Digitally Processed Geophysical Data Sets for Identification of Geological Features in Southern Iraq

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Abstract

   The conventional remotely-sensed satellite imagery is suited for regional investigations in areas of good exposures which are reduced in southern Iraq due to vegetation, water – covered areas and flat terrains. An imagery produced from digitally processed geophysical data is an extremely powerful technique for identification of geological features in such areas of extreme economic importance . By utilizing an appropriate digital processing, the geophysical contour maps have been converted to geophysical images. Images produced from digitally processed geophysical data (gravity and aeromagnetic) have been analyzed by polynomial filtering (using several degrees) allow major features to be delineated clearly. An integrated image of gravity and aeromagnetic data sets has been produced using the best of polynomial filtering (6th degree residuals) . The interpretation of final output images shows the association of negative gravity and magnetic residual anomalies with some anticlinal structures , while positive residuals are associated with the others. The positive residuals could be due to basement uplift , and the reversed values could be due to deep- seated light core probably salt beds. Basrah depression exhibits negative residuals.

Keywords: GIS; Digital image processing; Polynomial filtering; Geophysical data; Geological features.

معالجة رقمية للبيانات الجيوفيزيائية لتحديد الظواهر الجيولوجية في جنوب العراق

الخلاصة

    ان التصوير الفضائي التقليدي ملائم للتحريات الاقليمية في المناطق ذات المكاشف الجيولوجية الجيدة والتي تكاد تنعدم في مناطق جنوب العراق بسـبب النباتــات والمنــاطق المغطــاة بالميــاه والتضاريس المنبسطة . ان الصور الناتجة من المعالجة الرقمية للبيانات الجيوفيزيائية هــي تقنيــة فعالة في تحيد الظواهر الجيولوجية في مثل هذه المناطق ذات الأهمية الاقتصــادية . تــم تحويــل الخرائط الكنتورية الجيوفيزيائية الى صور جيوفيزيائية باستخدام معالجة رقمية ملائمة . تم تحليــل الصور الناتجة من البيانات الجيوفيزيائية المعالجة رقميا (الجذبية والمغناطيسية الجوية) باستخدام تقنية الترشيح متعدد السطوح (وبدرجات مختلفة) . ســمحت الصــور علــى تحديــد الظــواهر الجيولوجية الرئيسة بوضوح . أنتجت صورة متكاملة للبيانات الجذبية والمغناطيسية باستخدام متعدد السطوح (الدرجة السادسة) . أظهرتفسير الصور الناتجة مصاحبة الشــواذالجذبية والمغناطيســية السالبة مع التراكيب المحدبة, بينما صاحبت الشواذ الموجبة البعض الأخر منها . وقد تكون الشواذ الموجبة ناتجة عن نهوض تركيب القاعدة , بينما القيم المعاكسة قد تكون بسبب اللب الخفيف (ربما

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طبقات الملح)الموجود على أعماق كبيرة . ويتميز منخفض البصرة بوجـــود المتبقيــات الســــالبة.

Introduction

Unlike the common other remote sensing data, geophysical data have traditionally been present as contour maps in order to acquire regional information [1,2]. However, contour plots do not fully express all information available from geophysical data sets. This is because they only show fixed (and arbitrarily defined) intervals rather than the entire continuum of intensity variation. In addition, the human visual system evolves to optimize information extraction from an 'image' rather than the analyses of mapped lines .On the other hand, when more than one method are applied the integrated data interpretation will be done as a comparison between two or more separated maps even when these data are plotted at the same sheet [3,4] . Furthermore, most of remote sensing data interpretation programs deal with images rather than contour maps. Moreover, it is easier to study the relationship between geophysical data and satellite data when geophysical data are represented as an image [1]. Therefore this study aimed to apply appropriate digital processing techniques for conversion of geophysical contour maps to geophysical images to overcome the disadvantages of using such contours and to utilize different processing operations for geophysical images and synergistic display of data recorded by different remote sensing systems.

Geology of the Area

The area under investigation (Fig.1) is situated in the southern part of Iraq, between 30º - 31º latitudes and 47º- 48º longitudes which is a bout 12,000 km^2. This area is generally featureless except the presence of Jabal Sanam uplift , but it lies on alluvial mud laid down by the river and the original ground level varies between minimum 0.0 m and maximum 4.0 m (GTS). The other main features within the area are Tigris, Euphrates and Shatt Al-Arab rivers , the large marsh (Hor Al-Hammar) in the northern part , and Al -Batin fan [5,6].

Geologically , the area is covered mainly by recent late Pleistocene sediments of Al-Batin fan and recent sediments of Tigris – Euphrates rivers . Besides, other sediments of older ages recognized by Dibdibba, Zahra and Injana formations . Dibdibba formation is exposed through extensive flat and slightly wavy terrains of the area .

Tectonically , the area is located within the limits of Mesopotamian Zone (Unstable Shelf). It exhibits the presence of gently plunging subsurface structures generally N-S trending anticlines and synclines of different sizes having poor reflection on earth surface . Most of these structures resulted from basement block movements and salt tectonics and are of extreme economic importance for their huge amounts of hydrocarbons [5,7] .

Methodology (Geophysical Data Sets and Digital Image Processing)

As aforementioned , contour plots do not fully express all the information available from geophysical data sets that is mainly because they only show fixed and arbitrarily defined intervals

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rather than the entire continuum of intensity variations. It is possible to overcome these disadvantages because the appropriate digital processing the geophysical data can be interpolated to a regular grid of values analogous to an image composed of pixels. Geologists look for geophysical methods to exploit the synoptic view of large regions, besides images of such regions may analyze geological provinces as entities rather than in a piecemeal fashion. Thus imagery was ideally suited for regional investigations in areas of good exposure though results in temperate terrain often proved disappointing because of extensive vegetation cover [8] .

Consequently, geologists had to rely on geophysical data which have traditionally been presented as contour maps, in order to acquire regional information. So, this section will deal converting potential field maps (both gravity band magnetic fields) to Digital Elevation Model (DEM) raster images. These DEMs are processed as images. Different processing operations used for this section will be discussed in detail later.

