GRAVITY AND MAGNETIC SURVEYS TO DELINEATE SUBSURFACE STRUCTURES IN HOR AL-HUWAZAH AREA, SOUTH IRAQ

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ABSTRACT

Gravity and magnetic surveys were carried out to study an area located between, Amara and Qurna Cities, The results of the present survey are merged with those of the previous surveys carried out exIPC; using Oasis Montaj software to produce a unified database, which considered a new addition to update the gravity and magnetic field maps of Iraq.

The most impressive result of the present gravity survey is the negative anomaly (**A**), found in the middle part of the studied area with NE – SW trend. This anomaly is a completion of the more extended important negative anomaly present in the vicinity of Qalat Saleh – Uzair – Qurna. It is surrounded by high gravity gradient that may be related to fault and/ or contact and may reflect the occurrence of a restricted basin, or it may reflect the negative background of Zagaros root effect. It is worth to mention that most oil fields occur along the high gradient flanks of this anomaly.

The expressive positive gravity anomaly (**G1** and **G2**), are located in the upper middle part of the area with a trend of NW – SE extending beyond the studied area. It may be attributed to uplift in the sedimentary cover corresponding to uplifts in the basement, as indicated in the basement relief map of exIPC. This anomaly may be attributed to the presence of coral reef or anhydrite elongated body present within the sedimentary column.

The magnetic map of the studied area reflects mainly the effect of the basement, but several local anomalies are also detected, some of which are related to local buried iron artifacts, which act as sources of noise. Therefore, some filters were applied to enhance the magnetic picture.

مسح جذبي مغناطيسي لتحديد التراكيب تحت السطحية في منطقة هور الحويزة، جنوب العراق

غالب فاضل أمين، عباس محمد ياس، حيدر عدنان البهادلي و احمد سالم موسى

المستخلص

أجريت مسوحات جذبية ومغناطيسية في المنطقة الواقعة بين مدينتي العمارة والقرنة عند خطي طول '00 °47 الى '45 °47 وخطي عرض '45 °30 الى '00 °32 وذلك لتحديد التراكيب تحت السطحية بالإضافة إلى مليء الفجوة الموجودة (منطقة) في المسوحات الجذبية المتوافرة ،حيث كانت هذه المنطقة سابقا مغطاة بواسطة مياه هور الحويزة ماعدا الجزء الشمالي من منطقة الدراسة التي لا تزال حاليا مغطاة بالمياه (هور أم النعاج).

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أجريت القياسات الجذبية والمغناطيسية على طول الطرق والمسالك الغير معبدة وذلك حسب ما تقتضيه ظروف المنطقة وعلى شكل مضلعات وكانت المسافة بين نقطة قياس وأخرى هي واحد كيلومتر.

إن نتائج هذه المسوحات قد دمجت مع المسوحات السابقة التي أجريت بواسطة شركة نفط العراق (IPC) باستخدام برنامج أو أسس مونتاج لإعداد قاعدة بيانات موحدة والتي اعتبرت معلومات أضافية جديدة لتحديث خرائط المجال الجذبي والمغناطيسي للعراق.

من النتائج المهمة لهذه المسوحات هو الشاذة الجذبية السالبة (A) التي تقع في وسط منطقة الدراسة وباتجاه شمال غرب – جنوب شرق، هذه الشاذة مكملة لشاذة جذبية سالبة مهمة تمتد بالقرب من منطقة قلعة صالح – العزير– القرنة وهي محاطة بانحدار جذبي عالي ربما يعود إلى صدع أو تماس أو ربما يعكس تواجد حوض محدد أو ربما يعكس تأثير الخلفية السالبة لجذر حبال زاكروس، ومن الجدير بالذكر إن معظم حقول النفط تتواجد على طول الانحدار الجذبي العالي لهذه الشاذة الجذبية السالبة.

من الشواذ الجذبية المهمة أيضا هي الشواذ (G1 و G2) والتي تقع في الجزء الوسطي العلوي من منطقة الدراسة وباتجاه شمال غرب – جنوب شرق وتمتد خارج منطقة الدراسة. إن هذه الشواذ ربما تعود إلى نهوض في الغطاء الرسوبي والناتج عن نهوض في صخور القاعدة والمشار إليه في خريطة تضاريس سطح القاعدة المعدة من قبل شركة نفط العراق، إن هاتين الشاذتين من الممكن أن تفسران كشعاب مرجانية أو امتداد طولي لجسم انهايدرايتي موجود ضمن العمود الرسوبي.

أما الخريطة المغناطيسية لمنطقة الدراسة، فهي تعكس بشكل أساسي تأثيرصخور القاعدة ؛ومع ذلك تم تحديد عدة شواذ محلية بعضها تعود إلى تأثير محلي لأجسام حديدية صناعية مدفونة والتي تمثل كمصدر للضوضاء (noise) لذلك تم تطبيق عدة مرشحات لتحسين الصورة المغناطيسية للمنطقة. كذلك أجريت مضاهاة لمسار على طول الخط C – C′ للمعلومات الجذبية والمغناطيسية وذلك لتحديد الشواذ الرئيسية ضمن المسار بواسطة تعزيز الاستجابة لهذه الشواذ وبالتالي يجعل الشواذ سهلة التمييز والتحديد.

INTRODUCTION

Gravity and magnetic surveys were carried out to detect and delineate the subsurface structures at a region that extend from Amara to Qurna cities. The studied area was previously covered with marshes, especially Al-Huwaizah marsh. Both surveys were performed by 1206 stations distributed along roads and tracks present in the studied area (Fig.1).

Processing and interpretation of gravity and magnetic data revealed good results complementing the gravity and magnetic data of the surrounding areas, which were achieved previously by exIPC. These results are finally presented in this study using different computer techniques. The studied area (figure 4), lies within Latitude 30° 45' to 32° 00' N and Longitude 47° 00' to 47° 45' N.

▪ Scope of Work

The scope of this survey is to detect and delineate the subsurface structures as well as to fill a gap in the available gravity survey. This gap in the area was previously covered by water of Hour Al-Huwaizah, except an area in the northern part of Hor Al-Huwaizah that is still filled by the water of Hor Aum Al-Na'age. Also to achieve regional geophysical mapping characteristically entails measurements on stations distributed along polygons lying along paved and unpaved roads as well as tracks (Fig.1).

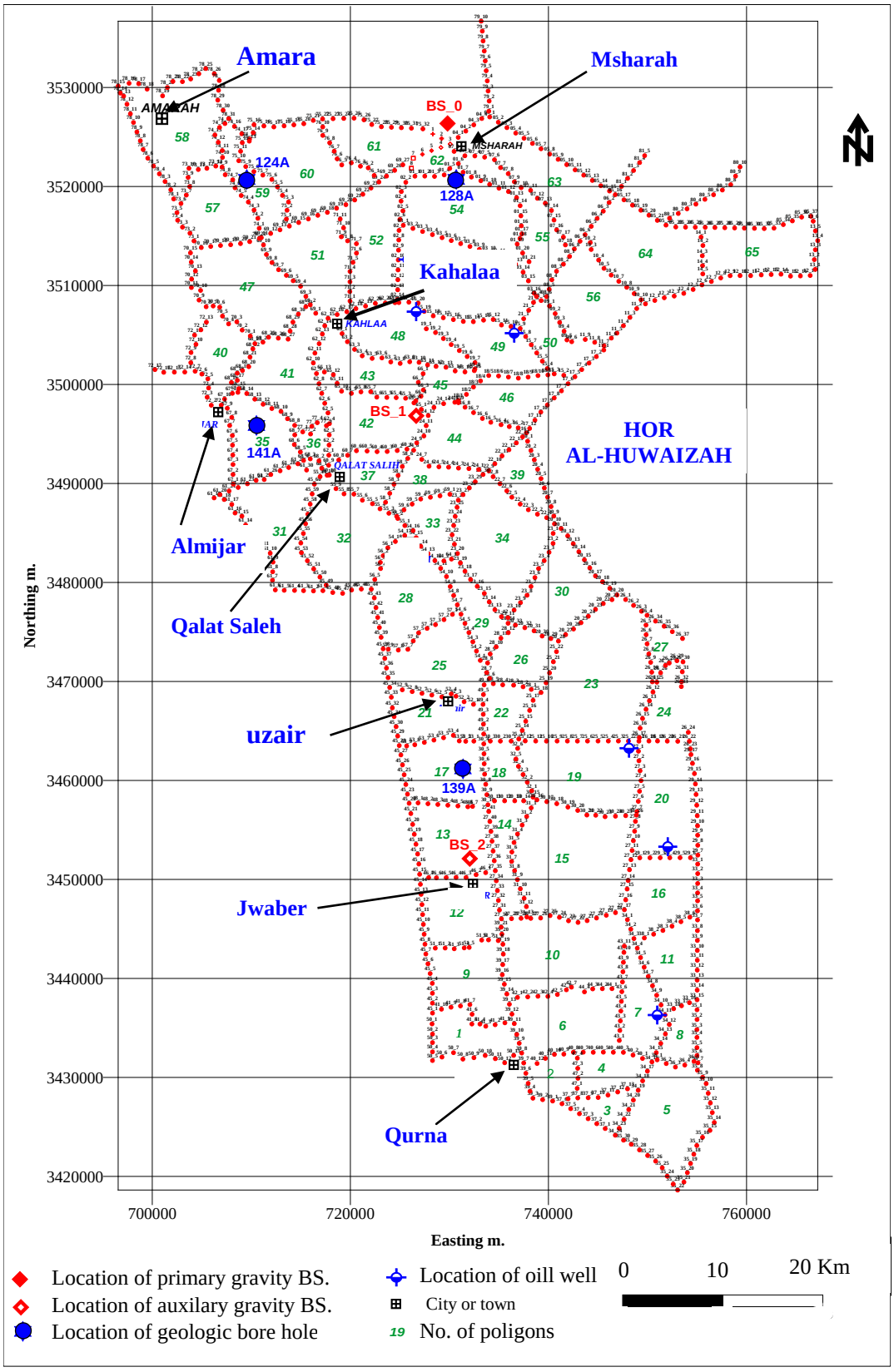

Fig.1: Network of gravity and magnetic stations in the studied area

GENERAL GEOLOGY OF THE STUDED AREA

According to Fouad**,** (2012) the studied area lies within the Outer Platform (Mesopotamian Fore deep) (Fig.2). No structural features observed on the surface throughout the area; however, it contains a broad subsurface syncline and narrow anticline trending predominantly NW – SE (Jassim and Goff, 2006). Iraqi National Oil Company referred to the presence of subsurface structure in the study area (I.P.C., 1979) (Fig.3).

Geological correlation of the drilled boreholes indicates that most part of the studied area lies within the deeper parts of the Mesopotamian Quaternary basins (syncline) (Yacoub, 1994).

The studied area is completely covered by Quaternary sediments that have mainly fluvial and lacostrine origin and partly Aeolian. Marine-estuarine sediments of Quaternary age are also recognized in subsurface sedimentary sequence, the Quaternary deposits are represented by; sheet run-off sediments, flood plain sediments, shallow depression sediments and marsh sediments, (Fig.4).

