# THE SUBSURFACE STRUCTURE OF AR'AR – AL-BIREET AREA, SOUTH IRAQ, FROM GEOPHYSICAL ANALYSIS

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## ABSTRACT

The area includes the locations of Ar'ar, Ma'ania and Al-Bireet in southwest Iraq. The area is bounded by 30° 40' – 31° 40' northing and 41° 40' – 42° 50' easting. The available gravity and aeromagnetic maps are analysed with the aim of producing a geological picture of the subsurface. The gravity map is filtered to produce a smooth regional map that amplifies the broad anomalies over Ar'ar area and Ma'ania area. The filter also gives a residual map that shows sharp local anomalies over Ar'ar area such as, Khaliga and Ashoria as well as a series of long anomalies trending N – S in the Bireet area. Over Ar'ar area, both the magnetic and the regional gravity anomalies are interpreted together so as to have a better constrain on the solution. The interpretation shows that the anomalies are related to a single source within the basement. A sheet of possible basic igneous rock occurs mainly within the basement but its top penetrates the overlying sediments by about 0.5 Km. Such model is seen to satisfy the gravity and magnetic observations at the surface.

The residual anomalies over Ar'ar area are explained by up warping of Lower Cretaceous rocks in addition to probable faulting on top of the upwarp. The residual elongated undulations that trend N – S in Bireet area are explained by correlation with the seismic section in the southwest as due to parallel folds in the lower Cretaceous and older strata. The difference in the trend of these residual anomalies in Bireet area from that of Ar'ar area is explained in that the latter folds are to some extent influenced by the deeper sources trends.

# التركيب الجيولوجي العميق لمنطقة عرعر – البريت، جنوب العراق، من الأدلة الجيوفيزيائية

**زهير داود الشيخ و عبد العظيم محمود المشهداني**

**المستخلص**

تتضمن المنطقة مواقع عرعر، المعانية والبريت في جنوب غرب العراق. وتحدد المنطقة بين (41° 40' – 42° 50') شرقا و (30° 40' – 31° 40') شمالا.

لقد تم تحليل الخرائط الجذبية والمغناطيسية الجوية المتوفرة بهدف التوصل الى تصور واضح للجيولوجيا العميقة في المنطقة. وتم ترشيح الخارطة الجذبية للحصول على الخلفية الإقليمية التي توضح الشواذ الواسعة لمنطقتي عرعر والمعانية. كما وفر المرشح الخارطة المتبقية التي تبين الشواذ المحلية الحادة فوق منطقة عرعر أمثال شواذ الخليجة والعاشورية. كما بين الترشيح سلسلة من الشواذ الطولية الممتدة باتجاه شمال – جنوب في منطقة البريت. وفي منطقة عرعر استعملت خارطة الشواذ المغناطيسية سوية مع الشواذ الجذبية الإقليمية للحصول على سيطرة اكبر للحل النهائي لمصدر الشذوذ. وقد بين التفسير بأن المصدر المنفرد (صخور نارية قاعدية على الأكثر) يقع بشكل رئيس ضمن صخور القاعدة وتتداخل قمته وبارتفاع نصف كيلومتر ضمن الصخور الرسوبية فوق القاعدة. مثل هذا النموذج يحقق بشكل مرض القياسات الجذبية والمغناطيسية.

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وقد فسرت الشواذ المحلية فوق تركيب عرعر على إنها ناتجة عن تقبب بصخور الكريتاسي الأسفل وما تحته إضافة الى فوالق محتملة على قمة التقبب.

كما فسرت الشواذ الطولية التي تمتد باتجاه شمال – جنوب في منطقة البريت، بالمقارنة مع الصور المعطاة في المقطع الزلزالي المأخوذ جنوب غرب المنطقة بأنها طيات متوازية لصخور الكريتاسي الأسفل وما تحته. أما الاختلاف بين اتجاه محاور هذه الطيات في كل من منطقتي عرعر والبريت فان محاور منطقة طيات عرعر قد تأثرت بالتقبب القديم في صخور القاعدة الذي يظهره المقطع الزلزالي إضافة الى تأثرها بحركات الانضغاط في الفترات ألاحقة التي كونت طيات منطقة البريت.

## INTRODUCTION

The area under study lies at the extreme southwest of Iraq, adjacent to the Iraqi – Saudi borders. Jadaidat Ar'ar, which lies within the study area is a border point through which the pilgrim route to Mecca runs. The area is bound by (30° 40' – 31° 40') northing and (41° 40' – 42° 50') easting. It consists of flat, wide, mainly gravely desert that has a gentle regional inclination towards the east, (Fig.1).

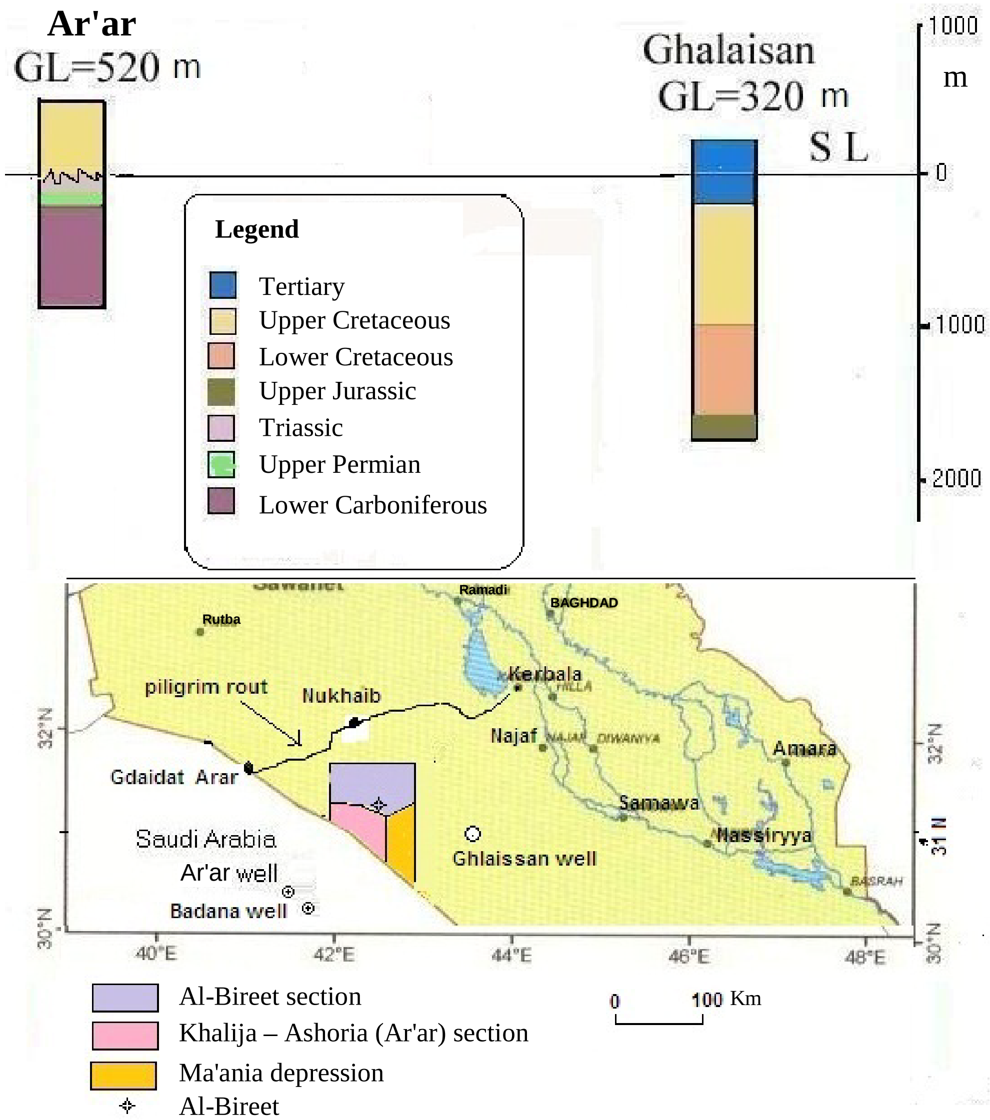


Fig.1: Location of the study area (squared) and bore hole geological logs

Figure (1) shows the location of the study area, nearby wells (Ar'ar 1 within the Saudi territory and Ghlaisan.1 to the east of the area) and the three locations within the square area Khaliga – Ashoria (Ar'ar uplift), Ma'ania depression and Al-Bireet, that form the subject of the present paper.

- **The Geology**

The surface gravels of the area, mainly limestone and some chert, are brought from the elevated plateau of the west by east – west flowing vallies. These vallies form a series of alluvial fans whose apecies, adjacent to each other, form the western irregular boundary of what is known as the Nukhaib depression. The depression of the present area is the continuation of the northern depression, which extends between the town of Nukhaib and Wadi Ghadaf. This northern part of the depression has been the subject of a study made by the present authors, (2012).

