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Determination the Boundaries of the Tectonic Zones Southern Iraq, Using Trend Surface Analysis Method

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Abstract

A geophysical study investigation was conducted in the southern part of Iraq bounded by coordinates; longitudes (39◦ - 48◦) East and latitude (29◦ - 32◦) North. This study includes analysis and interpretation of the potential data (gravity and magnetic) derived from the Bouguer anomaly map and Aeromagnetic total field intensity map of Iraq both of them is within the scale of (1: 1,000,000) and do comparison with the information available from geological maps, which include Tectonic, Hydrological and Geological information.

Gravity and Magnetic maps of the study area were digitized at a grid interval of (1×1) cm which is equivalent to (10×10) km on the land. The trend surface technique was applied on the Bouguer anomaly map of the area. Through these analyses there are three tectonic boundaries have been proposed (A, B, and C). Results were compared with potential analyses of available geological information which match some faults proposed through data analysis with other geological information.

Keywords: Potential Information, Plate Boundaries, Tectonic Zones.

تحديد المناطق التكتونية جنوب العراق باستخدام طريقة التحليل السطحي الاتجاهي

الخلاصة:

اجريت دراسة جيوفيزيائية للجزء الجنوبي من العراق والمحصوره بين خطي طول (48◦ – 39◦) شرقا ودائرتي عرض (32◦ –29◦) شمالاً، اذ شملت هذه الدراسة تحليل وتفسير البيانات الجهدية (الجذبية والمغناطيسية) المأخوذة من خارطة شذوذ بوجير للعراق وخارطة الشدة المغناطيسية الكلية وكلاهما بمقياس 1:1000000 ومقارنتها بالمعلومات الجيولوجية المتوفرة والتي تتضمن معلومات الخرائط التركيبية، الهيدرو لوجية والجيولوجية.

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تم تشبيك منطقة الدراسة للخرائط الجذبية والمغناطيسة بفاصلة شبكية (1 × 1) سم أي ما يعادل (10 × 10) كم على الأرض، تم تطبيق طريقة التحليل السطحي الاتجاهي وتم رسم الخرائط الاقليمية والمحلية باستخدام (Surfer) و (ArcMap).
من خلال هذه التحليلات تم اقتراح ثلاثة حدود تكتونية المتمثلة بـ (A,B,C)، قورنت نتائج التحليلات الجهدية مع المعلومات الجيولوجية المتوفرة وقد تطابقت هذه الحدود التكتونية المقترحة من خلال تحليل البيانات الجهدية مع المعلومات الجيولوجية الاخرى.

1. Introduction

This study considered as geophysical applications that help to detect the tectonic and subsurface structures of the study area. Structures and the geological features influence the individual physical properties that related to each one. These physical variations may be projected on the gravity and magnetic maps as anomalies.

Regional magnetic anomaly mainly reflects the basement morphology and the eruptions of the igneous intrusion's, while the residual gravitational anomaly usually represents the overlying sedimentary rocks and targets above.

In this study the potential data (gravity and magnetic) are analyzed and interpreted in conjunction with other available geological data; this information's include structure, hydrological, and geological maps information.

2. Study area

The study area located in the southern part of Iraq covering an area of about (165270) km^2, Figure (1).

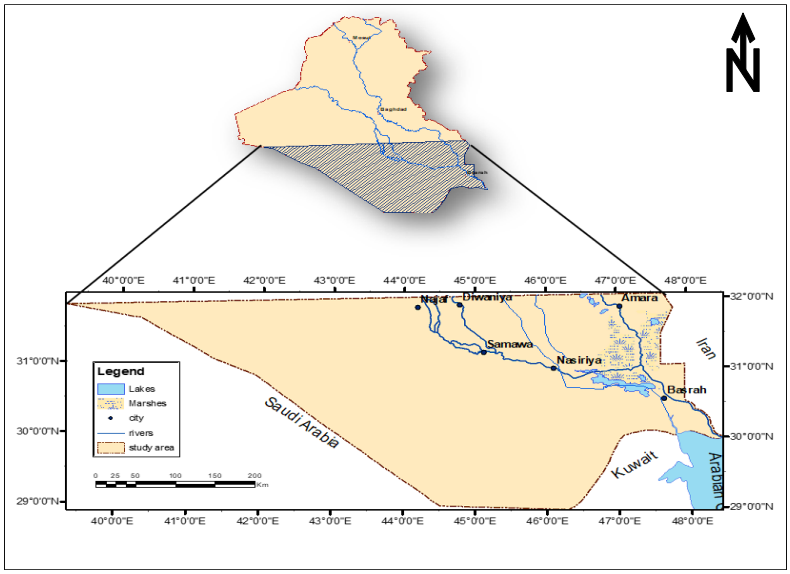

Fig. (1): Location of the study area.

Open Access
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3. Aim of the Study

As a complementary fashion of tectonic image, we gathered the gravity and magnetic interpreted data with the other available geological information to detect the major tectonic boundaries of the area.