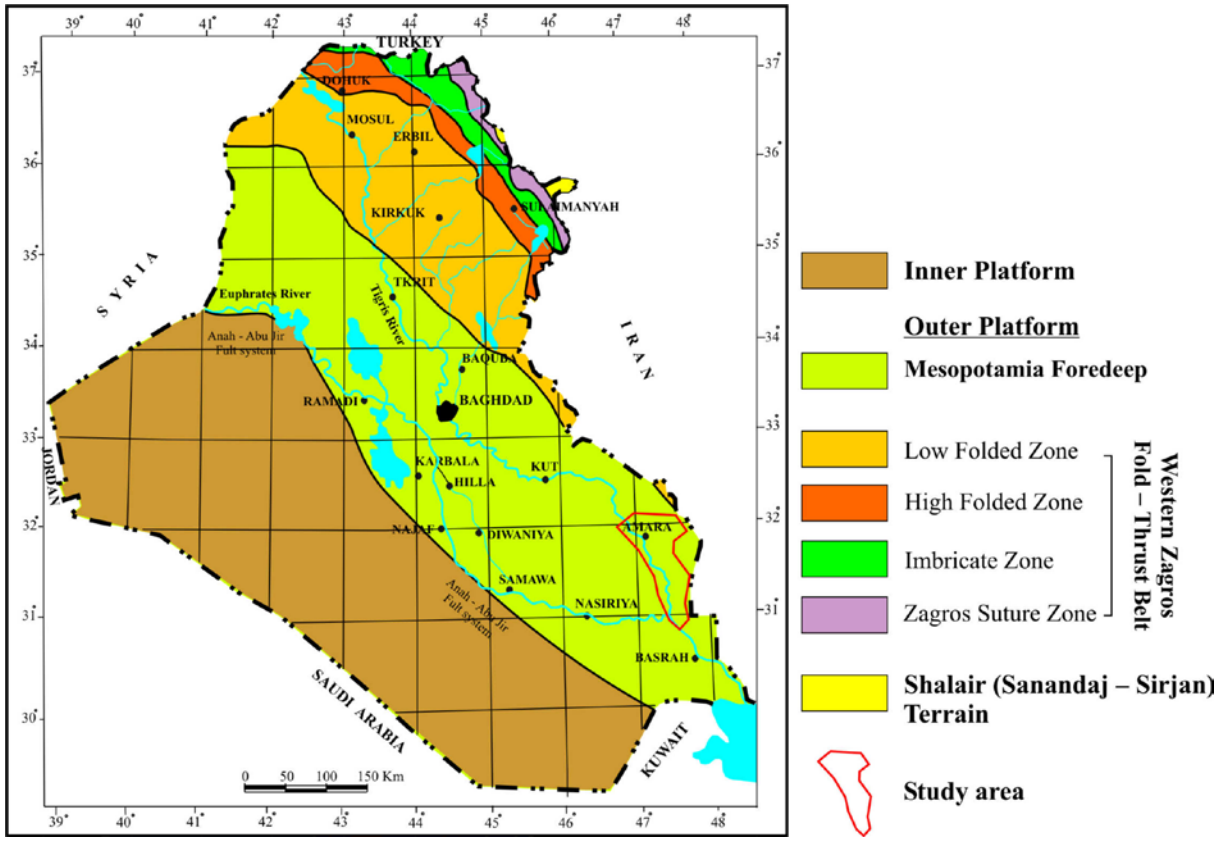

Fig.2: Tectonic zones of Iraq (after Fouad, 2012) shows the studied area

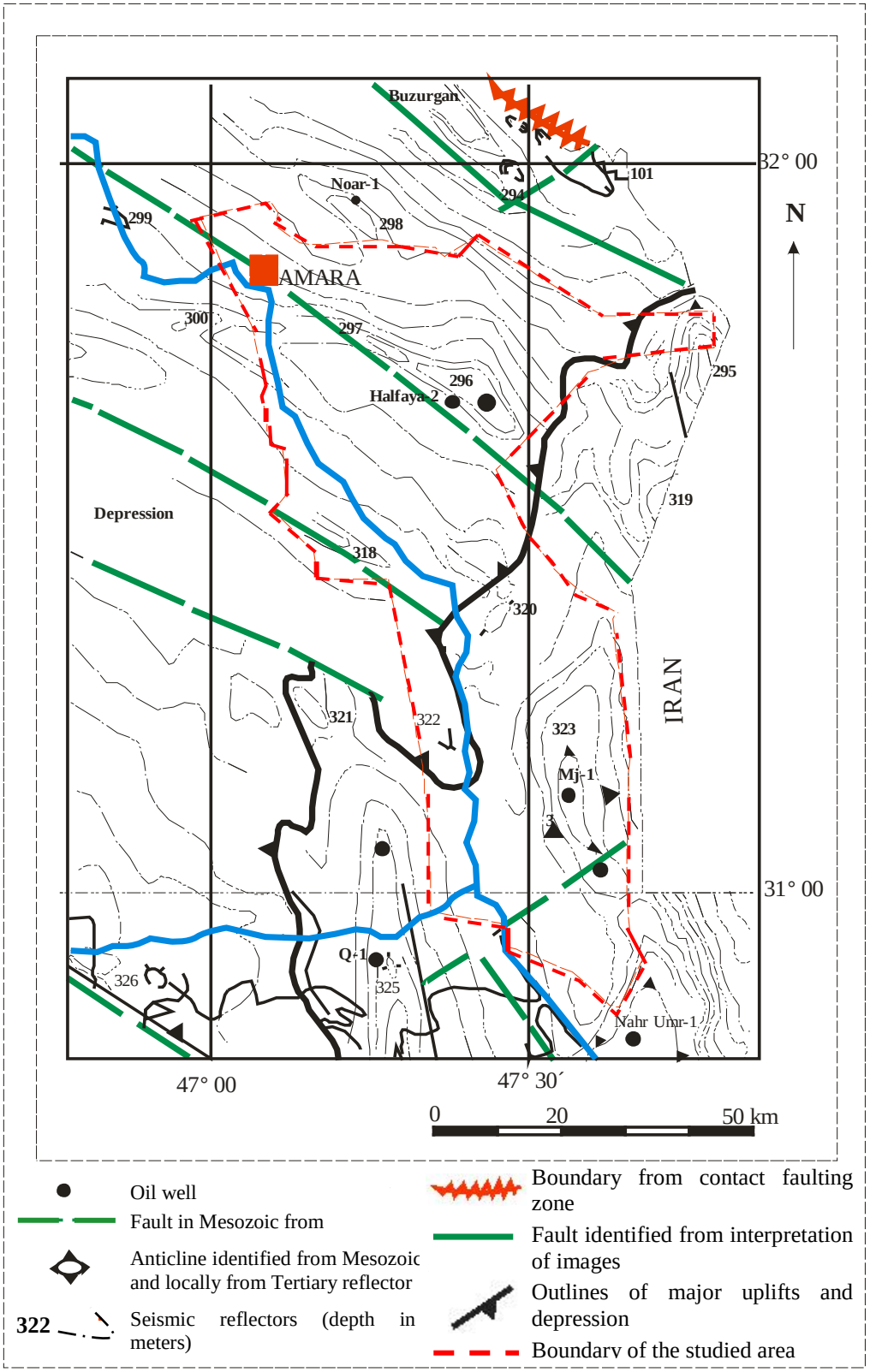

Fig.3: Structural-tectonic map of Amara – north part of Basrah
(after I.P.C., 1972)

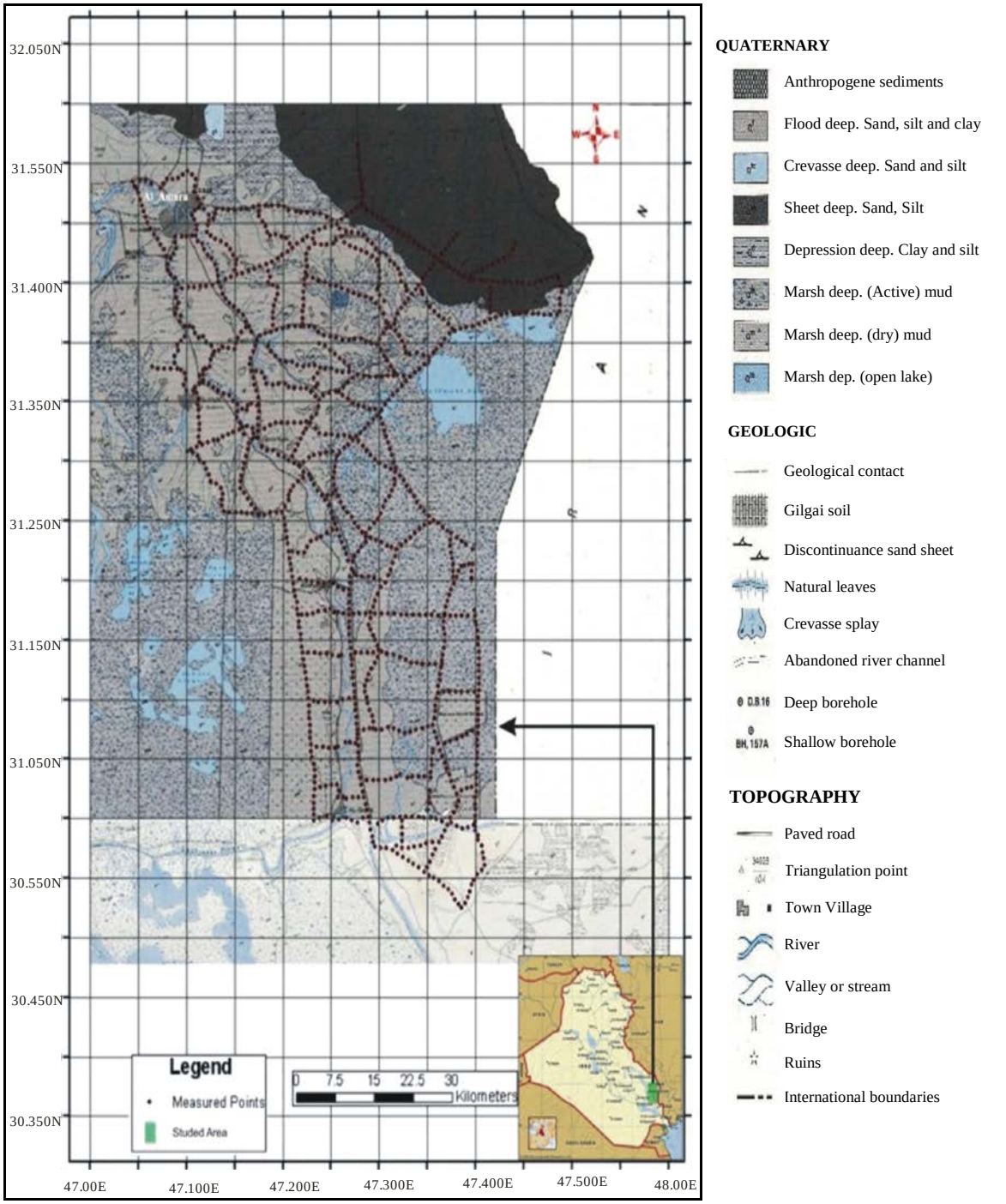

Fig.4: Network of gravity and magnetic stations superimposed on geologic map of the studied area (Geosurv)

▪ Data Collection and Methodology

The Topographic measurements were conducted using Total Station Top con 7501, 721 (with accuracy of one second) and total station Leica 405 instruments (with accuracy of five seconds). The coordinates of each station are given in UTM and geographic system using GPS – GARMN-XL12 (with accuracy of ± 5 m).

The stations spacing was chosen to be 1 Km to fulfill such regional survey. The gravity survey was carried out with CG-5 (Scintrex Autograv System) gravity meter, with reading resolution of 1 μGal.

The triangulation point number (43027) was chosen to be a reference basic station with absolute gravity value of 979406.44 mGal, proper reference. Two local auxiliary basic stations (Bs1 and Bs2) were established in the studied area and tide with the reference basic station (Fig.1). The same gravity basic stations were used as magnetic basic station to conduct the magnetic survey using Proton magnetometer (with maximum sensitivity of 1 nT) as a portable magnetometer, while ENVI PRO magnetometer, which measures and saves reading automatically with three minute interval, was used as a stationary system to monitor the diurnal variation for each workday. The mean quadratic square error (μ) in this survey is ± 0.02264 mGal for gravity survey and μ = ± 2.195 nT for magnetic survey

DATA PROCESSING

▪ Gravity Data

It is necessary to apply many corrections to the raw meter readings to obtain the gravity anomalies that are the target of a survey. This is because geologically uninteresting effects are significant and must be removed. This correction comprises: Drift correction, latitude correction, free air correction, and Bouguer correction, the corrected data introduce Bouguer values, which are plotted as a map (Reynolds, 2003) (Sheriff, 2006).