The geophysical data sets are presented as two contour maps. The first is the Bouguer anomaly with scale 1 : 1000 000 compiled by Iraqi Petroleum Company, IPC (1960) with contour interval of 1 mgal. The second is the aeromagnetic map that carried out by C.G.G.(1974) with contour interval of 0.5 gamma. The original Bouguer map, which incorporated negative and positive values , was

initially rescaled to a positive one. The conversion of the geophysical contour maps and their datasets to raster

images using the following processing steps :

1-The scanning process by which the hard copy contour map is converted to digital image as a matrix of pixels , each pixel holds a reflectance value in the scanned map .

2-Geometric corrections of the scanned maps with World Geometric System (WGS84) by using ERDAS .The original coordinates of geophysical maps grid intersections, in Clark 1880 ellipsoid and UTM projection, were converted to (WGS 84) ellipsoid and still in UTM projection by using the geographic translator program (GEOTRANS) which is an application that converts geographic coordinates among a wide variety of coordinate systems, map projections, grids and datums. Besides, the digital copy of the scanned map has many geometric errors incoming from hard copy paper shrinkage and from scanner itself. Therefore it needs to be geometrically corrected. This process had been done by using ERDAS package, to correct these maps and change their datum according to the new coordinate of known grid coordinates.

3-Vectorization process of the geometrically corrected contour maps. Vectorization (or digitization) that attempts to distill points, lines and polygons from a scanned image .

4-Computing geophysical points on regular grids (1 km.) by creating a surface from all contour lines and creating points as (X,Y,Z coordinates) from that surface . A surface model created from these data, is a three-dimensional geometric representation of the surface of an area of land. These surfaces represent phenomena that have values at every point across their extent. They are usually used to represent terrain and created from

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values sampled at height values for an elevation surface, but here it refers to the geophysical value. A TIN , or triangulated irregular network , is a surface data structure composed of triangular facets defined by nodes and angles. To create TIN lines, Autodesk Land Desktop connects the surface points that are closest together. These TIN lines interpolate surface elevations, filling the gaps where no survey data or contour data is known, to create an approximation of the surface. The

shape of TIN surface is controlled by the triangulation of these spot elevations

(geophysical values). TINs capture the variation in a surface better than do rasters. The spot elevations (geophysical values) can be irregularly distributed to accommodate areas of high variability in the surface and their values and exact positions are retained as nodes in the TIN. This makes TINs well suited to geological and engineering applications.

5-Converting the geophysical points into image using ERDAS IMAGINE package to create a Surface of Digital Elevation Model

(DEM), but here the word elevation refers to the geophysical value in the image . This system incorporates the functions of both image processing and GIS . These functions include importing, viewing, altering, and analyzing raster and vector data sets .

6-Combining geophysical single band images into one image (multi–band image) with three bands. After creating various geophysical "single band " images, each three of these images can be combined in one image with three layers "three bands". Each one of these layers is represented in one color. The resulted image is RGB image.

7-Data enhancement and interpretation. Images produced from digitally processed geophysical data (gravity and aeromagnetic)

(Figs. 2 and 3) have been analyzed by polynomial filtering , using several degrees, to allow major features to be delineated clearly.

Results and Discussion

The original gravity and aeromagnetic images are shown in figures (2 and 3). Generally, pixels of original Bouguer gravity images are of negative values which were rescaled to a positive grayscale range 0 - 255. Bouguer values are generally decreased from

- 37 mgal in the southeast to - 81 mgal in the northwest .High gravity gradients and low negative Bouguer values are at the southern part, whereas low gravity gradients and relatively strong negative Bouguer values at the northern part.

Pixel Values of aeromagnetic image within the area are positive and decrease slightly from NW to SE. the maximum and minimum values are 4920 gammas in NW and 4833 gammas in the SE of the area respectively . The general

horizontal gradient of the magnetic field appears high in W and NW portions of the area, while low gradient is presented in E and SE portions of the area.

One of the most flexible analytical techniques for residual –regional separation is the polynomial . A computer program written in MATLAB language was used for polynomial equations. The regional is represented by low order analytic surface.

Polynomial filtering in various degrees (from 1st to 6th degrees) have been applied for both gravity and aeromagnetic images in order to

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separate the residual field (or the local field which is related to shallow structures) from the trend field (which is the regional field and related to deeper structures) . For each original image, two images have been obtained for each degree as shown in figures 4 and 5 for gravity and aeromagnetic respectively .

The application of polynomial filtering gives clear signatures for both local and general trend anomalies. It is clearly shown that the sizes of these anomalies are directly proportional to the degree of the polynomial degree. Thus the 6th degree polynomial (and 5th degree to the some extent) are the best degrees for residual separation as they reflect well the local anomalies and their related subsurface structures. So values resulted from applying the MATLAB program to the 6th degree polynomial were converted to raster images as shown in figure 6 .

For gravity images, there is a great similarity between images of 5th and 6th trends with low pass filter (LPF) results and residuals with high pass filter (HPF) results .The main structures appeared in HPF and polynomial residual images are N. Rumaila, S. Rumaila, N. Zubair ,S. Zubair, Nahr-Umr, Siba and Ratawi anticlinal structures besides Basrah depression.

For aeromagnetic images, the general trend resulted from LPF and polynomial surface images are more complex than those in gravity images. Images of HPF and polynomial residuals reflect more anomalies referring to the same subsurface structures, but with less reflection to Nahr-Umr, Siba and Ratawi structures and better reflection for N. and S. Zubair structures.

To avoid low brightness and obtaining a clear representation for subsurface image of gravity and aeromagnetic data sets is produced by using the results of 6th degree polynomial residuals and displaying a resulted image as three layer image (RGB), by using the principal component (PC) and aeromagnetic / gravity ratio as the third input band (Fig.7 a and b) . Results show that the effect of the third layer is very regional in both third layer (aeromagnetic / gravity ratio and PC) . Thus the output geophysical image consists practically two layers only, Green-gravity and blue-aeromagnetic on red background . From the latter image (Fig.8), it is clearly shown that the main anomalies have been well emphasized and one may indicate these anomalies and their structures by their DEM values in order to describe their signature in the images as shown in table1 .