4. Basic Theory

The gravity and magnetic investigations measure a certain amount of change in the physical properties of the rocks from place to place. The real interest of the two methods gravity and magnetic is drawing anomaly maps, which may show the extent of certain structures geological beneath the surface.

In each case, the interest and application methods vary depending on the relative importance of the physical characteristic of the teams included in various geological conditions. The lateral change in density and susceptibility of the surface are reflected on the gravity and magnetic measurements as an anomaly.

The gravity exploration method depends on the measurement of small changes in gravity. The small differences or confusion in the field of gravity on the land could happen due to the lateral changes in the distribution of the blocks in the Earth's crust. The geological variations under the surface contain blocks with different densities; they allow the distribution of mass fraction is found irregularly and then causes changes in the intensity of gravity. [1]

The high frequency (Shallow) anomalies are subtle by the low frequency anomalies (Deep). Therefore, many graphical and analytical methods are used to separate these anomalies.

The Magnetic method is one of the oldest geophysical exploration methods that use the natural magnetic field of the Earth, which is a quick and inexpensive way and used in ground surveys, sea and air, which is an effective tool in the exploratory survey of basins sedimentary service for the purposes of oil and mineral, as well as their use in geological mapping, and in engineering activities at shallow depths. [2]

This method is based on the measurement of few changes in the magnetic field, and these changes are attributable to differences in the distribution of magnetic rocks and the heterogeneity in the composition of the basement rocks, as well as structures and topography of the surface of the base (Sharma, 1986). These changes in the area measured by sensitive devices and then interpreted in terms of geological conditions below the surface. [1]

The aim of a magnetic survey is to investigate subsurface geology on the basis of the anomalies in the earth's magnetic field resulting from the magnetic properties of the underlying rocks. [3]

Open Access
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5. Analysis and Interpretation of potential data (Separation of Anomalies: Regonal and Residual)

The output of the final potential field survey (gravity and magnetic) after applying the necessary corrections is a contour map [4]. These corrected maps did not give a clear picture of the subsurface structures unless treated ways analytical or graphic that work on the separation of anomalies from each other. [2], [5]

There is an ambiguity in the potential interpretation where it is not conclusive or definitive, but requires a great deal of conjecture and assumptions, and this is clear by the large number of methods used to solve this problem, but this ambiguity can be reduced by using other available information, such as geophysical and geological information from wells. [1], [6]

Generally, the mathematical analysis can have applied for any digital values. Therefore, some of the following methods are applied for gravity, magnetic and hydrological data. Several analytical methods were used to separate residual from regional anomalies, including Trend Surface Analysis method for Gridding part, because these methods are compatible with the objectives of the study that is looking for studding of the tectonic boundary of the studied area.

5.1. Trend Surface Analysis method

It is a statistical method applied to the structural surfaces or topography. The purpose of this method is to separate of trends in the data, potential observation and to find their relationship to geological trends method least square, as it shows this type of structures anomalies analysis, which are important for geophysicists, and also provides us with important geological information about the (Linear structures) related tectonic phenomena. [7]

Indicated that it can represent the regional area as a (Polynomial surface) with a neat and low-lying and the difference between the observed values of the gravity field of the surface and this represents residual anomaly to this area. [1]

The polynomial surface depends largely on the complexity of the regional geology, if the regional planar sloping field, the first order of mathematical surface expressed in the following relationship:

$$Z = AX + BY + C$$

While expressing the most complex phase in the regional geology polynomial of the second order is used to express the surface of the regional field as follows:

$$Z = AX^2 + BY^2 + CXY + DX + EY + F$$

Open Access
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The Coefficients as A, B, C.... etc. is determined by the minimum squares, while residues determine by subtracting polynomial of Physical measured values of surface area values. [8]

6. Data Analysis and Interpretation

It is known that the potential maps (gravitational and magnetic) rarely represent a simplified picture of single geological feature. They reflect mostly two types of effects of sharp local effects resulting from geological structures specific dimensions close to the surface, and other effects for the areas resulting from the structures that are located at greater depths.

In addition, there is always an ambiguity surrounding the process of separating anomalies from each other and returning to the source which resulted from it, as well, the interpretations of potential methods of ambiguity, so are relying on potential maps in studies to identify the structures under the surface in areas where the worse the quality of data and depths which are undiscovered.

Several analytical operations carried out on potential maps and these processes used to identify and confirm a section of the anomaly and the separation of anomalies that are or sources close overlapping, in order to reduce uncertainty in the possibilities that cause abnormalities and give a clearer picture to the subsurface.

6.1. Analysis of Gravity data

It is one of the analytical methods more flexible to analyze the physical field to be separated to the regional compounds with regional sources and wide spread and deep. For the residual compounds (local) with limited resources shallow, using the appropriate method is a (polynomial) method that depends on the method of minimum squares. [9]

The Bouguer anomaly map of the study area was digitized at a grid interval of (1×1) cm that is equivalent to (10×10) km on the earth, Trend surface technique was applied on the Bouguer anomaly map of the area by using the (Surfer) and (ArcMap), and a set of three orders of the regional maps were plotted, Figures (2) and (3).