▪ Magnetic Data

Diurnal correction and normal field correction (Geomagnetic correction) are applied to the raw magnetic data to eliminate the effect of magnetic diurnals and the systematic increase of the magnetic field with latitude. Figure (5) shows the aeromagnetic total field map of Amara – Basrah Quadrangles, which represent the surrounding of the studied area; some parts of which are not covered by C.G.G. (1974) aeromagnetic data.

Figure (6) represents the geomagnetic survey as total magnetic intensity field (TMI) at the studied area, which partly has no aeromagnetic data. Comparison between Figs. (5 and 6) gives the same magnetic picture. The anomalies A, B and G have the same location and shape, as in the aeromagnetic map; this is also true for the positive anomaly E that has its negative part towards the north.

Several positive and negative anomalies within the studied area are related to noise due to buried iron materials and the near occurrence of high-power lines.

The reduction to the pole (RTP) filter reduces the dipolar field to a monopole field. The analytical signal calculated from the vertical integration of the magnetic field is very close to the optimum function represented by the gravity field over the anomalies (Fig.18), (Blakly and Simposn, 1986).

RTP grid has been converted also to pseudogravity map (Fig.7); this map may define the relation between the gravity and magnetic anomalies in such a way that, if the magnetic and gravity anomalies are coincident, it will confirm that the gravity anomalies are related to the same deep sources. Otherwise, then it may indicate different sources or effects of remnant magnetization.

The Energy Spectrum is a 2D function of energy relative to wave number and direction. The radials averaged spectrum is a function of wave number alone, and is calculated by

averaging the energy for all directions for the same wave number. The above estimates can be used as a rough guide to the depth of the magnetic and gravity sources.

Figures (8 and 9) that illustrate the typical reduction in energy with increasing wave number; the depth estimated from the spectrum file are statistical depth estimated to the top of the sources (Spector and Grant, 1970).

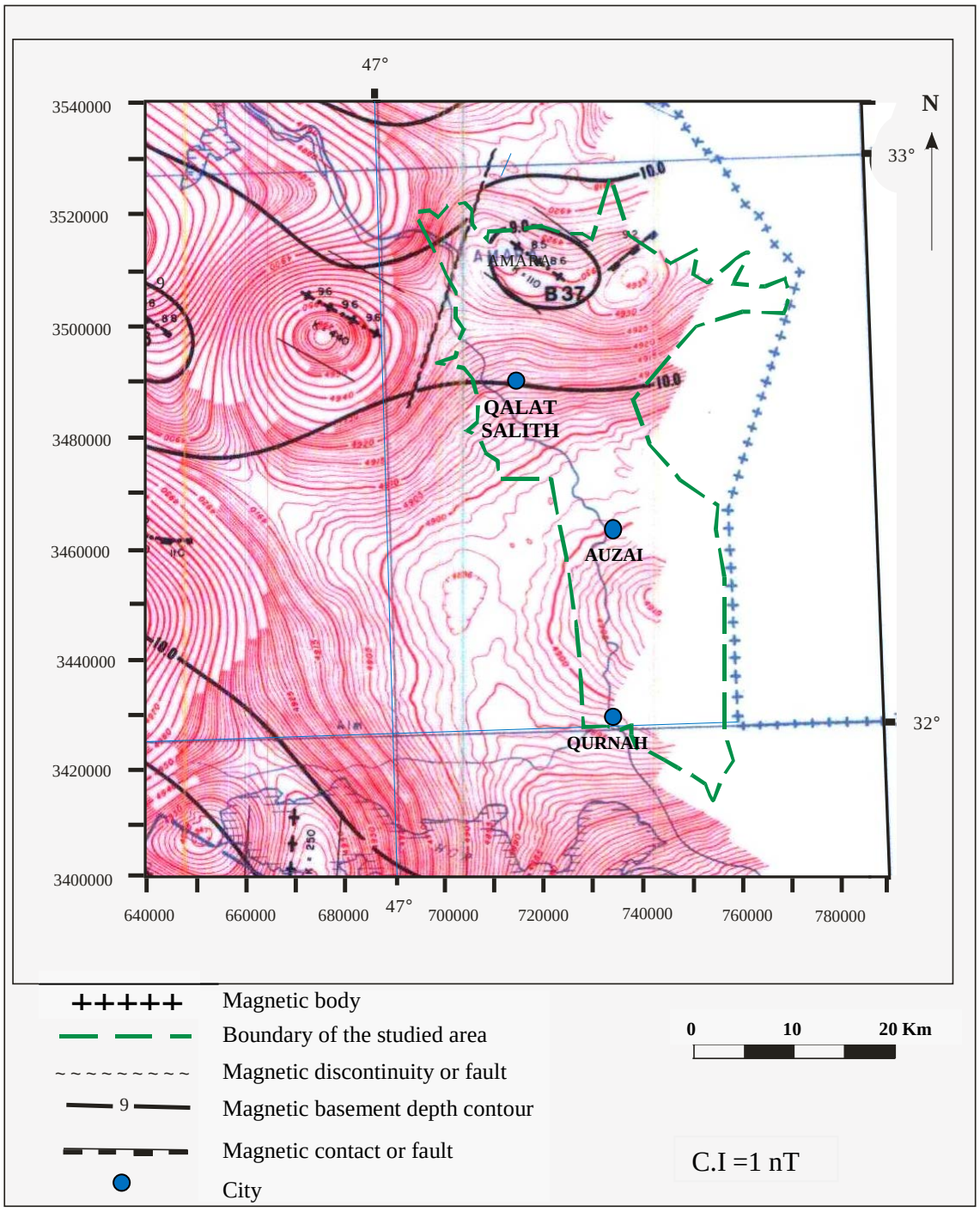

Fig.5: Aeromagnetic map of Amara – north part of Basra Quadrangle boundary of the studied area

