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Quantitative Interpretation of Gravity and Magnetic Anomalies in West of Tikrit City and Surroundings, Iraq

Mahmoud Abdullah Al-Mufarji[1], Emad Mohammed Salih Al-Heety[2*], Losyan Habeeb Al Esho[3]

[1] Department of Applied Geology, University of Kirkuk, KirKuk, Iraq
[2]Department of Applied Geology, University of Anbar, Rammadi, Iraq
[3]Department of Geology, University of Mosul, Mosul, Iraq

Abstract

A quantitative interpretation of gravity and magnetic anomalies in west of Tikrit city and surroundings, has been completed utilizing Grav2dc and Mag2dc (2D, 2.5D) forward techniques. The modeling has been carried out along four profiles, two NW-SE profiles along the distinct gravity residual anomalies and two NE-SW profiles along the magnetic residual anomalies. The most geologic plausible model that matches the data was picked. The model along the gravity profile (A-A') reveal faulting of the basement, whereas along the profiles B-B', C-C' and D-D' did not present faulting. The models comprise of two rock units, the first is the sedimentary cover and the second unit is the basement rock. According to the results of modeling, thickness of the sedimentary cover and basement depth values are in good agreement with the results of previous studies. The upper part of sedimentary cover exhibited different density and susceptibility contrasts. These contrasts may be interpreted in term of lithological lateral variation.

Keywords: Gravity; Magnetic; Residual anomaly; 2D and 2.5D modeling; Iraq.

التفسير الكمي للشواذ الجذبية والمغناطسية لغرب مدينة تكريت وما يجاورها، العراق

محمود عبد الله المفرجي[1]، عماد عبد الرحمن محمد صالح الهيتي[2*]، لوسيان حبيب ال ايشو[3]

[1] قسم الجيولوجيا التطبيقية، كلية العلوم ، جامعة كركوك، كركوك، العراق.
[2]قسم الجيولوجيا التطبيقية، كلية العلوم، جامعة الانبار،الأنبار، العراق.
[3]قسم علوم الأرض، كلية العلوم، جامعة الموصل،الموصل، العراق.

الخلاصة

أجري تفسير كمي للشواذ الجذبية والمغناطيسية في غرب مدينة تكريت وما يجاورها باستخدام تقنيات النمذجة الأمامية (Grav2dc and Mag2dc, 2D, 2.5D). أنجزت النمذجة على امتداد أربعة مقاطع ، أثنان باتجاه شمال غرب – جنوب شرق بالنسبة للشواذ الجذبية المتبقية ومقطعان على امتداد الشواذ المغناطيسية المتبقية في اتجاهات شمال شرق – جنوب غرب. تم اختيار الموديل المقبول جيولوجيا والذي يتطابق مع البيانات المستخدمة. الموديل على امتداد المقطع الجذبي (A–A') يظهر تصدعا في صخور القاعدة، بينما لايظهر تصدع في المقاطع (B–B') و(C–C') و (D–D'). تتضمن الموديلات وحدتين صخرية، الأولى هي الغطاء الرسوبي والوحدة الثانية صخور القاعدة. أظهرت نتائج النمذجة تطابقا جيدا لسمك الغطاء الرسوبي وعمق صخور القاعدة مع نتائج دراسات سابقة. سجلت اختلافات في الفارق الكثافي والفارق

*Email: salahemad99@gmail.com

في السماحية المغناطيسية في الجزء العلوي من الغطاء الرسوبي، ويمكن تفسير هذه الاختلافات في سياق التغير الجانبي في الليثولوجي.

Introduction

Gravity and magnetic anomalies interpretation range from qualitative, to comprehensive quantitative modeling of anomaly data [1]. Gravity and magnetic modeling is never unique so several models may fit the data equally well [2]. The non-uniqueness of gravity and magnetic modeling generates from the ubiquitous presence of data errors and the inherent source ambiguity of the gravity and magnetic potentials [1]. The purpose of gravity and magnetic modeling is to produce a geologic model satisfying their data and fitting all other available geological or geophysical data which can bear on the problem [3]. An important reason for using auxiliary geological and geophysical data is to decrease the ambiguities of gravity and magnetic interpretation [4].The study area lacks published gravitational and magnetic studies with exception of study [5]. They interpreted qualitatively the gravity and magnetic anomalies and presented gravity and magnetic lineaments maps. There are few geophysical studies were carried out in adjacent regions to the study area [6,7]. The current work aims to employ 2.5 modeling of gravity and magnetic anomalies in the study area to define the geometry, depth and geophysical parameters (density and susceptibility) of the causative bodies of anomalies. The scarcity of the geophysical studies conducted and the geologic and tectonic importance of the study area motivated us to carry out this study. We expect that contribute new information on the subsurface geology.

Geologic and Tectonic Setting

The study area locates to the west of Tikrit City between latitudes 34^o-35^{o}N and longitudes 42^o-43^{o}E, Figure-1. The majority of the study area is flat except of the south –western part and the eastern bank of Tharthar Lake, in which the region is crossed deep valleys and tributes and lead to a form of hills and barren land. The outcropped formations within the study area have ages ranging from Oligocene to Pliocene with the presence of different types of Quaternary deposits, Figure-2. The subsurface formations beneath the study area and their lithology are listed in Table-1.

