the source region. The zero contours are also the edges of the structures.

$$\mathrm{Tilt} = \arctan\left[\frac{\frac{\partial f}{\partial z}}{\mathrm{TDX}}\right] \qquad (3)$$

where TDX is total horizontal derivative of magnetic field and $\partial f/\partial z$ is derivative of magnetic field, in *z*-direction.

4. Total Horizontal Derivatives of Tilt

The total horizontal derivative of Tilt (THDR) is independent of the geomagnetic field and it becomes maximum value over the edge of magnetic sources. The method is defined as;

$$\mathrm{THDR} = \sqrt{\left(\frac{\partial \mathrm{Tilt}}{\partial x}\right)^2 + \left(\frac{\partial \mathrm{Tilt}}{\partial y}\right)^2} \qquad (4)$$

by Verduzco et al. (2004). Tilt is the value obtained from tilt angle method. $\partial_{\mathrm{Tilt}} / \partial_x$, $\partial_{\mathrm{Tilt}} / \partial_y$ derivatives of tilt, in the *x*, *y*-direction, respectively. Results of THDR show that the method is more effective for shallow bodies.

5. Radially Averaged Power Spectrum

Radially averaged power spectrum (RAPS) developed by Spector and Grant 1970 is theoretically based on a Fast Fourier Transform (FFT) and it takes advantage of appearance of the spectrum curve to obtain mean depths to interfaces of significant density contrasts in the crust. The mean depth of each source can be expressed as;

$$z = -\frac{m}{4\pi} \qquad (5)$$

where z is the depth and m is the slope.

Results and Discussions

The edge detection methods are applied to RTP magnetic data in order to emphasize the boundaries of the geological structures. The maps obtained by utilizing those methods are given in Fig 2. The eastern part of the study area is dominated by positive magnetic values with trending NW-SE which range from 100 nT to 880 nT (Fig 2a-b). This situation can be explained by the presence of the igneous rock complexes in the region. The analytic signal image map shows that the maxima values correspond to boundaries of igneous rock complexes, Sabalan and Sahand Volcanos (Fig.2c). When the tilt angle map (Fig 2d) and THDR map compare with each other, igneous rock complexes are observed prominently in the maps. However, volcanos located in the region are not shown clearly in THDR map (Fig 2e).

The RAPS indicates the averaged depth estimate to top of the magnetic bodies caused the anomalies. The calculated RAPS for the magnetic map is shown in Fig. 2f and it could be divided into three segments. While frequency ranges of the first segment vary from 0.01 to 0.08 cycle/km which represents the long wavelengths is called regional or deep sources component, frequency ranges of the third segment vary from 0.2 to 0.26 cycle/km which characterizes the short wavelengths stem from residual or shallow sources.