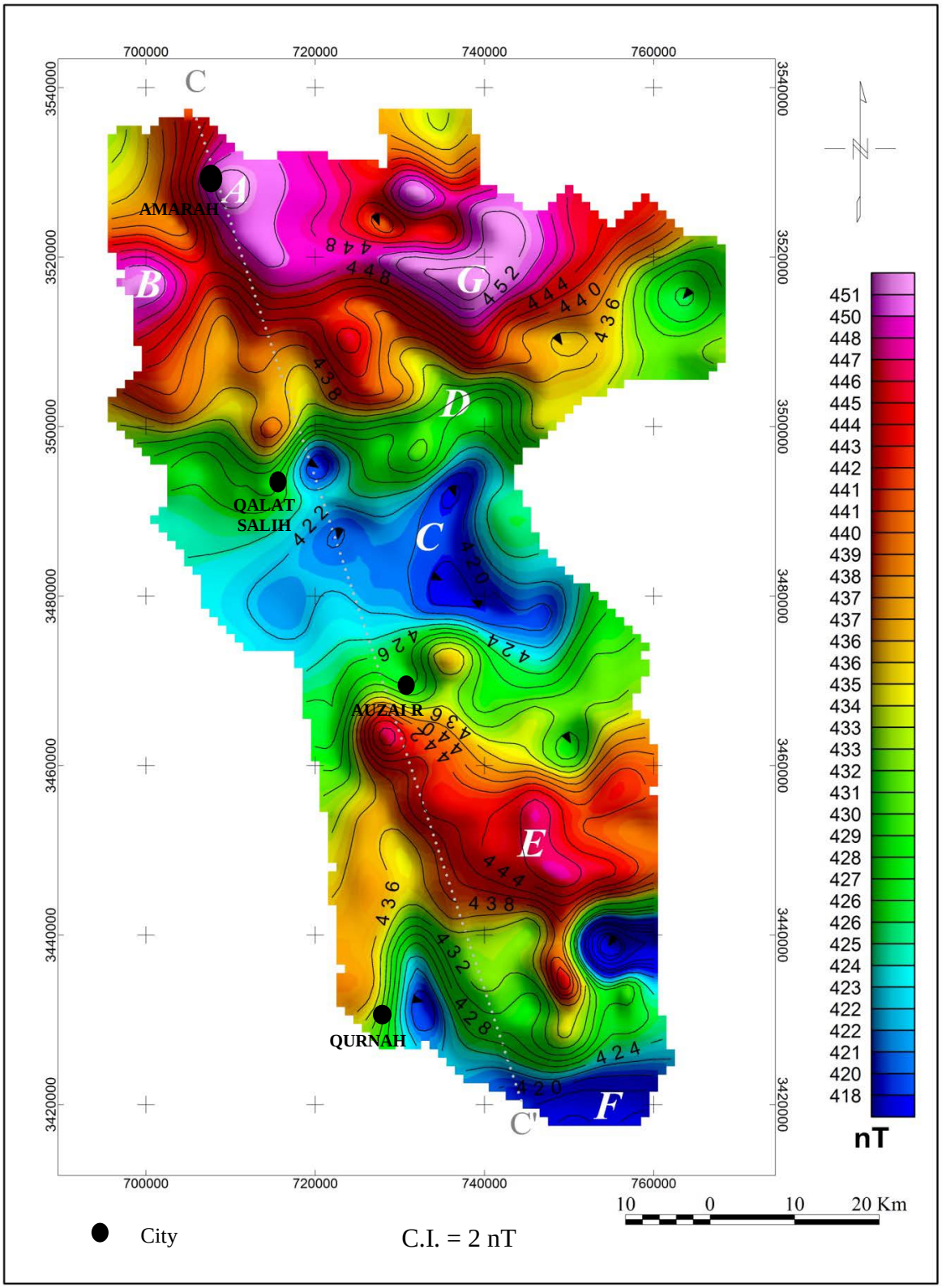

Fig.6: TMI of the studied area after 150 m upward Continuation filter

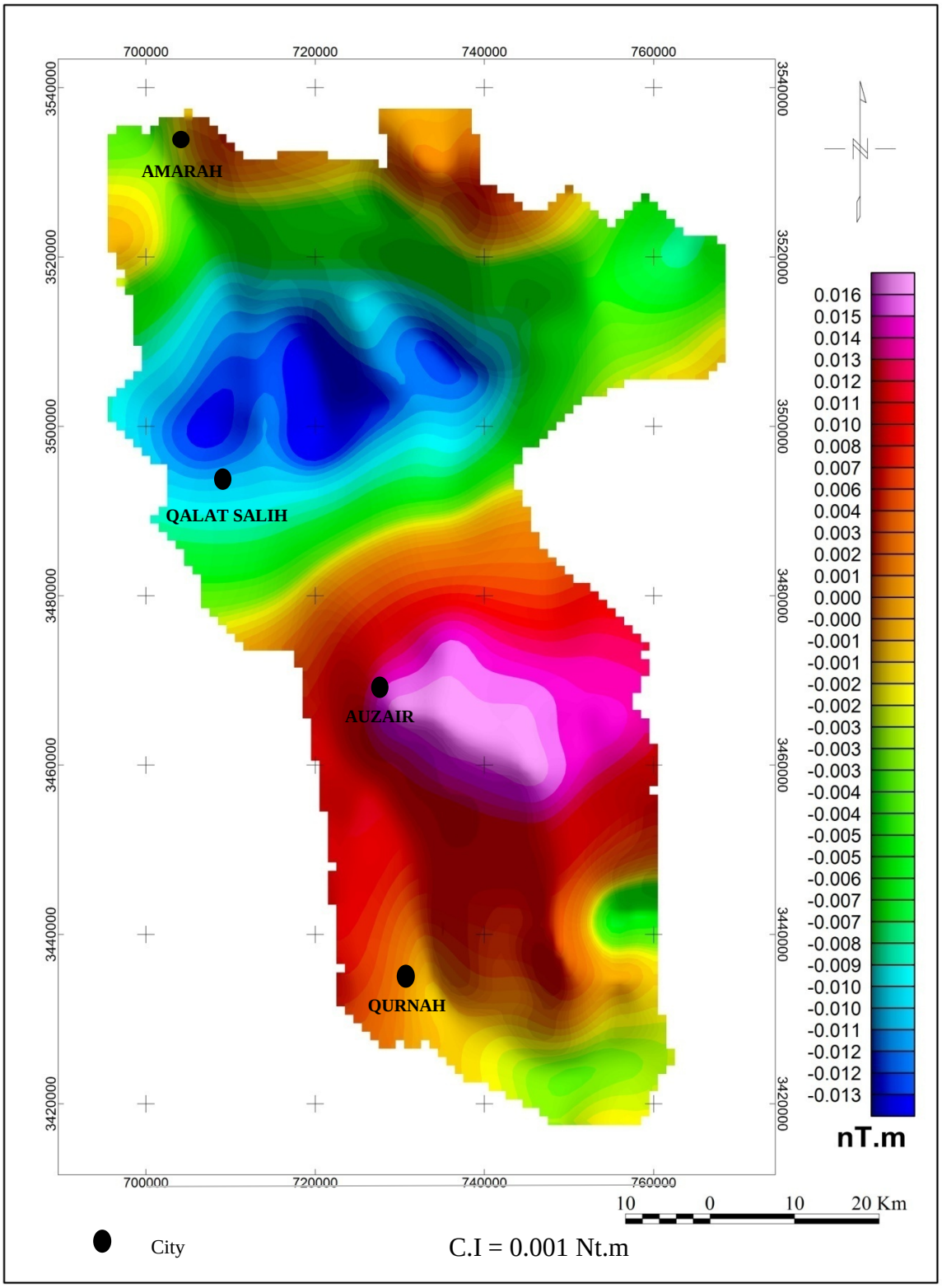

Fig.7: Pseudo gravity map after applying
Vertical integration of RTP map

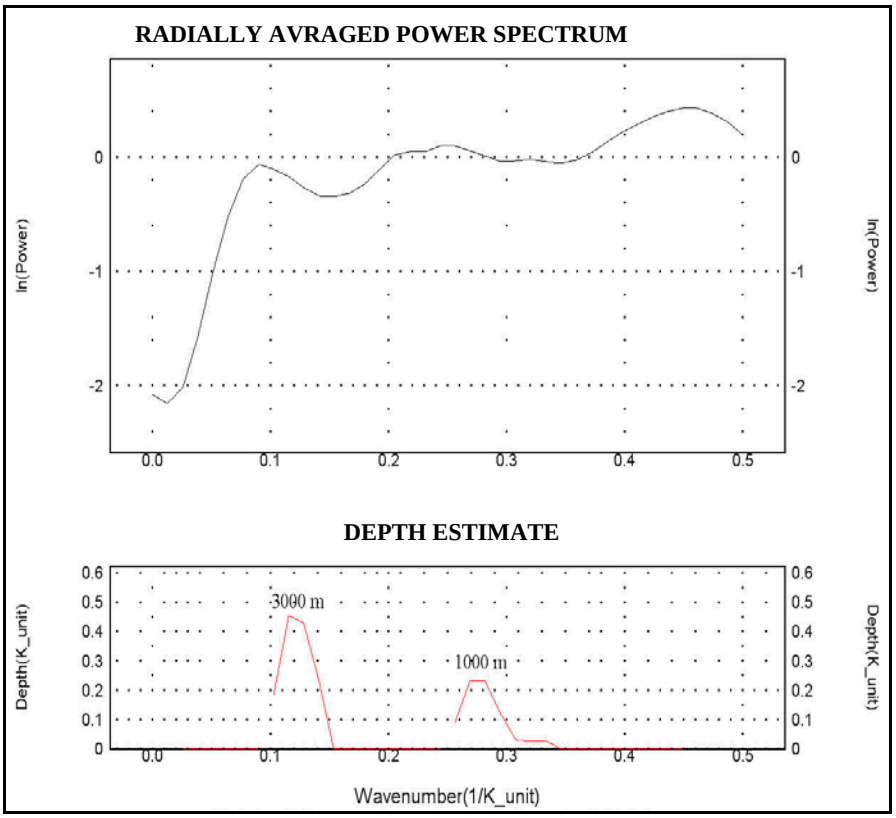

Fig.8: Radially averaged power spectrum of gravity field data

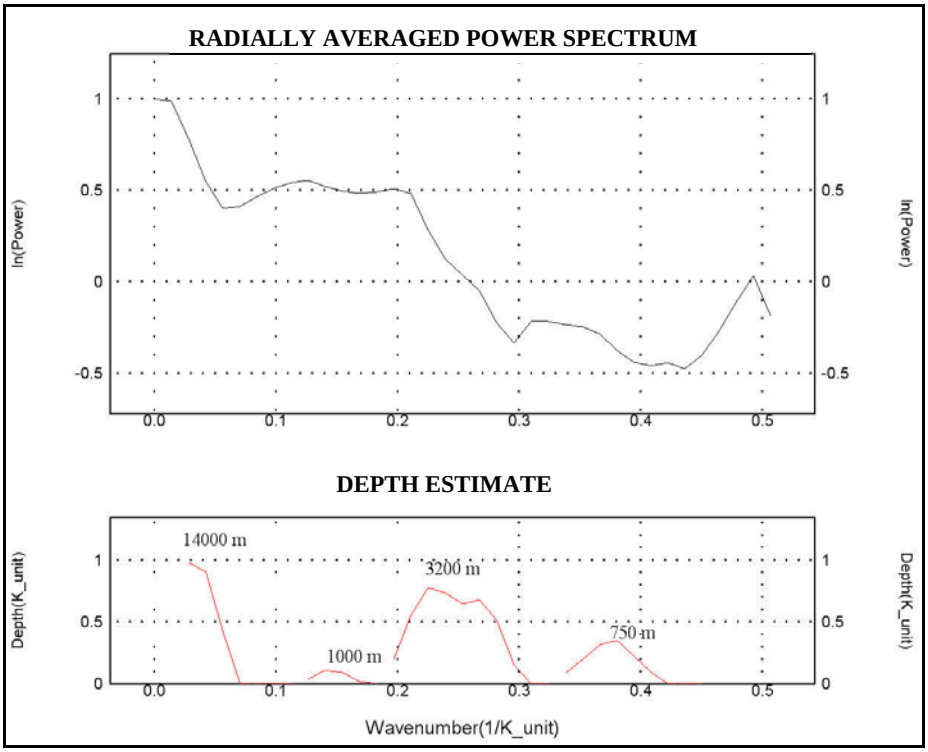

Fig.9: Radially averaged power spectrum for magnetic field data

DATA INTERPRETATION

- **Gravity Data**

Bouguer gravity maps of Iraq and that which cover Amara – north part of Basrah Quadrangle, both obtained from IPC data (Figs.10 and 11, respectively) include an area without gravity data located between latitude 30° 45' – 32° 00' N and longitude 47° 00' – 48° 00' E.

The main aim of this study is to fill this uncovered area with land gravity survey. The gap in the area was successfully covered, except the area of Hor Aum Al-Na'age, the northern part of Hor Al-Huwaizah that is still filled with water. Figure (12) shows the same area in Fig. (10) After merging the data with the gravity data of the studied area using Oasis Montage Software.

Figure (13) shows the Bouguer gravity map of the studied area deduced from the gravity surveys. Some of the inferred gravity anomalies (symboled as G, Gr and F for regional residual and fault, respectively) have the same extension and complement as that of the surrounding area, such as G1, G2, G3, G4 and the main negative anomaly within the studied area. G2 and G3 are the main two positive anomalies within the studied area, which may represent the southeastern part of Ramadi – West Amara High Gravity Anomaly, which extends farther to the SE across the Iraq – Iranian border (Fig.12), (Al-Bdawi *et al*., 2010). These two highs may be related to the same source and may represent an uplift or antiform with NW – SE direction.

The main negative anomaly (A) is bounded from the north and south by two gravity gradients interpreted as normal faults (F2 and F3, respectively) the anomaly F1 could be also interpreted as a normal fault because of its high gradient. It has two parts displaced from each other's by the gravity high G1, which may be interpreted as local antiform or nose imposed on the main gravity high G2, which extends almost WNW – ESE direction and has a deep source. The residual positive anomaly Gr5 may be interpreted as an important anticline structure superimposed on local gravity low, which could be affected by the occurrence of salt similar to several cases, such as Zubair, Rumaila and Nahr Umar structures in the Mesopotamia foredeep. The same is true for the residual positive gravity anomaly Gr7, imposed on the main gravity low A.

Another residual positive gravity anomaly (Gr8) is imposed on the regional gravity high G4, located in the southeastern part of the studied area. The latter may represent the northern part of the Kuwait Arch, where most of the hydrocarbons traps are distributed along its flank (Al-Bdaiwi *et al*., 2010). The same condition is right in the studied area, where the oil fields are distributed along the flank of the gravity gradient F1, F2 and F3.

There is another gravity gradient represented by the anomaly F4 located in the northeastern part of the studied area, it may be interpreted as a strike slip fault according to its effect that disturbs the gravity field and affect the located gravity anomalies, within its vicinity, (Fig.13).

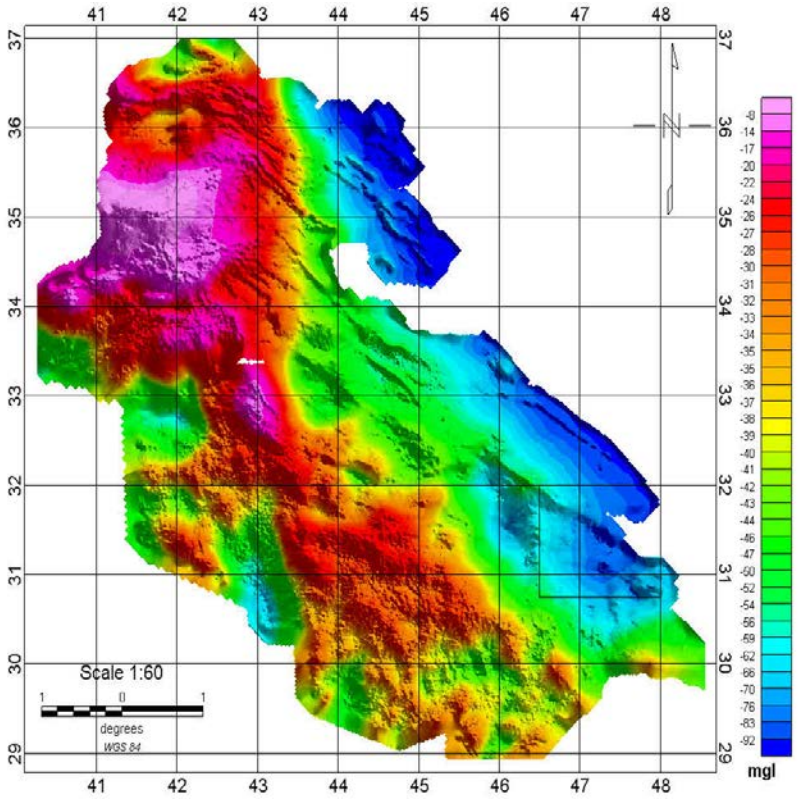

Fig.10: Bouguer gravity map of Iraq (after IPC, 1972)