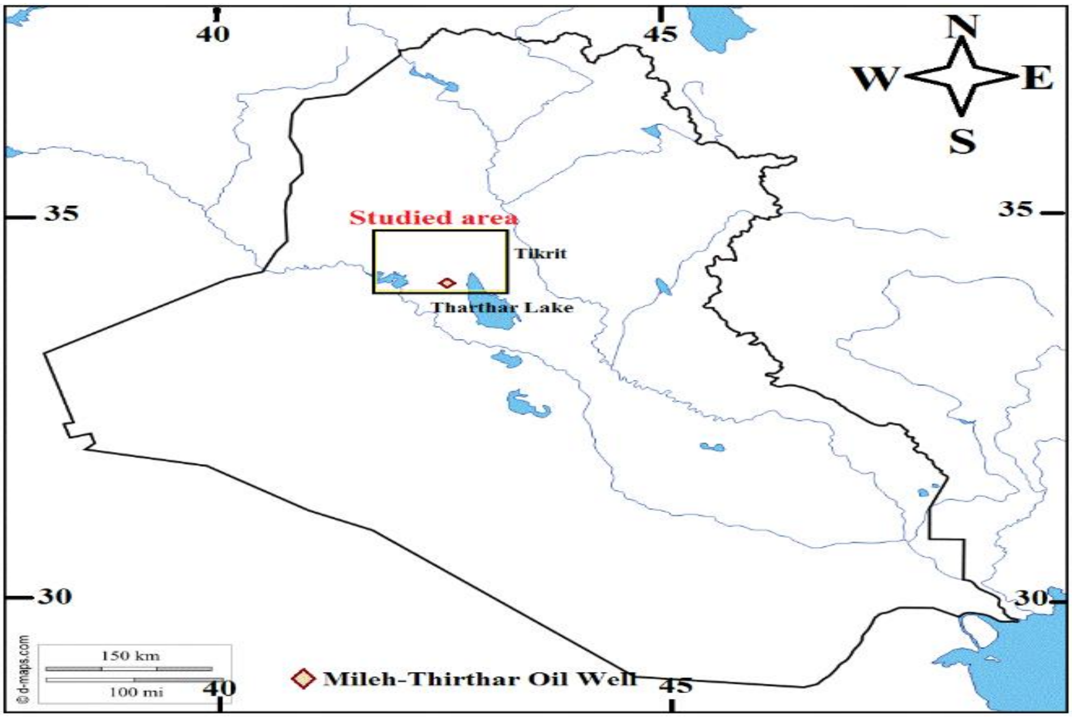

Figure1-Location map of the study area

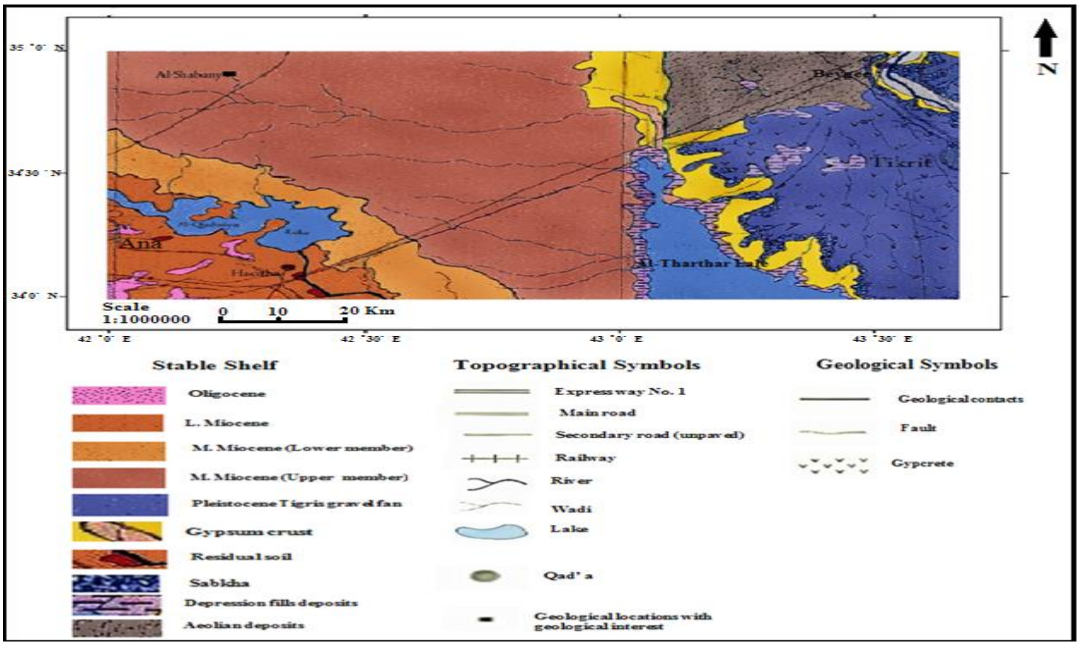

Figure 2-Geologic map of the study area (Modified from geologic map of Iraq prepared by GEOSURV [8]).

Table 1-Melih Thirthar oil well (MTn-1) [**9**]

FORMATIONS	DEPTH	THICKNESS
Fatha	Surface	184
Jeribe	184	72
Euphrates	256	24
Anah	280	20
Azkand	300	58
Tarjil	358	28
Palani	386	30
Jaddala	416	34
Aaliji	450	181
Hartha	631	71
Sadi	702	48
Tanuma	750	60
Mauddud	810	312
Nahr Umr	1122	65
Shuaiba	1187	41
Zubair	1228	340
Gotnia	1568	272
Najmah	1840	30
Sargelu	1870	242
Alan	2112	87
Mus	2199	55
Adiyah	2254	148
Butmah	2402	393
Kurra chine	2795	655
Geli khana	3450	324
Beduh	3774	

Tectonically, the study area locates within the stable shelf, Figure-3. The stable shelf covers most of the central south and west of Iraq and extends westwards into Syria and Jordan and southwards into Kuwait and Saudi Arabia. The stable shelf is a tectonically stable monocline little affected by Late

