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A Reconnaissance Gravity and Magnetic Investigation along Erbil-Shaqlawa Highway, NE Iraq

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ABSTRACT. A reconnaissance gravity and magnetic study has been carrid out along the road between Erbil-Shaqlawa, NE Iraq in order to throw light on the subsurface geological structures, in particular the basement's configuration, since it has not been covered by any previous geophysical investigation.

This area represents the transition between the foothill zone and the high folded zone. It was found that the regional gravity and magnetic anomlies are increasing towards Shaqlawa, which suggests that the basement depth decrasing in this direction. Also, there is possibility of the presence of basement fault southwest of Salahaddin Summer Resort. The local gravity anomalies have been interpreted due to subsurface structures within the sedimentary succession.

The study area lies withen the folded zone of Iraq, along the main road of Erbil-Shaqlawa, NE Iraq (Fig. 1).

The tectonic setting of any area can be elucidated with the aid of gravity and magnetic anomaly maps. Variations in the subsurface structural pattern and lateral changes in the mass distribution affect the surface gravity anomalies. The magnetic field variations can be attributed to changes in the subsurface structures or magnetic susceptibility of rocks (Dobrin 1976).

Geophysical data are few for this part of Iraq. There is a gravity survey carried out on Harir anticline by Al-Shaikh *et al.* (1975). The gravity map of Iraq prepared by the Iraqi National Oil Company in 1960 did not cover this part of Iraq. Therefore, the present work can be considerd as a reconnaissance survey to establish characteristics of the gravity and magnetic field that could be related to the subsurface geology of the area.