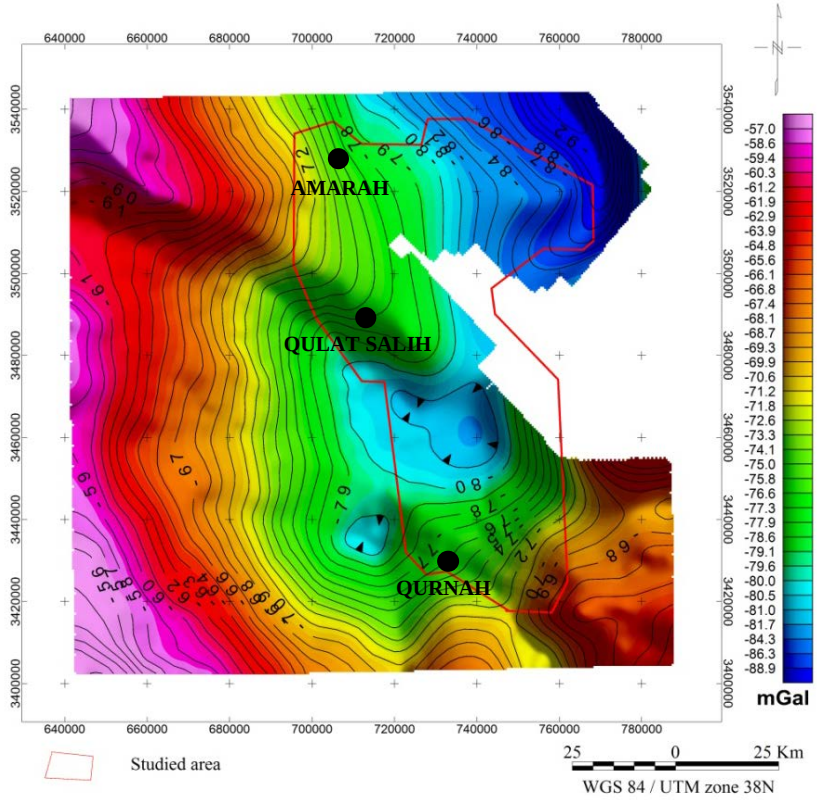

Fig.11: Bouguer gravity map of Amara – north part of Basra Quadrangles before merging with studied area gravity data (after IPC, 1972)

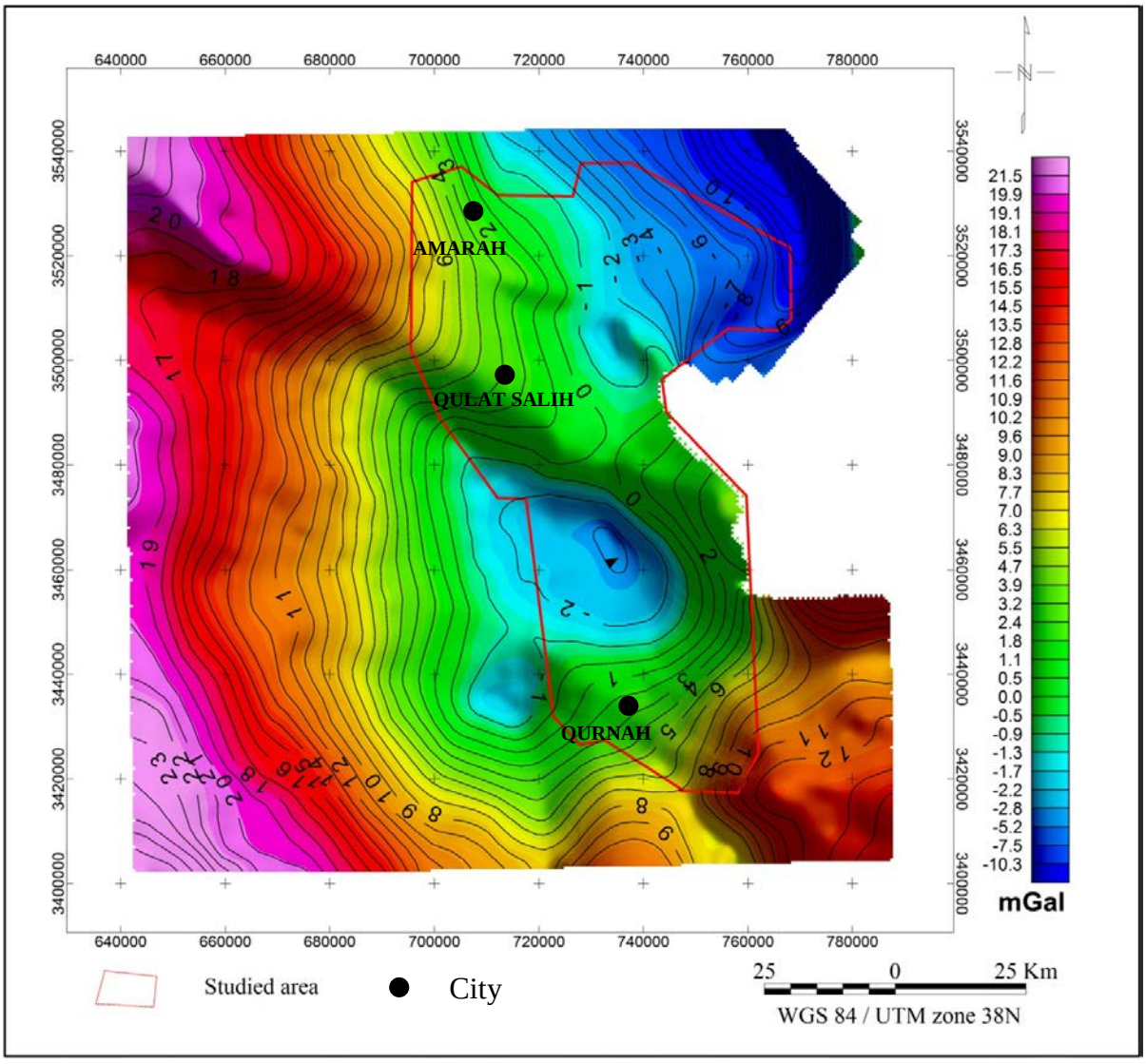

Fig.12: Bouguer gravity map of Amara – north part of Basrah (IPC, 1972) after merging it with the studied area data (C.I. = 1 mGal)

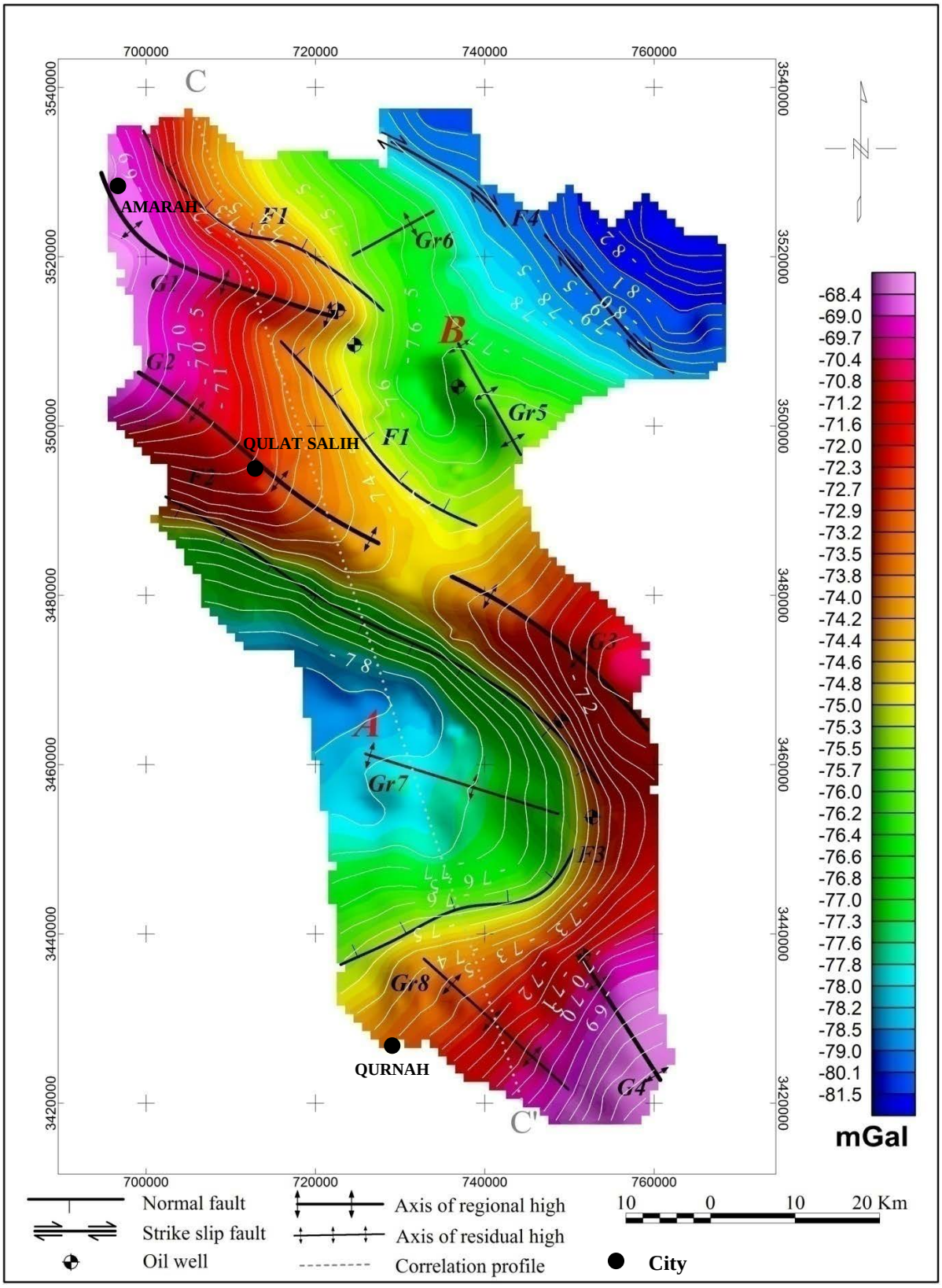

Fig.13: Bouguer gravity interpretation imposed on Bouguer gravity map of the Studied area (C.I. = 0.5 mGal)

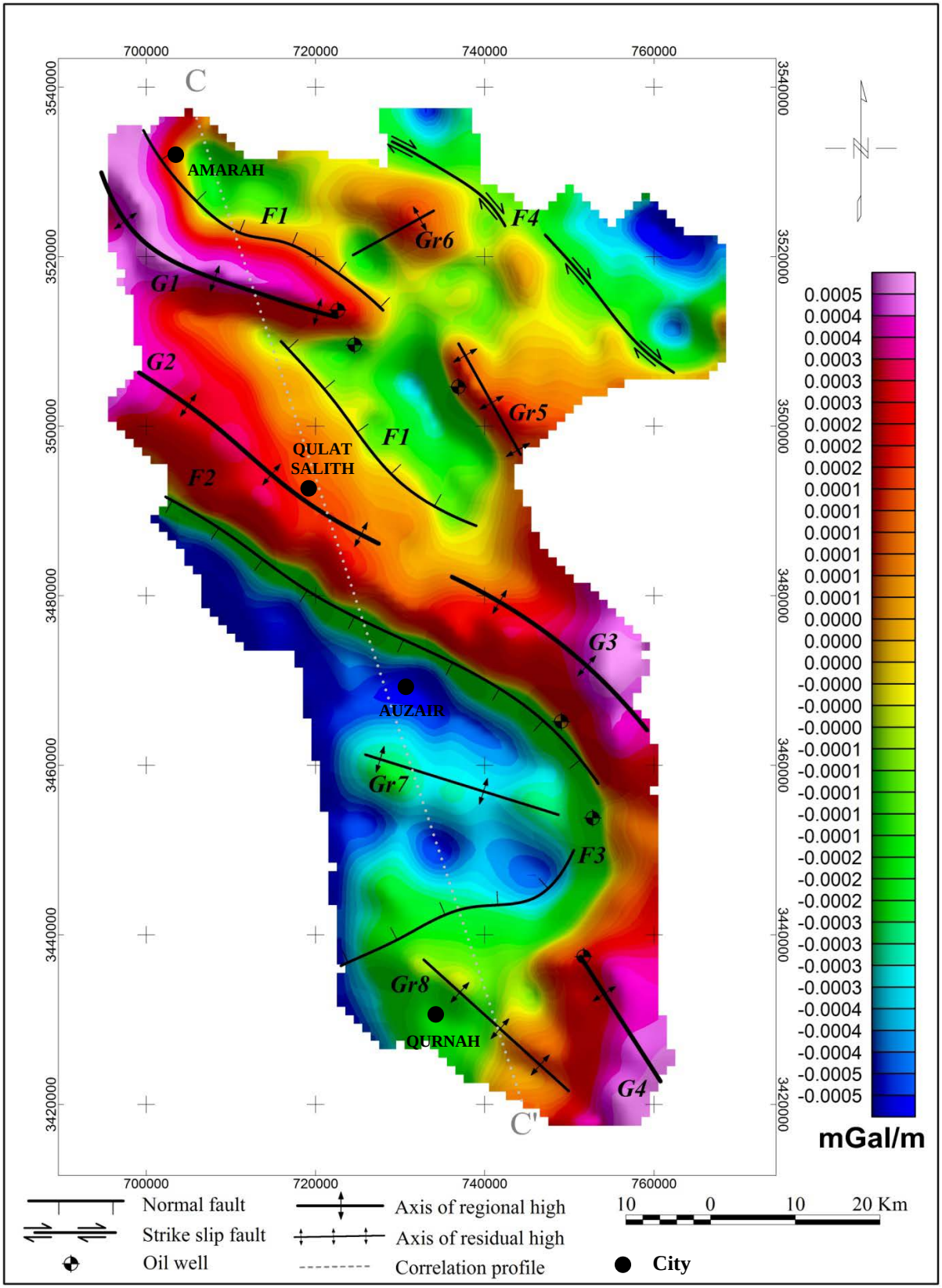

Fig.14: Bouguer gravity interpretation imposed on VDV filter of Bouguer gravity map of the studied area

