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# Application of Source Parameter Imaging (SPI) Technique to Gravity and Magnetic Data to Estimate the Basement Depth in Diyala Area, Eastern Central Iraq

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**Abstract**
The Bouguer gravity and magnetic RTP data were used to detect the depth of basement rocks in middle and south Diyala Province, east Iraq. The depth of the basement rocks was calculated by using the Source Parameter Imaging (SPI) method. New attempt is achieved to applied the SPI technique to the gravity values to estimate the depth of basement rocks. The depths of basement map derived from gravity data range 8-14 km, the depth of basement map derived from magnetic data range 9-13.5 km and the basement depth prepared by C.G.G, 1974 range 9-11 km. The derived maps from SPI method and that prepared by C.G.G, 1974 show good matching in the distribution of the depths of the study area. This study showed that basement's depth range from 8-14 km with gentle increasing toward the east. A main basin trending NW-SE is found in the study area laying eastern Diyala river. It is believed this basin may contain hydrocarbon reservoirs.

**Keywords:** Gravity , Magnetic RTP, Source Parameter Imaging, Basement Depth, Diyala-Iraq

# تطبيق تقنية صورة معامل المصدر (SPI) على المعطيات الجذبية والمغناطيسية لتقدير عمق صخور القاعدة في ديالى- شرقي وسط العراق

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**الخلاصة**
أستخدمت المعطيات الجذبية والمغناطيسية لتحديد عمق صخور القاعدة لوسط وجنوب محافظة ديالى, شرق العراق. استخدمت تقنية صورة معامل المصدر (SPI) في عملية حساب عمق صخور القاعدة. جرت في هذه الدراسة محاولة جديدة لتطبيق تقنية (SPI) على المعطيات الجذبية للحصول على عمق صخور القاعدة. وقد وجد أن عمق صخور القاعدة من المعلومات الجذبية يتراوح (8-14) كم ومن المعلومات المغناطيسية (9-13.5) كم فيما قدمت شركة .G.G.C عام 1974 عمقآ لصخور القاعدة مابين (9-11) كم. الخرائط المستحصلة بطريقة (SPI) و .G.G.C عام 1974 أظهرت جميع الخرائط تطابق جيد في توزيع أعماق منطقة الدراسة. ان معدل عمق صخور القاعدة في منطقة الدراسة يتراوح مابين (8-13.5) كم ويزداد هذا العمق تدريجياَ بأتجاه الشرق. من خلال دراسة الخرائط تبين وجود حوض يمتد بأتجاه شمال غرب- جنوب شرق ويقع هذا الحوض شرق نهر ديالى, يعتقد أن هذا الحوض قد يحوي مكامن هيدروكاربونية.

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## Introduction

The Source Parameter Imaging method has been used widely in the recent years to estimate the basement depth [1].

The Source Parameter Imaging (SPI) function is a quick, easy, and powerful method for calculating the depth of magnetic sources. Its accuracy has been shown to be +/- 20 % in tests on real data sets with drill whole control. This accuracy is similar to that of Euler deconvolution, however SPI has the advantage of producing more complete set of coherent solution points and it is easier to use. A stated goal of the SPI method is that the resulting images can be easily interpreted by someone who is an expert in the local geology [2]. Oasis Montaj software(version 8.4) [3] was employed to compute the SPI image and depth. SPI method makes the task of interpreting magnetic and gravity data significantly easier as shown by the SP images generated from gravity and magnetic data of the studied area.

This paper is an attempt to calculate the average basement depth in Diyala region, eastern Iraq using the gravity and magnetic data. The Compagnie General De Geophisque C.G.G,1974 [4] interpreted the Aeromagnetic map through the application of the Inflection Tangent Intersection (ITI). They found that basement depth of the study are range (9-11) km.

### Location of the study area

The study area is situated in the middle part of the eastern side of Iraq in Diyala province. This area is located at the western side of the Zagros Fold-Thrust Belt. In fact it lies partly in the low folded and partly in the Mesopotamian Foredeep, which extended from the southern Hemrin lake to the south of the province (Figure-1).The area is bounded by: latitudes (33º 54′ 08″- 34º 00′ 04″ North) longitudes (44º 15′ 36″- 46º 10′ 83″ East).

