Evaluation of the Tectonic Boundaries Using Potential Data at Al-Tharthar Lake and Surrounding Area, Middle of Iraq

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Abstract

The gravity and magnetic data of Al-Tharthar lake and surrounding areas in central Iraq were considered to study the tectonic situation in the area. The residual anomalies were separated from regional using the polynomial method with three orders. The Total Horizontal Derivative anomalies of gravity and magnetic are used with the residual anomalies to identify the faults and their trends with the basement rocks. The predominant trends are approximately N45W and N60E. Many faults and tectonic boundaries were detected and traced on the tectonic map of the study area.

Keywords: Al-Tharthar lake; Total Horizontal Derivative; Polynomial method; Fault

1. Introduction

It is common practice to use gravity and magnetic methods to investigate the subsurface features. Compared to other geophysical methods, these methods are inexpensive, fast, and straightforward (Hinze et al., 2013). Anomaly interference is a problem since anomalies are always larger in area than the body that causes them, making it difficult to identify particular sources. One approach to solve this problem is to do anomaly derivative calculations on the magnetic or gravitational fields to isolate and/or separate these anomalies in some way (Fairhead, 2011). The polynomial method is widely used to separate the regional from residual anomalies, but its application efficiency is constrained by the selection of polynomial parameters, which can affect the results. The polynomial parameters have been selected using a set of fairly objective selection procedures. For complex anomalies (when higher order polynomials are needed), the polynomial fitting method is likely to produce aliasing anomalies (Zhang et al., 2009). This research attempt to study the lineaments trends of the main gravity and magnetic anomalies of Al-Tharthar lake and surrounding areas. Many tectonic boundaries were delineated in Iraq near the study area using gravity and magnetic methods, (Abdul-Jabbar, 2013; Al-Banna and Atwan, 2019; Al-Banna and Al-Namar, 2019; Al-Banna and Daham, 2019; Al-Banna, Al-Karadaghi and Abdullah, 2020) The study area covers a wide swath of central and western Iraq (Fig. 1). Table 1 shows that the affected area is about rectangular in shape, measuring about 160 km in width by 196 km in length.

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2. Tectonic Geology Setting of Study Area

The study area is located in two tectonics parts of map, according to (Fouad, 2015), (Fig.1).

- The Inner Platform: Characterized by the no significant Permo – Triassic rifting, and the Alpine compressional deformation can be recognized the studied area represent by the Western Desert Subzone at the northwest of this part (Fouad, 2015). This classification according to the physiography of the area. At the same time the studied is at the transition tectonic zone according to (Al-Banna and Ali, 2018).

- The Outer Platform: The main part of the Mesozoic Arabian plate passive margin and the Late Cretaceous foreland basin. It is significantly involved by the Alpine orogenic deformation, (Fouad, 2015).

Table 1. The study area coordinates, UTM System

<table>
<thead>
<tr>
<th>ID</th>
<th>Eastern (m)</th>
<th>Northern (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>249770</td>
<td>3837363</td>
</tr>
<tr>
<td>B</td>
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<td>3837025</td>
</tr>
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<td>3640346</td>
</tr>
<tr>
<td>D</td>
<td>249770</td>
<td>3640008</td>
</tr>
</tbody>
</table>

Fig.1. Location and tectonic map of study area (Fouad, 2015)
According to (Al-Kadhimi et al., 1996), the eastern side of the study region is situated in the unstable shelf zone (Mesopotamian zone, Tikrit - Amara subzone). The west region located in the stable shelf (Salman Subzone, Anah-Ba’aj Subzone, Ubaiyidh Subzone) (Fig. 2).

Fig. 2. Tectonic map of the study area (Al Kadhimi et al., 1996)

3. Surface Geology

Several Tertiary and Quaternary sedimentary strata were outcropped in the research region, according to the findings (Buday and Jassim, 1987) are: Fatha Formation (Middle Miocene): This formation is one of Iraq's most ubiquitous and economically significant formations. As a result of Iraq's substantial oil exploration efforts, the formation has been rather extensively studied in terms of geology. It comprises anhydrite, gypsum and salt, interbedded with limestone and marl.

The Injana Formation (Upper Miocene): To the west of Salah Aldin governorate, on the eastern coast of Al-Razazah Lake, this structure can be found, it is either covered in the Dibdiba Formation sediments or thick layers of newer deposits. Sand and clay rocks of various hues make up the bulk of this formation (Green, grey, and brown). It emerges as a soft layer of gravel along the boundary between the Injana and the Dibdiba formations. Deposition occurs in a variety of environments, ranging from the marine to the continental. Quaternary Deposits: Salah Aldin & Al Anbar governorate outcrops these deposits, which reach to the Euphrates River and consist of sand, shale, clay, and gravel in some sections, particularly Pleistocene deposits in the northern half of the investigated area. As we go closer to the Euphrates River, the thickness of these deposits changes and rises in density.