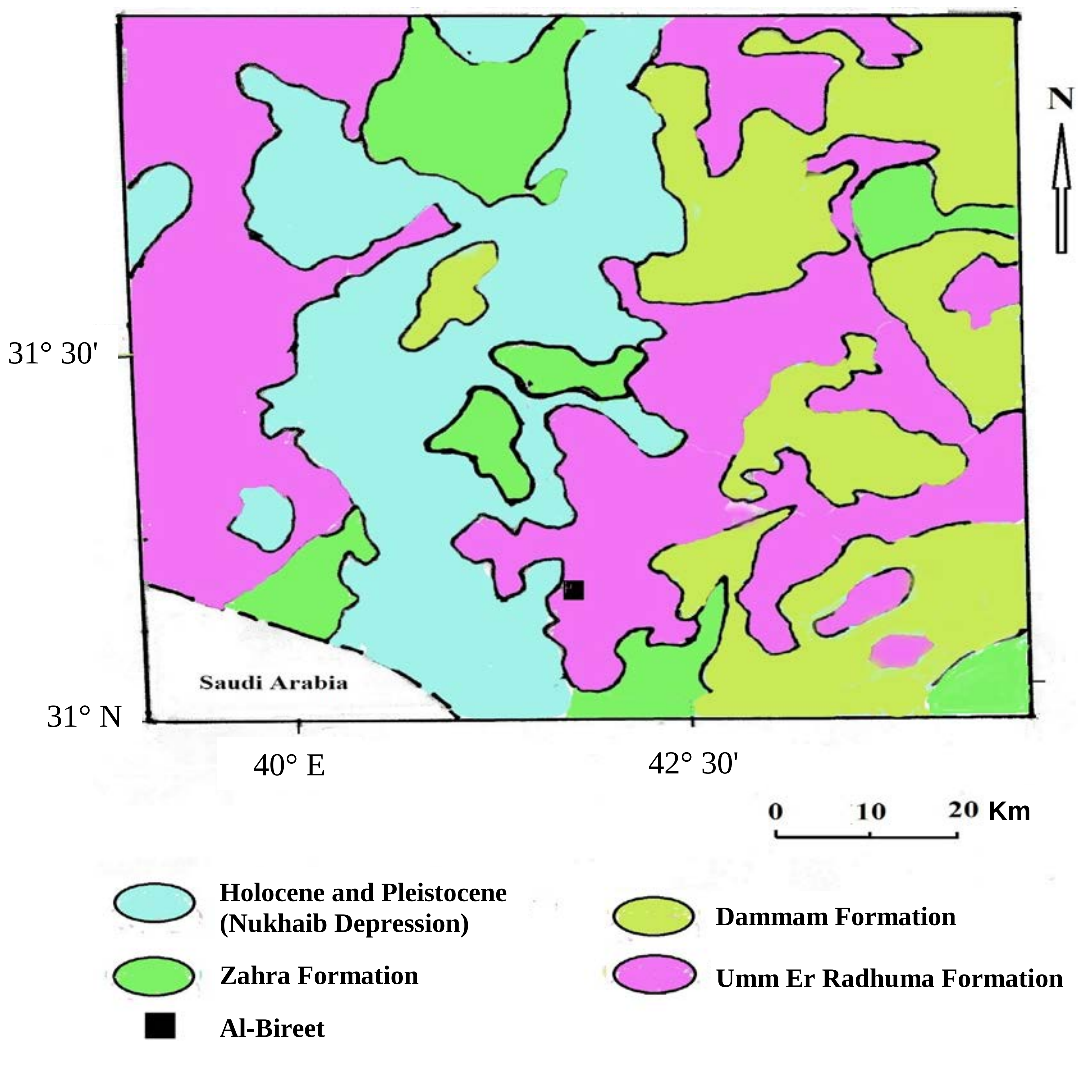


Fig.2: The Geological Map of the area

Figure (2) shows the surface geology as obtained from the one million geological map of Iraq, (Sissakian, 2000). The outcropping formations are mainly Tertiary in age. The Umm Er Radhuma (Middle – Lower Paleocene) is widespread and consists of some (120 – 180) m thick anhydrite, dolomitic and porous limestone (Sissakian and Mohammed, 2007). Dammam Formation (Middle – Lower Eocene) is essentially a porous dolomitic limestone. This is followed by Zahra formation (Miocene), which are cyclic deposits of sandstone and limestone and are named by Al-Mubarak and Amin (1983) as Zahra Formation. Quaternary sediments fill existing vallies, depressions, sinkholes and other karsts, which are quite abundant (Al-Naqib, 1967).

- **Geophysical Characteristics**

The surface geology is, therefore, simple consisting of flat lying Tertiary strata covered thinly at places by Quaternary and recent deposits. What attracted attention to the area, however, is its geophysical characteristics.

The Bouguer anomaly map (Fig. 3) obtained as part of the gravity map of Iraq (IPC, 1960) and produced in different scales with contour interval of one mGal, shows a prominent broad, N – S trending low on the southeastern side of the map overlying a wide topographic depression known as the Ma'ania depression. The western side of the Ma'ania gravity low shows a sharp gradient with an elongated gravity high that runs in a NW – SE trend parallel and close to the Iraqi – Saudi borders in the area. This high is the other important feature of the map. It will be refered to as Ar'ar anomaly and Ar'ar uplift (Fig.1 for location). The Ar'ar anomaly has two positive culminations along its length. That occurring to the north is refered to as Khaliga anomaly and the southern culmination is named here as Ashoria. The Ar'ar anomaly was first noticed by Ditmar *et al*. (1972) and named it as Khaliga – Abu Qur uplift. It was also studied later by Sallomy and Al-Khatib (1981) and Al-Bodani (2000).

Figure (3) also shows that the broad gravity low associated with Ma'ania depression, when traced northwards into the Bireet area (Fig.1), splits into two elongated broad lows with an intervening high. There is also a broad gentle low in the northwest corner of the map beyond the Ar'ar anomaly.

Ar'ar gravity high is further associated with an elongated magnetic anomaly that has an approximately similar trend, (Fig.4). The map shown on this figure is taken from the total field aeromagnetic map of Iraq (C.G.G., 1974) drawn in different scales with contour interval of one nT. The scale used for the present study is 1: 500 000. This Ar'ar magnetic anomaly consists of a southern positive part followed by a negative northern part. Slightly to the north, there is another large smooth magnetic high that impinges to the south against Ar'ar anomaly through a sharp gradient.

Additional geophysical information is available through the megaseismic reflection line, which runs across Iraq in a SW – NE direction starting from the vicinity of Ashoria anomaly, (Mohammed, 2006). It is an integration of 2D short seismic reflection lines extending from Ashoria in the SW to the Iraqi – Irani borders in the NE. A short part of this lines crosses the study area in its SE corner, (Fig.3). It passes over the gravity gradient occurring between the southern part of Ar'ar anomaly (Ashoria) and the Ma'ania anomaly. Clear Mesozoic reflectors are observed on the section. The gravity gradient refered to above is seen in the form of disturbed irregular reflectors. These reflectors are identified as Gutnia Formation (Late Jurassic) and Lower Cretaceous formations such as Ratawi, Shu'aiba and Mauddud. These reflectors are seen undulating gently. The closures of these undulations as can be detected on Mohammed's (2006) section to vary up to 250 m. The closures appear to increase when followed along the section eastwards.