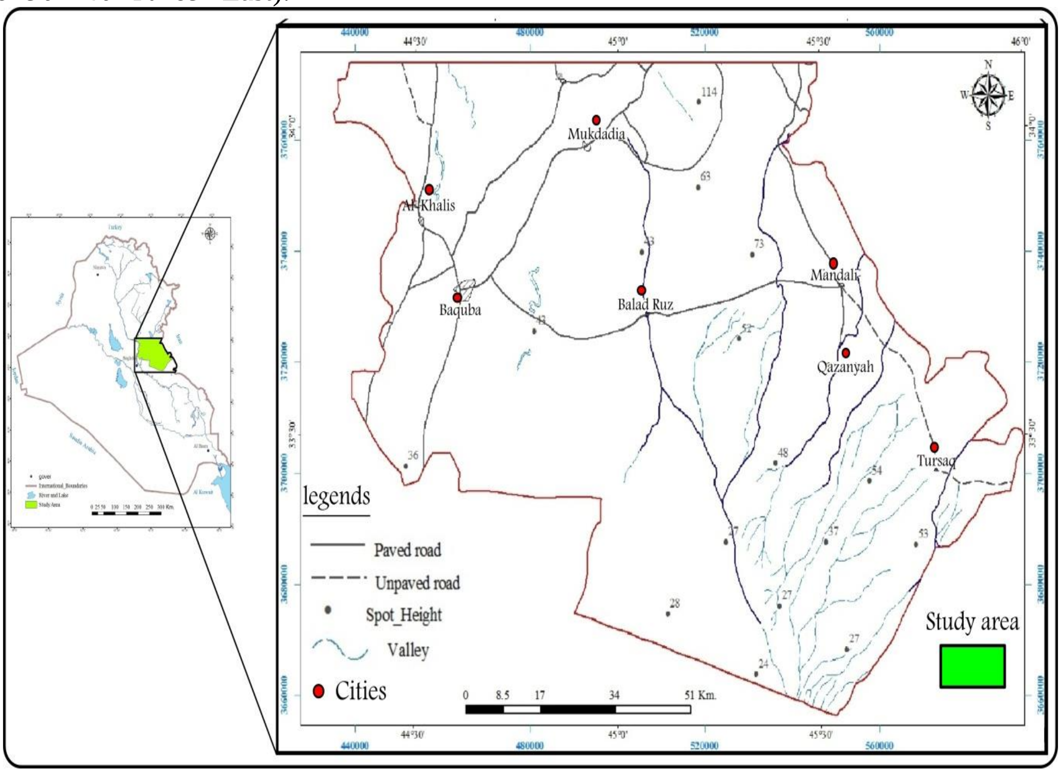


**Figure 1-**Location of the study area.

### Geology of the Study Area

The study area is covered mainly by Quaternary and Pre-Quaternary sediments[5] (Figure-2). The Pre-Quaternary sediments Include: The Middle Miocene Sequence comprises carbonate and marls of the Fatha (Lower Fars) Formation. Late Miocene-Pliocene includes a fluvial system of Fatha, Injana, Mukdadiya and Bai Hassan Formations [6]. Quaternary sediments of the Mesopotamian zone were deposited by the Tigris and Diyala rivers. The alluvial fans emanating from the surrounding elevated areas. Flood plain deposits include channel deposits and flood plain depression, sabkha and deltaic deposits [7].