4. Available Data and Processing

Fig.3 shows the Bouguer anomaly map of Iraq at a 1:1000000 scale with 2 mgl contour intervals for the study area (A) IPC published this map. Iraq's overall Aeromagnetic total field intensity map
includes the study area (B). In Iraq, the survey's grid lines were drawn with a 2 km gap interval. The total magnetic intensity (TMI) image and the Bouguer anomaly map were cropped from the Iraqi aeromagnetic total field intensity map and the Iraqi Bouguer anomaly map for this investigation and it has been digitized by (surfer 11) software. Using the TMI data, the reduction to the pole (RTP) map was created so that anomalies were symmetrically placed atop the causing bodies (Fig.3(C)). This is how it's done : (Geosoft Oasis montaj Version 8.4, 2015) software.

They demonstrate that the western section of the research area has a high gravity and magnetic anomalies. Gravity and magnetic values tend to be lower in the eastern section of the study area. Fig.3 shows a magnetic value that overlaps between low to middle values to the east and high values to the southeast (Fig.3(C)).

Fig. 3. (A) The Bouguer Gravity anomaly map of the study area (IPC,1984); (B) TMI map of study area (IPC,1984); (C) RTP magnetic map of study area, achieved by using software (Geosoft Oasis Montaj, Version 8.4, 2015)
5. Methods

5.1. The Regional-Residual Separation (Polynomial Method)

When numerous sources' potential effects overlap, the result is a potential field that can be difficult to separate from one another. Both "residual" and "regional," regularly used terminology, serve to distinguish between anomalies originating from nearby surface masses and those originating from bigger, generally deeper features. There are a variety of ways to distinguish between the regional and potential fields. (Beltrao et al., 1991). These regional-residual strategies can be divided into Graphical, Spectral, and Polynomial fitting methods, according to Nettleton (1976).

Any field's regional trend can be determined using a polynomial analytical technique. Known as the observed data are utilized to compute the mathematically definable surface that provides the closest fit to the considered data according to the used order, using least squares fitting. This surface is considered to be the regional. When this data is removed from the original data, the resulting is said to be residual, (Dobrin and Savit, 1988). Polynomials are functions that have the form:

\[ f(x) = a_nx^n + a_{n-1}x^{n-1} + \cdots + a_1x + a_0 \quad (1) \]

The coefficients \( a_n, a_{n-1}, \ldots, a_1, a_0 \) are real numbers, which is a nonnegative integer, is the degree, or order, of the polynomial (Nakamura, 1995). The separation achieved using three orders (1st, 2nd and 3rd orders) by Polynomial method. Bouguer gravity map and RTP map were separated to regional and residual maps, three orders for each one of them. The three order of the polynomial method (1st, 2nd, and 3rd) which used for the regional, residual and THD of magnetic and gravity data of the study area shows only very little variation in all cases, therefore the first-order polynomial method was used to compare the gravity and magnetism data along the studied profiles.

5.2. Edges Detection Methods for Potential Anomalies

Potential field data interpretation relies heavily on edge detection (Ma & Li, 2012). Most commonly employed in geophysical research to map geological features including faults and dykes as well as ore deposits (Ibraheem et al., 2019). One of these methods was the Total Horizontal Derivative (THD) methodology, which was used on the gravity and RTP magnetic maps in the research area. The THD technique considered a supplement technique to the filtered residual gravity and magnetic maps (Salem et al., 2008). It is a process of calculation the change in gravity and magnetic values with the horizontal distance. This method usually is used to detect the maximum change in the potential field (it is drawn as lines shaped, and considered as possible faults).

6. Results and Discussion

6.1. Separation Results

The regional gravity value of the analyzed area has a slope of -0.225 mgal/km toward the east, as shown in Fig. 4A. The slope regional magnetic found to be trending toward the northeast with a gradient of 0.875 nT/km, (Fig. 4B). The both slopes of the regional gravity and magnetic values trending toward east and northeast. The western side of the study area represent an area of low thickness of crust (Al-Banna and Al-Heety 1994), and it is considered as an area of complete compensation (Al-Banna and Al-Rawi 1993). There is an increase in crustal thickness and deeper basement rocks on the eastern side of the research region compared to the western side. The residual gravity Bouguer map, shows the presence of a number of positive gravity anomalies in SW Ramadi and in the North of Heet, most of
them are sited in the south of Al-Tharthar lake (Fig. 5A). A negative gravity anomaly is located southwest and west Falluja. There is another negative gravity anomaly, these are south Kubaisa, eastern Haditha and western of Al-Tharthar lake. The residual of RTP magnetic map, shows the distribution of a number of positive magnetic anomalies in SW Ramadi extends toward the middle, west and in far NW, another positive magnetic anomaly in the far NE of the area. A large negative magnetic anomaly is present in the north part of Al-Tharthar lake and another negative anomaly is located east of Ramadi (Fig. 5B). Analyzing maps of the residual gravity and magnetic anomalies could be very helpful in locating faults and tracking their extension (Al-Khafaji and Al-Yasi, 2021).