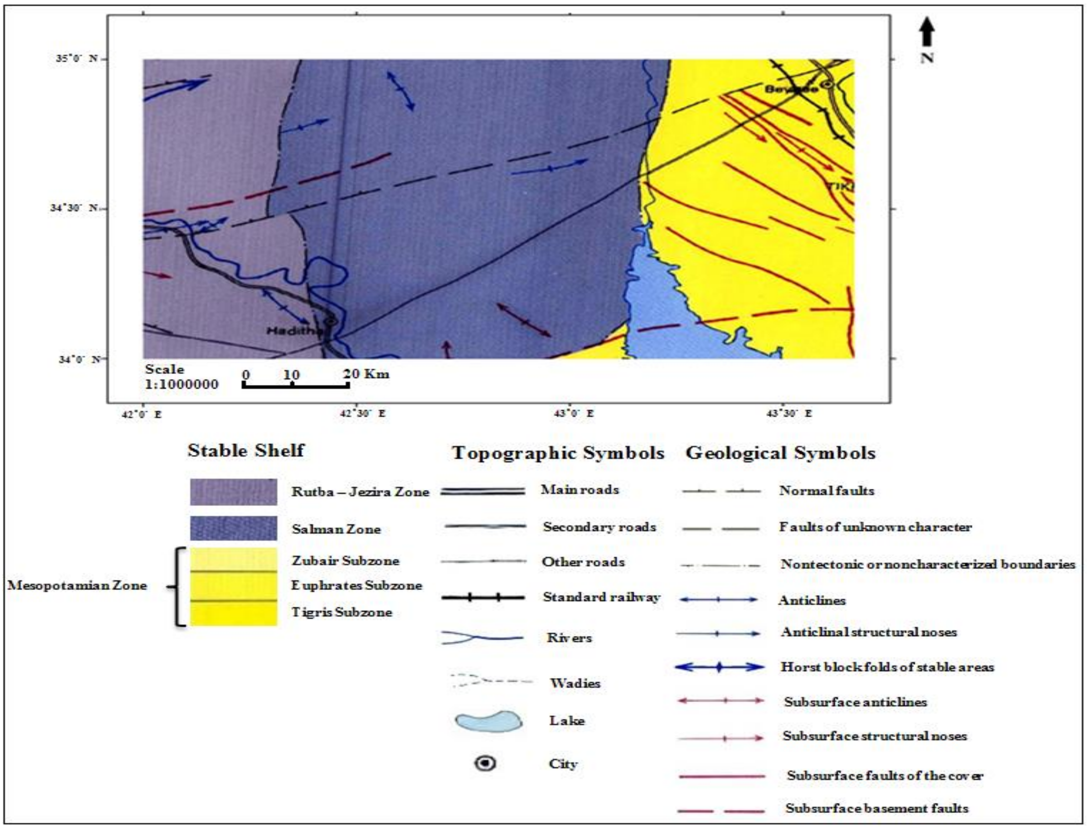

Figure 3-Tectonic map of the study area (Modified from tectonic map of Iraq prepared by GEOSURV [10]).

Cretaceous and Tertiary deformation. The orientations of the structures in this tectonic unit influenced by the geometry of the underlying basement blocks and faults, Paleozoic Epeirogenic events and Mesozoic arching [11]. The stable shelf is divided into three major tectonic zones comprising the Rutbah –Jezira zone in the west, Salman zone, and the Mesopotamian zone in the east [12].

Data Acquisition and Processing

The sources of gravity and magnetic data are the Bouguer gravity and aeromagnetic maps of Iraq compiled by Abbas et al. [13] and CGG [14], respectively. Both maps have scale of 1:1,000,000 with contour interval of 0.5mGal and 5Gamma for the Bouguer gravity and aeromagnetic maps, respectively. The original maps were digitized and shown in Figures-(4, 5). In quantitative interpretation, isolation techniques are applied to gravity and magnetic data to extract anomalies of interest in the survey [1]. In this study, polynomial technique was employed for residual- regional isolation.

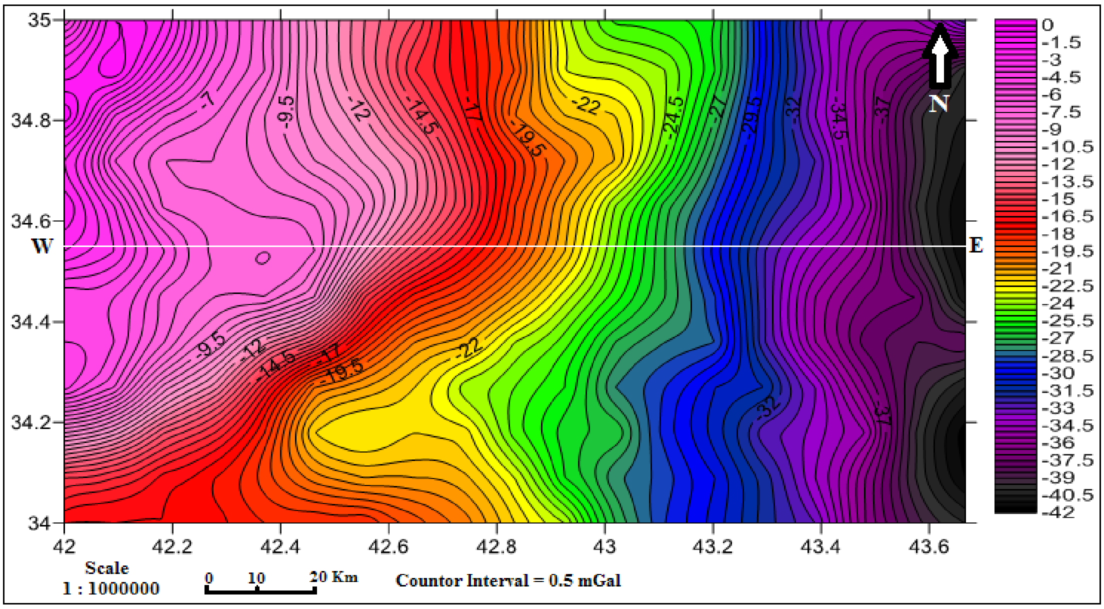

Figure 4-Digitized Bouguer gravity map of the study area (After Abbas et al. [13]).