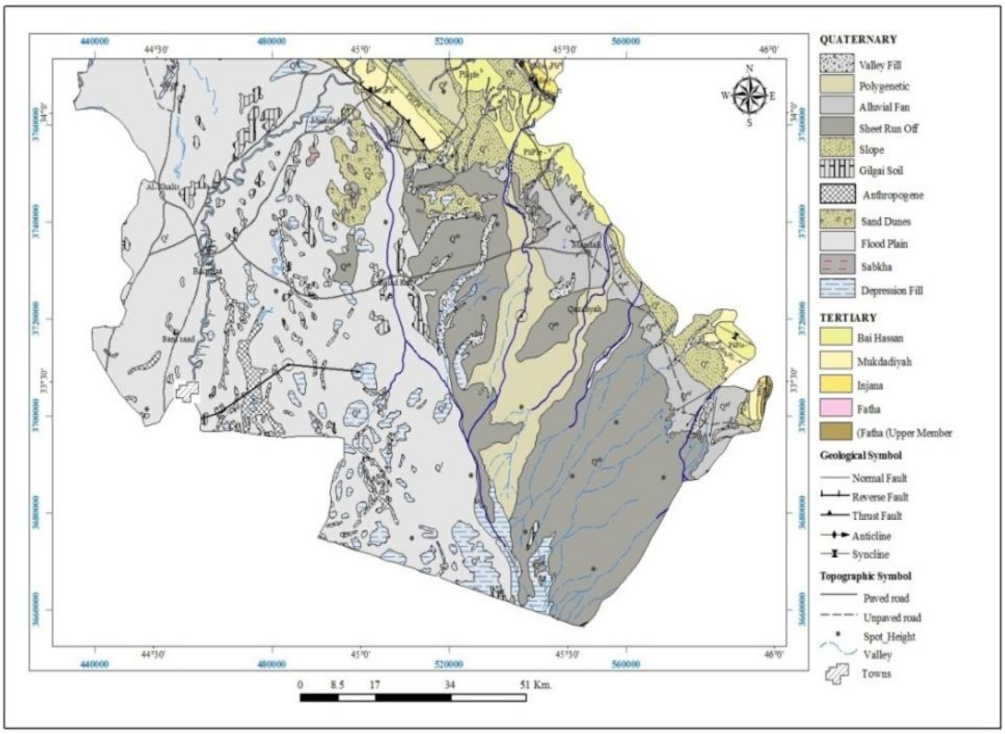


**Figure 2-**Geological map of the study area [5].

**Tectonic Setting**

The studied area is located within the low folded zone and Mesopotamian Foredeep. Tectonically the study area is part of the unstable shelf, most of this area represented by Tikrit - Amara subzone and northeastern is belong to Hemrin subzone [8] (Figure-3), which are affected by the late regional intensive tectonic movements of the Alpine orogeny [9]. This tectonic movement caused the uplifting of Hemrin structure, in the Low Folded Zone and the development of asymmetrical sinking basin in the Mesopotamian Foredeep. In the Late Pliocene , the influence of this movement is extended to deform the sediments of the Mesopotamian Foredeep. The evidence of this deformation is the uneven paleo-surface of the pre-Quaternary rocks, which is now covered by thick Quaternary sediments [10].

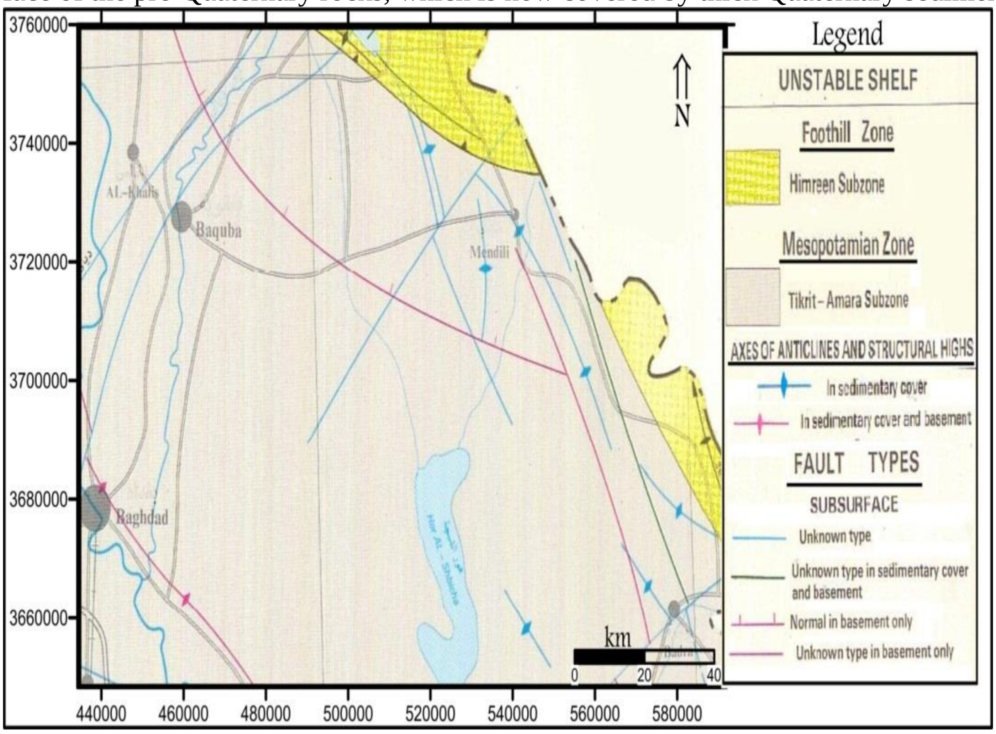


**Figure 3-** Tectonic map of study area [8].

**Data Acquisition and Processing**

Bouguer anomaly map of the studied area (Fgure-4) is a part of the Bouguer anomaly map of Iraq. It is constructed by Iraqi GEOSURV and reprocessed in (2010) by Getech group (British Institution) [11], and it was compiled at a scale1:1000,000 and contour interval of (1) mgal. The Bouguer anomaly values within the studied area range from (- 48) mGal in the southwestern parts and (-86) mGal in the northeastern parts of the map.

The aeromagnetic map of the study area is part of the aeromagnetic (total magnetic intensity) map of Iraq. This map were constructed by Iraqi GEOSURV and reprocessed in ($2010_s$) by Getech group (British Institution) [11]. The scale and contour interval of the aeromagnetic map is 1:1,000,000 and 1 nT. The Total Magnetic Intensity (TMI) data was processed to obtain the Reduction To Pole (RTP) map (Figure-5) in order to symmetrically position the anomalies above the causative bodies. This process is achieved by GET GRID program. The grid lines of the survey were done with space interval of (1) km in Iraq. The magnetic values of the Reduction To Pole (RTP) within the studied area range from (5010) nT in the NW and SW parts of the study area, to (4830) in the northeastern parts of the map.

The gravity and magnetic values decreasing toward the northeast coincide with increasing of the depths basement rocks [4].