Conclusions

From this work one can say that there is an ability to overcome the disadvantages of using contour maps to study the geophysical fields. The use of conventional contour plots is completely superseded by the processing techniques. Therefore many geophysical maps can be individually processed and displayed in pseudo-color imagery. Generally, the main conclusions derived from this study are:

1- The data are quickly manipulated when imagery is produced and the analyses are speedily performed and extremely powerful for the acquisition of geological information.

2- Polynomial filtering with 5th and 6th degree showed the best separation techniques among others degrees by allowing the

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major geophysical structures and features in southern Iraq to be delineated.

3- An integrated image of gravity and aeromagnetic data sets is produced using the results of 6th degree polynomial residuals and displaying a resulting image as RGB image is a powerful technique to analyze the geophysical data sets of gravity and magnetic data.

4- Interpretation of geophysical images shows the association of negative residual gravity anomalies with N. Zubair, N and S. Rumaila, Nahr-Umr, Ratawi subsurface anticlinal structures and Basrah depression. The reversed negative sign of anomalies could be due to deep-seated light core of probably salt beds, whereas positive residuals are associated with Siba anticlinal structure. Jabal-Sanam is another positive gravity anomaly but with lower residual than the surrounding area. This contrast may be caused by salt dome.

5- The difference between gravity and aeromagnetic results is attributed to the fact that magnetic method is sensitive to magnetized rock, so that most magnetic effects observed by airborne way are essentially the same as if the sediments were not present at all. Besides the complexity nature of the vertical distribution of rocks in the studied area.

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Table (1) Anomolies associated with the main features

