BASEMENT TECTONICS IN THE AL-SALMAN AREA, SOUTHWESTERN DESERT, IRAQ

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الخلاصة :

إستخدمت خرائط شواذ بوجير الجذبية وخرائط المسح الجوي المغناطيسي لدراسة تركيب وتكتونية القاعدة الصخرية لمنطقة السلمان في الصحراء الجنوبية الغربية في العراق . أوضحت نتائج التفسيرات الجذبية عن وجود إرتفاع تركيبي في القاعدة الصخرية بحدود ٨٠٠ متر يمر إثره بقرية السلمان . إلا أن نتائج تفسير معلومات المسح الجوي المغناطيسي جاءت بصورة مختلفة لتركيب القاعدة الصخرية وأعزي هذا الإختلاف لوجود تغييرات وتعقيدات في الخواص المغناطيسية للقاعدة الصخرية . كذلك لوحظ توافق جيد بين إتجاه التراكيب التي إستنتجت من المعلومات الجذبية والمغناطيسية والصور الفضائية .

أما وجود تكوين جيولوجي في عصر المايوسين في منحفض السلمان والمنخفضات الأخرى في المنطقة فلقد فسر نتيجة للهدم الحاصل بسبب تجاويف المياه الجوفية . وأتي هذا الإستنتاج مناقضاً لتفسيرات الصور الفضائية التي إفترضت وجود منخفض تركيبي يمتد للقاعدة الصخرية في المنطقة .

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ABSTRACT

The Bouguer gravity map and the aeromagnetic map of the Al-Salman region in the southwestern desert of Iraq were utilized in the study of basement configuration and tectonics in the area. The results of gravity interpretation indicated an uplift zone passing through Al-Salman village. The uplift in the basement was estimated to be within 800 m. Interpretation of the aeromagnetic data yielded a different picture of basement configuration and the data have been explained by intra-basement magnetic variations. Lineament interpretation from LANDSAT imagery, gravity, and magnetic data showed good correlation.

The presence of a younger formation of Miocene age in the Al-Salman and other depressions in the area has been explained in terms of subsidence caused by karsting, prior to the deposition of the younger formation. This conclusion is in contrast to the previously assumed graben structure, as interpreted from the satellite data.

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INTRODUCTION

The study area is located in the southwestern desert of Iraq, between latitudes 30° to 31°N and longitudes 44° to 45°E. The only major township in the area is Al-Salman, located at its center (Figure 1).

Topographically, the area is generally a flat desert with a few scattered hills rarely exceeding 10 m in altitude. This region is also known to have numerous depressions and sink-holes, most conspicuous of which is the one at Al-Salman. The Al-Salman depression is an elongated hollow 10 km in length and 5 km in width, extending in an almost north–south direction and being about 40 m lower than the surrounding areas.

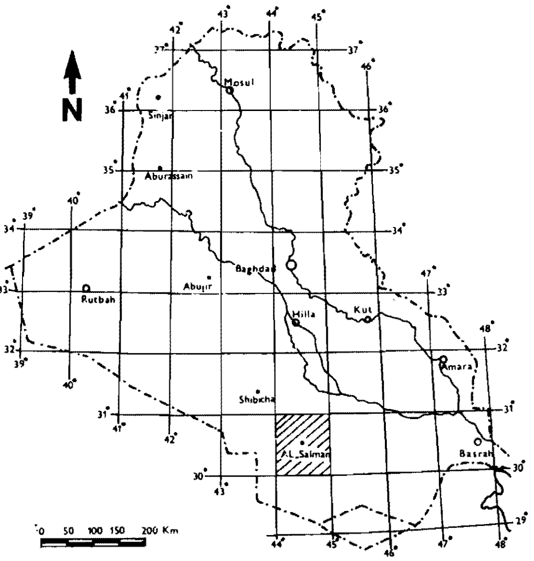

Figure 1. Location Map of the Study Area

Recent work on satellite and air-photo interpretation made by the corresponding departments of the Directorate General of the Geological Survey and Minerals Investigation, Iraq showed major lineaments along the northwest–southeast direction which were interpreted as 'deep-seated faults having a graben character' [1]. The area was also covered by the regional gravity survey of the former Iraqi Petroleum Company (IPC) [2] and the airborne geophysical survey of Iraq conducted by the Compagnie Général de Géophysique for the State Organization for Minerals (CGG–SOM) [3]. Presently the area is being investigated geophysically and hydrogeologically as part of a major project covering the southwestern desert of the country. The preliminary results of resistivity soundings could not unambiguously confirm a graben structure in this area [4]. The outcome of previous work initiated interest in studying the basement tectonics of this area.