These analyses were applied to the magnetic from The Aeromagnetic total field intensity map.

The 1st order regional map shows parallel straight contour lines trends NW-SE direction with values ranging between (-65) mgal at the eastern parts of the area to about (-25) mGal at the west parts. This may lead to the existing of regional plane surface which slops from the west and southwest towards east and northeast parts (increasing in the sedimentary overburden and basement depth towards east). On the other hand, as seen from the remaining two orders regional

Open Access
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E- ISSN: 2710-1096

maps, that there is an increase in the gravity values has occurred at the central zone of the area to about (-30) mGal, as shown in Figure (2). The zone (A) can be determined in 2nd order and 3rd order maps, which extend on the eastern part of the study area towards the NW - SE, as well as the zone (C) can be determined on the western side of the study area.

This range of values is appeared on these orders maps as a contour closure trending NW-SE; as well as it may occur owing to the presence of the basement uplift, lateral variations in rock densities or/and regional anticline. Also, there are wide areas inside this zone with empty features have highly gravity anomalies however, it may reflect the existence of tough rock layers far away from the horizontal tensional stresses that coming from the east.

Figure (3) represents the orders of residual maps, all these maps declare the existence of the positive (blue) and negative (yellow) anomalies depend on the nature of the rocks and lithology. Relatively, highly dense rocks yield positive anomalies, whereas the weak zones, such as faults, joints, fissures, voids and cavities surely represent the negative low dense rocks. In addition, it was observed that the positive anomalies for the first three orders were positioned within the similar areas; and were distributed along NW-SE trends, especially at the central parts of the 1st order map.

The orders residual maps contain positive and negative anomalies, positive anomalies are concentrated in central areas and they have the same location in all residual maps. The most important of these anomalies are a large anomaly at NW-SE direction, and it is located in the Salman zone, North (Al-Shabjah), west of (Samawa). The positive anomalies have been interpreted in Salman zone as uplifts in the basement rocks. [10]

These axes of positive anomalies with different directions, either negative anomaly are concentrated in the eastern Al-Shabjah region and Salman zone. This anomaly may be caused by the presence of acidic igneous rocks have a low density, axes which have been identified for these anomalies are found to have several directions.

By identifying positive and negative axes of these anomalies and through different patterns of anomalies, three zones of boundaries have been identified (A, B, C), That correspond to the boundaries locations that have been identified through the horizontal gradient method on the residual anomaly maps.

Open Access
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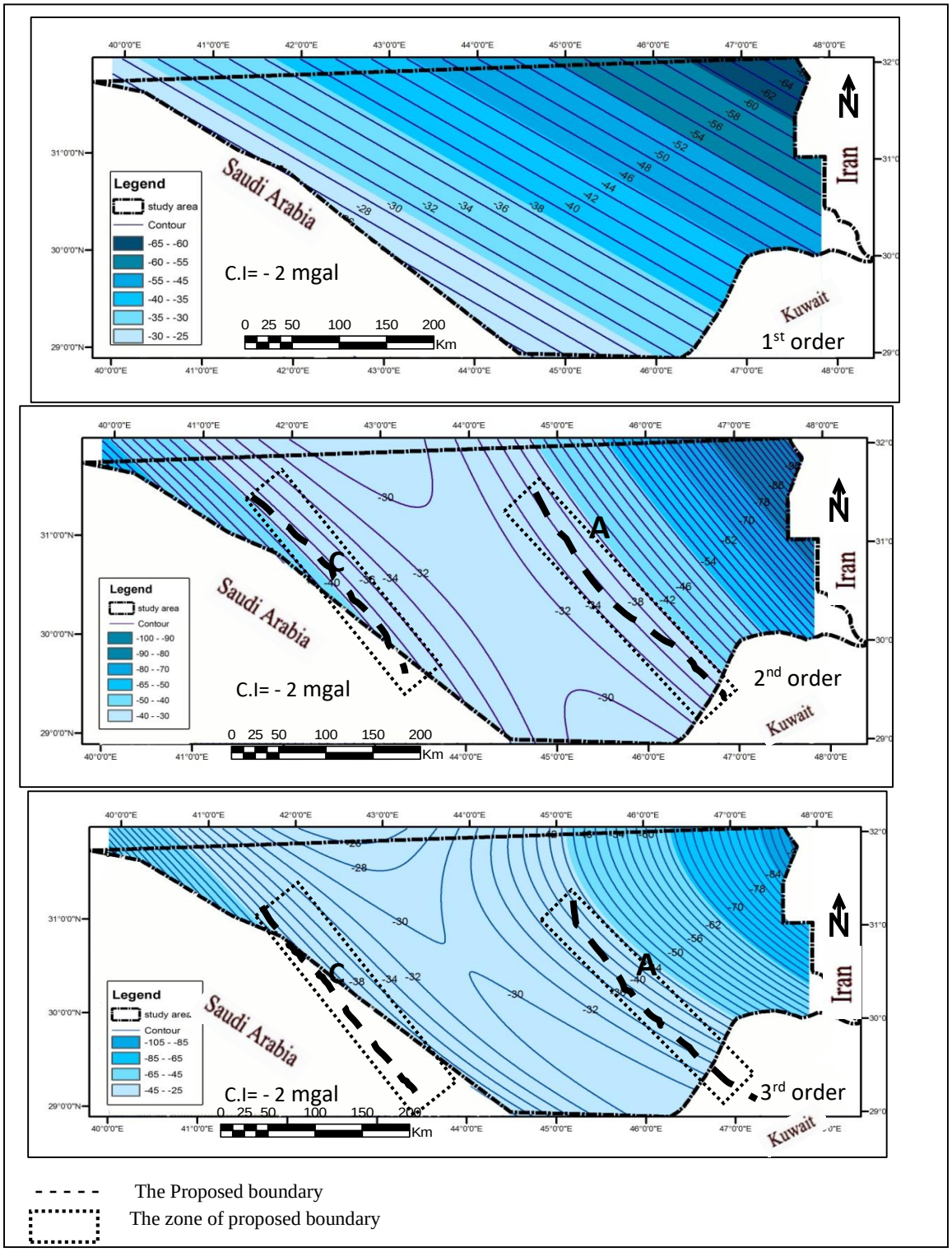