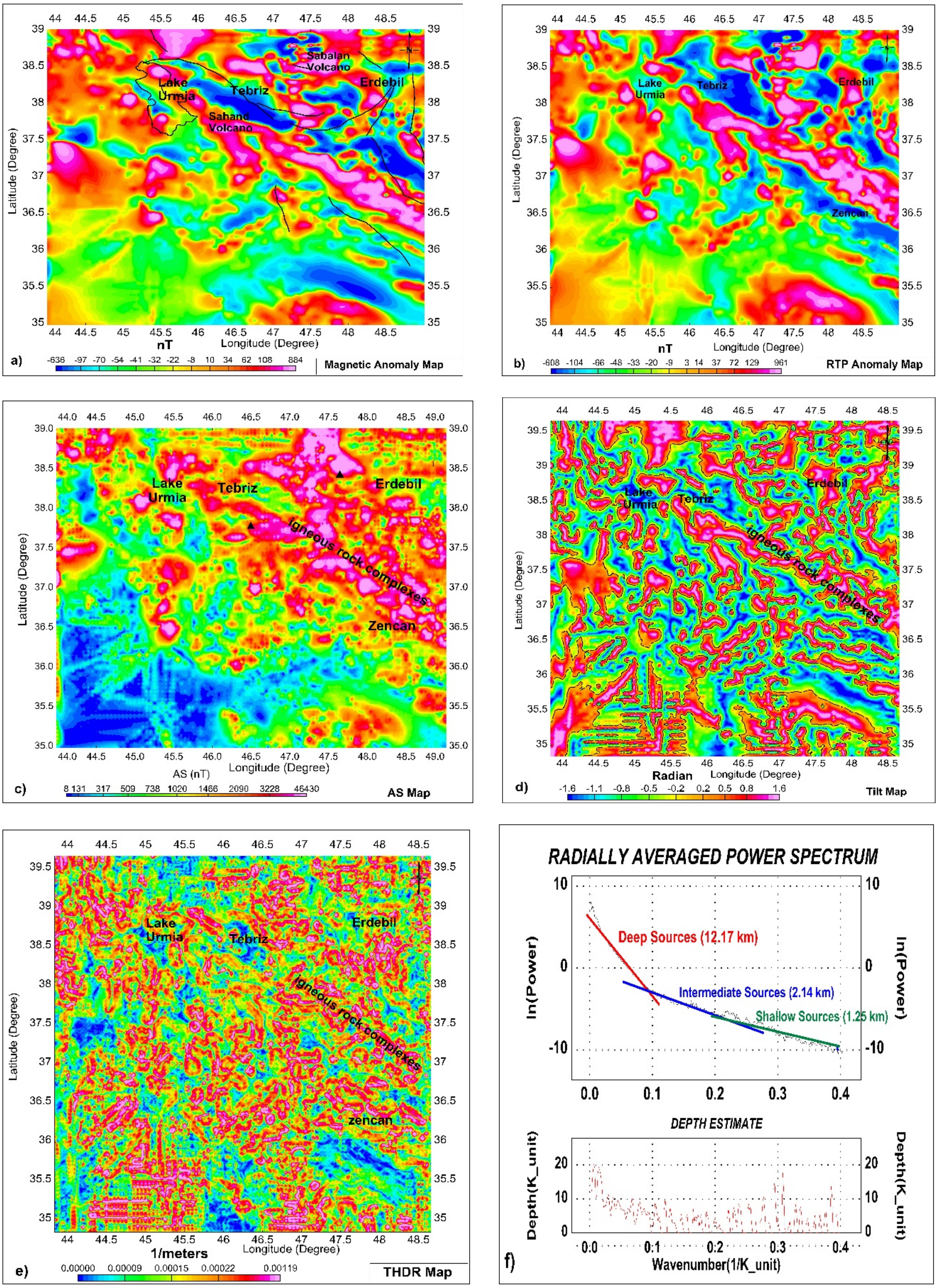

Figure 2. A comparison of edge detection methods: a) Magnetic anomaly map. b) Reduce to pole of magnetic data. c)Analytic signal. d)Tilt angle map of magnetic data (the dashed black lines show the zero contour line). e) Horizontal gradient of tilt of magnetic data. f) Eadially averaged power spectrum.

Conclusions

The edge-detection methods exhibit the boundaries of the structures such as fault, volcano and the correlation between the maps obtained from applying these methods provides substantially convenience for interpretation. According to the maps, AS and tilt angle derivative methods gave better results. While volcanos were monitored in the AS map, igneous rock complexes with trending NW-SE also observed clearly in tilt map. The averaged depth estimations were conducted on in the study by using radially average power spectrum of RTP magnetic data. The spectrum consists of three segment: First segment includes low wavenumber (red segment) and they represent deep sources. The maximum depth of the basement is calculated as 12.17 km. Second segment (blue segment) reflects intermediate depth and find to be 2.14 km. High wavenumber is observed in the third segment (green segment) and this segment correspond to shallow sources (1.25 km). Finally, the study can be concluded that the eastern part of the study area is largely affected igneous rock complexes.

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