Anomaly number in figure (8)	Feature Name	6th degree polynomial residual anomalies DEM values	
		Magnetic anomaly (gamma)	Gravity anomaly (mgal)
1	N. Rumaila	+1.5	-1.5
2	N. Rumaila	+0.5	-2.0
3	S. Rumaila	+1.0	-1.0
4	Nahr-Umr	+0.6	-2.5
5	Ratawi	-4.0	-2.0
6	N. Zubair	-0.5	-2.3
7	S. Zubair	+5.0	-0.5
8	Siba	+1.5	+0.7
9	Basrah depression	-2.0	-1.0
10	Jabal Sanam	-1.9	+0.9
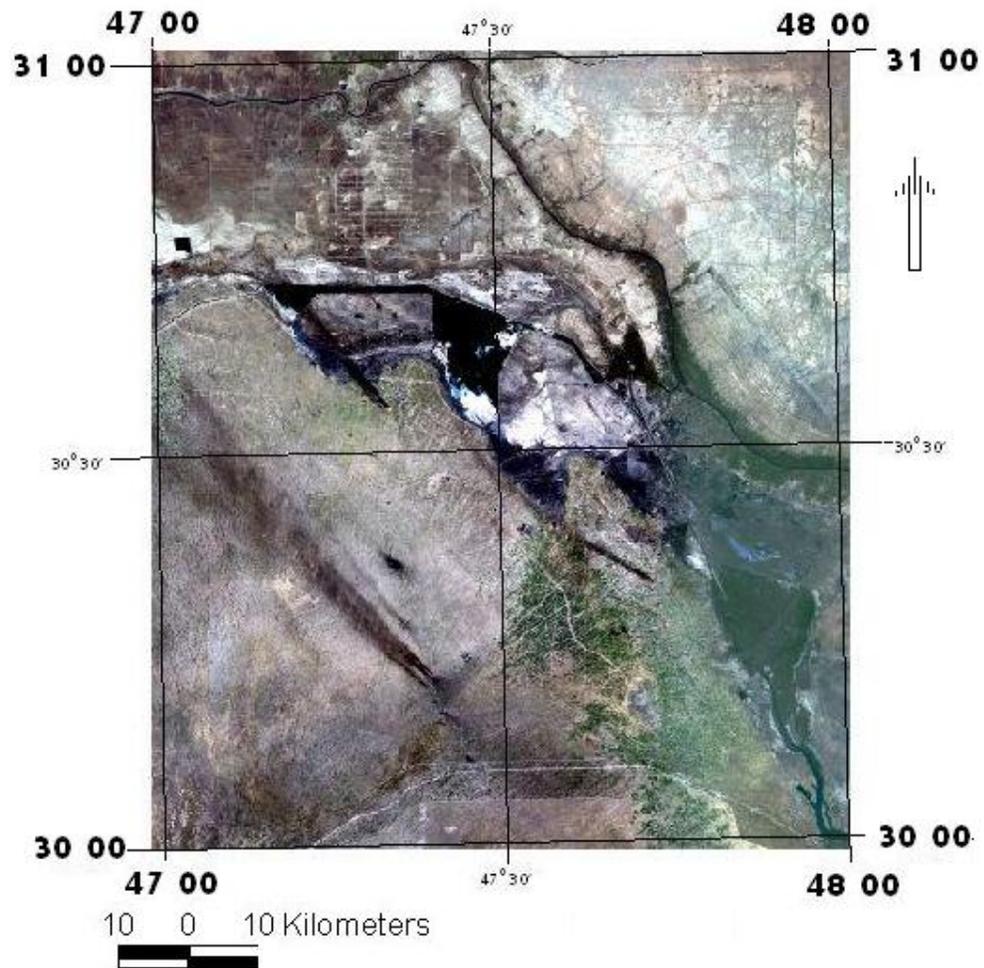
Figure (1) Area of study
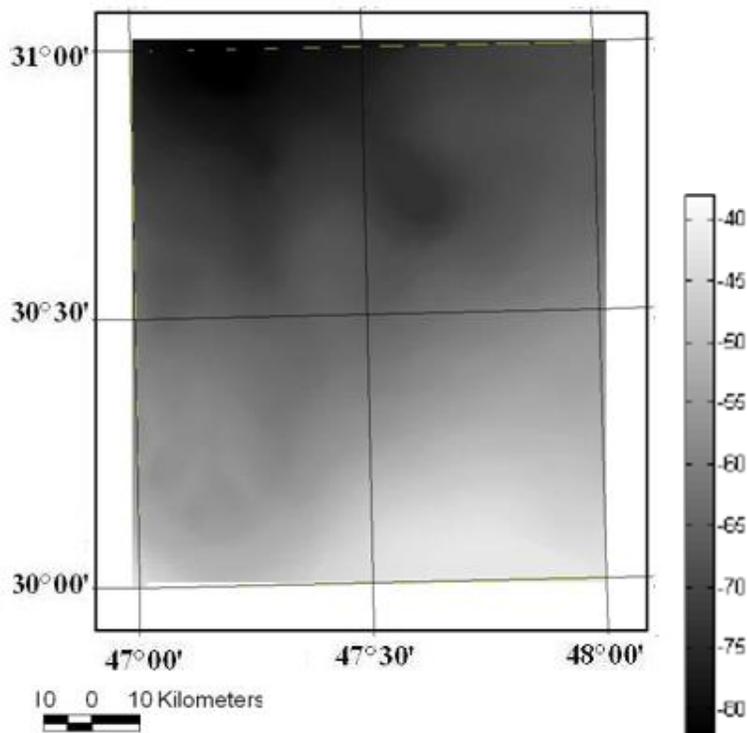
Figure (2) Original Bouguer gravity image
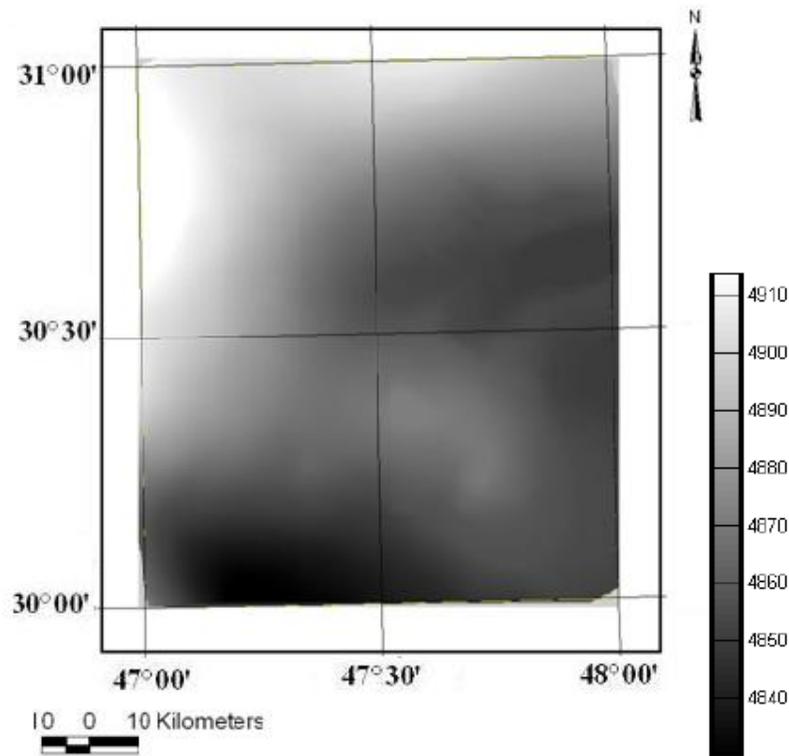
Figure (3) Original aeromagnetic image