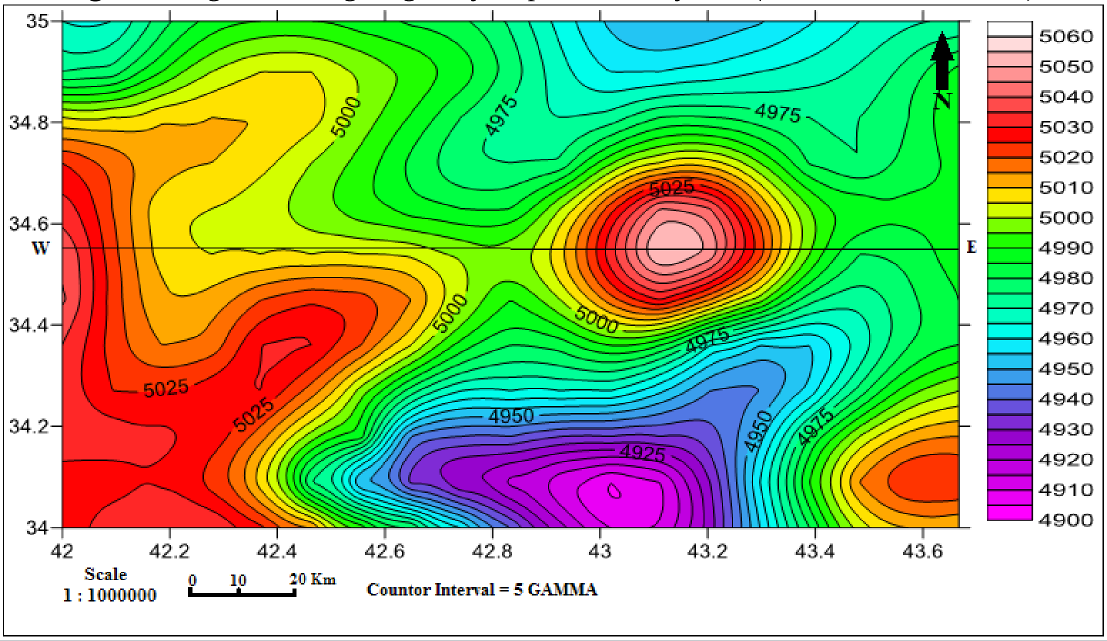

Figure 5-Digitized aeromagnetic map of the study area (After CGG [14]).

This technique represents the residual-regional anomalies as least squares polynomial approximations or trend surfaces [15, 16]. Trend surface analysis is one of the most flexible analytical techniques for isolation regional anomaly from residual anomaly [17]. The results of isolations of residual anomaly from regional anomaly using first order of polynomial techniques are shown in Figures-(6, 7).

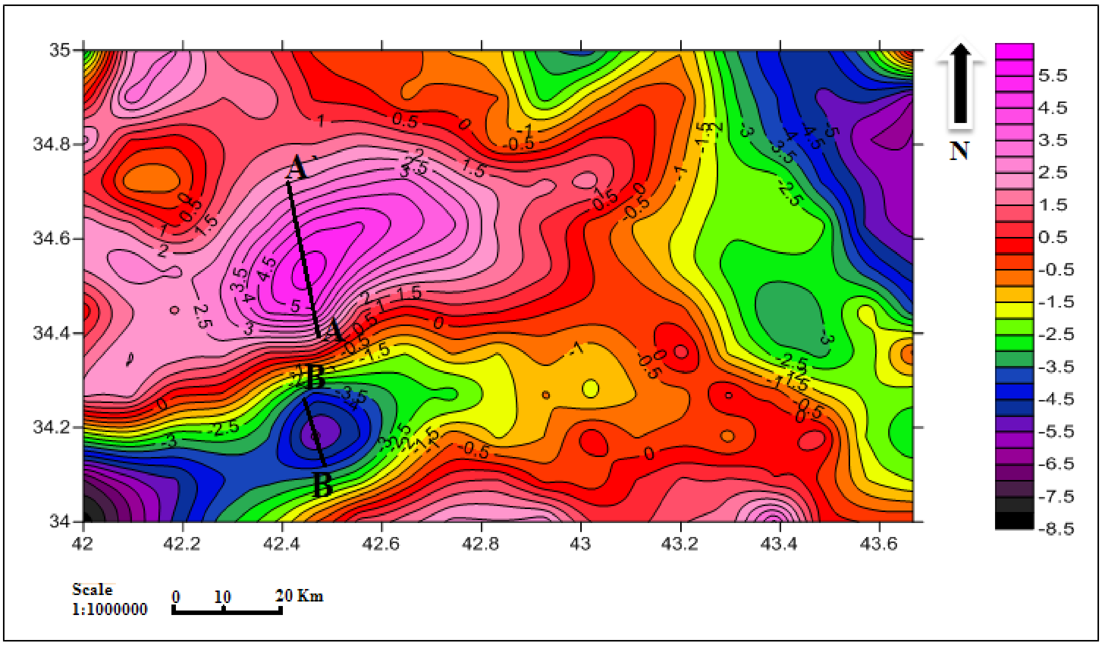

Figure 6-Residual gravity anomaly map of the study area.

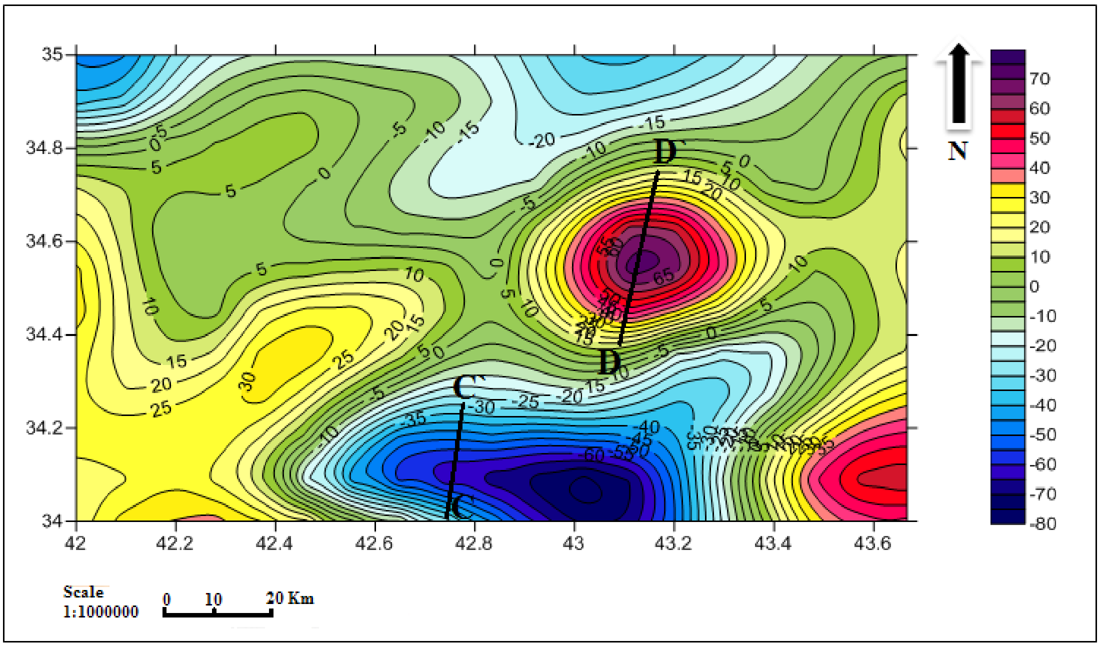

Figure 7-Residual magnetic anomaly map of the study area.