GEOLOGY AND TECTONICS

The surface geology of the Al-Salman area is generally composed of the Dammam formation of Eocene age, consisting of various types of limestone. It is characterized by karst depressions, which are believed to have been controlled by solution action along structural planes [5].

More geological information was given in the progress report of the satellite and aerial data analysis center [1]. In this work, the presence of the younger Zahra formation of Miocene age within the depression was interpreted as evidence of faulting having a graben character. The faulting was considered to have taken place before the deposition of the Zahra formation.

Interpretation of satellite and aerial data revealed that simple folding and rather complex block faulting affected the area. The folding is of open type with dips not exceeding a few degrees. The folds have a general northwest–southeast trend, which deviates to east–west in the northern part of the area. Three systems of 'interpreted faults' were outlined from the LANDSAT and aerial photographs: north–south, northwest–southeast and northeast–southwest sets (Figure 2). Among these, the northwest–southeast set is the most prominent on the LANDSAT image, and it was interpreted as old deep-seated faults, having a graben character, which had been rejuvenated during the Miocene [1].

Tectonically, the region is located in the southern Shibicha subzone within the stable platform [6]. This subzone is subdivided into two blocks; the Salman block and the Busaya block. The Salman block is characterized by a general absence of late Miocene–Pliocene cover, and on the basis of magnetic details, it is divided by a fault zone into a northwest, magnetically positive and generally more uplifted and stable part, and a southeast, more basinal part designated by

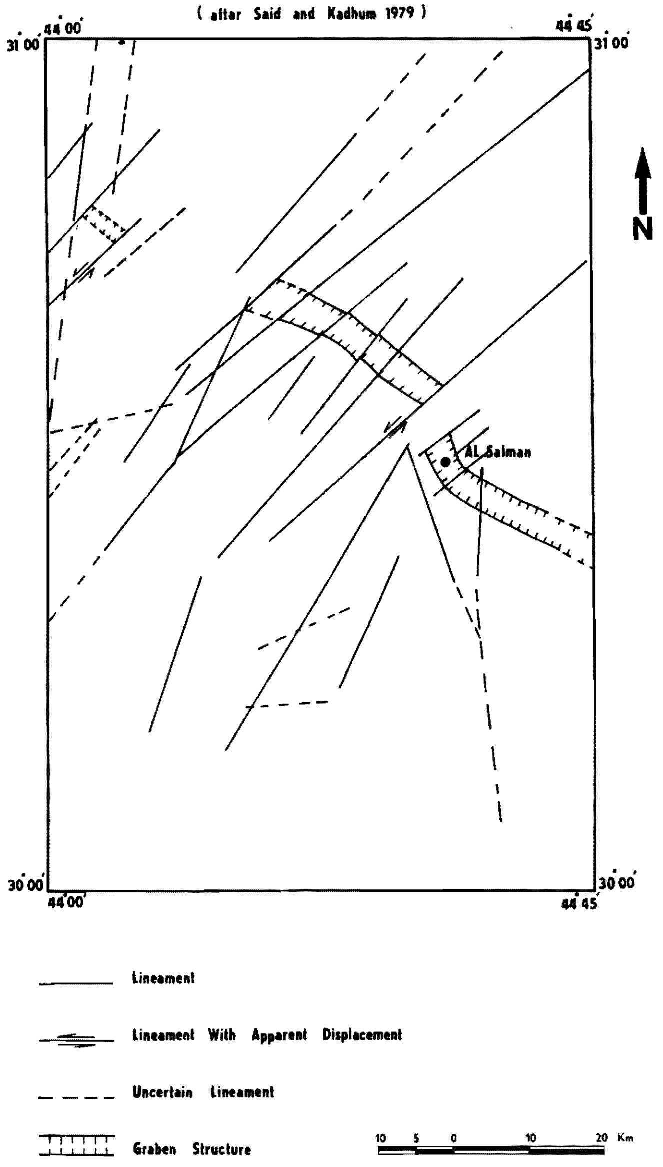

Figure 2. Lineaments Interpretation of LANDSAT Imagery

Ditmar and others [7] as the Ansab depression. The area studied is located within the uplifted and stable part of this block.