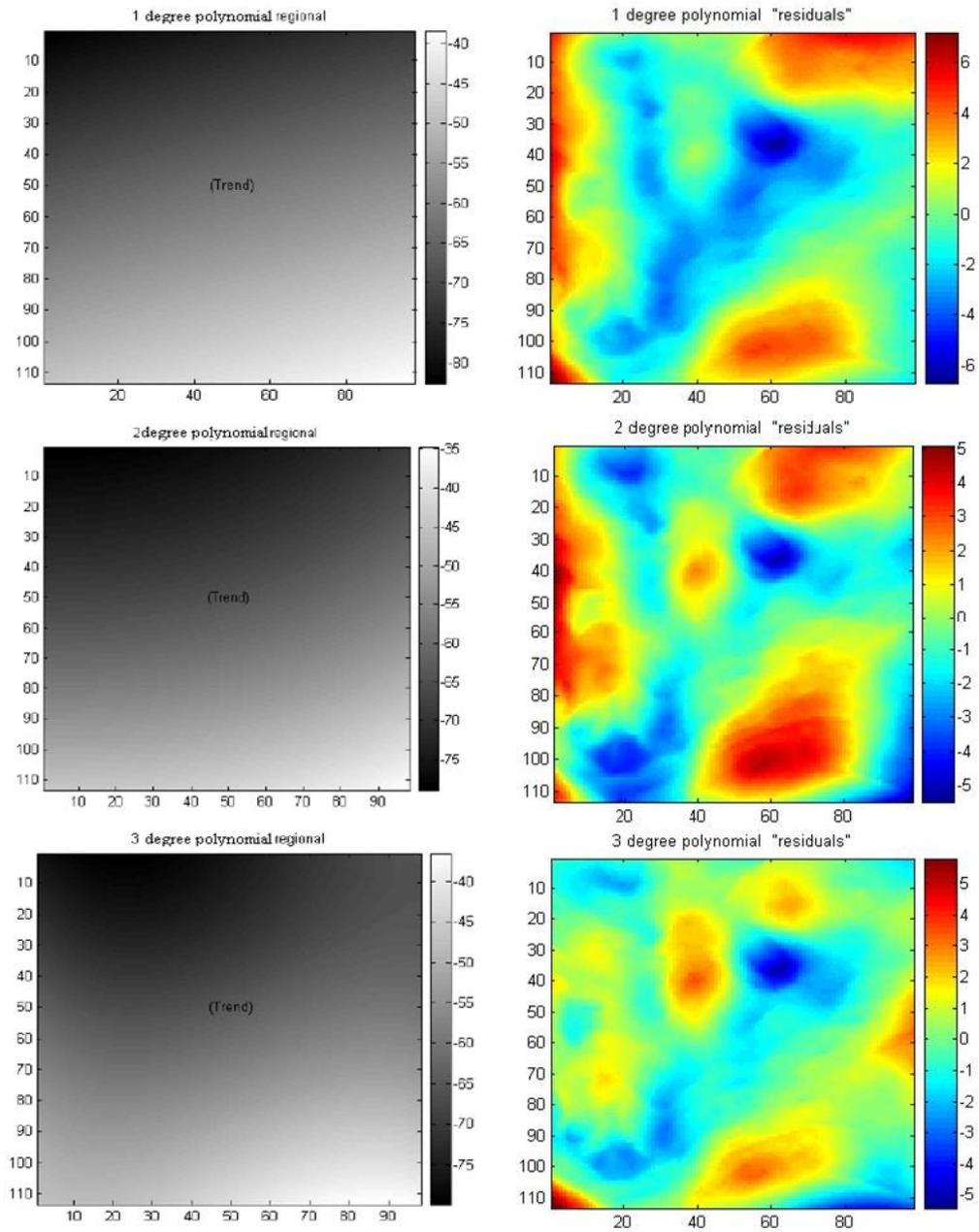
**Figure (4) Output figures of applying 1ˢᵗ to 6ᵗʰ degrees polynomials for gravity
data. Residual images (right side); trend surface images (left side)
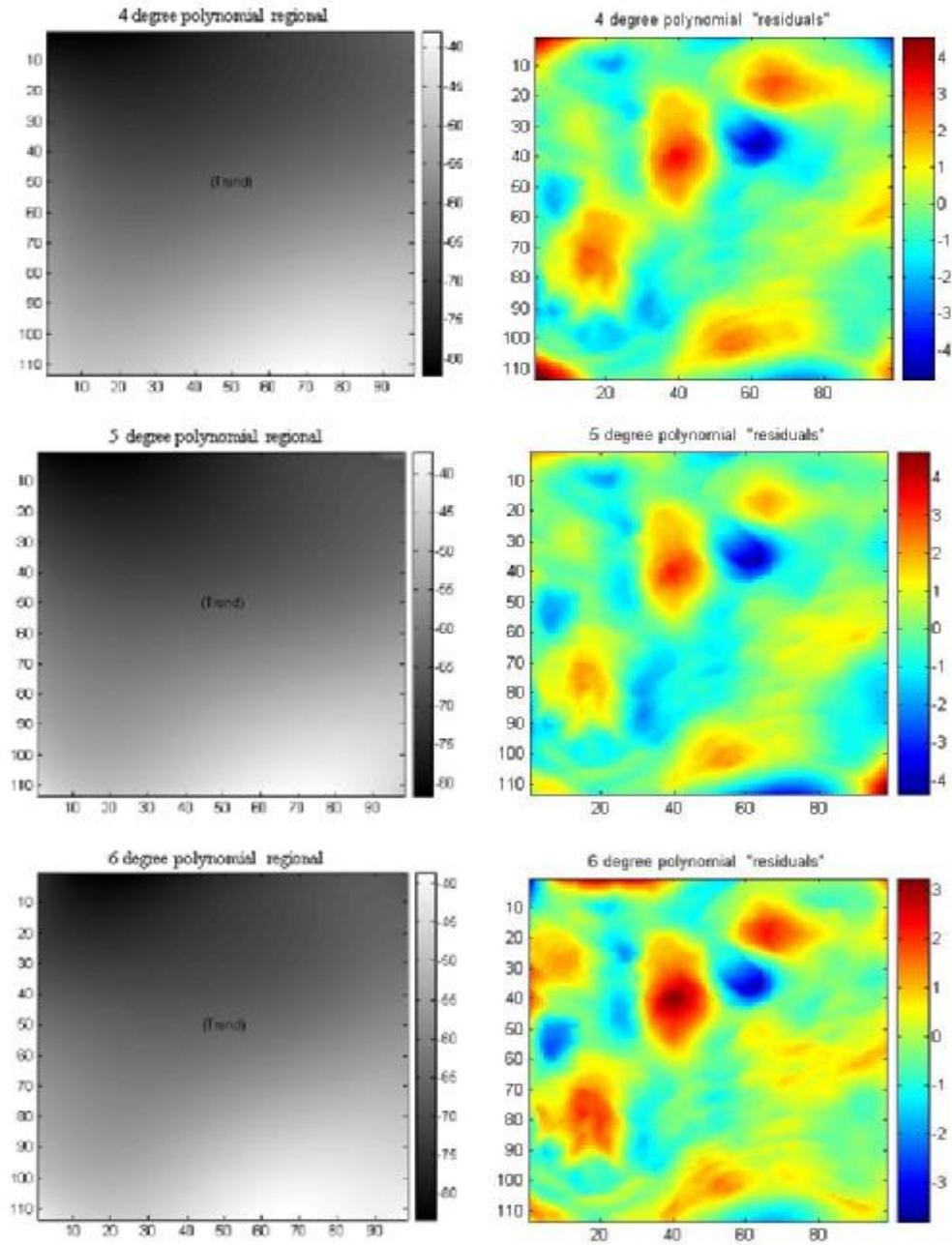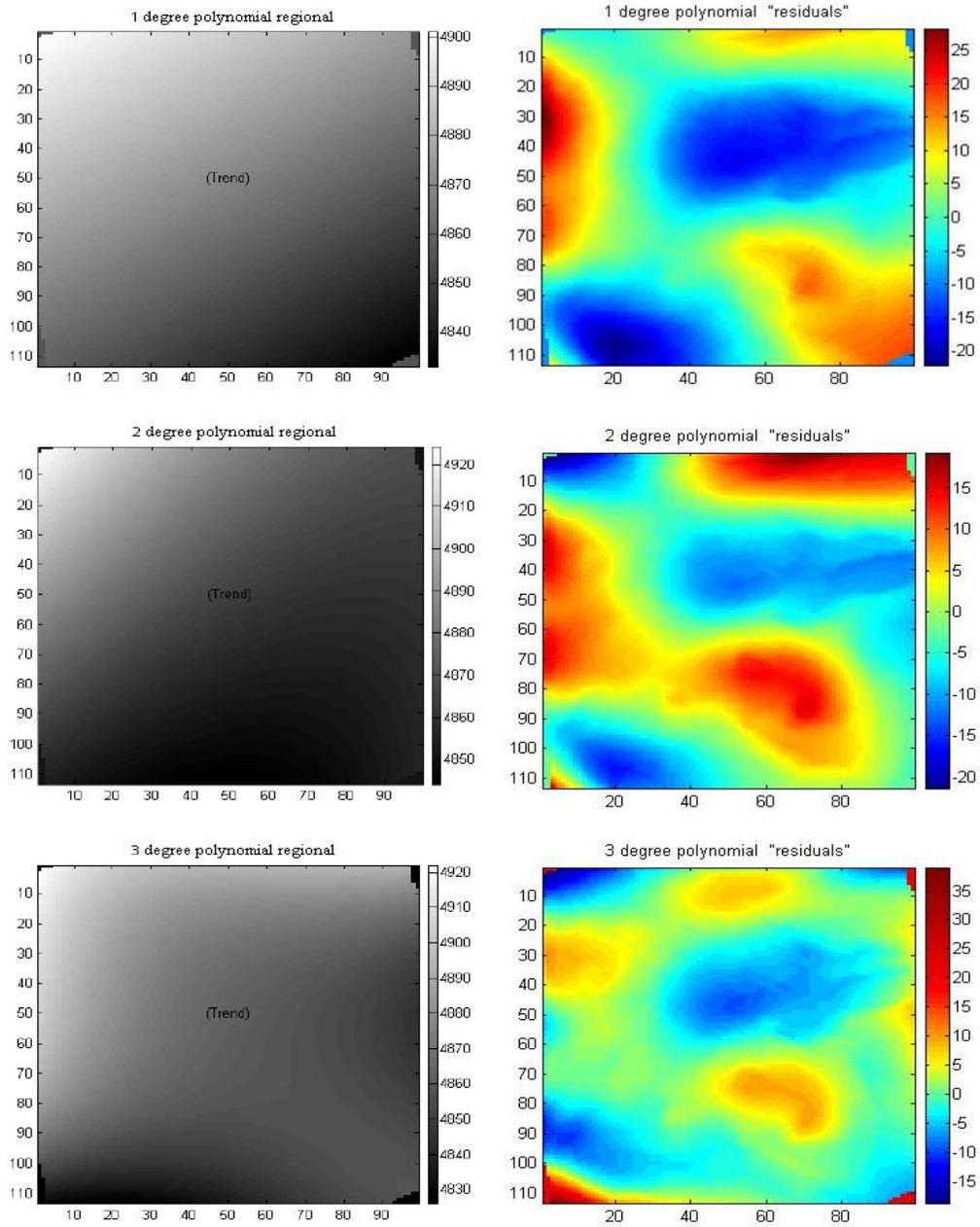(To be continued)**