Fig. (2): Three orders of the regional gravity Trend Surface analysis anomaly maps for the study area.

Open Access
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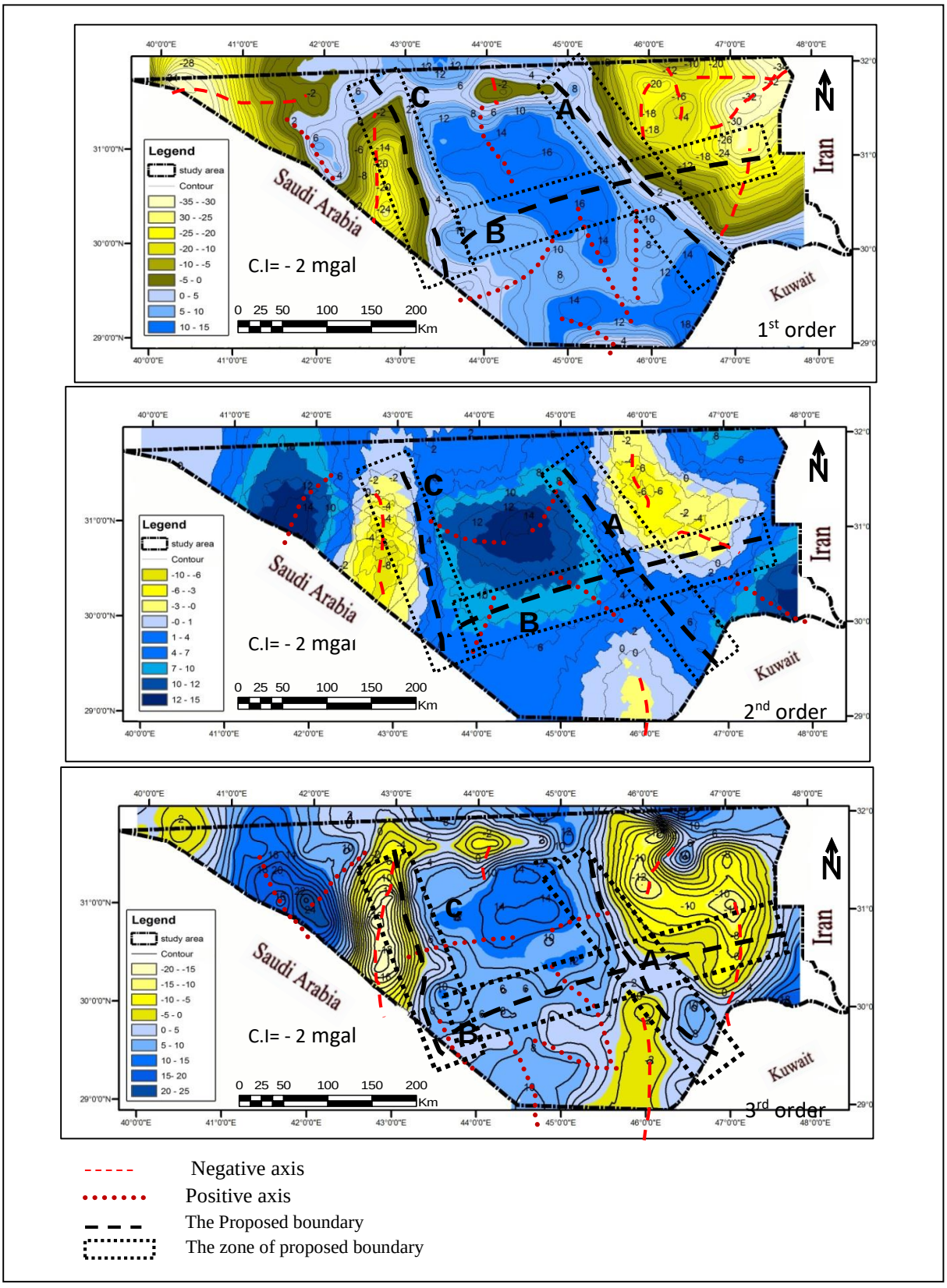

Fig. (3): Three orders of the residual gravity Trend Surface anomaly maps for the study area.