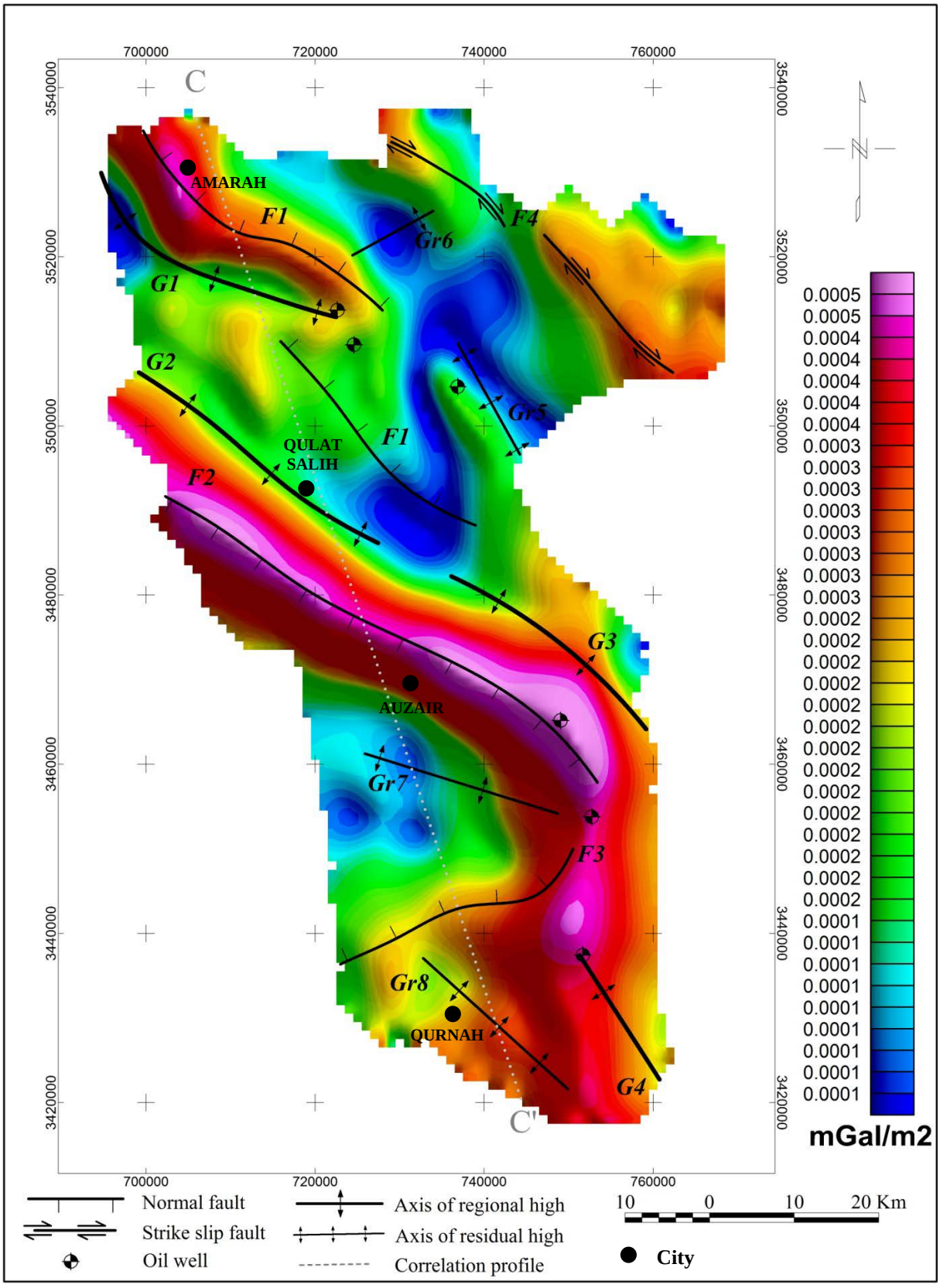

Fig.15: Bouguer gravity interpretation imposed on THD filter of Bouguer gravity map of the studied area

Figure (16) shows regional gravity map after application of the third order trend surface of polynomial regression filter. The regional anomalies G1, G2 and A re still exist; G1 becomes one anomaly with negative gradient towards the east and the G2 with negative gradient towards the north, which means they have depth extent.

Figure (17A) shows correlation profile along C – C' between Bougure (BOUG) vertical derivative (VDV) and total horizontal derivative (THD) filters for gravity data (Figs.14 and 15 respectively) these filters were applied to ascertain the main anomalies within the profile by enhancing the response of these anomalies and make them easier to be located and recognize. These anomalies are as fallows; F1, F2 and F3 interpreted as normal faults, whereas G1, G2, Gr7 and Gr8 as a gravity highs. G1 and Gr7 are two positive gravity highs superimposed on the main gravity high and low in the studied area (G2 and A, respectively).

- **Magnetic Data**

Figure (18) shows the reduction to the pole map (RTP) of the studied area; this correction simplified the complex magnetic anomalies shapes, so that they appear as positive anomalies located directly above (induced magnetized) sources; as if they were at magnetic pole.

The main magnetic highs within the studied area are as fallows; M1 and M2 are located in the NW, M3 and M6 in the N, M7 in the NE, M4 and M5 are two magnetic highs superimposed on the regional magnetic low A and affect the sedimentary cover through its expression in the gravity field (Fig.13).Anomalies M8, M9 and M10 may relate to intrusions. Whereas M8 and Gr7 may relate to the same deep source affecting the sedimentary cover. The magnetic anomalies F1, F2, F3 and F4 were interpreted as normal faults.

Figure (19) shows the regional RTP magnetic field at the studied area after application third order trend surface of polynomial regression filter. At northern part of the map. There is a trend of high positive gradient, while at the southern part of the map, there is a dipolar anomaly with negative pole to the north (at the middle) and positive pole to the south, and both anomalies represent deep sources.

Figure (17B) shows the same correlation profile along C – C' between reduction to pole (RTP), total horizontal derivative (THD) and vertical derivative (VDV) filters for RTP data. In this profile, the main interpreted anomalies are as fallows; F2 interpreted as a normal fault, whereas M1, M3 and M8 as a magnetic highs, Mr4 and Mr12 are residual magnetic highs, whereas M3 and Mr4 are two positive magnetic highs superimposed on the main magnetic low A, while Mr12 is a residual magnetic high superimposed on the magnetic low B, these anomalies have affected the sedimentary cover through its expression in the gravity field in the same localities. On the other hand, M8 is well correlated with Gr7, which is imposed on the main gravity low A indicating the possibility of salt occurrences (see Figs.13 and 18).

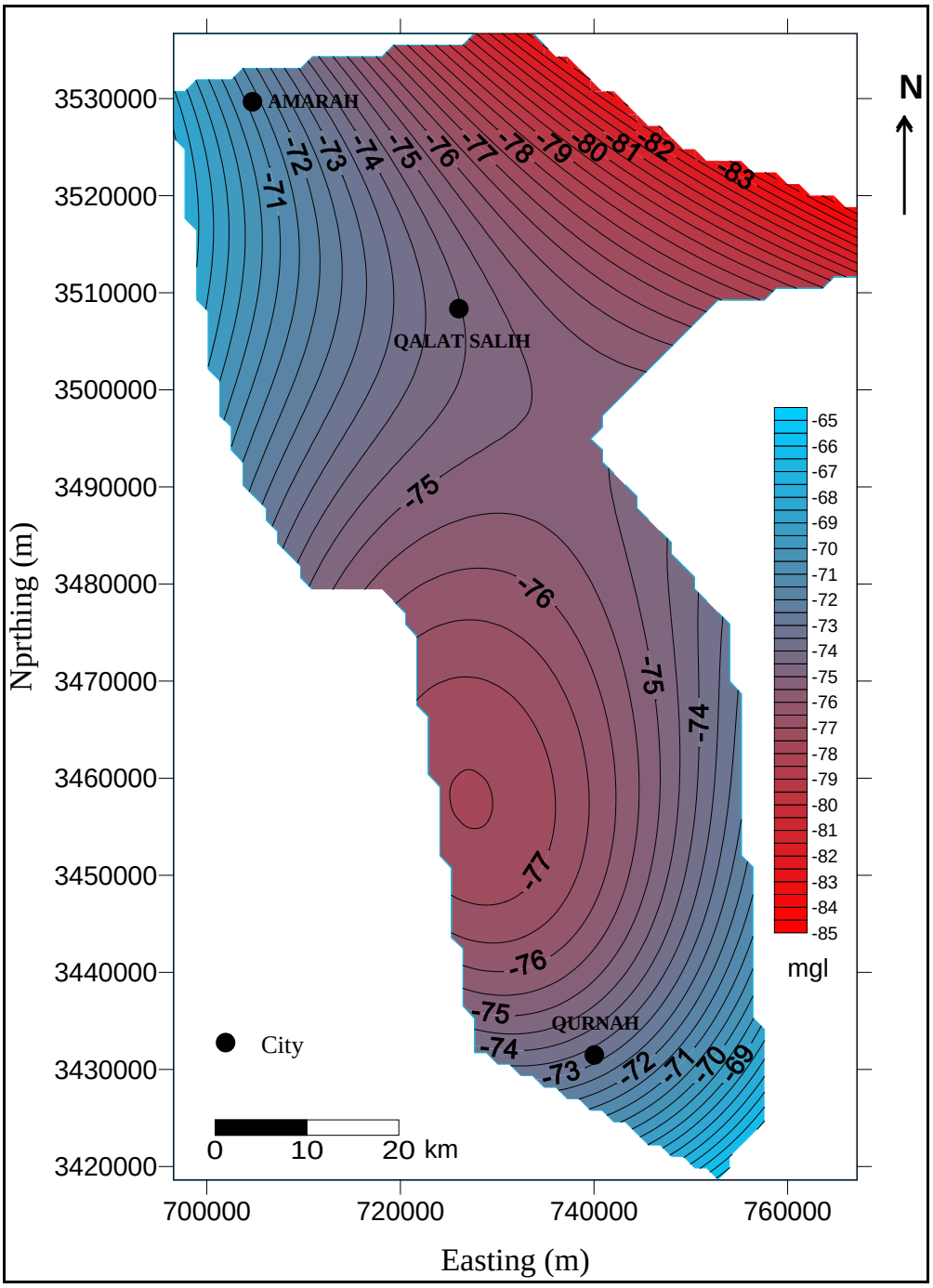

Fig.16: Regional Bouguer gravity map of the studied area (C.I. = 0.5 mGal)