2.5D forward modeling

The modeling of anomaly sources concerning determine a solution by trial and error alterations of unknown parameters until predictions of the forward model replicate the observed data within a specified margin of error is called forward modeling, while demonstrating the unknown parameters directly from the observed data using an optimization process comparing the observed and predicted data is called inverse modeling [1]. Anomaly modeling includes 3D attempts over anomaly maps compared with 2D and 2.5D attempts that apply to profile across the gravity and magnetic anomalies. If the longitudinal extent of anomaly is at least five times greater than transverse width, we assume strike extent and the modeling is 2D [18, 19]. If the ratio of main extension to transverse extension is smaller, modeling should take into account the limited length of the body, modeling is called 2.5 dimensional (2.5D), [17]. This forward modeling technique involves computing the effects from a simplified mathematical model of the presumed subsurface conditions with iterative re-computation of the effects based on alterations to the parameters of the forward model until matching with the residual anomaly is conducted. The selection of the best matching between the residual and calculated anomalies is highly subjective and likely to vary with interpreter, amount of geological and geophysical subsurface control and objective [1]. 2.5D modeling was employed to model the residual gravity and magnetic anomalies in many studies [2, 20- 24]. In the current study, a 2.5D modeling softwares grav2dc and mag2dc [25, 26] were used for forward modeling along the selected profiles. Both softwares use the Talwani algorithm [27] to calculate the gravity and magnetic anomalies produced by the causative bodies. Two and one half dimensional gravity forward modeling has been applied along two profiles AA' and BB' on the residual gravity map (Figure-6). Densities, gravity anomalies and distances are measured in gm/cm^3, mGal and meter or kilometer, respectively. The density of the various rocks under the study area obtained from Ditmar et al. [28] and Oglo [29]. The density of the sedimentary cover in the area under study area ranges from 2.31 to 2.89 gm/cm^3 with average value of 2.60 gm/cm^3. The density of the basement rock as estimated by Ditmar et al. [28] equals to 2.77 gm/cm^3. The density contrast between the sedimentary cover and the basement rocks was chosen to be 0.17 gm/cm^3 for the gravity data modeling. 2.5D magnetic forward modeling has been carried out along CC' and DD' profiles on the residual magnetic map (Figure-7). According to the National Geophysical Data Center (NOAA), the magnetic intensity, the inclination and declination angles were determined for each profile due to latitude and longitude of the study region. The magnetic intensity, the inclination and the declination angles along the CC' profile are 28465.2nT, 52.5016^o and 4.8593^o, respectively, while are 28727.1nT, 51.8911^o and 4.8744^o along DD' profile, respectively. The magnetic susceptibility of the basement rock and the susceptibility contrast between the basement and the sedimentary cover estimated while modeling the profiles.

Results and Discussion

Gravity Modeling

The forward models along the AA' and BB' profiles are shown in Figures-(8, 9). The models contain two main lithological units, sedimentary cover unit and basement rock unit. The gravitational models showed that the sedimentary cover units includes two lithological subunit with a density contrast ranging between -0.097 to 0.0797 gm/cm^3 for the first model (Figure-8), and between -0.145 to 0.0365 gm/cm^3 for the second model (Figure-9). The upper subunit of the sedimentary cover reveals lateral variation in density contrast in both models while the lower subunit does not show any variation in the density contrast. Variation of the density contrast in the upper subunit can be attributed to lateral lithological variation whilst the density contrast in the lower subunit may be interpreted in term of similar lithological properties. The second main unit represents the basement rocks with granitic composition [28]. Ditmar, et al. [28] determined the composition using the basement outcrops in the surrounding countries. The first models exhibited existence of fault dividing the basement into two blocks along the AA' profile.