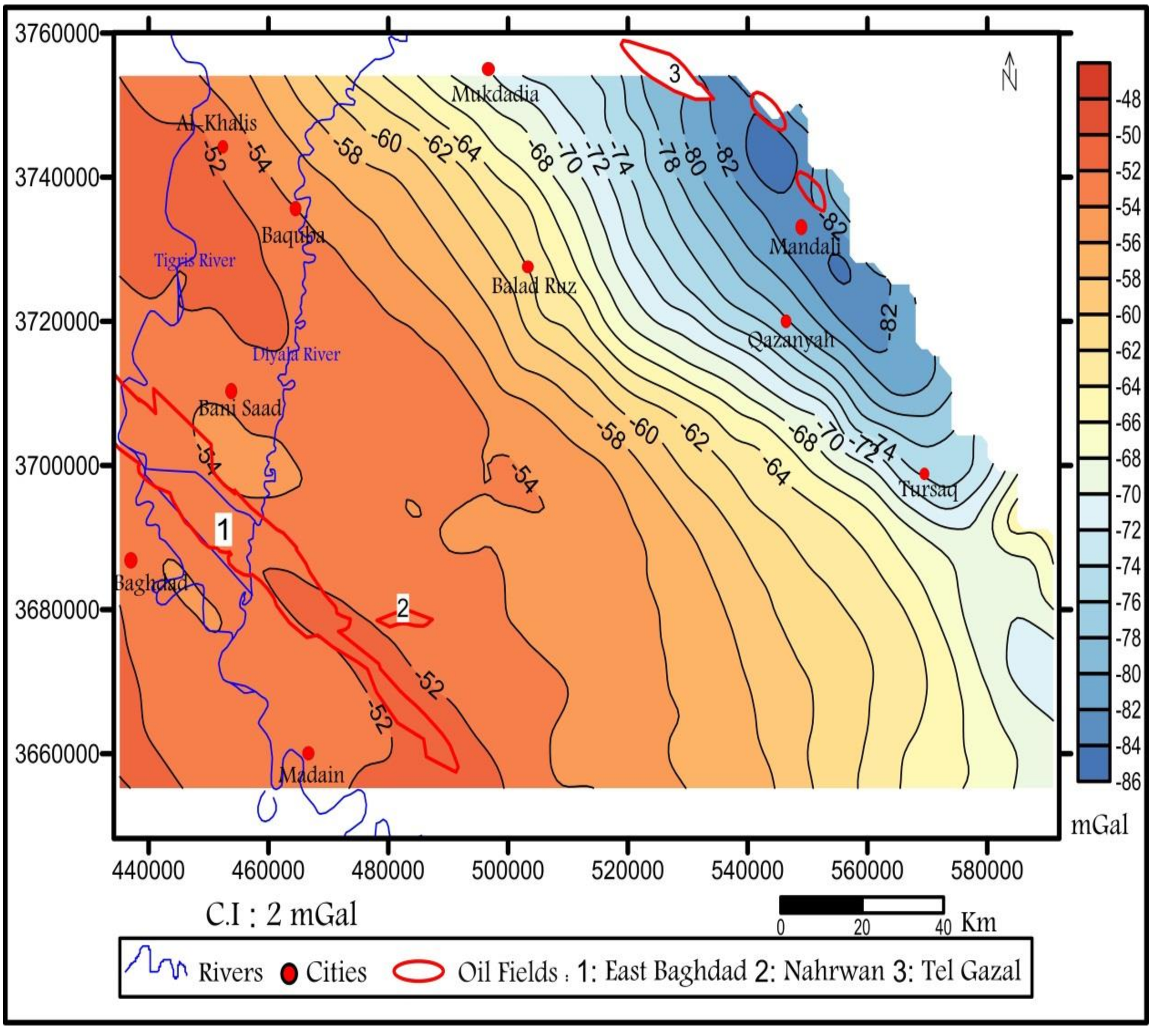


**Figure 4-**Bouguer Gravity anomaly map and oil fields [12]

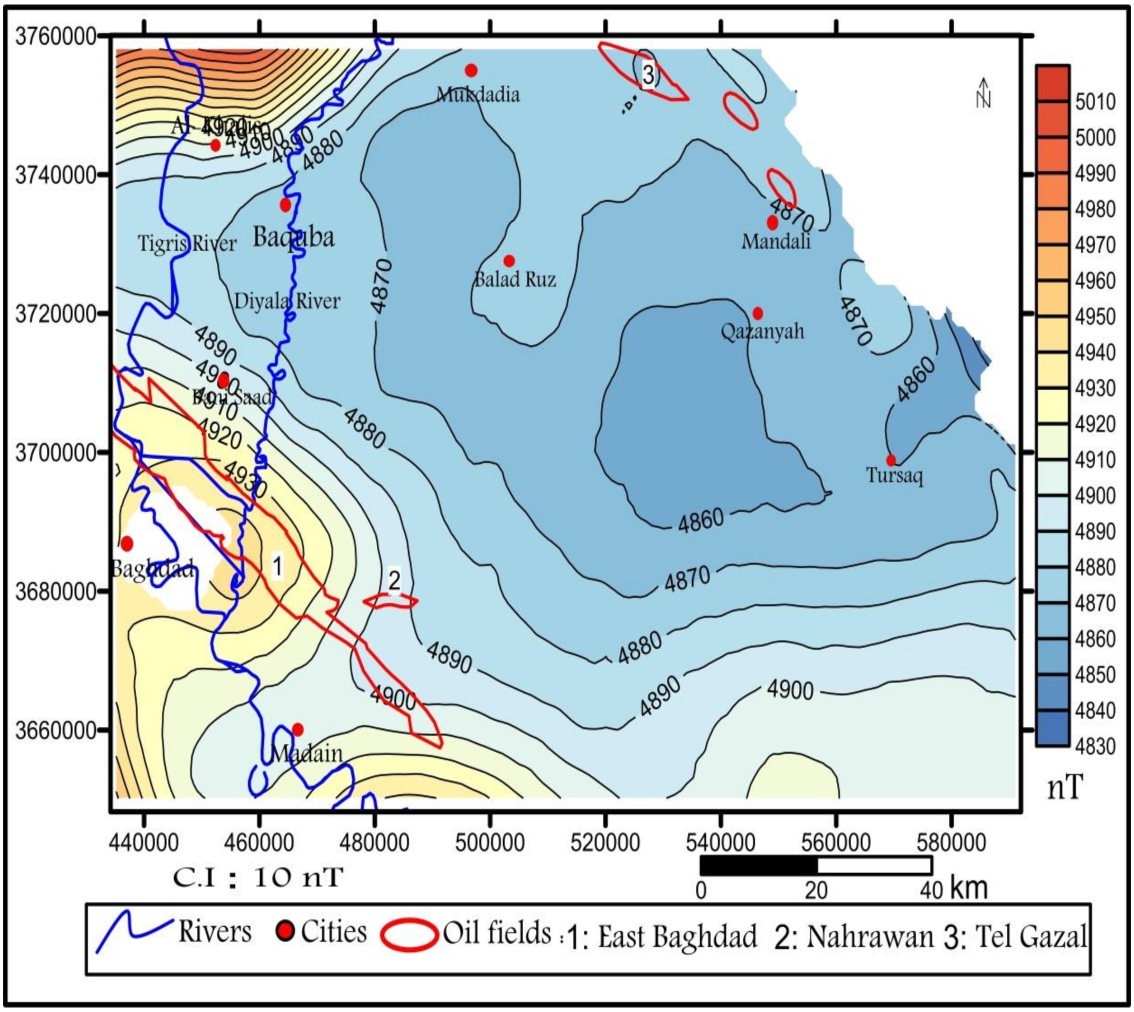


**Figure 5-**Magnetic RTP anomaly map and oil fields [12]

**Depth Estimation Method for Potential Anomalies**

**Determination of Depth Basement by the Source Parameter Imaging SPI (local wavenumber) Method**

The Source Parameter Imaging (SPI$^{TM}$) is a technique using an extension of the complex analytical signal to estimate magnetic depths. This technique developed by [2] sometimes referred to as the local wavenumber method is a profile or grid- based method for estimating magnetic source depths. The method utilizes the relationship between source depth and the local wavenumber (k) of the observed field, which can be calculated for any point within a grid of data via horizontal and vertical gradients .

Interpretation of an anomalous magnetic response involves determining the parameters that characterize the source of the anomaly. The depth to the top of the structure is a parameter that is commonly sought, and the source parameter imaging (SPI) method is one way of determining this depth estimate. One advantage of the SPI method is displaying the depths map as an image [13]. The application of SPI method needs the following:-