Fig. 4. A) The regional gravity Bouguer map, 1st order; B) Regional RTP magnetic map, 1st order

Fig. 5. A) The Residual gravity Bouguer map, 1st order; B) Residual RTP magnetic map, 1st order.
The lineaments of the axes of negative and positive residual anomalies of the gravity and RTP magnetic maps were traced (Fig. 6A and D). The trends of these lineaments were plotted on a rose diagram (Fig. 6B, C, E, and F). The trends of lineaments results were summarized in Table 2. It is found that the predominant trends (with approximation) of both magnetic and gravity anomalies in the study area are N45W, N60E and N15E. The N45W coincide with the Najd fault system and considered as longitudinal faults trend. The Conjugate fault system considered as transvers faults.

**Fig. 6.** A) The axes of residual gravity anomalies, (Polynomial method 1st order) map; (B)and (C) the Rose diagrams of positive and negative anomalies axes of residual gravity map, respectively; (D) The axes of residual magnetic anomalies (Polynomial method 1st order) map; (E) and (F) are the Rose diagrams of positive and negative anomalies axes of residual magnetic axes, respectively According to Table (2), the first predominant trend is approximately N 45 W (its values colored with red) and the second one is about N 60
E (its values colored with blue). To detect subsurface structures, especially faults, the combination of gravity and magnetic data processing, filtering and interpretation is quite useful (Eshanibli et al., 2021).

**Table 2.** The main trends of anomalies axes

<table>
<thead>
<tr>
<th>Anomalies</th>
<th>Gravity</th>
<th>Magnetic</th>
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<tr>
<td>Positive anomaly</td>
<td>N 40 W</td>
<td>N 35 W</td>
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<tr>
<td></td>
<td>N 75 W</td>
<td>N 10 E</td>
</tr>
<tr>
<td></td>
<td>N 70 E</td>
<td>N 45 E</td>
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<tr>
<td>Negative anomaly</td>
<td>N 15 W</td>
<td>N 45 W</td>
</tr>
<tr>
<td></td>
<td>N 50 W</td>
<td>N 10 W</td>
</tr>
<tr>
<td>Lineaments of</td>
<td>N 45 W</td>
<td>N 35 E</td>
</tr>
<tr>
<td>maximum THD</td>
<td>N 10 W</td>
<td></td>
</tr>
</tbody>
</table>

6.2. Edges Detection Results

The THD of the gravity and RTP magnetic were determined (Fig. 7A and C). The maximum THD values traced as lines to represent suspected fault locations, which indicated the boundaries of causative source in the subsurface, or the discontinuities and the fault locations (AL-Banna et al., 2017).

![Fig. 7. A) The THD of the residual gravity map, 1st order; B) Rose diagram of THD greatest values from residual gravity map, 1st order; C) The THD of the residual RTP magnetic map, 1st order; D) Rose diagram of THD greatest values from RTP Magnetic map, 1st order](image-url)
6.3. The Major Tectonic Boundaries

The detection of key tectonic boundaries is critical to distinguishing the various geophysical and geological zones (Al-Banna, 1992). The primary tectonic limits of the research area are determined using the THD technique and residual potential maps (Figs. 8 and 9). The boundaries traced by the results of residual potential anomalies from the current investigation and earlier studies have been adjusted. Some boundaries traced according to the lineaments of THD of gravity results. Other boundaries are traced at the location of discontinuity or change of groups of gravity or magnetic anomalies (Fig.10). These tectonic boundaries are close to certain previously traced tectonic faults on Iraq's tectonic. The faults which previously traced were colored by black color, but the new suggestion faults were colored pink, as shown in Fig.10. The main faults in the study area can be partitioned into two groups. These are the longitudinal faults trending NW-SE (Najd faults system), while the transverse faults trending NE-SW represent the conjugate faults of Najd fault system.

Fig. 8. The anomalies axes of the residual gravity and magnetic maps
Fig. 9. The anomalies axes of the THD of gravity and magnetic maps.

Fig. 10. The main tectonic boundaries of the study area.
7. Conclusions

- Good results are shown by The THD technique to detect the faults in the study area.
- The structural interpretation and analysis of gravity and magnetic data reveal two main structural trends in the Al-Tharthar area. These are approximately represented by N45W and N60E.
- The lineaments of anomalies axes and the maximum THD of the gravity and magnetic map of Al-Tharthar and surrounding areas were used to trace many faults on the tectonic map of Iraq.

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