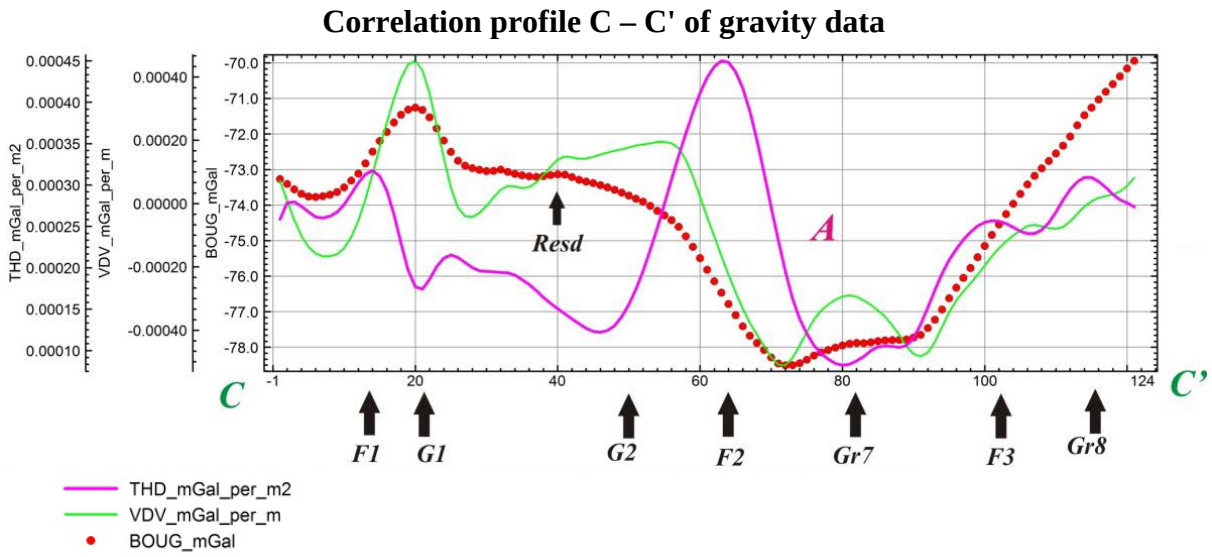

Fig.17A: Correlation between different curves resulted from different kinds of grids along cross-section C – C', BOUG in mGal, VD in mGal/m, THD in mGal/m^2
(For location refer to Figs.13, 14 and 15, respectively)

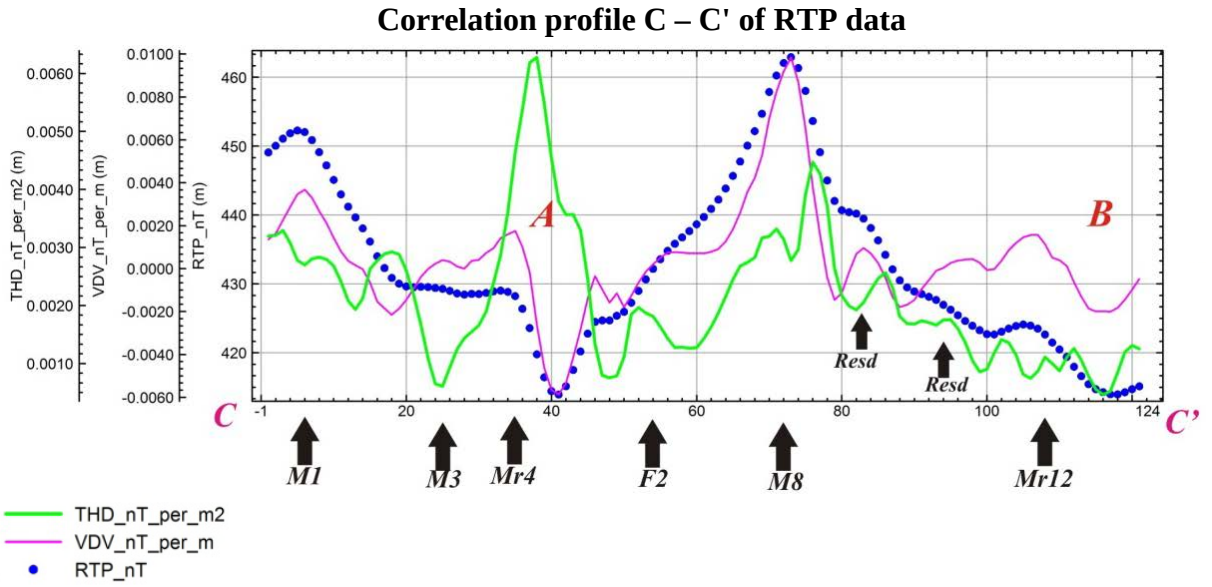

Fig.17B: Correlation between different curves resulted from different kinds of grids along cross-section C – C', RTP in nT, VD in nT/m, THD in nT/m^2
(for location refer to Fig.18)

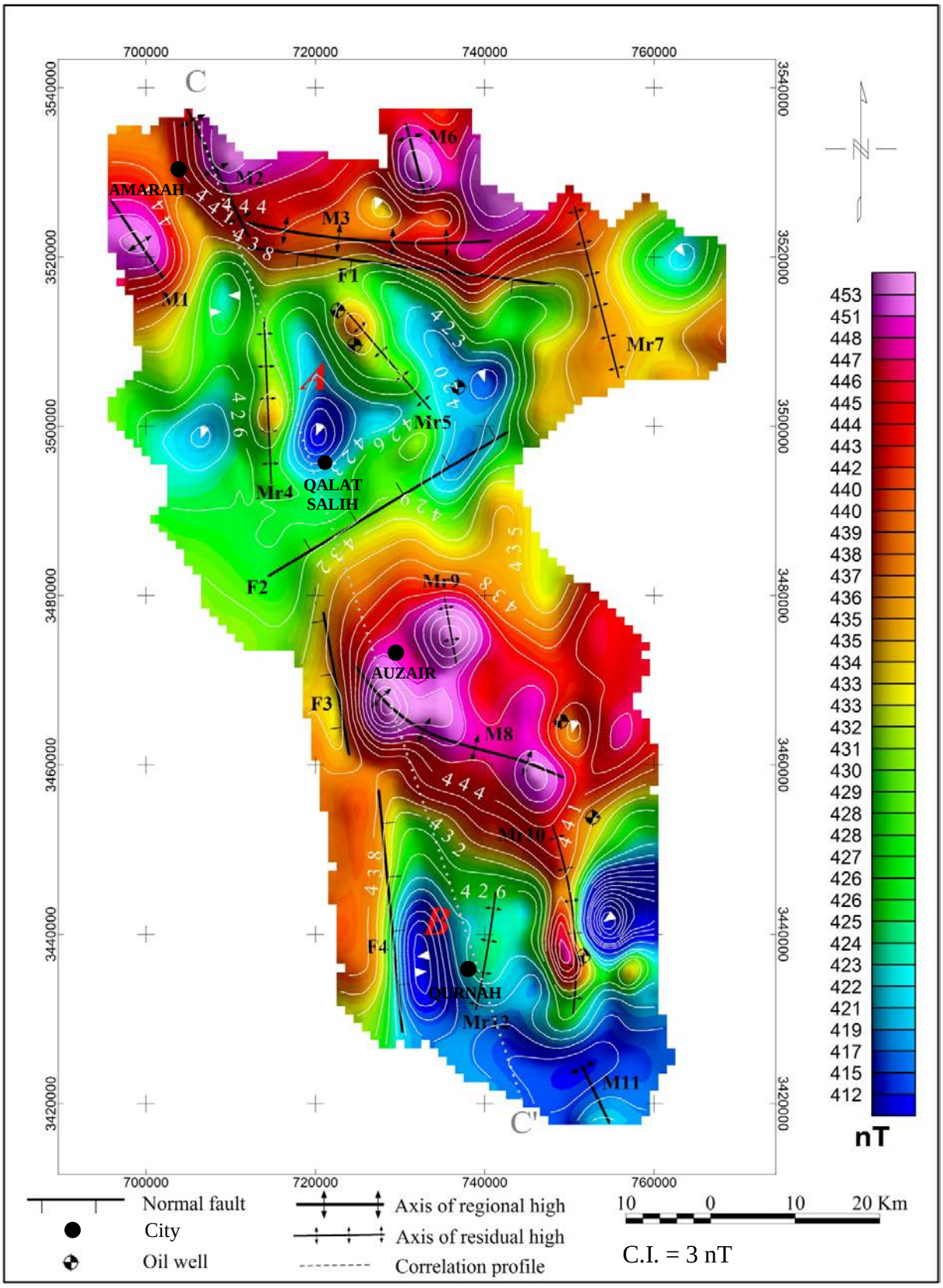

Fig.18: Magnetic interpretation imposed on RTP filter of total magnetic Intensity map of the studied area

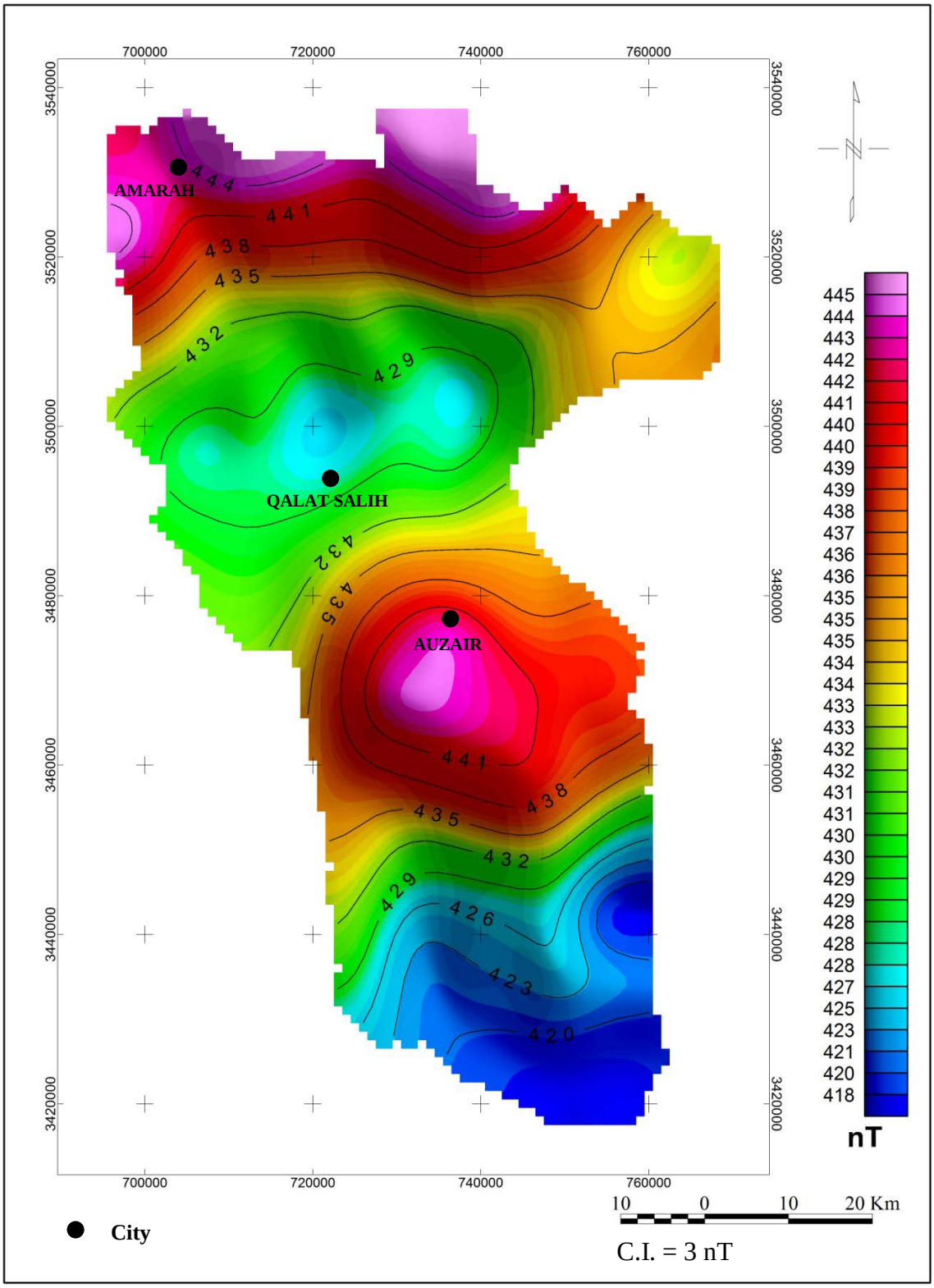

Fig.19: Regional RTP map of the studied area after applying 5 Km upward continuation filters

DISCUSSION AND CONCLUSIONS

- **Gravity Method**

It is essential to say that the Bouguer gravity map of the studied area (Fig.13) reflects mainly the structures that lie above the basement, i.e. intrasedimentary anomalies and these anomalies complete those of the surrounding map area (Fig.12). Inspection of this map may delineate several anomalies.