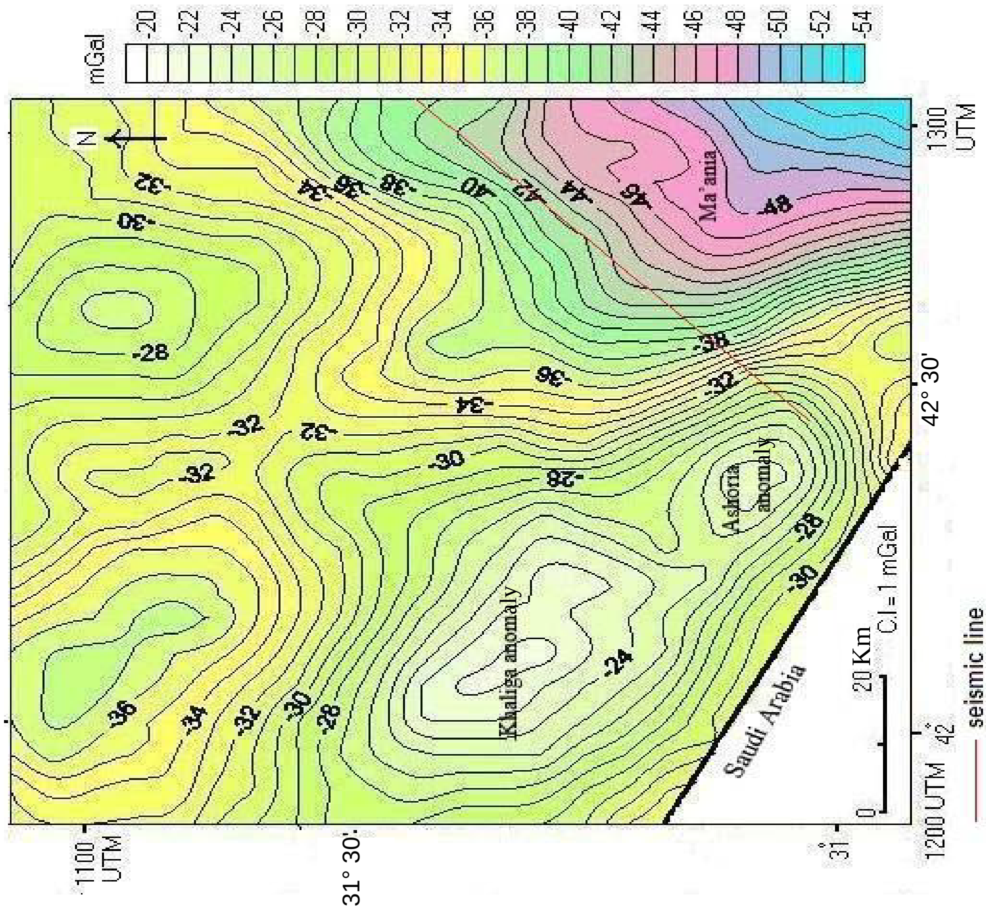


Fig.3: The observed Bouguer anomaly map
(IPC, Geophysical Atlas, 1960)

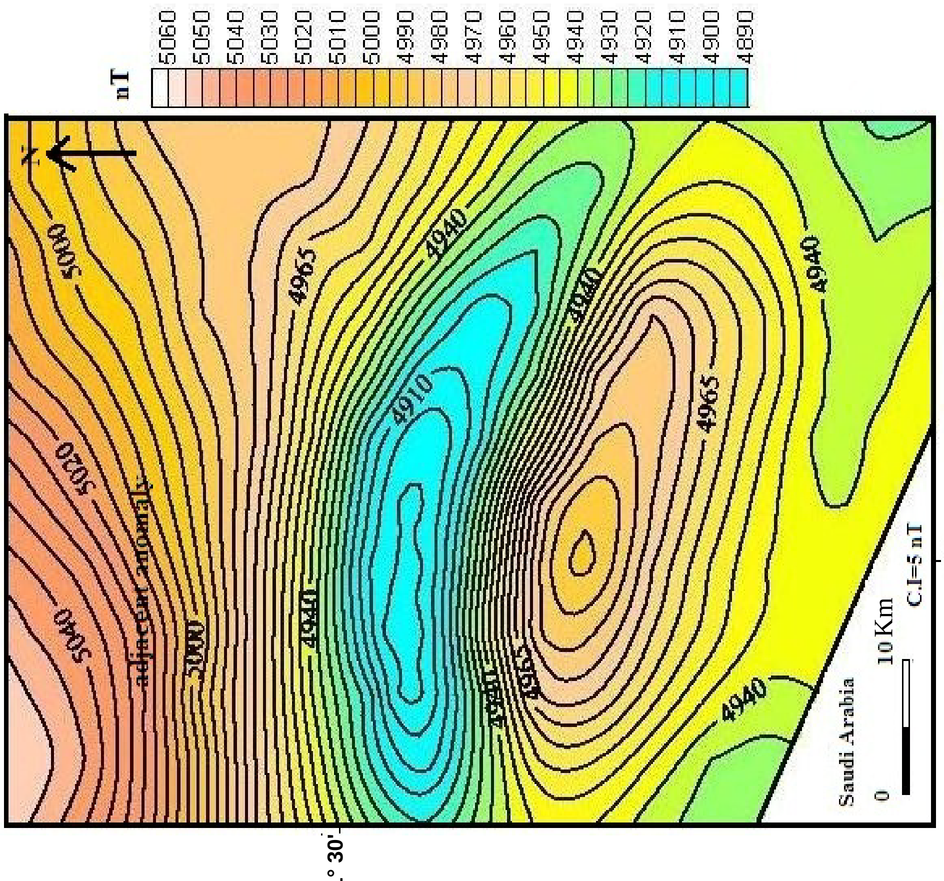


Fig.4: Aeromagnetic anomaly over Ar'ar area, (C.G.G., 1974)
(Counter value = total field – 45596.42 nT)

─ **The present paper deals** with the interpretation of the gravity and magnetic fields over Ar'ar and Al-Bireet areas with the hope of producing a subsurface structure that explains all the surface observations and be acceptable within the regional structural framework.

─ **To achieve that**, all available data including borehole results and seismic information are used to support the detailed gravity and magnetic interpretation in producing the required authentic geological models.

## ISOLATION OF GRAVITY ANOMALIES

Examining the Bouguer anomaly map of figure (3) local anomalies of sharp nature can be seen superimposed on broad smooth anomalies. The sharp local anomalies of Khaliga and Ashoria on the southwest of the map stand conspicuously above the smooth Ar'ar anomaly. Isolation of the local anomalies from their regional background is usually conducted using an efficient filtering technique. In the present work a low-pass filter given by the Surfer version (Surfer 8, 2010) is employed to construct the regional map. It is a process of moving averages, which is a form of linear convolution applied to the digital gravity map. The residual map is obtained by subtracting the regional values from the observed map.

After digitizing the observed Bouguer map (Fig.3) into a 5 Km grid, the data is filtered as described above. Filters of 3 × 3, 5 × 5 and 7 × 7 each with various number of passes (the number of times the filter is applied) have been tested. The size of the local anomaly isolated increases with increase of filter size. Two extreme filters (7 × 7 no.20 and 3 × 3 no.30) are shown in figs.5 and 6. Figure 5 shows the regional and the residual maps as separated by the filter 7 × 7 no.20 and figure 6 shows the same maps as separated by the sharper filter of 3 × 3 no.30. Comparison between the two figures shows that filter 7 × 7 produces much smoother background than does filter 3 × 3. Furthermore, the local residuals produced by the two filters, though essentially similar in outlines and trends, they differ in their amplitudes and dimensions. Both filters, however, produce the same linear positive and negative anomaly axes. In other words, parts of the anomalies, which are not isolated by the filter 3 × 3 remain within the regional background as it is apparent in the irregularities of the regional field of figure (6). In the present study the results of filter 7 × 7 have been chosen for further interpretation since it produces a completely smooth regional field and, hence, a maximum residual field. Figure (5a) shows the residual anomaly field and figure (5b) shows the corresponding regional anomaly field. On the regional map (b), the anomalies are smooth and broad with large half-widths indicating deep origin. Two prominent regional anomalies having these characters are the Ar'ar high and the Ma'ania low, both occupying the southern part of figure (5b) with Ar'ar high on the west and Ma'ania low on the east. Two less conspicuous anomalies occur in the northern part of the study area.

The residual anomaly map (Fig.5a) shows the elongated anomalies that occupy all of the NE half of the map with a near N – S trend. The Khaliga and the Ashoria anomalies which occur over the Ar'ar anomaly, however, tend to show a more NW – SE trend.