Open Access
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6.2. Analysis of Magnetic data

It is a suitable method in determination of regional magnetic phenomena using Polynomial surfaces; they separate the potential field to regional and residual compounds. This process is performed by using the (surfer) and (AecMap) software on the magnetic information directly. In the first order map of magnetic regional (Figure (4)) Observed that the magnetic gradient increases towards the NW, and that the highest value of the magnetic intensity observed in the northwest, while the lowest value of the magnetic intensity is the southeast due to increase in sedimentary cover thickness in this direction. In the map of regional second and third orders, the direction of the magnetic field is northwest - southeast also but contour lines in these two orders differ from the contour lines of the first order. While the contour lines on the first order map are in NE – SW direction, these maps become curved toward the southeast, as they reflect the lines of magnetic gradient in this direction, and that the highest value located in northwestern part and its minimum value is located in the Southeast.

The maps of the three residual orders as in Figure (5) are similar in general form with some few differences, these maps contain negative magnetic anomalies, and positive different in size and direction.This anomaly may represent structures in the form of anticlines or declines or changes in lithology, and that the direction of most of these anomalies follow major tectonic trends which is north - south, northeast – southwest, and northwest – southeast, Most of these anomalies with forms or circular elongated and there is a great similarity in the residual magnetic maps of all orders and that may confirm the same depth or source of the anomaly.

Axes of magnetic anomaly are directed in all orders; noting there are similarities in the positions and directions of these axes and all orders. Three zones of boundaries (A), (B) and (C) identified depending on the pattern and direction of the magnetic anomaly axes.

It is thus clear that this analytical method is a good method to separate the Potential field to its local and regional compounds, as the regional maps which are obtained from this method describe the direction of the gradient magnetic field only. Increase the order of regional maps, the contour lines become more complicated and does not give specific direction to the decline of the magnetic field. The residual maps are similar to the total magnetic field maps, but the anomalies became negative and positive and become more acute and clear so that they can determine the tectonic phenomena such as the presence of faults or structures or igneous bodies.

Open Access
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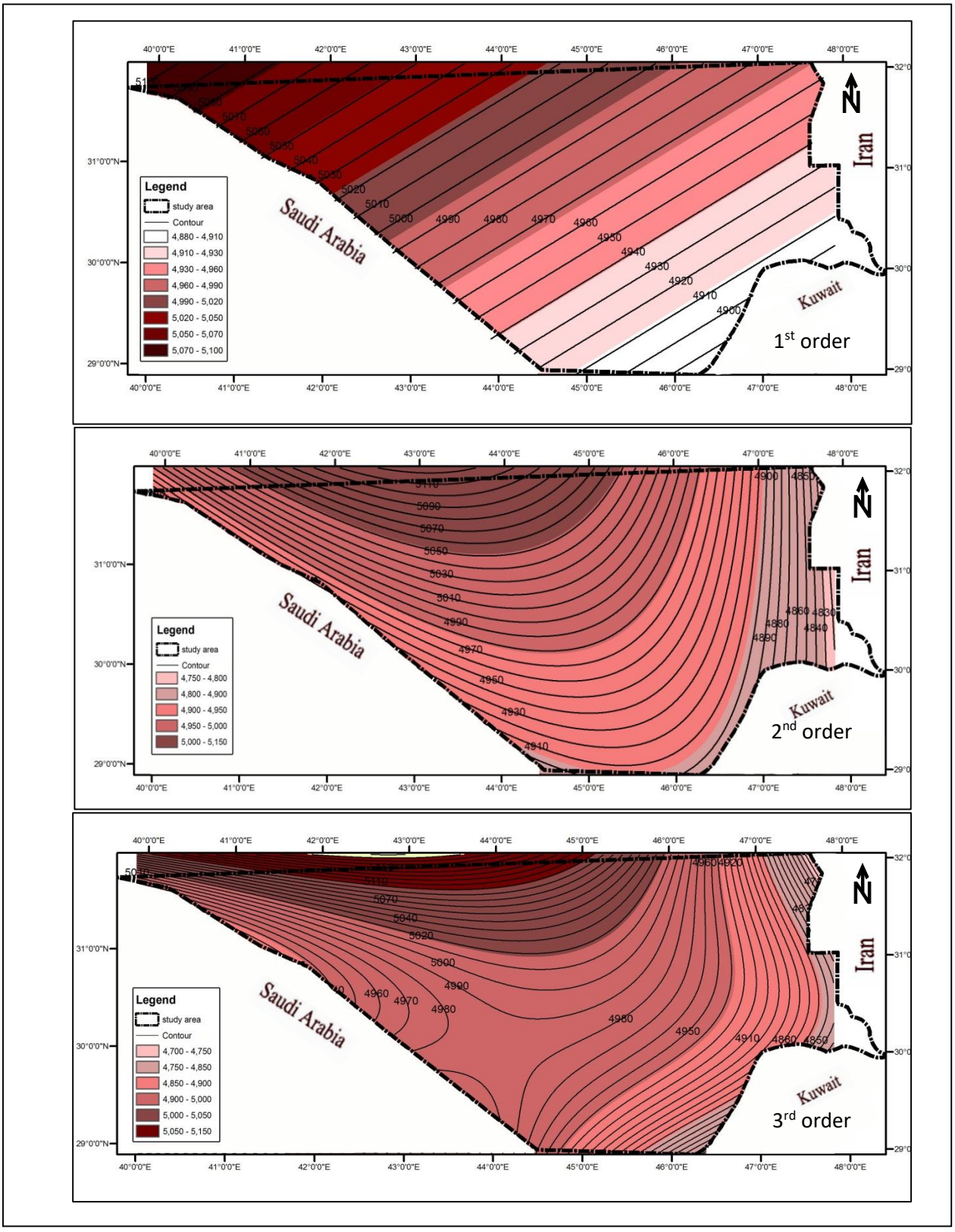