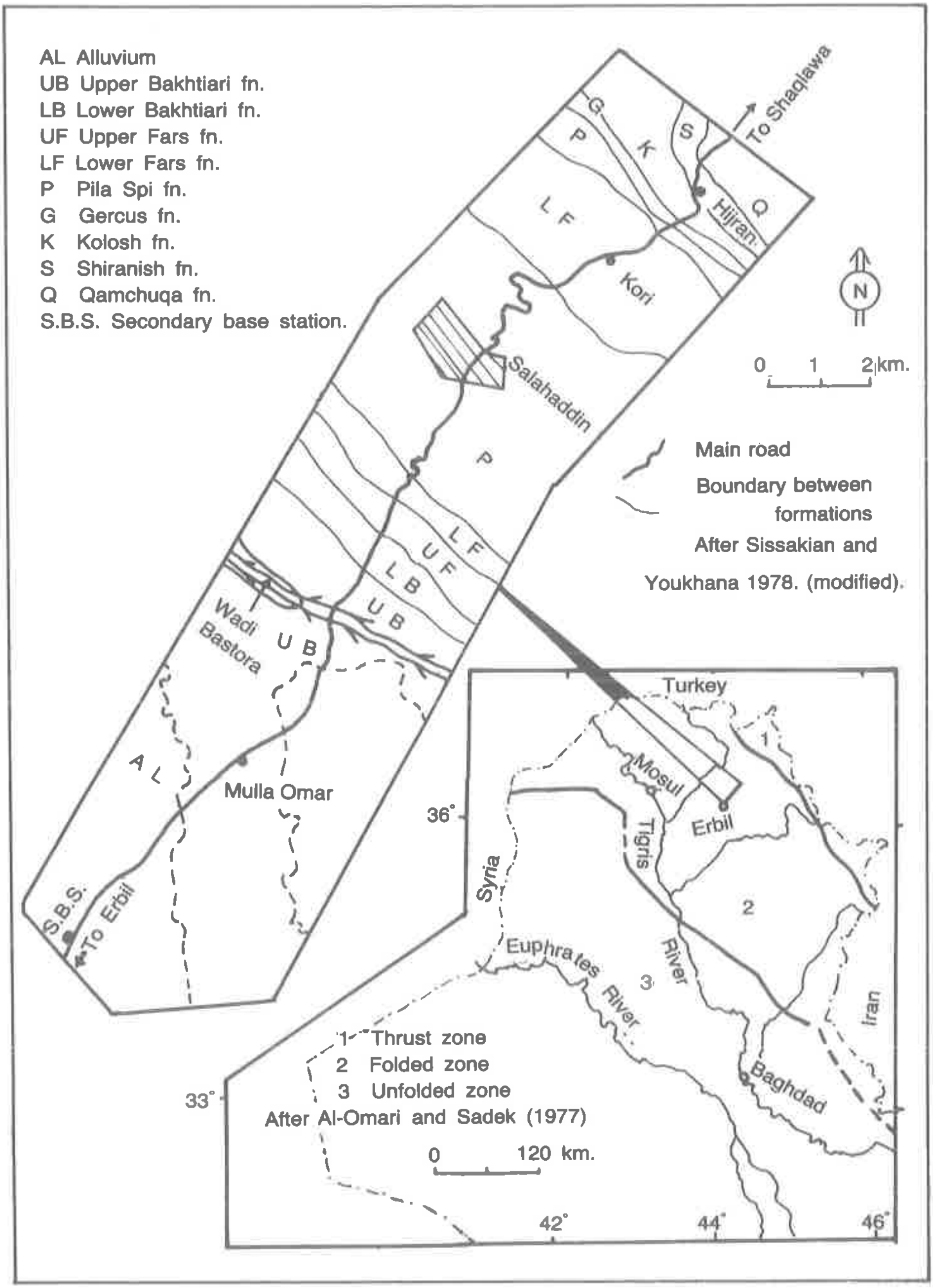

Fig. 1. Location and geological map of the area

The geophysical data used in this study are in the form of gravity and magnetic field profiles observed along the Erbil-Shaqlawa Highway (Fig. 2).

Geological and Tectonic setting of the Area:

The lack of deep drilled holes and geophysical investigations in this part of the country makes the depth and lithology of the crystalline basement rocks unknown. Knowledges of the subsurface sedimentary sequences comes mainly from rocks out-cropping at the surface. Buday (1973), suggested that the depth of the basement in this part of the country could be greater than 10 km. The rocks that out-crop in the area are shown in Fig. 1 and Table (1).

The area is charecterized by a thick sedimentary cover and well-marked folding. The folds are arranged in narrow long assymetrical anticlines and broad flat synclines trending NW-SE. Buday (1973) indicated that cores of the first sharply uplifted anticlines which are built up by Paleogene or Late Cretaceous sediments are the first structures of the high folded zone of Iraq (fig.1). Such anticlines are the Chia-i-spi, Shaikh Adra, Shaikh Adi, Aqra,Permam-Dagh, Bana Rawi and Qara-Dagh anticlines, Thus, the studied area reprresents a transition between to the foothill zone and the high folded zone. Buday (1973) suggested that the transition might be associated with the crystalline basement structure.

The profile runs across the Permam-Dagh anticline and the south western part of the Safine anticline separated by a syncline. These structures are genarally conformable with the topograghy of the area.

The core of the Permam-Dagh anticline consists mainly of Pila Spi Limestone with a thickness of about 120 m (Sissakian and Youkhana 1978). According to Ameen (1979), the study area is a part of the southwestern limb of the Safine geoflexure. The hinge line of this geoflexure coincides with the axis of Safine anticline. Numan (1984) suggested that vertical oscillations due to interplay between basement blocks have played an important role in sedimentary basin location and configuration. Also the major longitudinal faults in the steeper limbs of some anticlines, such as Bashiqa and Permam-Dagh anticlines, could be best deciphated as surface expressions of deep seated displacement.

Ditmar (1971) analysed the available geological and geophysical data and interpreted the slope of the gravity gradient towards the east is due to the increase thickness of the sedimentary cover. Also, the linear negative and positive gravity anomalies with steep gradients are due to anticlinal and synclinal structures associated with systems of graben and horst in the basement rocks. Airborne magnetic survey by Compagnie General De Geophysique during 1974-1975, reflects surface structures, and the folds that follow Zagros trend are due to horizontal compression with-out any uplift in the basement (Ziyaioglu 1983).