The basement relief map of Ditmar and others [7] shows no evidence of any basement feature passing through Al-Salman. Instead, three isolated basement uplifts are indicated on their map; a major one with a minimum depth of 5 km trending northeast–southwest in the northwestern part of the area, and two minor basement uplifts of about 6 km depth range, located to the east and southeastern parts.

GEOPHYSICAL DATA AND INTERPRETATION

Gravity Data

The available gravity data are shown in the 1:200 000 scale Bouguer gravity map of the former Iraqi Petroleum Company [2], which was established by measurements taken on a grid of 10 × 10 km with a point spacing of 1 km along the grids. The Bouguer gravity map shows a well-defined positive gravity anomaly surrounded by small negative anomalies, extending in an almost northwest–southeast direction

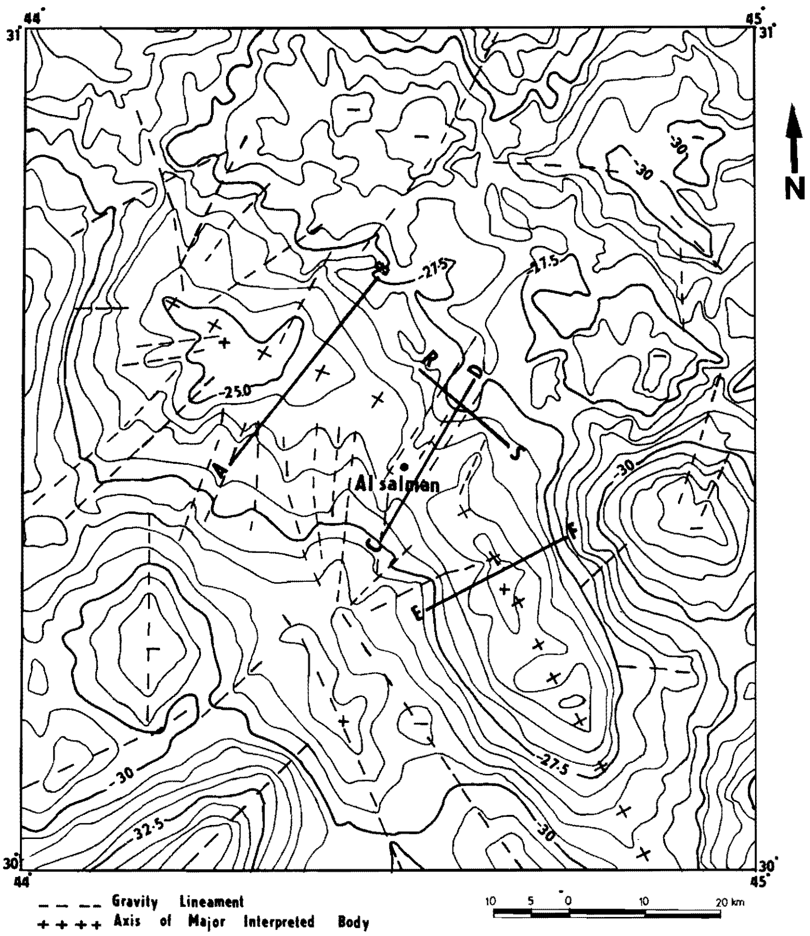

Figure 3. Bouguer Gravity Map of the Study Area, Showing Location of Interpreted Profiles (AB, CD, EF) and Lineaments (contour interval: 0.5 mGal)

and having a maximum amplitude of 3 mGal (Figure 3). Al-Salman village is located at the center of the positive gravity anomaly.

The Al-Salman positive gravity anomaly is suggested to be the extension of the well-known Abujir–Shibicha positive gravity high, which is a part of the positive gravity axis affecting Iraq from Sinjar in the north, through Aburassain, Abujir, and Shibicha to Saudi Arabia southwards [8].

An extremely narrow gravity anomaly extending in a northeast–southwest direction can be observed distorting the major positive anomaly near Al-Salman. This anomaly is of local character and could represent a fault zone of a relatively shallow nature, not influencing the basement rocks.