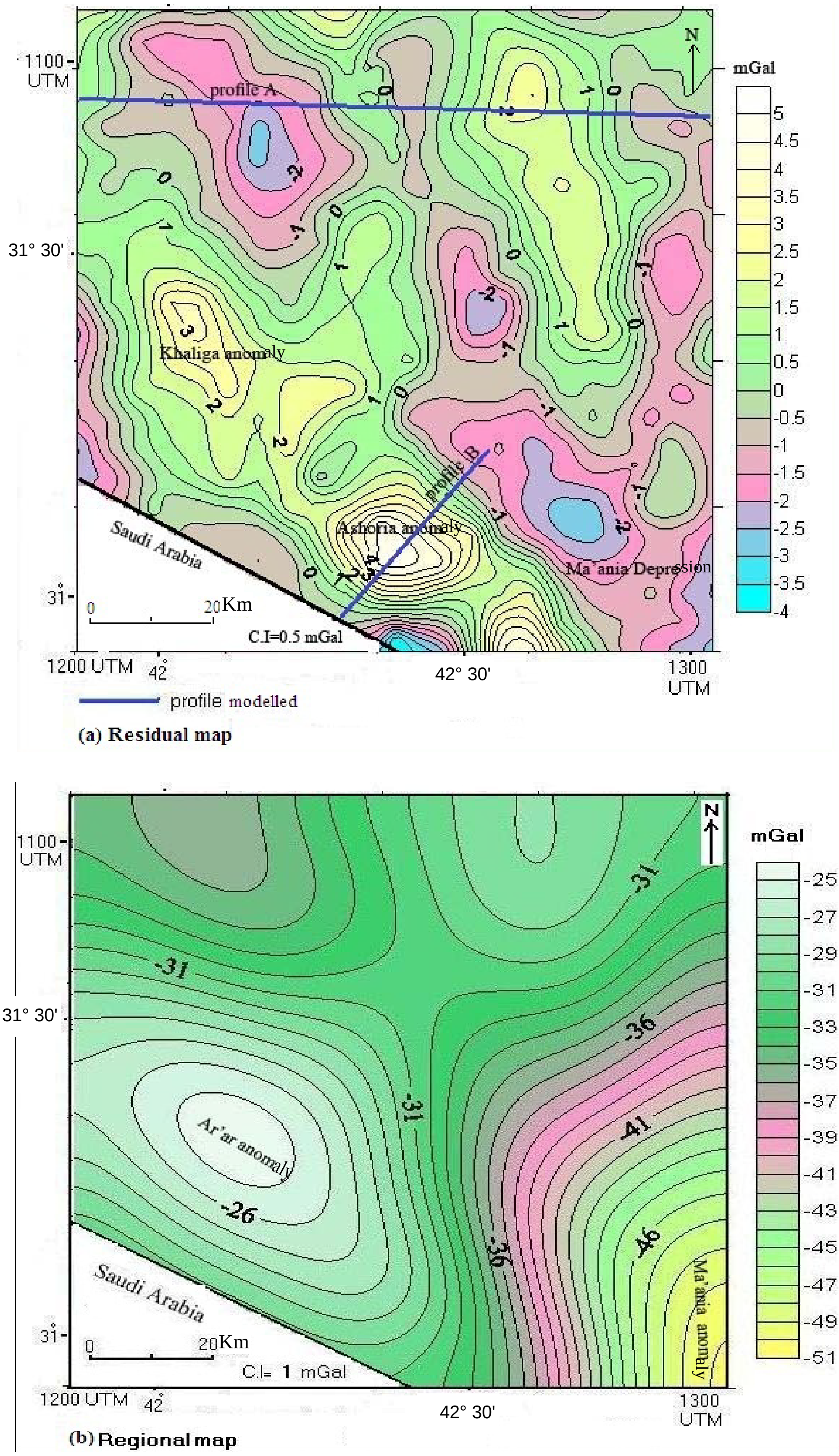


Fig.5: The use of filter 7 × 7 no.20

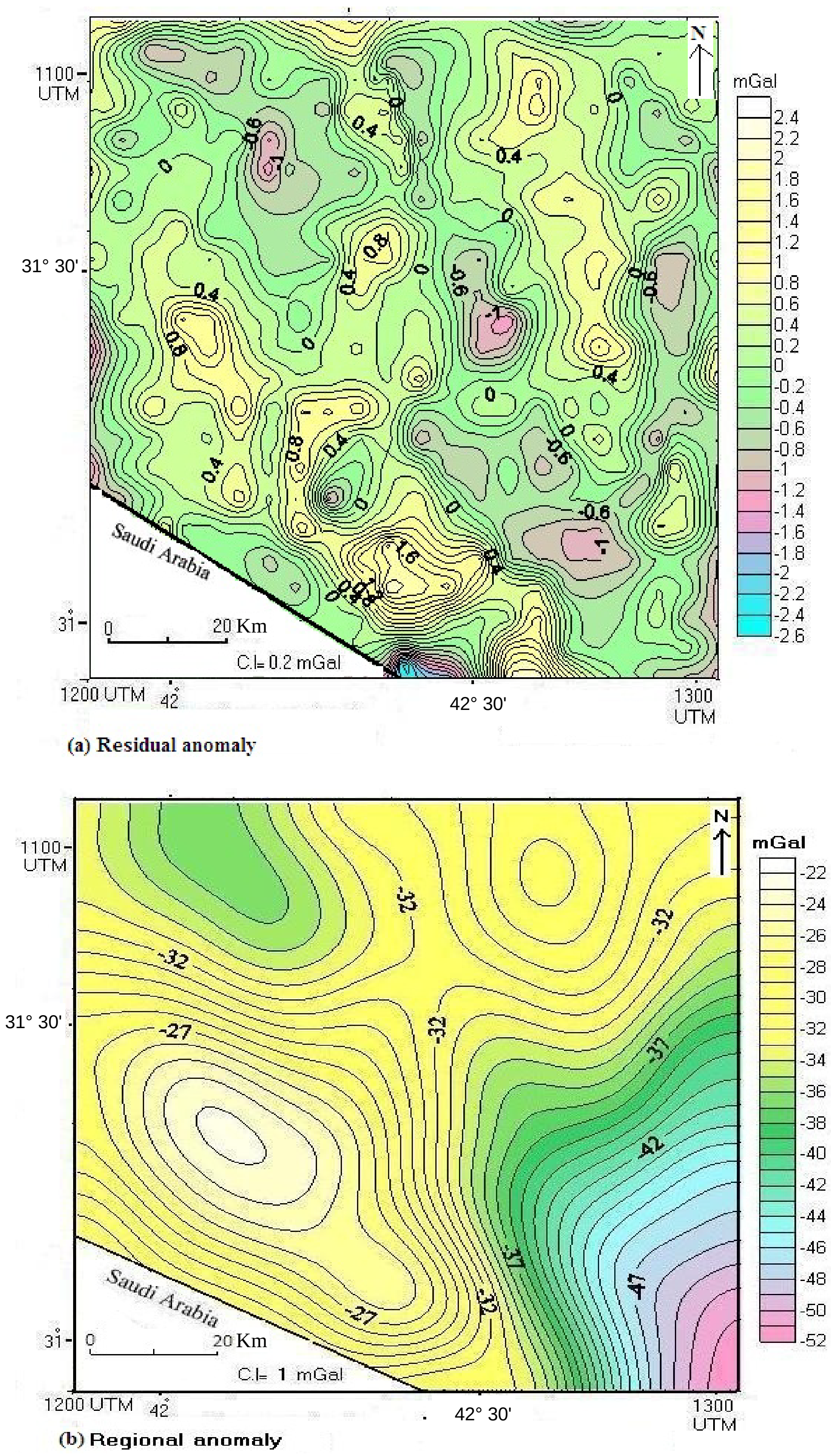


Fig.6: The use of filter 3 × 3 no.30

## INTERPRETATION BY MODELING

For the purpose of interpretation, all the available geophysical and geological data are used to construct a subsurface structure that is accepted geologically and gives geophysical effects close to those actually observed. The more geological and subsurface constrains used, the more authentic the solution is. Due care is taken of the problem of ambiguity of the solutions whenever it arises.

### ▪ The Regional Anomaly Fields

─ **The Ma'ania Anomaly:** The southern half of the study area (Fig.5b) is occupied by broad low of Ma'ania on the east and the elongated broad high of Ar'ar on the west.

The Ma'ania gravity low is associated with a wide topographic depression as well as a pronounced magnetic low. The gravity and magnetic fields (both regional and local) have had very little consideration so far and as such, any attempts at further interpretation on their origin at this stage will be groundless. For the purpose of the present study, it suffices to note that the western geophysical boundaries of the depression with Ar'ar structure are marked by sharp gradients as well as being observed on the seismic section.

─ **The Ar'ar Anomaly:** Figure (5b) is the gravity anomaly of Ar'ar after the removal of the sharp local variations. It is made up of smooth contours whose maximum reaches a value of – 25 mGal. It is slightly elongated and trends NW – SE and has a sharp gradient with the adjacent Ma'ania anomaly on its east where the central contour values exceed – 49 mGal.

The total field aeromagnetic anomaly associated with the gravity anomaly of Ar'ar is shown in figure (4). Once more it is elongated, but closer to an E – W trend than NW – SE as does the gravity anomaly. The anomaly consists of two elongated parts: a southern high and a northern low. Furthermore, the field increases rapidly immediately north of the Ar'ar anomaly forming a much broader anomaly that is obviously related to a different adjacent sources. The sharp gradient of this northern anomaly must have induced some distortion to the Ar'ar anomaly, a distortion that has to be taken in account in the interpretation.

It extends in an E – W direction and is magnetized by induction from the present earth’s field. This model produces the anomaly profile along a N – S line shown in the figure with the given field and source parameters. It can be seen that with earth’s field intensity and inclination in the area and with magnetic susceptibility expected for the basement, the calculated anomaly over the N – S line shows an anomaly having a southern high and northern low with the southern high being slightly bigger than the northern low. This model anomaly is, to a large extent, similar to the Ar'ar anomaly profile shown in figure (9). It is, therefore, deduced that Ar'ar source is similar to the model and magnetized by induction from the present earth’s field. The only difference between the model anomaly and that of Ar'ar is the rapid increase of the observed intensity to the north of Ar'ar anomaly. This difference has already been mentioned above and is attributed to an adjacent northern source.