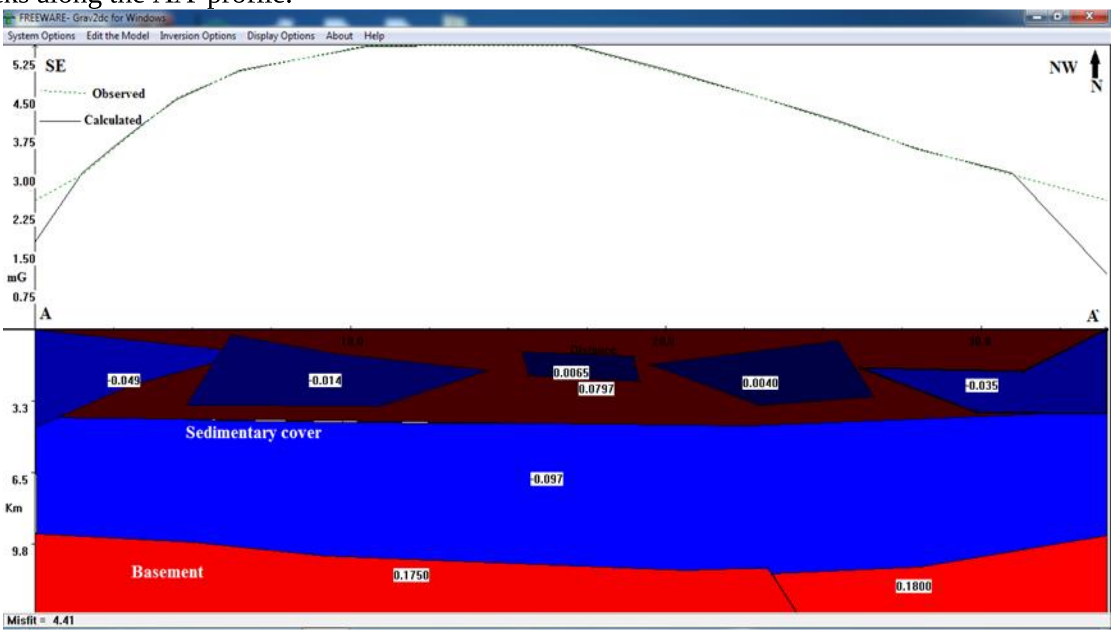

Figure 8-2.5 gravity model along the A-A' profile

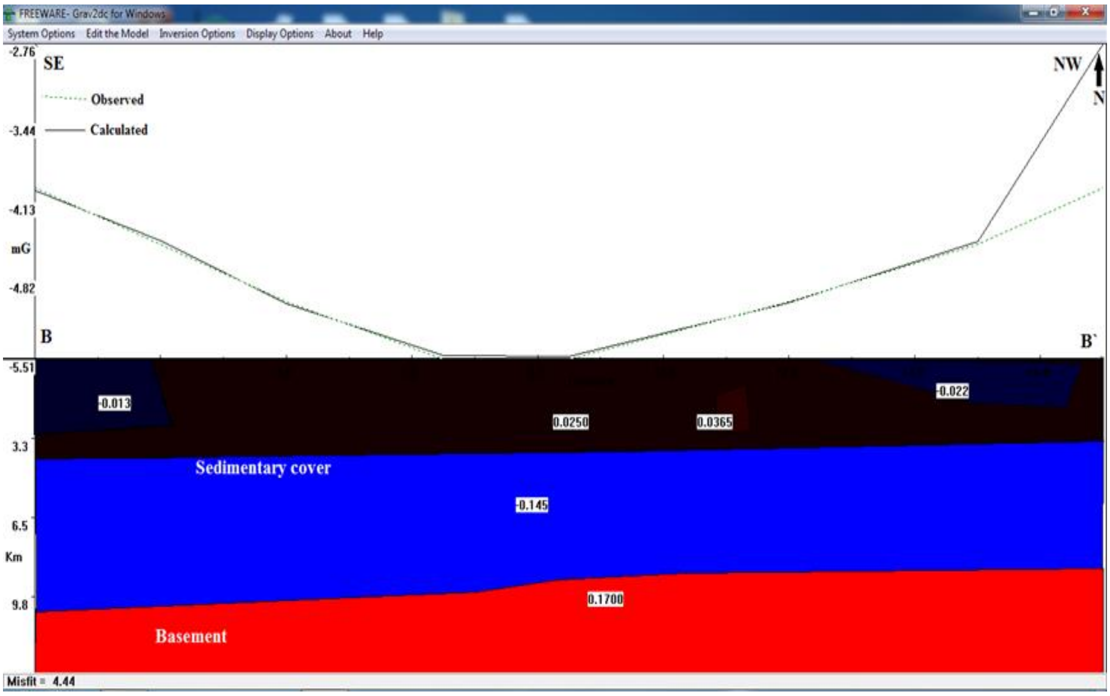

Figure 9-2.5D gravity model along B-B' profile

The basement depth ranges from about 8 km in the southeastern parts to 11 km in the northwestern parts along AA' while the depth along BB' profile equals to 10 km in the southeastern parts to 8.5 km in the northwestern parts, Figures-(8, 9). These obtained values are in good agreement with that reported by CGG [14], Figure-12. The basement rocks along the AA' profiles showed variation in density contrast may be interpreted in term of lateral variation in basement composition.

Magnetic Modeling

Results of the forward magnetic modeling along the CC' and DD' profiles are shown in Figures-10 and 11. Both magnetic models consist of two main lithological units: the sedimentary cover and basement rocks. The thickness of sedimentary cover ranges from 10 to 11.5 km. The magnetic models revealed that the sedimentary cover unit subdivided into two subunits with magnetic susceptibility contrast ranges between -0.003 to 0.0005cgs for the first magnetic model, Figure-11, and between -0.002 to 0.0017cgs for the second magnetic model, Figure-12. The upper subunit of the sedimentary cover showed variation in magnetic susceptibility contrast suggesting lateral variation in lithology, while the lower subunit did not show any variation reflecting similar lithological properties. The first magnetic model reveals variation in the magnetic susceptibility contrast between basement and sedimentary cover rocks in the study area. Variation of the magnetic susceptibility contrast (0.0020 to 0.0029 in the basement rocks may be attributed to variation in composition of the basement rocks. The obtained magnetic susceptibility contrast of the basement rocks was in good agreement with that (0.002) reported for a region adjacent to the studied area [30]. The depth of basement along CC' resulted from magnetic modeling ranges from 10 km in the northeastern parts to 12 km at the south western parts, while the depth along the DD' profile equals to 10 km at the south western parts to 11 km at the north eastern parts. These results are in consistence with the basement depth maps of the study area, Figure-12, derived from the basement depth map of Iraq prepared by CGG [14]. Both magnetic models revealed variation in the magnetic susceptibility contrast in the upper subunits of the sedimentary cover suggesting lateral lithological variation in it.