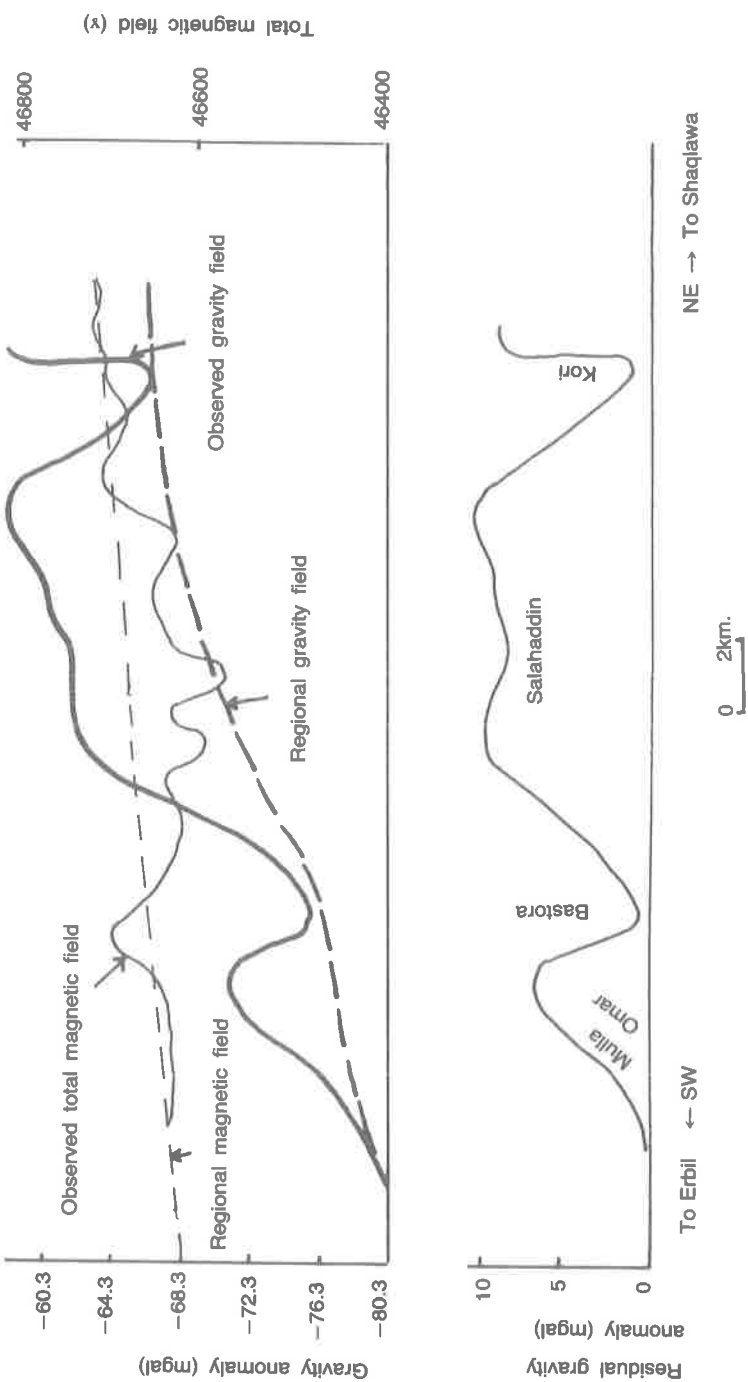

Fig. (2). The regional gravity and magnetic anomalies across the area

Field Work:

Sodin Gravimeter, Proton Precission Total Field Magnetometer and Surveying Micro Altimeter Model MM-5 were used for the survey. Gravity and magnetic readings were taken at each 500 m interval along the main road of Erbil-Shoqlawa (Fig. 1). The profile extending SW-NE, approximately at right angle to the main trend of the geological structures in the area, as well as, it crosses the boundary between the foothill zone and the high folded zone. This boundary is not indicated in any geophysical measurments (Buday 1973).