In their interpretation of the same anomaly, Sallowmi and Al-Khatib (1983) made the northern increase in the intensity a part of Ar'ar anomaly. In this case, the simple model interpretation of figure (7) will not be possible. Their subsurface basement model would have to be completely modified to produce an effect close to the observed anomaly.

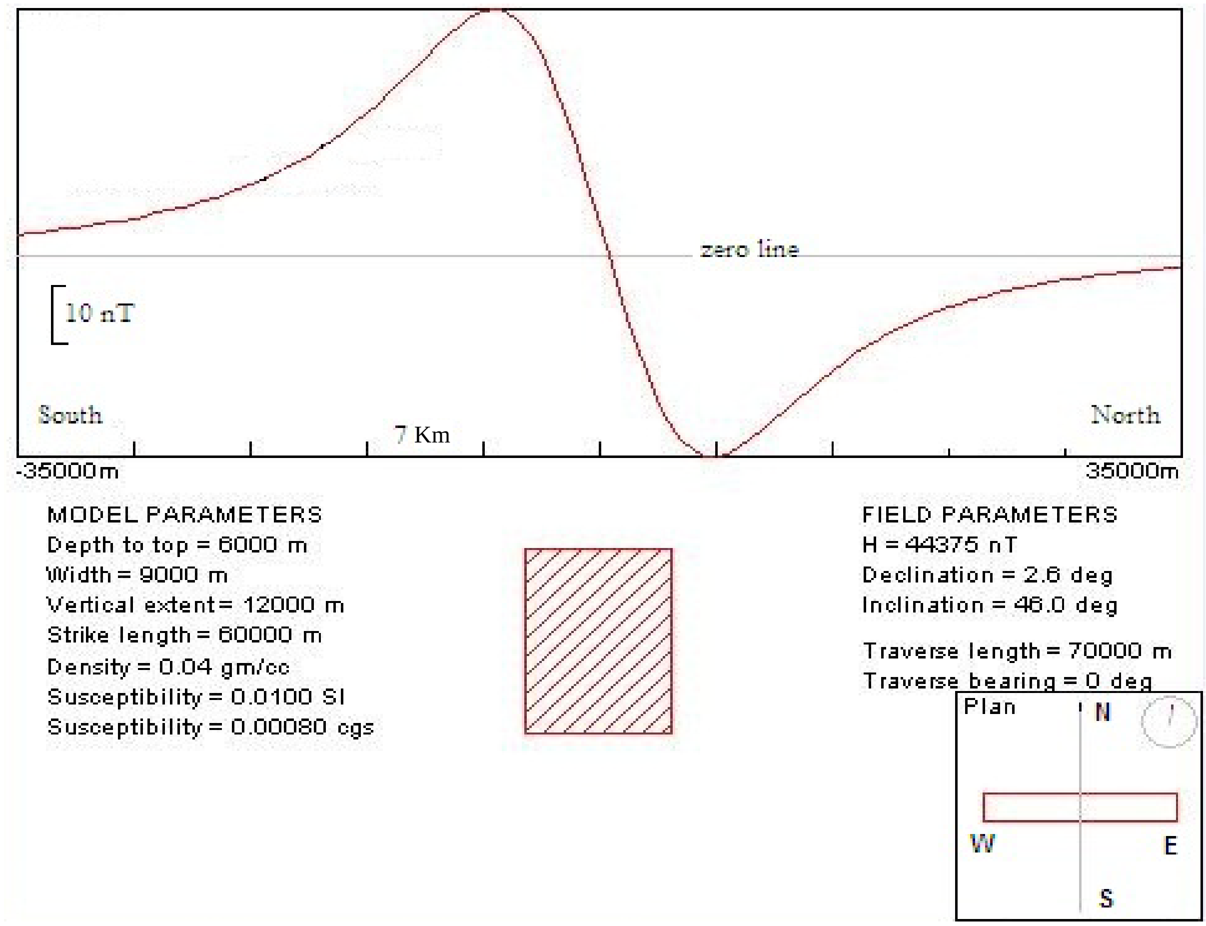


Fig.7: Model interpretation

To explain Ar'ar anomaly, a uniform 2D source, whose cross – section is shown in figure (7) is used.

In the present attempt, both gravity and magnetic anomalies are addressed together so as to provide a better constrain and hence reduce the ambiguity factor of the solution. Figure (8) shows a map of regional gravity contours superimposed over the magnetic contours of Ar'ar anomaly. It can be seen that maximum gravity contour occurs over the middle part of the magnetic anomaly with a slight difference in the trends of the anomalies. Two close profiles are taken normal to the anomalies and reproduced on figure (9a).

Both gravity and magnetic anomalies (Fig.9) are interpreted as due to the same subsurface source. The occurrence of the magnetic anomaly itself suggests a basement source, since it is the basement's composition of igneous and metamorphic rocks that forms the only source of magnetic anomalies in most parts of Iraq. As such, both of the regional gravity as well as magnetic anomalies are attributed to the same basement source.

The magnetic anomaly is delineated by fixing the position of its zero line. To do that, the results from figure (7) is used whereby the source is made two-dimensional extending in E – W direction, magnetized by induction from the present earth's field which inclines at $46^{o}$ down.

The basement depth in the area varies according to the C.G.G. interpretations (1974) between 5 and 6 Km. The deep Badana well (Al-Mufarjy, 2000), which lies next to Ar'ar well within the Saudi territory (Fig.1) reaches the Precambrian basement at 4.8 Km. Physical properties of basement rocks in various parts of western Iraq (the Stable Shelf) have been discussed in connection with interpretation of magnetic anomalies related to deep sources by many workers. The C.G.G. group (1974) suggested a range of 0.0005 – 0.0007 emu/cm$^3$ for the susceptibility contrast between the basement with the overlying sedimentary cover (suprabasement). In the western desert, the intrabasement contrast used by Al-Najar (1999) varies between (0.0008 – 0.0013). Similar values are used in the Jazira area by Al-Mashhadani (2000). Susceptibility and density contrast in the Western Desert are also given by Abbas and Masin (1975). A review of these physical properties in western Iraq is also given by Al-Shaikh (1997).

A simple model, similar to that presented in figure (7) is used to interpret the gravity and magnetic anomalies of the profiles of figure (8). The density contrast between an igneous suprabasement and the sedimentary cover is assumed to be 0.15 gm/cm$^3$ and the intrabasement contrast is made 0.04 gm/cm$^3$. The corresponding susceptibilities are 0.0009 and 0.0008 emu/cm$^3$. These estimated values lie reasonably within the ranges refered to above. The adopted model (Fig.9) represents a vertical block of Igneous mass, 9 Km thick extending vertically down to some 18 Km. It rises about 0.5 Km into the overlying sedimentary succession. This suprabasement part seems, from figure (8), to continue for about 10 Km on either side of the location of the gravity profile before disappearing into the basement.

This solution produce an acceptable agreement between the observed and the calculated gravity and magnetic anomalies. Other solutions, such as a completely intrabasement igneous mass, are possible. However, the suprabasement structure is preferable as it support the uplift suggestion of Ditmar *et al*. (1972) and also agrees with the upwarping of the Paleozoic succession below Ar'ar area seen on the seismic section of Mohammed (2006).

It may be noted that field inclination in figure (9) is made 50° down instead of 46°. Such increase in the inclination would produce a better agreement to the observed field. It is possible that an increase of 4° in inclination may result due to a component of remanence within the present magnetic meridian.