SPI .GRD1 Grid of the horizontal derivative in the X-direction
GRD2 Grid of the horizontal derivative in the Y-direction
GRD3 Grid of the first vertical derivative
GRD4 Grid of tilt derivative
GRD5 Grid of local wavenumber k grid (horizontal gradient of tilt derivative)

The SPI technique assumes a step type source model. The following formula holds:

Depth = 1 / k max

Where k max represent the peak value of k which located over the step source [13]:

$$k = \sqrt{\left[\frac{dA}{dX}\right]^2 + \left[\frac{dA}{dY}\right]^2}$$

Tilt derivative (A) is described as below [14]:

$$A = a\tan\ \frac{[dM]}{[dZ]} / \sqrt{\left[\frac{dM}{dX}\right]^2 + \left[\frac{dM}{dY}\right]^2}$$

M = the total magnetic field value

**Determination Depth of Basement Rocks from Magnetic RTP and Gravity Data**

The depth to the magnetic and gravity sources were determined through several mathematical processing from various grids. The pre-processed grids from the residual grid as input grid are dx, dy and dz. These output grids were later served as input grids for SPI processing. First order derivative was adhered to, as the method (SPI) is much more sensitive to noise at higher derivative order. Therefore, careful filtering of data was ensured so as to have good estimates of the local wave number and hence the depth.