The survey work for any day was tied to the Control station (secondary base station 36° 21′ 07″ N and 44° 04′ 05″ E) near the police check point of Erbil-Salahaddin Road and this station was tied to a primary base station at Al-Risalah Secondary School in Erbil city, where the absolute value of gravity is (979679.15 mgal) as established by National Iraqi Mineral Company (NIMCO). Representative rock samples were collected during the course of the survey for density determination.

The gravity measurments were reduced relative to the secondary base station for latitude, topography and elevation, while the magnetic measurments were reduced for daily variations of the Earth's magnetic field.

Maximum error of station elevation was within 3 m, while that for latitude was not more than 300 m. An overall maximum error of 1.1 mgal is estimated in the Bouguer gravity values.

Density Measurments:

In order to reduce the gravity data and to represent a reasonable interpretation, density measurments of different out-cropping formations in the study area were carried out (Table 1). Densities were calculated by the convensional method (*i.e.*, from the ratio of the mass to the volume). Although there are some obvious limitations in this method due to the friability of the sedimentary samples and small expected errors in measuring volumes and weights, it seems that the results are reliable to use in this reconnaissance study. Densities for some of these formations were measured by Al-Shaikh *et al.* (1975) at Shaqlawa-Harir area and Ahmed (1980) at Aski Kalak area which show slight difference from the results obtained by the present study. This may reflect a lateral variation in lithology.

On the other hand, the magnetization of the source body was assumed to be caused by the induction of the earth magnetic field. The remanent magnetization is considered to be small to have an effect on the field or it has more or less the same direction of the present magnetic field.

Interpretation:

The gravity and magntic profiles clearly show regional field increasing from SW to NE (*i.e.*, from Erbil towards shaqlawa). Several local gravity and magnetic anomalies are superimposed on the regional trend (Fig. 2). The increasing gradients of 0.48 mgal/km and 2.2 ɤ/km for gravity and magnetic field respectively may suggest the regional shallowing of the basement towards shaqlawa. Using formula suggested by Fisher (1941), the calculated depth to the basement at the secondary base station is 12.7 km below sea level,while at Hijran village is 10.7 km below sea level, assuming that the density contrast between the basement and the sedimentary cover is 0.15 g/c^3 (Rezkalla 1981). This agrees well with the recent map of the basement depth conducted by Kassab and Abbas (1987). The calculated thickness of the crust near Erbil was found to be about 38.4 km below sea level using Woolard's formula (Woollard 1959). The morthward positive gradient may represent a local uplift in the basement or the southwestern limb of the Safine

Table 1. Mean densities of different formations in the study area

Formations	**Rock type**	**Mean density (g/cm^3)**		
		By the autors	**By Al-Shaikh**	**By Ahmed**
	Soil Cover*	1.70	–	–
Upper Bakhtiari	pebbly sandstone & conglomerate	2.41	–	2.41
Lower Bakhtiari	conglomerate	2.19	–	2.18
Upper Fars	silty marl, claystone & sandstone	2.23	2.25	2.00
Lower Fars	marl, anhydrite & limestone	2.33	2.45	2.26
Pila Spi	limestone	2.40	2.50	2.44
Gercus	red mollase sediments	2.38	2.30	–
Kolosh	shale & sandstone	2.41	2.30	–
Shiranish**	marl & limestone	2.64	2.60	–

* Carried out by the National Center of the Construction Laboratories, Erbil.
** Density of Pre-Shiranish Formations were assumed to be 2.7 g/cm^3 for modeling calculations.

geoflexure described by Ameen (1979). The extrapolation of the gravity and magnetic regional profles suggests maximum anomaly to be located near Shaqlawa where lies the hinge line of the Safine geoflexure.