An attempt has been made to outline features (lineaments) in the Bouguer gravity map of the area. This interpretation was mainly concentrated on the central gravity high and its immediate surroundings. Two major lineaments trends can be observed: a northwest–southeast trend, displayed as the axis of the gravity anomaly, and a northeast–southwest trend represented by the shallower features intersecting the major gravity anomaly. A radial pattern of lineaments is also observed affecting mainly the northern part of the major anomaly.

Quantitative interpretation was attempted along three profiles, AB, CD, and EF crossing the anomaly at the northern, central, and southern parts, respectively. Another profile, RS, was taken across the disturbing shallow feature affecting the major anomaly (Figure 3). The theoretical gravity response for profiles, AB, CD, and EF was computed assuming a

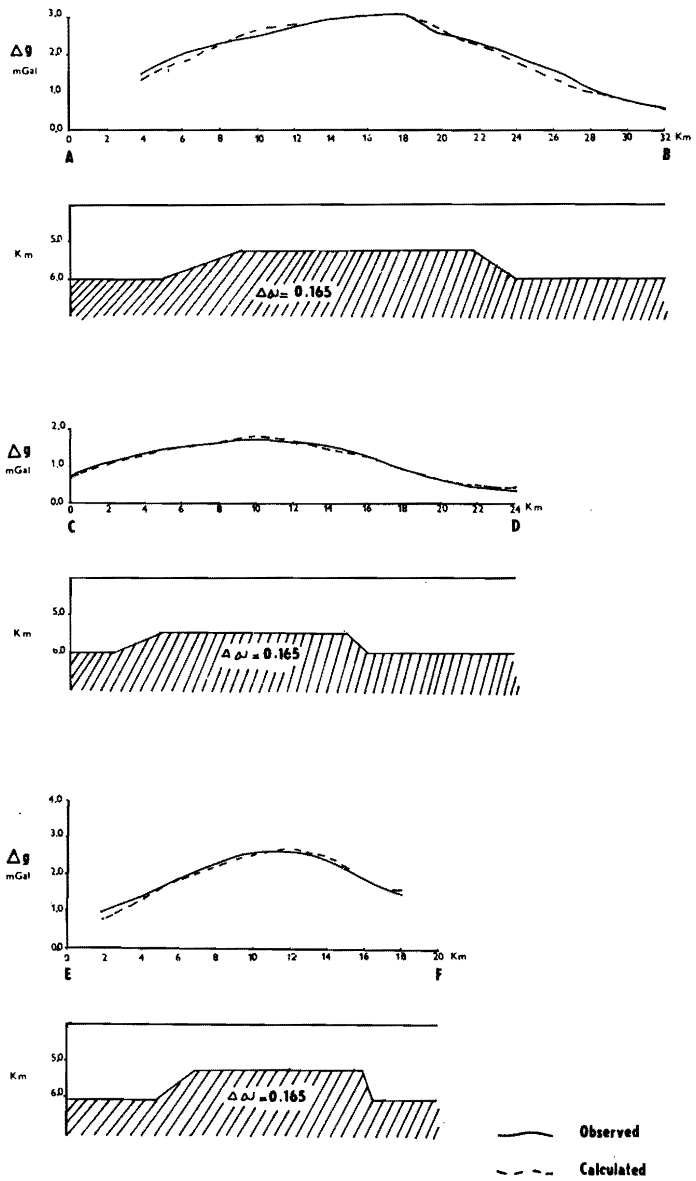

Figure 4. Interpretation of Gravity Profiles AB, CD, and EF

density contrast of 0.165 g/cc between the basement and the overlying sedimentary sequence. The adopted density contrast corresponded to the range given by Ditmar and others [7] as an average contrast between the basement and the overlying sedimentary cover. A regional gravity value for the study area was computed to be −28.0 mGal. This value was extracted from the 1:200 000 scale regional gravity map of the area, using a modified Griffin method with two rings. Modeling computations were performed using an interactive computer program based on the algorithm of Talwani and others [9], assuming a two-dimensional polygonal body. A reasonable fit between the observed and the theoretical data was achieved for a general basement depth of 6 km and an uplift, coinciding with the gravity high of 500 to 800 m. The results of computations are illustrated in Figure 4. A fourth model was attempted along profile RS crossing the local anomaly in a northwest–southeast direction. A geological model of two vertical faults was assumed for this anomaly. The density contrast adopted in the computations was 0.15 g/cc, and the best fit was achieved for a downthrow of 180 m at 820 m depth (Figure 5).