Fig. (4): Three orders of the regional magnetic Trend Surface anomaly maps for the study area.

Open Access
No. 38, March 2023, pp. 1-15

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E- ISSN: 2710-1096

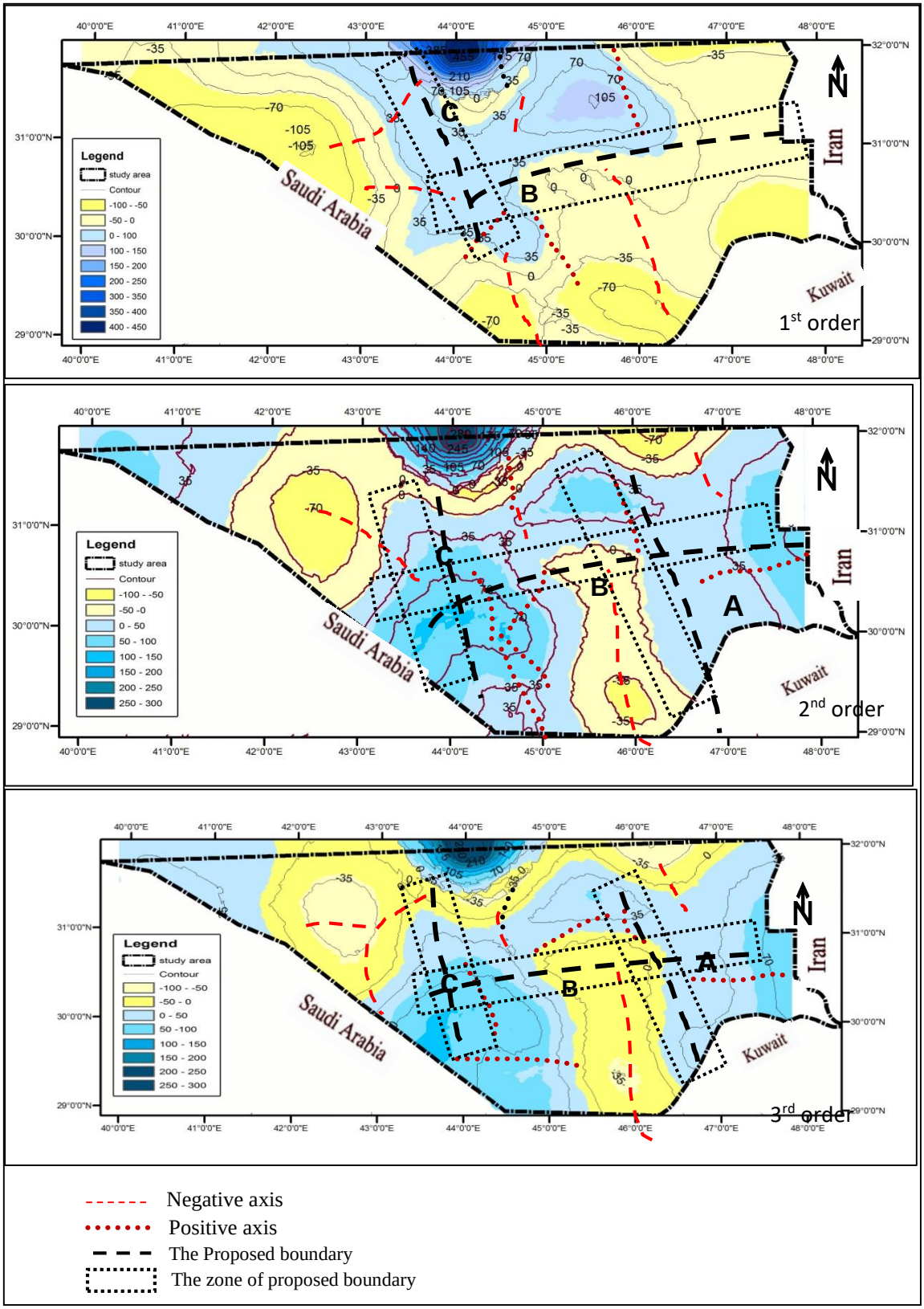

Fig. (5): Three orders of the residual magnetic Trend Surface anomaly maps for the study area.