The analytical signal calculated from the vertical integration and pseudogravity filters, (Fig.7) is very close to the optimum function represented by gravity field over the anomalies in presented Fig. (13).

It's believed that the anomalies G1, G2 and G3 are parts of one extended positive anomaly, which trends NW – SE; this positive anomaly has long extension outside the studied area (Al-Badawi, *et al*., 2010). This anomaly may be caused by uplift in sedimentary cover as indicated in the basement relief map of IPC (Fig.20). Part of this uplift occurs or may be caused by antiform structure represented by G1 that extends along the proposed fault F1 (Fig.13), or interpreted in term of coral reef or anhydrite elongated body present within the sedimentary column (Al-Badaiwi, *et al*., 2010).

The anomaly Gr5 could be important positive anomaly imposed on a local gravity low it is related to Halfaya anticline (Fig.3), but probably the occurrence of salt has caused its negative background signature.

The negative gravity anomaly A is the complementary of the negative anomaly outside the studied area. This anomaly is surrounded by high gravity gradient that may be related to presence of faults (F2 and F3). This anomaly may reflect the occurrence of a depression filled with low-density materials such as salt (Fig.3).

The positive gravity anomaly G4 at the southern part of the map (Fig.13) may reflect the northern part of Nahr Umer anticline, and could represent the northern flank of the Kuwait Arch as mentioned by Al-Badaiwi *et al*., (2010). The positive gradient F3 could be due to the effect of fault structure bounding the negative anomaly A from the south and it may be related to Majnoon oil field.

Another feature seen in the Bouguer map is the location of some oil wells, at the flanks of the high gradients of anomalies F1, F2 and F3, (Figs.13 and 14).

Jassim and Goff (2006) mentioned that there are groups of buried anticlines of relatively low amplitude associated with longitudinal faults, along the Ramadi – Musaiyib and the Tikrit – Amara Faults Zones, These anticlines are associated with sharp gravity gradients, and the same is also seen in the studied area.

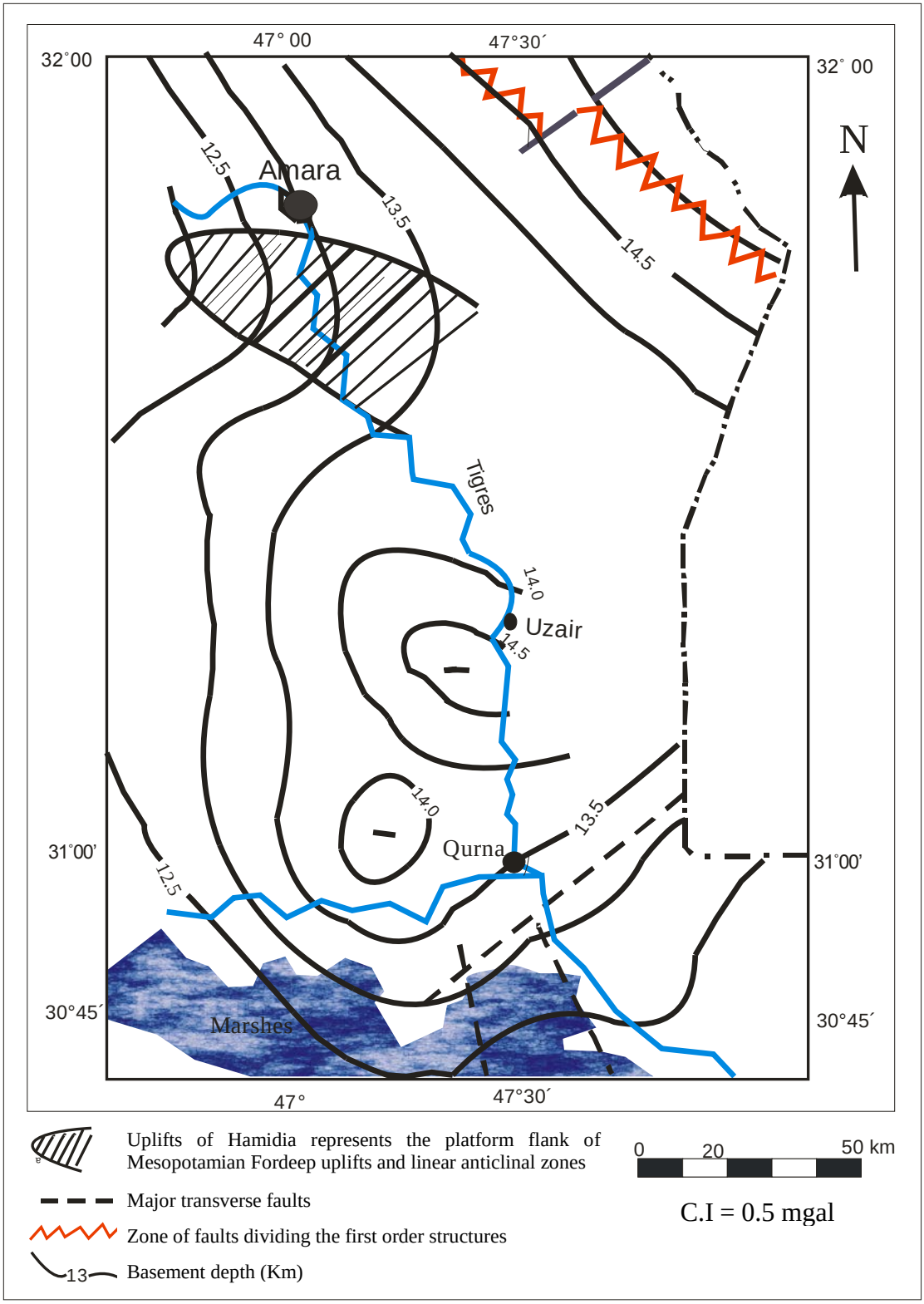

Fig.20: Basement relief map of Amara–north part of Basra Quadrangle (IPC, 1972)

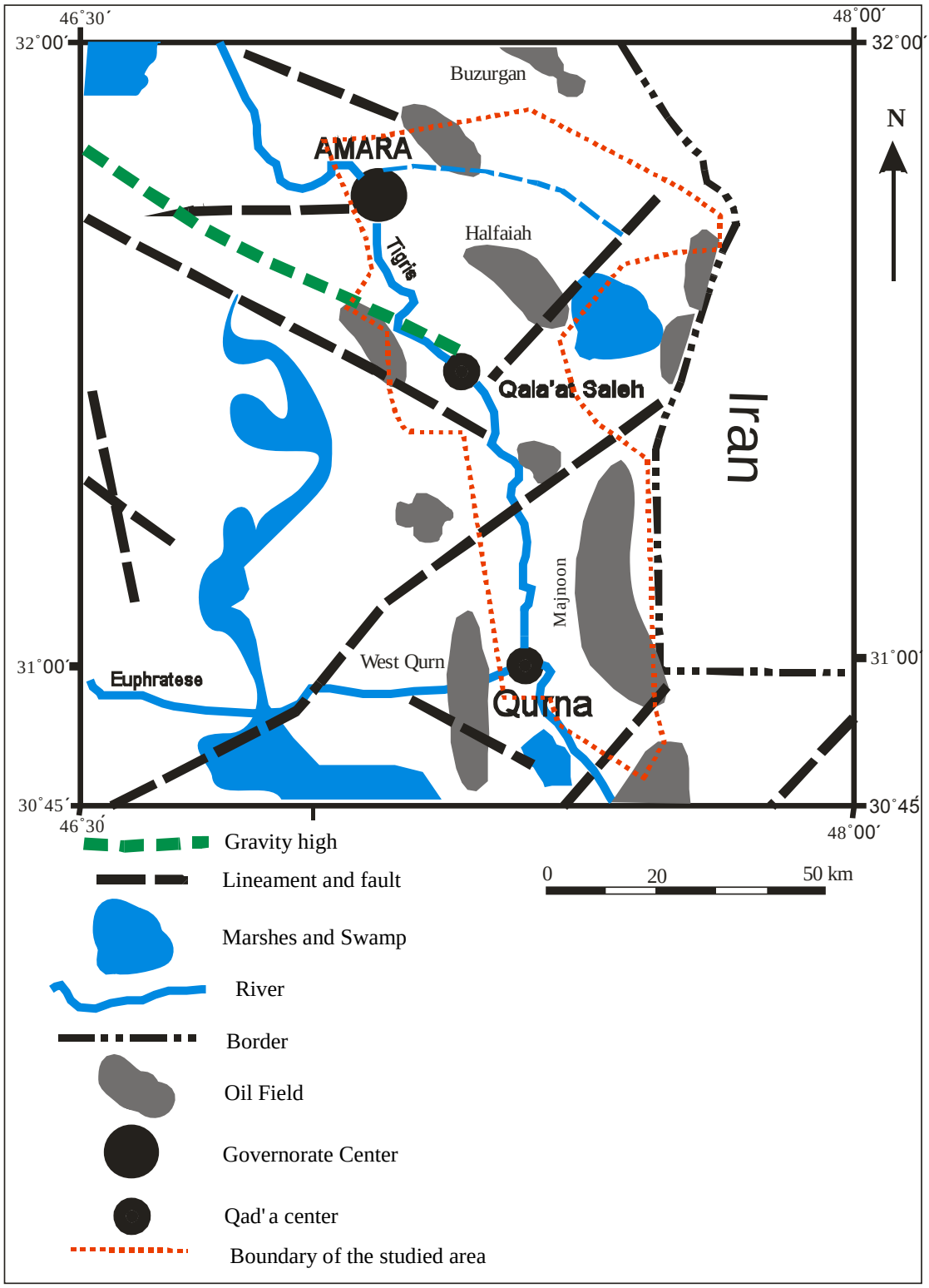

Fig.21: Modified map of Amara – north part of Basra Quadrangle shows the main structural axes with lineaments and oil field traces (Jassim and Goff, 2006).

- **Magnetic Method**

The magnetic anomalies of the studied area show the same features as those of the surrounding areas surveyed eromagnetically by C.G.G. in (1975), but the most important thing is that the area is very noisy due to the occurrence of the high-power lines and different buried iron objects.

The positive magnetic anomalies M1, M2 and M3 (Fig.18) may be related to the effect of the same source, represent the eastern part of the positive magnetic anomaly located at Amara city, which in turn represents the extension of the long positive anomaly South Najaf – Al-Shatra anomaly, (Al-Badaiwi *et al*., 2010).

Anomaly M8 is the main magnetic high in the studied area. This anomaly extends to the east and to the surrounding area and its complements. This anomaly is well correlated with the residual gravity anomaly Gr7, imposed on the main gravity low A, indicating the possibility of salt occurrences (see Fig.13, 17 and 18).

Anomaly M11, which is located in the southern part of the studied area, could be extended farther to the south outside the studied area. The direction and location of this magnetic anomaly is well correlated with the gravity high G4: both trending NW – SE. The latter may represent the north part of Kuwait Arch, where most of the hydrocarbon traps are located along its flank (Al-Bdaiwi *et al*., 2010). The same condition is seen in the studied area, where the same oil fields are distributed along the flank of the high gravity gradients F1, F2 and F3.

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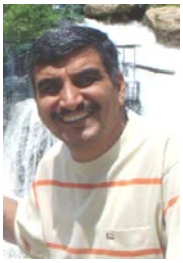

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