Figure (4) (continued)

Figure (5) Output figures of applying 1ˢᵗ to 6ᵗʰ degrees polynomials for aeromagnetic data. Residual images (right side); trend surface images (left side) , (To be continued)
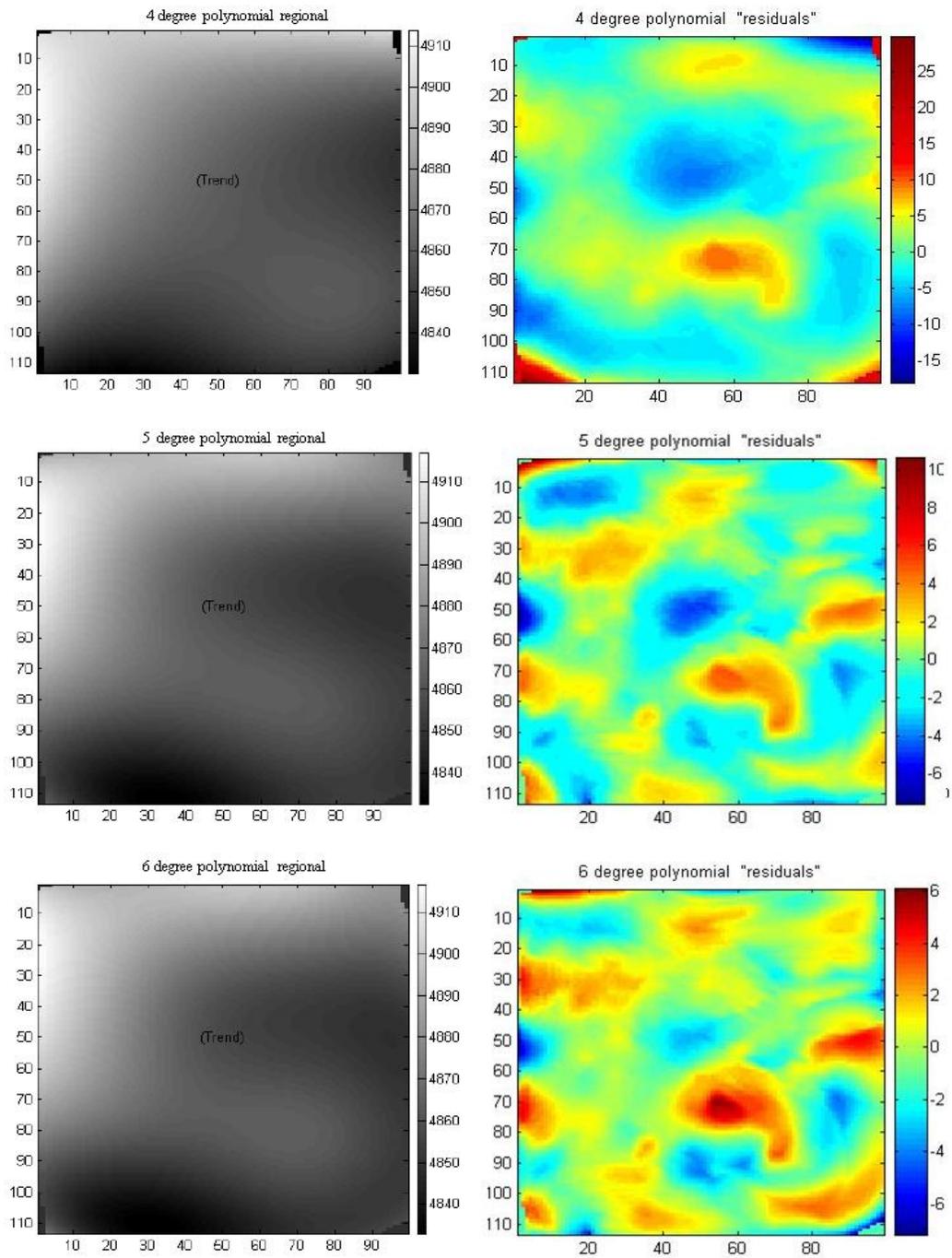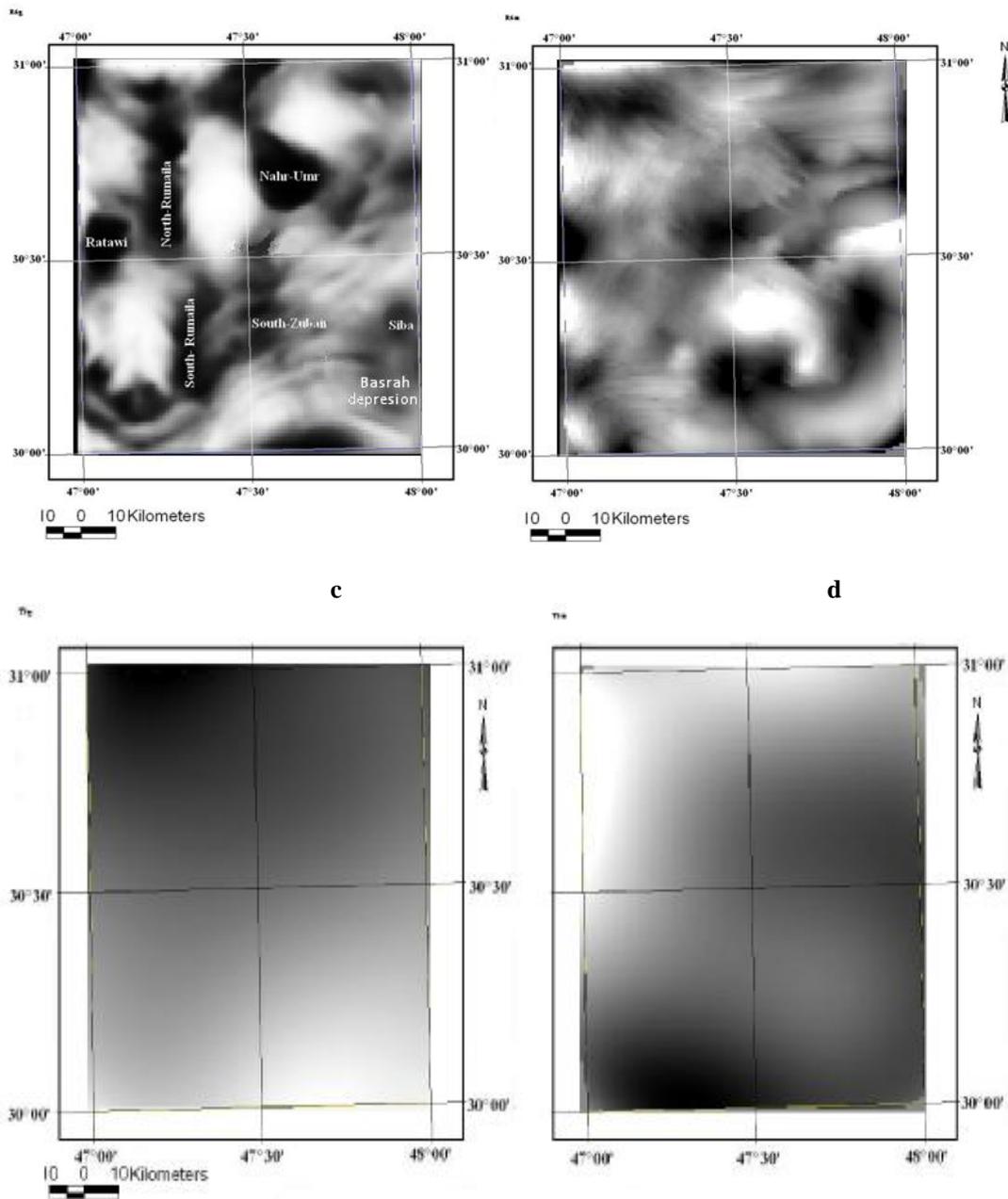
Figure (5) (continued)