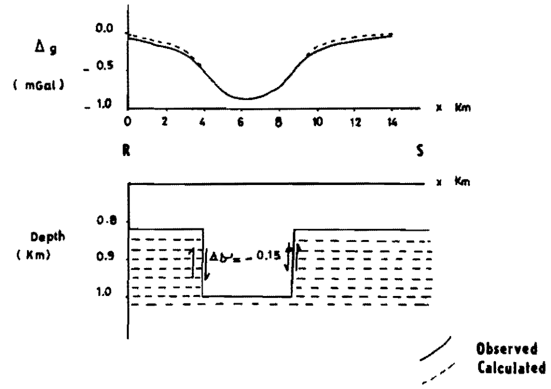

Figure 5. Interpretation of Gravity Profile RS

A maximum deviation of 0.2 mGal was encountered in the interpretation of the former three profiles. This could be the effect of one or more of the following: the interpolation process; inherent in accuracy in the original data; the generalization of the assumed models with respect to actual basement relief; and the distortion caused by inhomogeneities of the overlying sedimentary column. For profile RS, the deviation of the computed gravity from the observed one was negligible, not exceeding 0.07 mGal. Nevertheless, for the purpose of this work such variation was considered to be acceptable.

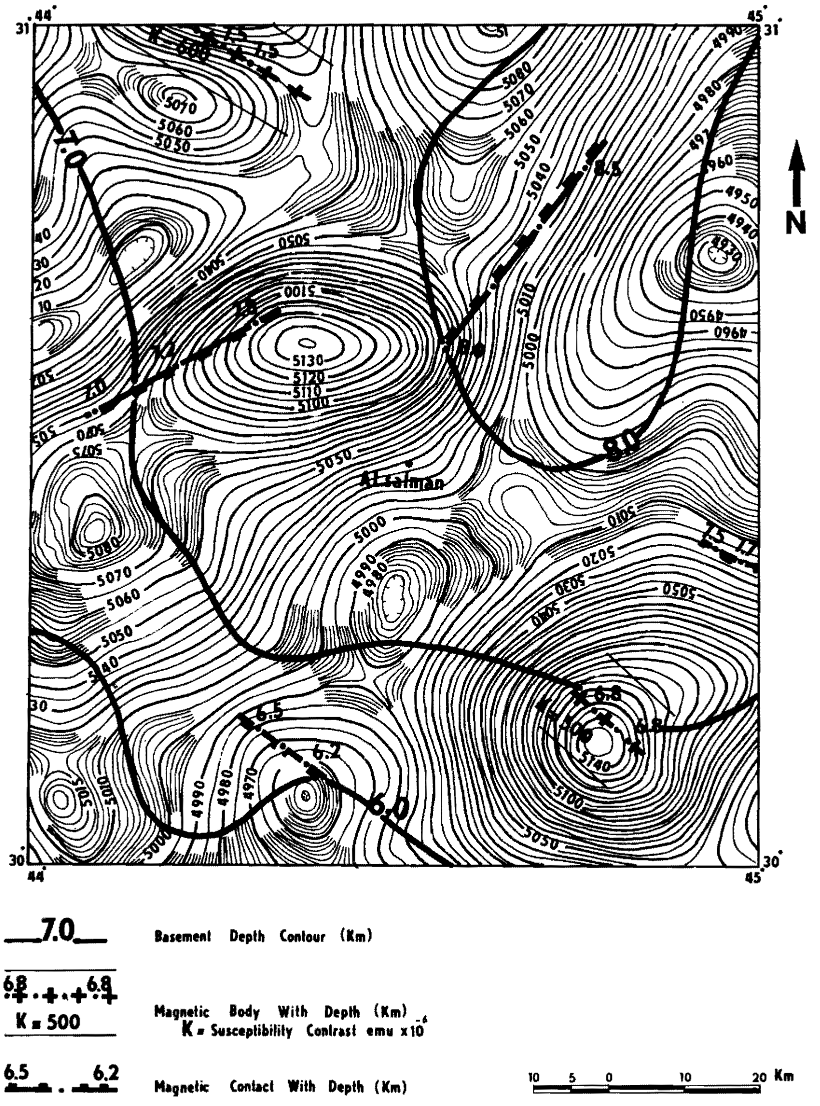

Figure 6. Aeromagnetic Map of the Study Area, with Interpretation (after CGG–SOM 1974; contour interval: 1 gamma)

Magnetic Data

The high-sensitivity airborne magnetic survey by the CGG–SOM of the study area was conducted along traverses 2 km apart and tie-lines at 10 km. The total magnetic field was measured with a cesium vapor magnetometer having a basic sensitivity of 0.01 nT (0.01 gamma). All in-flight information (magnetic, radiometric, altitude, and position) was recorded on a nine-track magnetic tape by the data acquisition system. The 'flight tapes' were later verified and corrections were made for the diurnal magnetic field variations and the international geomagnetic reference field. Basement depth interpretations were performed using an automatic basement depth computer program (CGG computer library) coupled with manual examination of selected anomalies.