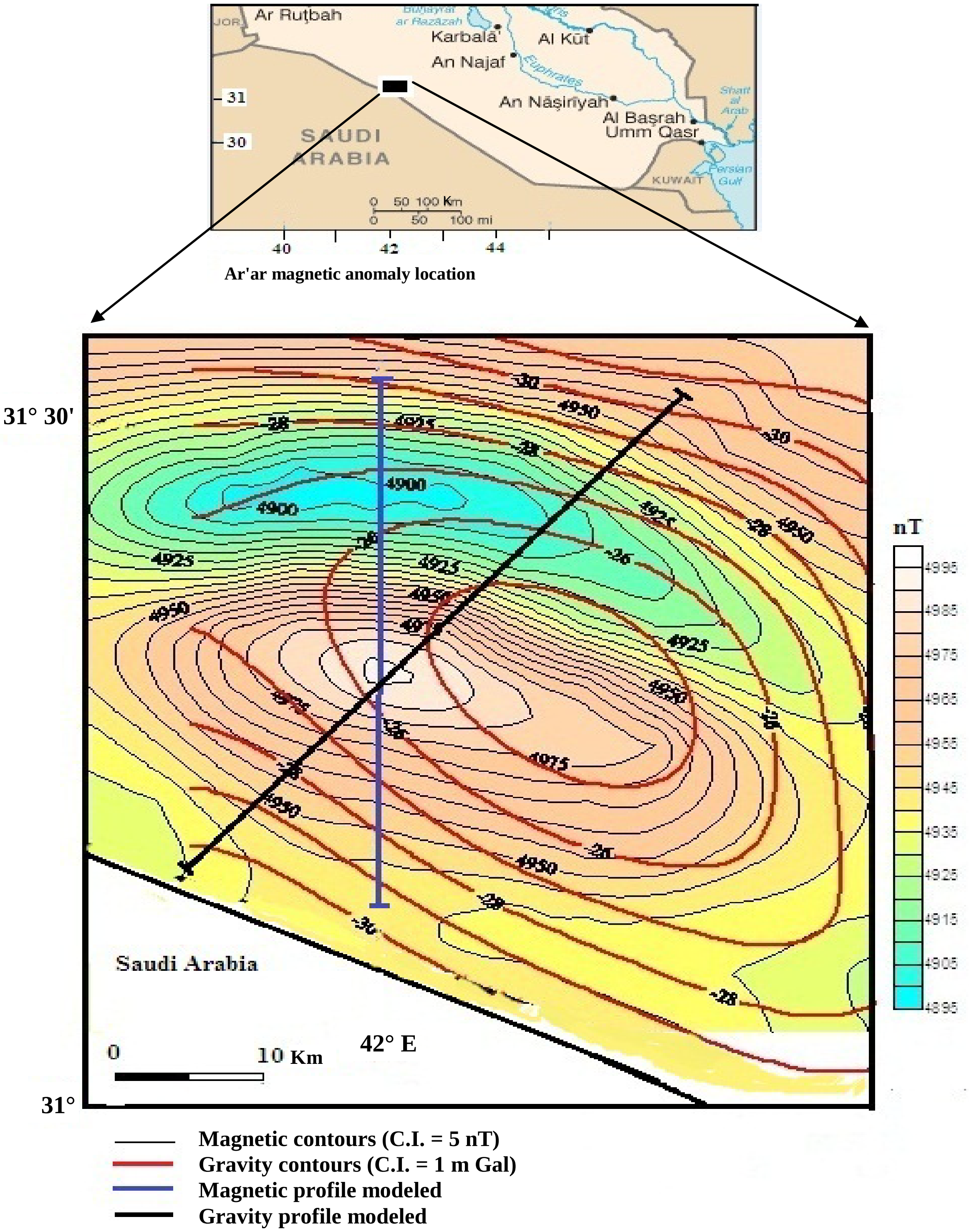


Fig.8: Regional gravity contours superimposed over the magnetic contours of Ar'ar anomaly

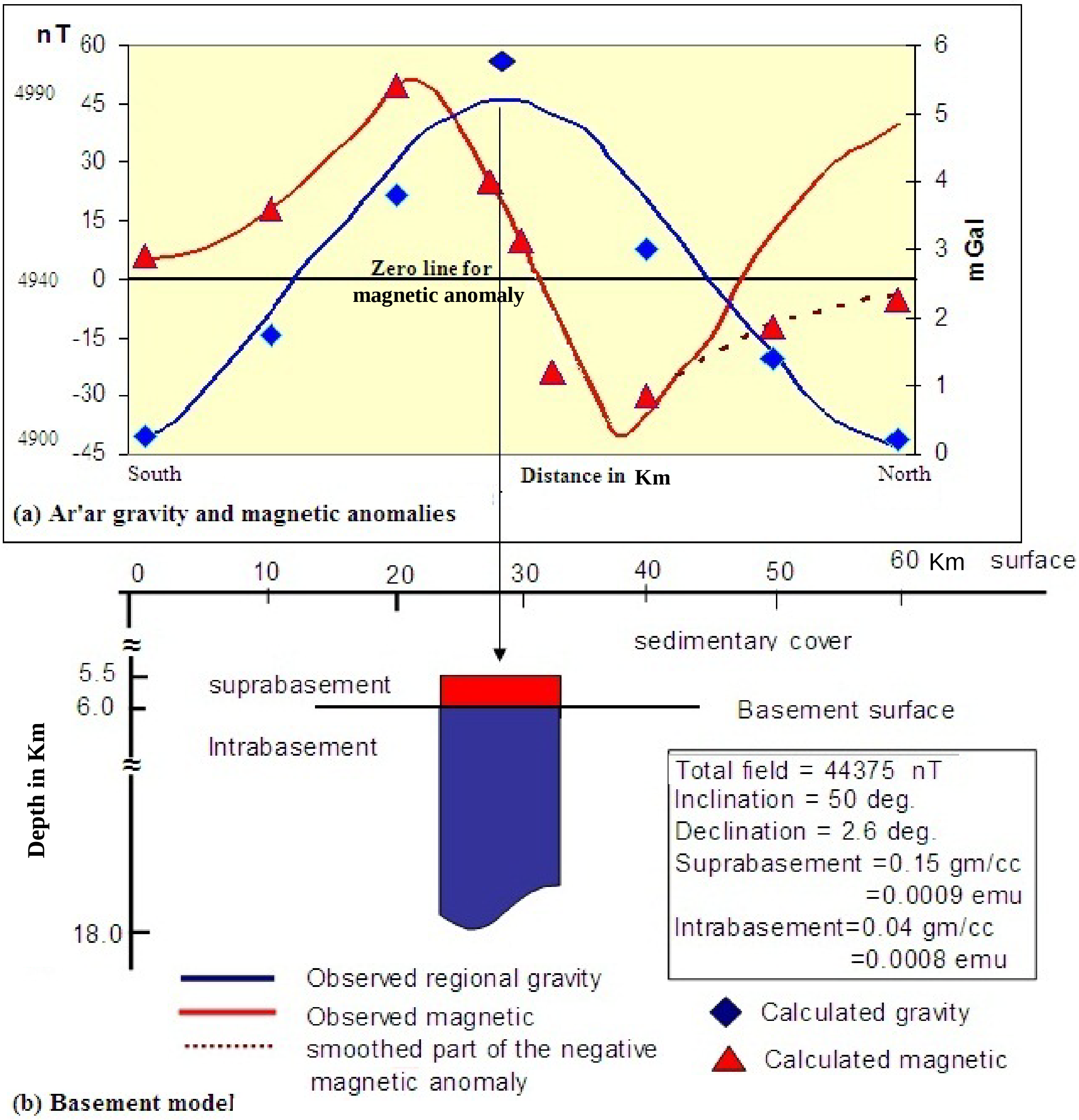


Fig.9: An interpretation of the gravity and magnetic anomalies in Ar'ar area along the profile shown in figure (8)

- **The Residual Field**

The residual field treated here is that obtained over Ar'ar as well as Al-Bireet areas from the application of the 7 × 7 no. 20 filter on the observed field of figure (3). The field over the whole area shows a number of elongated, parallel anomalies that range in trend from approximately N – S in Al-Bireet and Ma'ania areas to closer to NW – SE over Ar'ar area. These anomalies represent alternating gravity highs and lows and figure (10) shows the axes of these anomalies. The distance between the successive axes is variable so are the widths of the undulations.

Comparing this residual map with the geological map of figure (2), it can be seen that the gravity undulations are not reflected on the surface geology. What is refered to as Nukhaib depression of Pleistocene and recent deposits, which extends northwards across most of the gravity undulations, indicats that it is only a thin cover.