a   b

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Figure (6) Residual images and trend surfaces of 6th degree polynomial: a- Residual gravity data; b- Residual magnetic data; c- Trend surface gravity data; d-Trend surface magnetic data.
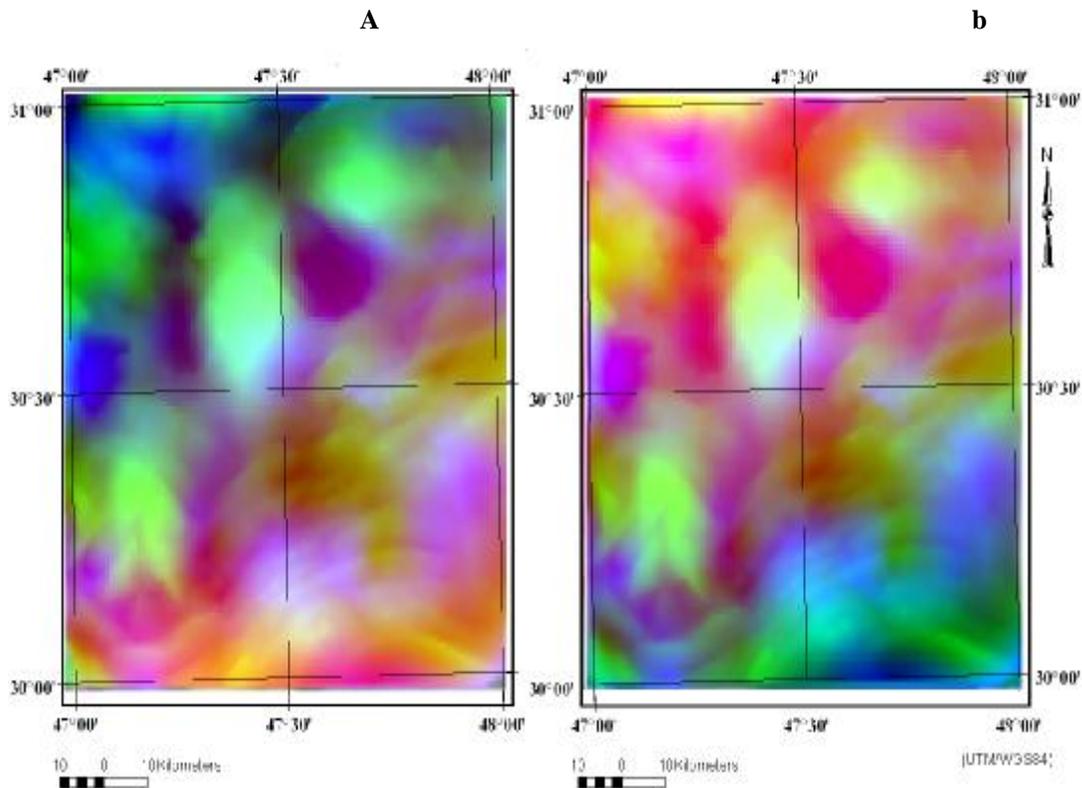
250

A　　　　　　　　　　　　　　　b

Figure (7) Three layers images (RGB mages)

a- Red- principal component (PC); Green- gravity and Blue- aeromagnetic.

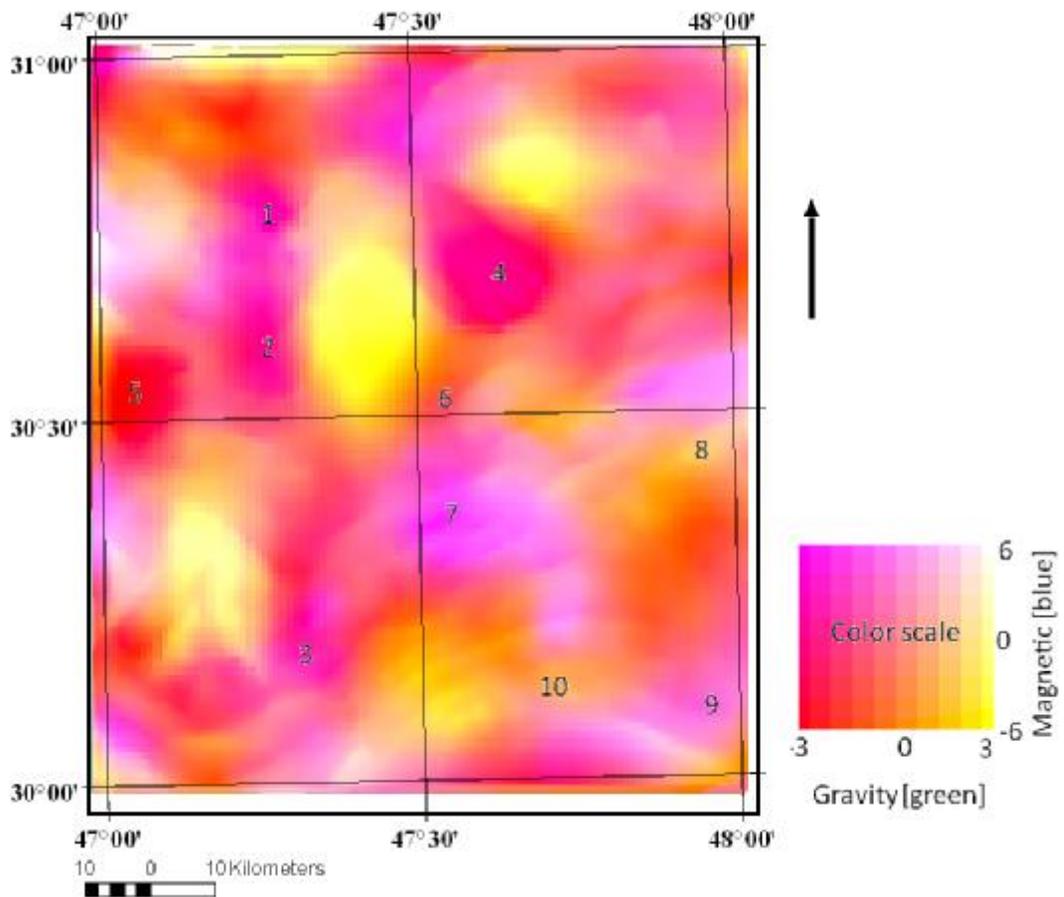b- Red- aeromagnetic / gravity ratio; Green- gravity and Blue- aeromagnetic.

Figure (8) Two layer geophysical image. Green- gravity; Blue- magnetic on a red background . 1 and 2- N. Rumaila ; 3- S. Rumaila ; 4- Nahr-Umr ; 5- Ratawi ; 6- N. Zubair ; 7- S. Zubair ; Siba ; 9- Basrah depression and 10- Jabal Sanam .