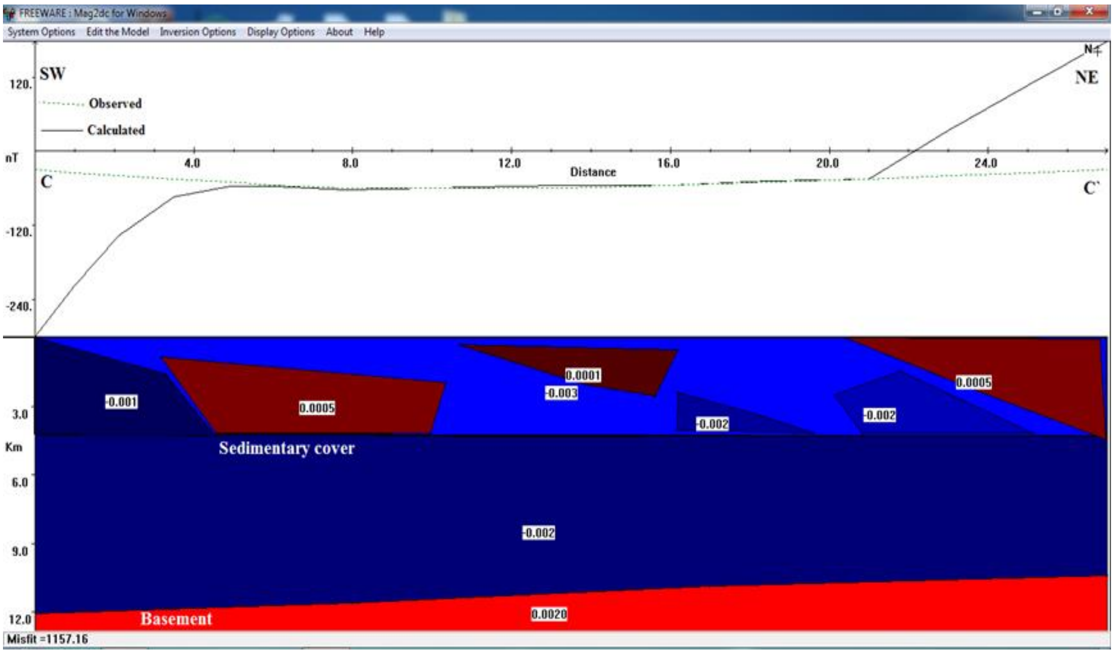

Figure 10-.5D magnetic model along the C-C' profile

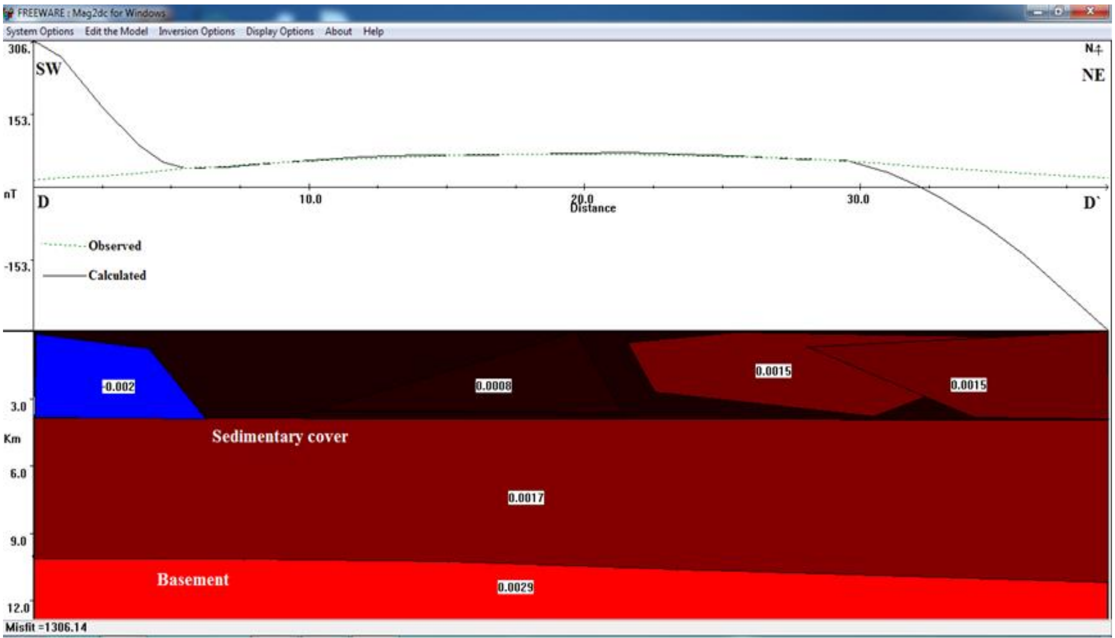

Figure 11-2.5D magnetic model along D-D' profile

Two seismic reflection profiles (West Tikrit-Makhul no-26 and 28, WTM-26 and WTM-28) were carried out in the study area. According to Abdul-Jabbar [31], interpretation of the WTM-26 section showed six reflector represent the top of the following formations Figure-13 from the youngest to the oldest: Fat'ha, Jeribe, Mauddud, Shuaiba, Alan and Kurra chine. Five reflectors were picked from interpretation of WTM-28 section. These reflectors represent top of the following formations from the younger to older Figure-14: Jeribe, Mauddud, Shuaiba, Alan and Kurra chine. The other formations listed in Table-1 and the others consisting of the stratigraphic sequence in both seismic sections couldn't characterize because they may have relatively similar acoustic impedance and some of them have very small thickness to produce strong distinctive reflection [31]. In general, the qualitative interpretation of both seismic sections showed that they present two lithological units,

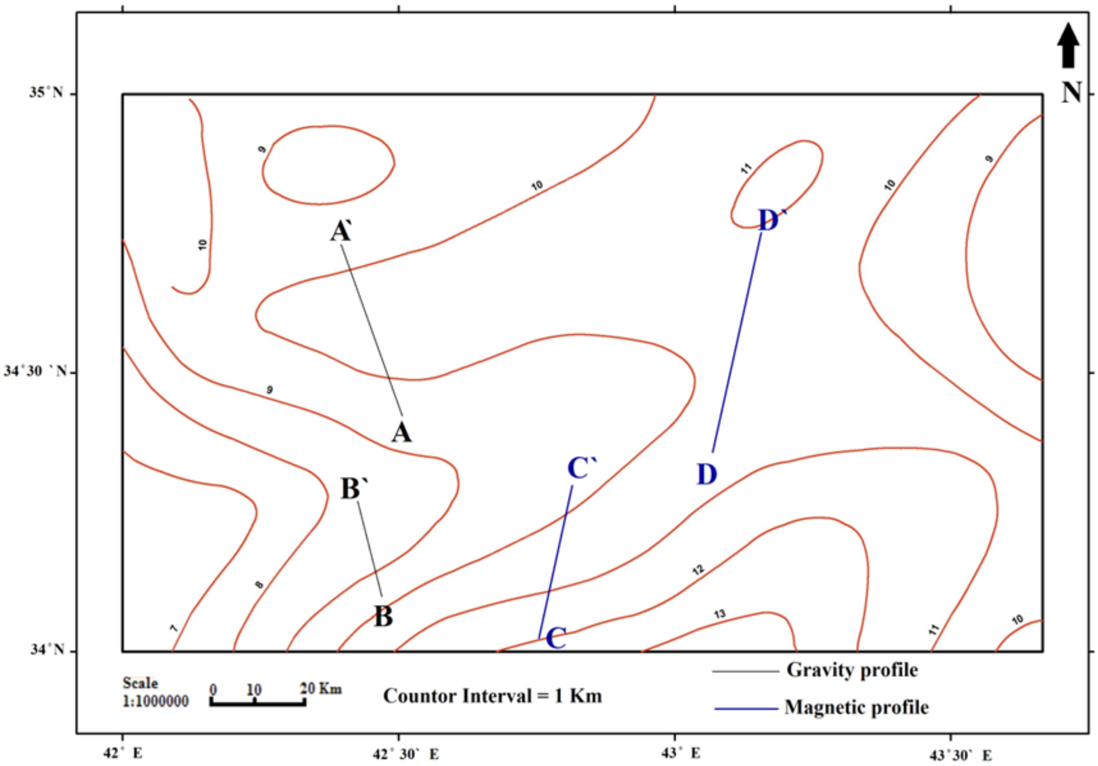

Figure 12-The basement depth map of the study area (After CGG [14]).

the upper is characterized by a number of formations, while the lower unit did not reveal distinct formations, but as a single block of similar acoustic impedance and in turn can be attributed to similar lithological properties. The result of interpretation of the available seismic sections supports the result of gravitational and magnetic modeling in terms of the sedimentary cover of the study area consists of two lithological subunits, the upper subunit characterize by different lithological properties while the lower subunit reflects similar lithological properties.