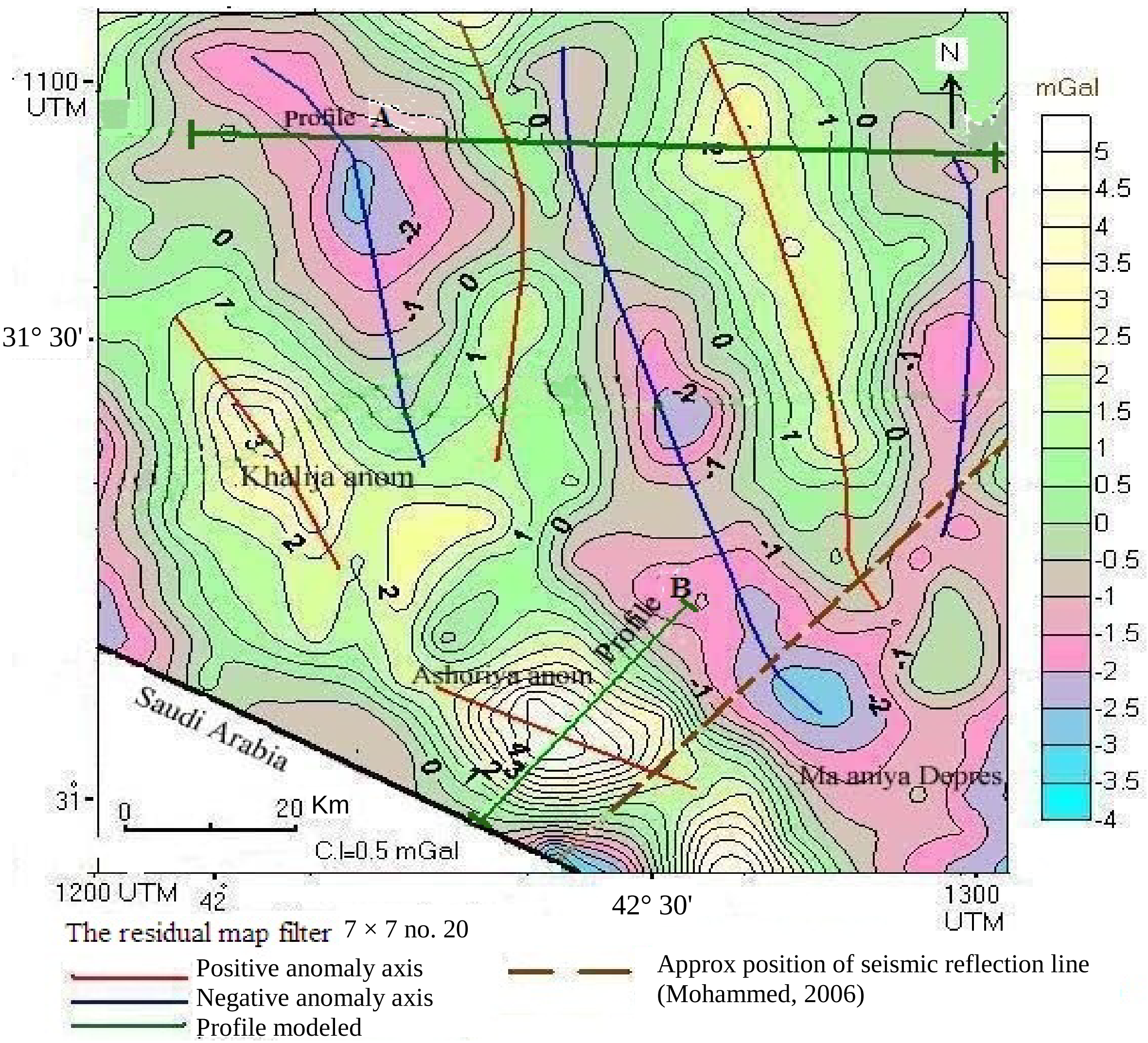


Fig.10: Residual Bouguer Map with undulations and their axes

– **Ar'ar Residual Anomalies:** This area is marked by a number of positive anomalies such as the Khaliga in the NW with a NW – SE trend and Ashoria in the SE with a WNW – ESE trend. These two anomalies overly the main regional Ar'ar anomaly (Fig.5). They are separated by a region of irregular gravity high and low. It is possible that the anomalies of Khaliga and Ashoria together may have been a single continuous gravity high. They become separated when their subsurface source is subjected to a process of differential solution similar to that described by Al-Shaikh and Al-Mashadani (2013) for the Nukhaib area.

Khaliga anomaly is about 40 Km long and some 25 Km wide and has a maximum amplitude of 3 mGal. Its NE and SW boundaries show gentle gradients.

Ashoria is a short tight anomaly having a maximum amplitude of 4.5 mGal. It has sharp gradients on all of its boundaries, the most pronounced of which is the gradient with the Ma'ania depression on the northeast. This gradient reaches about 0.6 mGal/Km along the seismic line, which crosses the anomaly on its SW end. The gradient increases as traced northwestwards along the length of the anomaly. Ashoria is near circular in outline with the long axis being 30 Km long and its width is some 25 Km.

To explain these anomalies two sources of additional information other than gravity are used. The first is the seismic reflection line that runs from the Ashoria anomaly and the adjacent Ma'ania gravity low and continues northeastwards. It clearly attributes the sharp gradient to distinct step faulting that upthrow old rocks of the Ma'ania area onto the top of Ashoria area. These rocks, as identified on the seismic section, include the formations of Gotnia (Late Jurassic), Ratawi, Shu'aiba and Maudud (lower Cretaceous). As a result, these rocks become relatively shallow at Ashoria location, which is the southern part of Ar'ar anomaly.

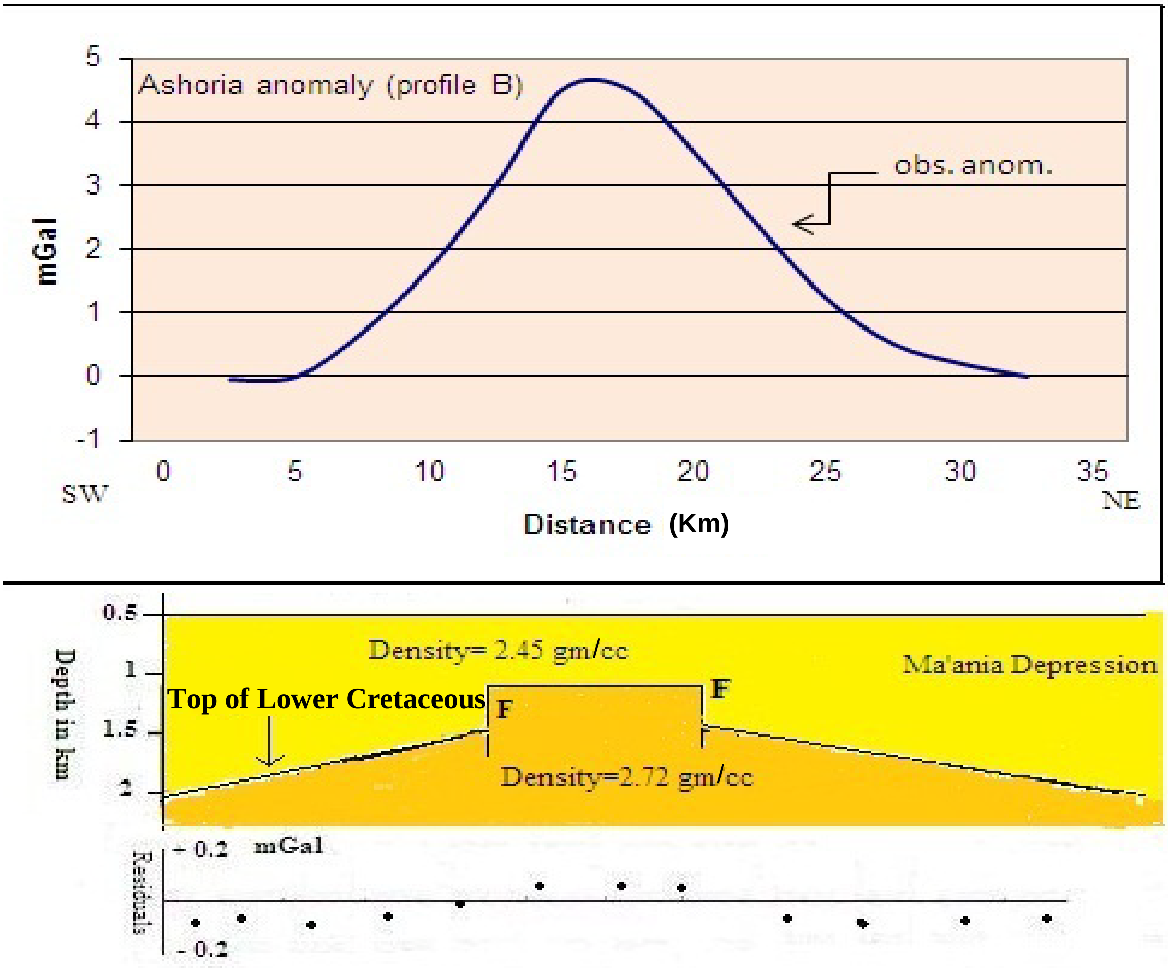


Fig.11: Possible interpretation of Ashoria gravity anomaly along profile B

The other source of additional information available is the magnetic anomaly described previously over the Ar'ar area. The main part of this anomaly occurs over Khaliga and persists southeastwards towards Ashoria.

The magnetic anomaly has been interpreted (Figs.8 and 9) as due to suprabasement intrusion that caused upwarping within the overlying sedimentary succession. It is believed that the upwarping has contributed to the residual Ar'ar anomaly in that its effect persisted to the shallow succession.

Therefore, combining these information together with the borehole data, the local anomalies over Ar'ar (Khaliga and Ashoria) can be explained. The borehole data shows that the Mesozoic and Tertiary succession become structurally more complex as followed from

Ghlaisan 1 (east of Ar'ar anomaly) to Ar'ar well within the Saudi territory (to the west of Ar'ar anomaly). Figure (1) shows that while the succession is normal in Ghlaisan 1, where Tertiary rocks overly the Cretaceous in structural conformity, it becomes much more complex in Ar'ar 1 where the outcropping Upper Cretaceous overlies Triassic rocks unconformably. Such structural disposition in Ar'ar 1 indicates a history of uplifting, faulting and long intermittent episodes of erosion. The area under study occurs between the two wells and, as such, faulting is expected that leads to creation of density contrasts between the faulted formations.