The Source Parameter Imaging (SPI) module from Oasis Montaj software was applied to the RTP data of the study area; the SPI statistics show a minimum basement depth of 9 km and a maximum basement depth of 13.5 km (Figure-6). The gravity values of the study area are negative. So to apply the SPI method to the gravity data, it must be transferred to positive value. A constant value (100) is added to the gravity data. The resultant gravity values were processed with SPI technique. The basement depth map obtained by applying SPI method to gravity data is shown in (Figure-7) this map show a minimum basement depth of 8 km and a maximum basement depth of 13 km. The Two obtained basement depth maps show general accepted coincidence values with previous studies.

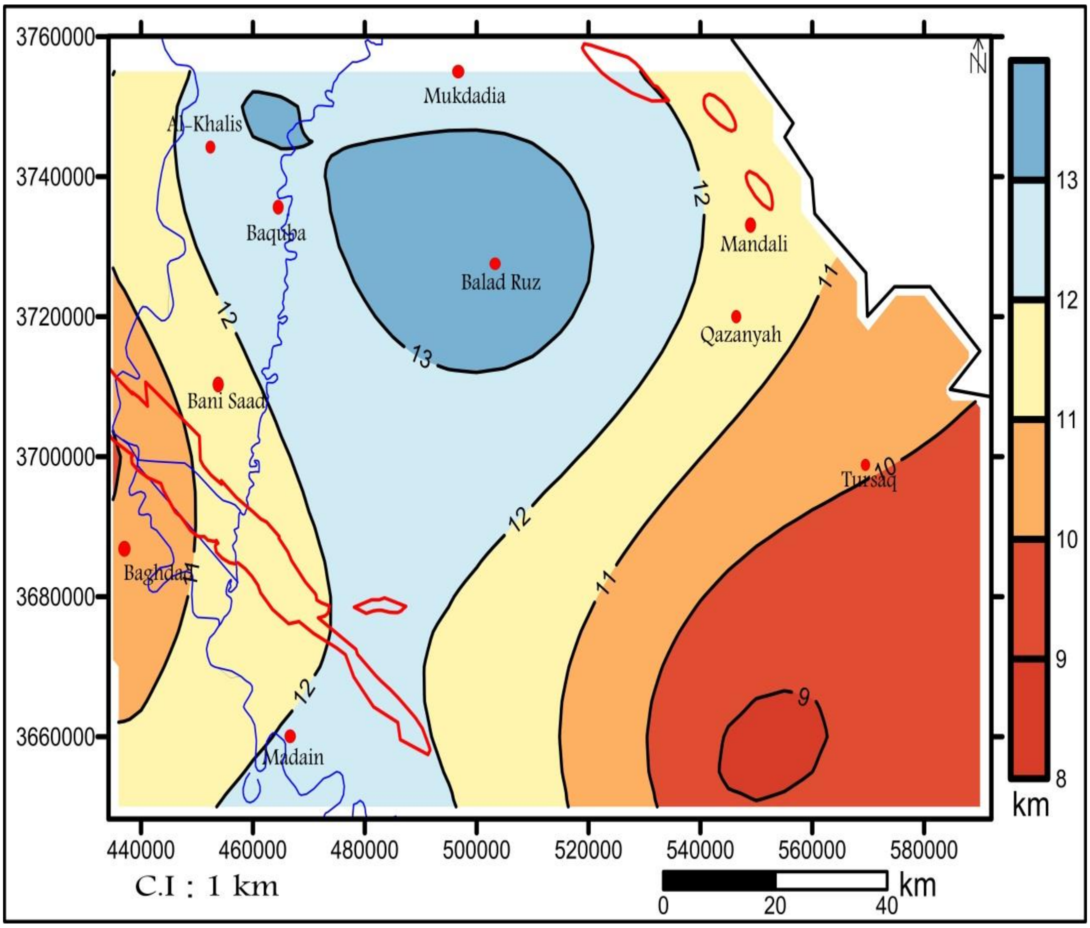


**Figure 6-**Estimated Depth for basement using SPI technique derived from RTP data

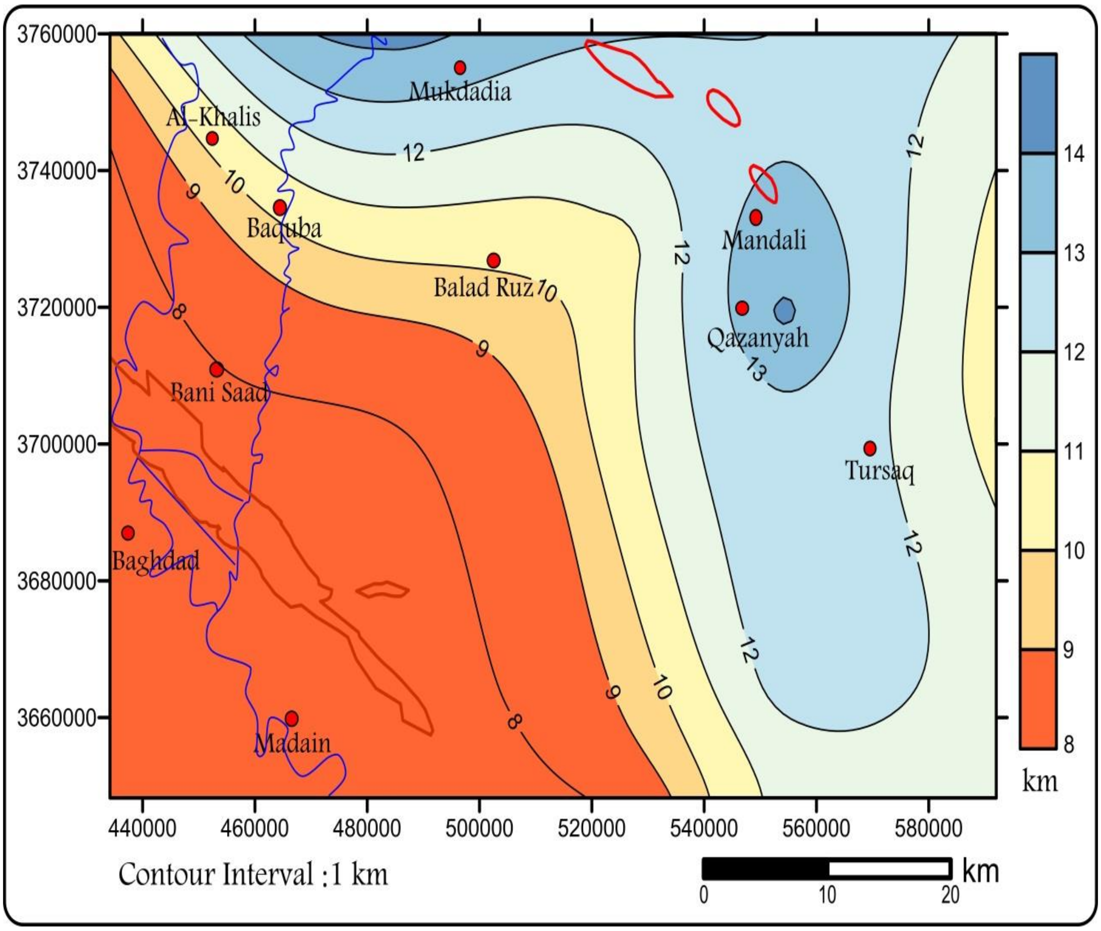


**Figure 7-**Estimated Depth for Basement Using SPI Technique Derived from Gravity Data

**Interpret and Compare the Maps of the Depths of the Basement Rocks Obtained by SPI with CGG Depth Map**

According to Jassim and Goff [6] the deepest basement depth in the study area located at eastern Iraq, which associated with continuous sedimentation precipitation of sediment in the Mesopotamian basin from Late Permian until the present. This low basement is segmented transversally into areas of deep and shallow basement.

The basement rocks depth which included these maps that obtained from magnetic and gravity data, using SPI method and the basement rocks depth prepared by C.G.G, 1974 were compared. The depth values of these maps are generally close to others. All maps show an increasing of basement depth toward the northeast part of the study area. The three maps shows presence a main basin trending NW-SE and located at eastern and southeastern of Mukdadia, Baquba, and Balad Ruz cities. The western boundary of the basin coincide with Diyala river , this direct relation between the basin boundary and the river , indicate that the origin of rivers due to the gradient of the basin or exist of faults on side of the basement basin. Also there is uplift laying south east Tursaq city which trending NE-SW which (Figure-8). Table-1 represent a comparison of the basement depth obtained by using SPI method for magnetic and gravity data and the basement depth prepared by C.G.G.1974. Generally good coincidence found with an error of ± 1.0 km. The only exception is shown at the southeastern part of Tursaq city which is different by 3.0 km in magnetic depth map. The comparison of the basement depth obtained by using SPI method for gravity value and the basement depth prepared by C.G.G.1974, shows generally good coincidence with an error of ± 1.0 km, except for some locations which is located in the middle of the study area with an error of 3.5 km .