Open Access
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6.3. Analysis of Geological information

From the geological map issued by the Iraq Geological Survey (GEOSURV), it is believed that there are boundaries (Despite the overlap) between geological outcrop formations which have already been mentioned in the description of the geological setting of the study area, there is the zone of boundary (A) between the Quaternary deposits, which represent deposits of modern Mesopotamia, which is located within the unstable shelf, and Tertiary deposits located within the stable shelf. This boundary extends towards the NW parallel to the Euphrates River begins from NE of Busayah to the NW of Najaf, this boundary appears in the tectonic map prepared by [11] as normal subsurface fault. While the zone of boundary (B) extended with extension of Euphrates River, completely this extension between the borders of the outcropping formations. Also, the zone of boundary (C) can be considered as the eastern border of the Salman zone while the western border of the Salman zone clearly appears on geological map as a separator boundary between formations or sediments, as in Figure (6).

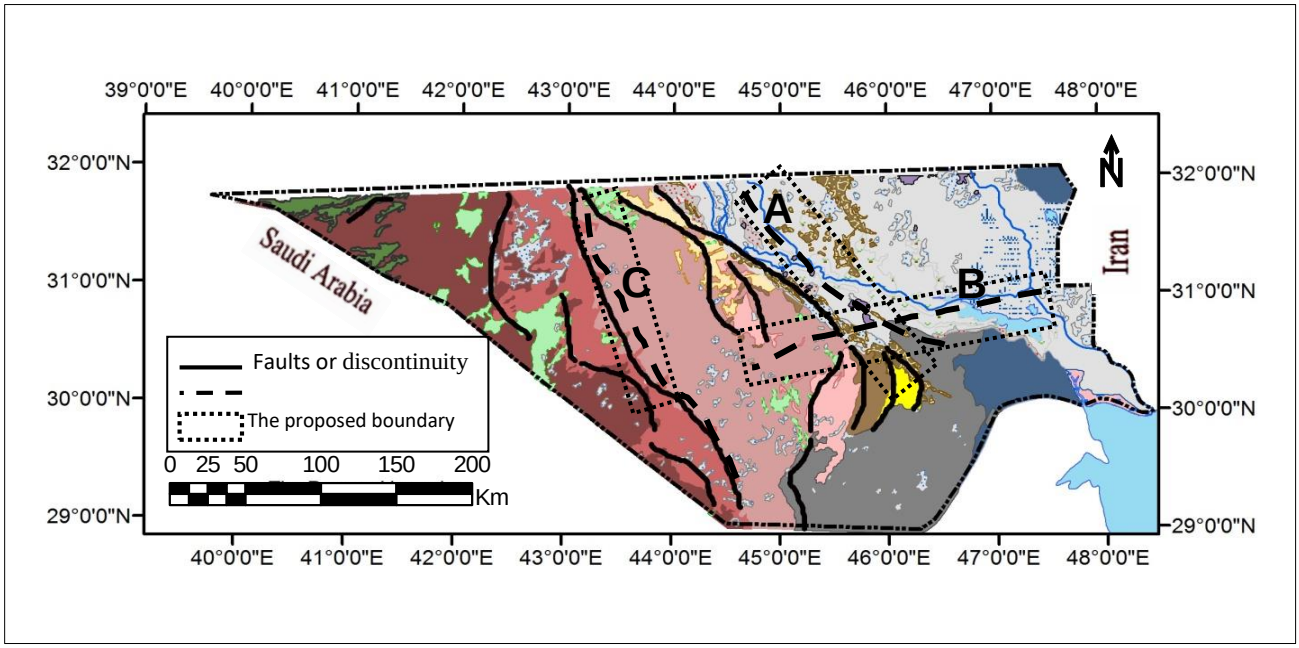

Fig. (6): Tectonic boundaries depend on the geological analysis of the study area.

6.4. Analysis of Tectonic Map information

By comparing proposed faults through potential and Hydrological analysis with the tectonic map by [11], it is observed that there are some of these boundaries may be matched or be close to faults or geological structures which are installed in the tectonic map, this is evidence that the

Open Access
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results of these analysis may be true. The proposed tectonic boundaries (A, B, C) of the previous analyzes when compared with the tectonic map prepared by [11], the boundary A parallel to the eastern borders of the Salman subzone, the B boundary parallel to the western borders of the Salman subzone, while C boundary parallel to the northern border of the Zubair subzone as in Figure (7).