The gravity residual anomalies described above are related to variations in the density of the Tertiary, the Mesozoic and Paleozoic rocks. The Paleozoic rocks in the Western and Southern Deserts are known to have a uniform density. This is found to be about 2.61 and 2.62 gm.cm$^3$ by Ditmar *et al*. (1972), Al-Najar (1999) in the northwestern Desert and Al-Mufarjy (2000) in the southwestern Desert. As such, these rocks are considered here to be the background reference of any other density variations. On the other hand, an average density of Tertiary and Upper Cretaceous of 2.45 gm/cm$^3$ (the formation of Fatha, Um Er Radhuma, Dammam and Tayarat) is calculated and used by Al-Shaikh and Al-Mashhadani (2012). The density of the Lower Cretaceous, Jurassic and Triassic is found by Ditmar *et al*. (op.cit.) to be 2.72 gm/cm$^3$. Therefore, contrasts between these groups of rocks are believed to be present below the area and are used to model the observed gravity anomalies.

Figure (11) shows one possible interpretation of Ar'ar structure over a profile taken across Ashoria anomaly. The geological model shows a positive, broad undulation of Lower Cretaceous and older rocks that are faulted up at the top of the culmination. The model produces an anomaly quite close to the observed anomaly. The model also portrays the picture shown by the seismic profile closely in that it brings the Jurassic Gotnia Formation to within the top one kilometer from the surface.

In a similar procedure, the anomaly of Khaliga (the northern part of Ar'ar anomaly) may be interpreted. However, its NE and SW boundaries show gentler gradient. A positive undulation of the Lower Cretaceous similar to that of Ashoria with no faulting on top would be a sufficient model to satisfy the available data.

─ **Al-Bireet Residual Anomalies:** Figure (10) shows five long gravity undulations (Al-Bireet anomalies) in addition to the Ar'ar anomalies. The axes of undulations are also marked. Three undulations on the eastern part of the map continue southwards towards the Ma'ania depression. The other two on the west of the map end or merge southwards with the Khaliga anomaly.

The location of the seismic line shown on the figure is seen to cross two of the eastern undulations. The seismic section seems to indicate gentle folding involving L. Cretaceous and Jurassic succession corresponding to these gravity undulations. It is believed, therefore, that the gentle folding of these succession are the only source of the gravity undulations. It is also expected that the closures of these undulations increase northwards away from the location of the seismic line as can be seen in the increasing of anomaly amplitudes and widths.

The fold axes of Al-Bireet area trend N – S, a trend that differs slightly from that of Ar'ar anomalies (NW – SE). Such difference in trend is believed to be due to the effects of the deep Paleozoic upwarping below Ar'ar. In other words, the effects of the deep seated origin of Ar'ar anomaly including the suprabasement intrusion and the resulting upwarping of the overlying Paleozoic succession also influence the trends of later shallow folds.

Profile A is taken in the north part of figure (10) in an E – W direction across the gravity undulations. 2D models trending N – S are used to represent the Lower Cretaceous folding. With the rock densities of the formations discussed earlier, the anomalies of these models are calculated and compared with the observed anomalies in figure (12). The two tight undulations occurring between the broad ones are explained by two alternatives; the first is tight Lower Cretaceous folds and the other is a faulted structure. Both alternatives give agreeable results. However, the available data are not sufficient to favor either of the two solutions.

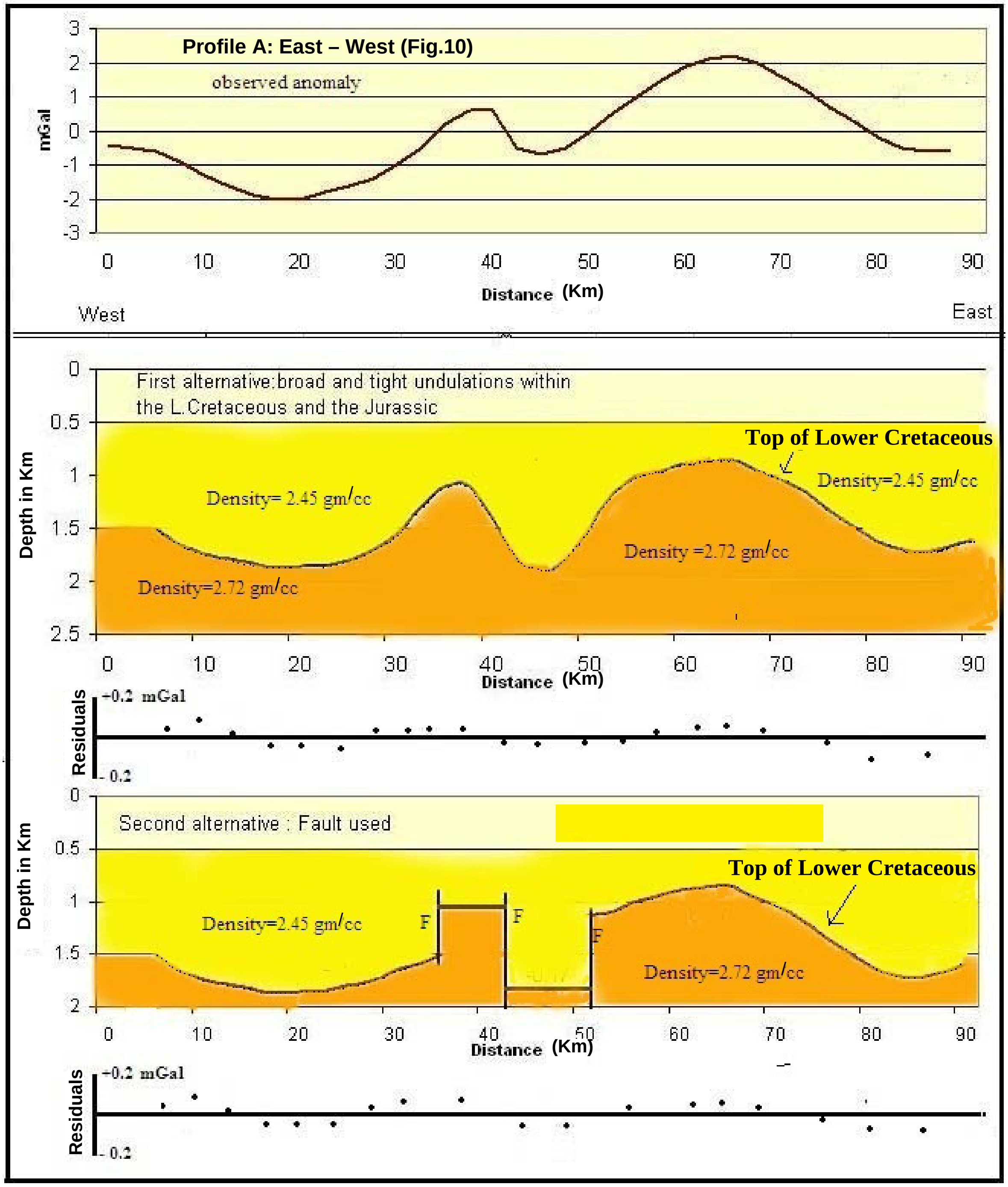


Fig.12: Interpretation of Al-Bireet gravity undulations

## CONCLUSIONS AND DISCUSSION

The gravity field of the area is filtered into regional and residual fields. The regional field coupled with the observed aeromagnetic anomaly over Ar'ar area are interpreted together and the results indicate a common basement source, which intrudes the overlying sedimentary succession for about 0.5 Km. The basement source (probably basic igneous mass) is thought to be a thick sheet stretching above the basement surface in an E – W trend for some 20 Km. Its age can not be estimated from the present information. Its effects on the overlying succession is, however, quite apparent. The seismic section which lie in the southeast corner of the area (Fig.10) shows an upwarping of the Paleozoic rocks whose thickness exceeds some 3 Km in the area. The trend of the upwarping must have been in a NW – SE rather than E – W trend. Its effect must have persisted upwards and influenced later Mesozoic tectonics in such a way as to produce a N – S trends for Al-Bireet and other areas. It hase also affected the Ar'ar local anomalies but in a trend that is to some extent controlled by the deep trend.

The faulting on top of Ar'ar uplift (Fig.11) agrees with the complex structure shown by the geological log of well Ar'ar, (Fig.1). The increases in the structural complexity westwards appears to be related to the closeness of Ar'ar structure to the Hail – Rutbah Arch in the Saudi territory. It is possible that Ar'ar uplift may form the easternmost limit of the Arch.

Al-Bireet gravity undulations are explained on the bases of correlation with folds observed on the seismic section as folds involving Lower Cretaceous succession.

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