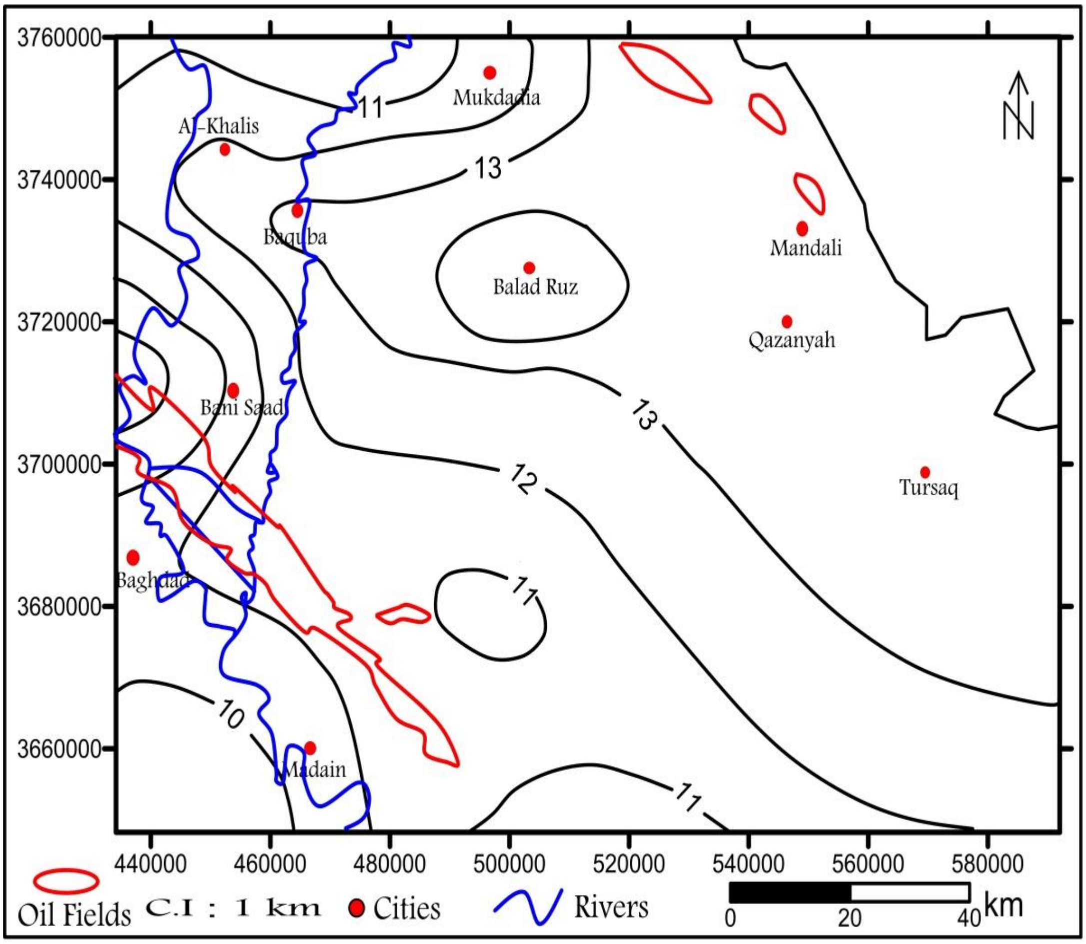


**Figure 8-**Show the basement depth map (C.G.G, 1974)

Most of the structure in the study area are their axes in the NW-SE, therefore the fields have the same trend NW-SW. There is a main basin is found in the study area laying eastern Diyala river and trending NW-SE. It is probably this basin may contain hydrocarbon reservoirs.

**Table 1-** Comparison between the basement depth obtained by using SPI method and those prepared by C.G.G. 1974 in the study area

| City | Basement Depth | | | Different in basement depth between the two potential methods (km) | |
|---|---|---|---|---|---|
| | SPI (Magnetic) (km) | SPI (Gravity) (km) | C.G.G. 1974 (km) | Gravity - C.G.G | Magnetic - C.G.G |
| Al-Khalis | 12.5 | 10.5 | 12.0 | - 1.5 | + 0.5 |
| Mukdadia | 12.5 | 13 | 11.5 | + 1.5 | + 1.0 |
| Baquba | 12.5 | 10.5 | 13.0 | - 2.5 | - 0.5 |
| Balad Ruz | 13.5 | 10 | 13.5 | - 3.5 | 0.0 |
| Mandili | 11.5 | 13 | 13.0 | 0.0 | - 1.5 |
| Bani Saad | 11.5 | 8 | 10.5 | - 2.5 | + 1.5 |
| Qazanyah | 12.5 | 13 | 13.0 | 0.0 | + 0.5 |
| Tursaq | 10.0 | 12 | 13.0 | - 1.0 | + 3.0 |

## Conclusions

1. It is possible to use the Source Parameter Imaging (SPI) method to calculate the depth of the basement rocks by using gravity data. This is the first attempt to use the gravity data for applied the SPI technique to obtain the basement depth. The depth of basement rocks derived from this study are confirmed with geological ideas.
2. Comparison of the basement depth of those obtained using SPI technique for magnetic and gravity data with that prepared by C.G.G 1974 gives a good coincidence.
3. The basement depth in the study area range from 8-14 km.
4. Major basin is found to be located east of Diyala river and trending NW-SE.

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