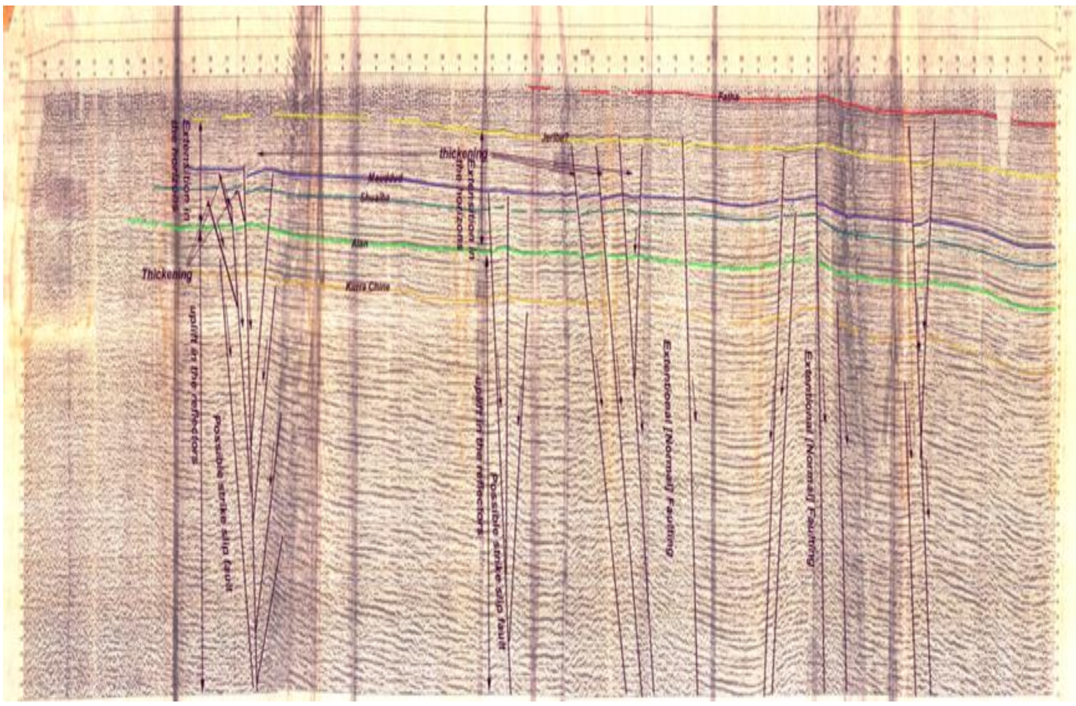

Figure 13-Seismic – time section WTM-26 (After Abdul-Jabbar [31])

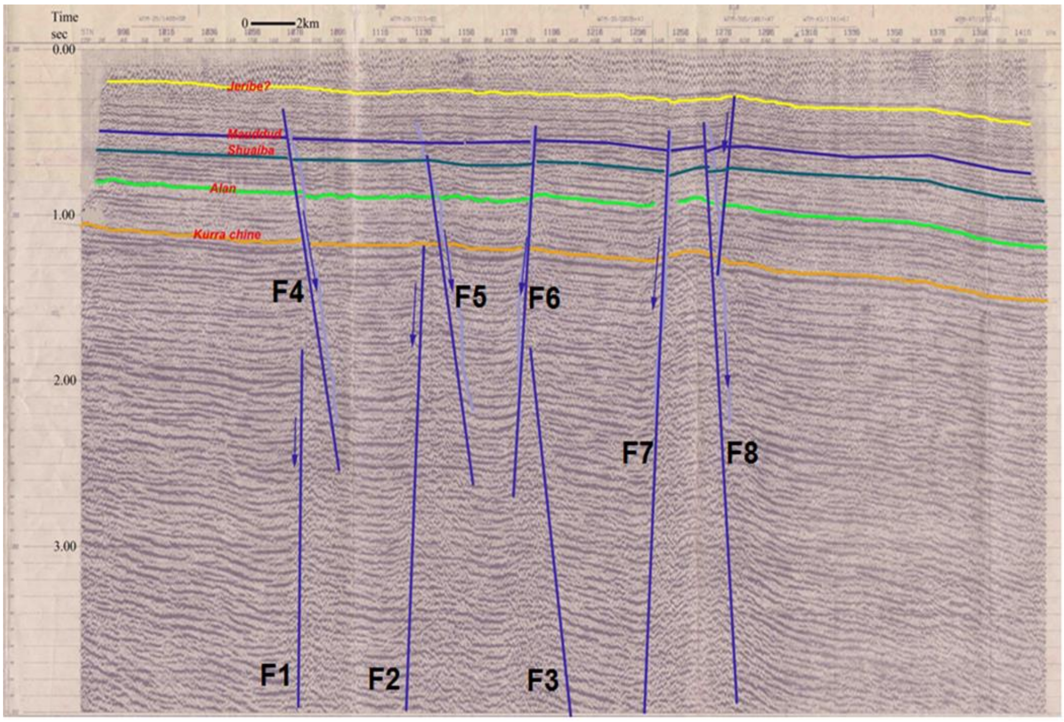

Figure 14-Seismic – time section WTM-28 (After Abdul-Jabbar [31]).

Conclusions

From the obtained results, the following conclusions were drawn:

1. Both gravity and magnetic models revealed a similar geometry of the subsurface view of the study area. All models consist of two main lithological units, the sedimentary cover and basement and the upper main unit includes two subunits.
2. Depth of the basement beneath the study area (8-12km) is in good agreement with that estimated in other study.

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