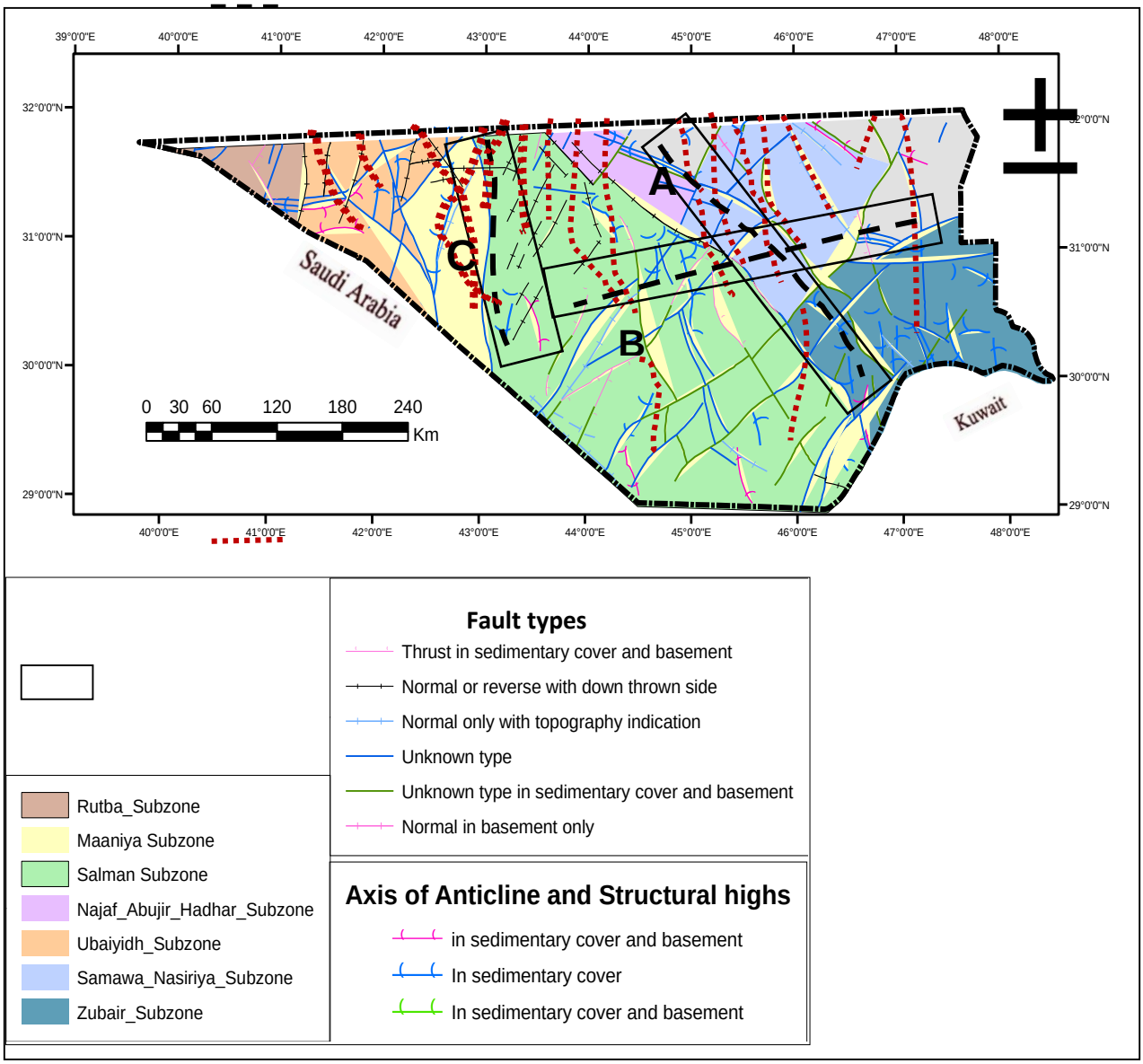

Fig. (7): Tectonic map of study area with the proposed boundary (Modified from [11])

Open Access
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7. Conclusions

Through qualitative analysis of available geological and geophysical data about the study area, and depending on the progress of the research and the results of geological and geophysical analyses, we can conclude the following:

1. Trend analysis maps of Bouguer anomaly in three orders were drawn for each of the local and regional anomalies. The first map order that the general direction of the field of gravitational is NW - SE, while the remainder orders maps have clearly appeared the presence of a semblance rise with the amount of high gravitational extends towards the northwest - southeast and divides the study area into eastern part and the western part which have few amount of gravity. While in the local gravity anomaly maps there are positive and negative anomalies. The positive and negative axes of this anomalies, gave a clear image of the zone of the tectonic boundary which are designated as (A, B, C).
2. Trend Surface analysis maps of Regional directional anomalies magnetic plotted for three orders. In the first regional order, the general direction of the magnetic field is northeast - southwest. The remaining Regional orders maps contain some secondary regional magnetic trends field in toward the Southeast, and Southwest. Either in surface residual analysis maps been appointed the positive and negative axes in these maps and set the zone of the tectonic boundary (A, B).
3. The data available from map lead to determine the surface geological tectonic boundaries of the study area, reflected well on the length of the boundary between geological formations outcropping to surface.
4. Comparison of the proposed tectonic boundary by the qualitative interpretation of geological and geophysical data installed in the tectonic map by [11] note that there is a consensus that confirms the correctness of these interpretations.

Open Access
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