A basement depth estimation from this method gave a value of 6 km at the south and southwestern parts of the area, to 8.5 km towards the northeast (Figure 6). The susceptibility contrast of the interpreted bodies were assumed to be within $6250–7500 \times 10^{-6}$ SI ($500–600 \times 10^{-6}$ emu) [3]. The interpretation of the airborne data failed to reflect the prominent gravity high described earlier. The only indication of this high is displayed in terms of a limited body interpreted in the southeast having a depth of 6.8 km (Figure 6). Other interpreted markers include magnetic contacts with varying depths and having almost northeast–southwest and northwest–southeast directions. The general northeast–southwest direction displayed by the magnetic anomalies can be interpreted as the result of preferred orientation in the basement structures.

TECTONIC IMPLICATIONS AND CONCLUSION

The interpretation of the gravity data supports the presence of an uplift in the basement rather than the suggested 'graben' as deduced from the interpretation of LANDSAT images. Nevertheless, the trend of the structure is somewhat similar in both studies. Despite this contradiction, both sets of data show good correlation in lineaments direction, especially those with a northeast–southwest trend. It is also suggested here that the proposed uplift would conform with the general tectonic setting of the area [2, 6, 7].

The age of the suggested uplift could be inferred from available surface and subsurface geological information. Subsurface information from seismic data indicate the presence of numerous uplifts in the Upper Cretaceous formations aligned on a northwest–southeast trend [10]. Accordingly, a Post-Cretaceous age is initially assigned to the uplift. The presence of the younger clastics within the Al-Salman depression would apparently contradict the suggested uplift origin. However, this is explained in terms of subsidence in the uppermost beds caused by karsting phenomena, before the deposition of the younger sediments. The karsting and collapsing processes might also be the reason behind the 'increased thickness of the comparatively conductive geoelectric layer, salt-water aquifer, or clayish hydrogeological reservoir' in the Al-Salman depression reported by Mazac [4]. The resulting depressions and valleys were later filled by clastics of a younger age as shown on the geological map of Iraq (scale 1:1 000 000), in which isolated Middle Miocene sediments occupy local depressions and valleys.

The northwest–southeast trend is the most evident trend dominating the geological picture of Iraq. This trend has the same direction as the Najd orogenic trend of Early Cambrian age, which can be traced over most of the Arabian peninsula [11]. The same direction was also evident during the later Alpine orogeny, presumably rejuvenated, at least partly, along the older weakness planes of the Najd orogeny. This direction is also prominent in the analysis of aeromagnetic linear features that was made on the interpreted magnetic markers (unpublished data of J. T. Sallomy).

The outcome of the interpreted profiles across different parts of the Al-Salman gravity anomaly showed a variation in depth of the interpreted uplift in the range 5.2 km at the south, 5.5 km in the Al-Salman depression, and 5.25 km to the north of the depression. The departure of depth, computed along the central profile, is most probably fictitious and certainly falls within the claimed accuracy of this study. This apparent variation in depth can be attributed, at least partly, to the topographic effect of the depression, which was not accounted for in the Bouguer gravity map used for this study. Another possible factor is that there is relatively less gravity point coverage in this part of the area. It is therefore suggested here that the depth of the uplift is within 5.2 km, rising about 800 m over the average basement depth in the area.

The somewhat poor correlation observed between the gravity and the magnetic results can be explained as the outcome of the rather complex nature of the basement with predominantly non-magnetic rocks comprising the top of the suggested uplift, varying to more basic and magnetic rocks downwards. Such a resolution conforms with the general conclusion of a complicated magnetic basement obtained from the airborne magnetic survey of Iraq [3]. The deeper depths resolved from the aeromagnetic interpretation might be an indication of intra-basement features.

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