The regional gravity field shows a relatively steeper gradient between Mulla Omar village and Salahaddin Summer Resort. This may suggent the presence of a fault in the area within the crystalline basement. Howerer, the regional magnetic field does not show this phenomenon clearly,

The local gravity and magnetic anomalies mostly reflect mass anomalies underlying the area at relatively shallow depths. A pattern seems to exist between the local gravity and magnetic anomalies. In general, areas of high magntic anomalies are correlatable with gravity lows and *vice versa.* This general relationship is consistent with the type of rocks forming the structure. Al-Shaikh *et al.* (1975) showed that anticlines with exposed Cretaceous cores are characterized by gravity highs, whereas gravity lows pervail over Tertiary basins. In the present study, similar observations appear to exist. However, a gravity high is associated with magnetic low observed over Permam-Dagh anticline. This is probably, because that Kolosh, Gercus and Pila Spi Formations forming the core of the Permam-Dagh anticline are denser than the surrounding Upper and Lower Fares Formations while the magnetic susceptibility of the Pila Spi Formation is lower than the surrounding Formations (Bakhtiari). Over Bastora valley there is a thick sedimentary cover (Bakhtiari Formation) of low density and relatively higher magnetic susceptibility.

The relationship between the residual gravity anomaly features and geological structures may be examined by model calculation (Figs. 3&4). This has been done by matching the gravity anomalies computed from density models with the residual anomalies using the two-dimensional modelling program developed by Talwani *et al.* (1959).

Magnetic effects have not been calculated. This is because, in general, the magnetization of the sedimentary rocks is too small that structural features confined to the sedimentary section seldom be reflected in magnetic profiles (Dobrin 1976). Magnetic anomalies due to structure alone *i.e.,* varying configuration of uniformaly magnetized rocks seldom produced anomalies greater than 10 or 100 gammas (Breiner 1973), while larger anomalies are mostly produced by magnetization contrast.

The most important features observed on the gravity profile are the two clear highs which are named here after "Mulla Omar" village and "Salahaddin Summer Resort". They are separated by gravity low named "Bastora low" while the Salahaddin high is terminated by "Kori low".

Mulla Omar Anomaly:

The width of this anomly is about 5.5 km with an amplitude of about 6.5 mgal. Modelling of this anomaly suggests a trough-like structure within the Lower Bakhtiari Formation (2.19 g/cm^3) which was filled later on by sediments of Upper Bakhtiari Formation (2.41 g/cm^3) with a density contrast of 0.22 g/cm^3 (Fig. 3).

Salahaddin Anomaly:

It is the most important and complicated anomaly following the Perman-Dagh anticline. It is a broad anomaly extending for about 15 km, with an amplitude of about 9.8 mgal. The calculated model is due to two prisms. The first one has a density contrast of 0.18 g/cm^3 between Pila Spi, Gercus and Kolosh Formations with the surrounding younger Upper and Lower Fars Formations, while the other prism has a density contrast of 0.19 g/cm^3 between Shiranish and older Formations with the surrounding Gercus and Kolosh Formations (Fig. 4). The effect of the model is to a depth of about 2 km below the datum level. The model also shows two faults, one dipping to the NE while the other one to the SW direction. The fault with the NE direction may represent the longitudinal fault on the southwestern limb of the Permam-Dagh anticline that was suggested by Numan (1984).

The matching between the observed and calculated anomaly has not been elaborated, since there are many alternative models in the absence of control points such as boreholes or other geophysical surveys.

Conclusions:

Gravity and magnetic surveys along the Erbil-Shaqlawa Highway show that the depth of the basement is decreasing from the southwest (Erbil) to the northeast (Shaqlawa). The survey also shows that ther are two gravity highs associated with geological structures within the sedimentary succession. The transition between the foothill zone and the high folded zone which was believed to have some relation with the besement features is not clearly indicated.

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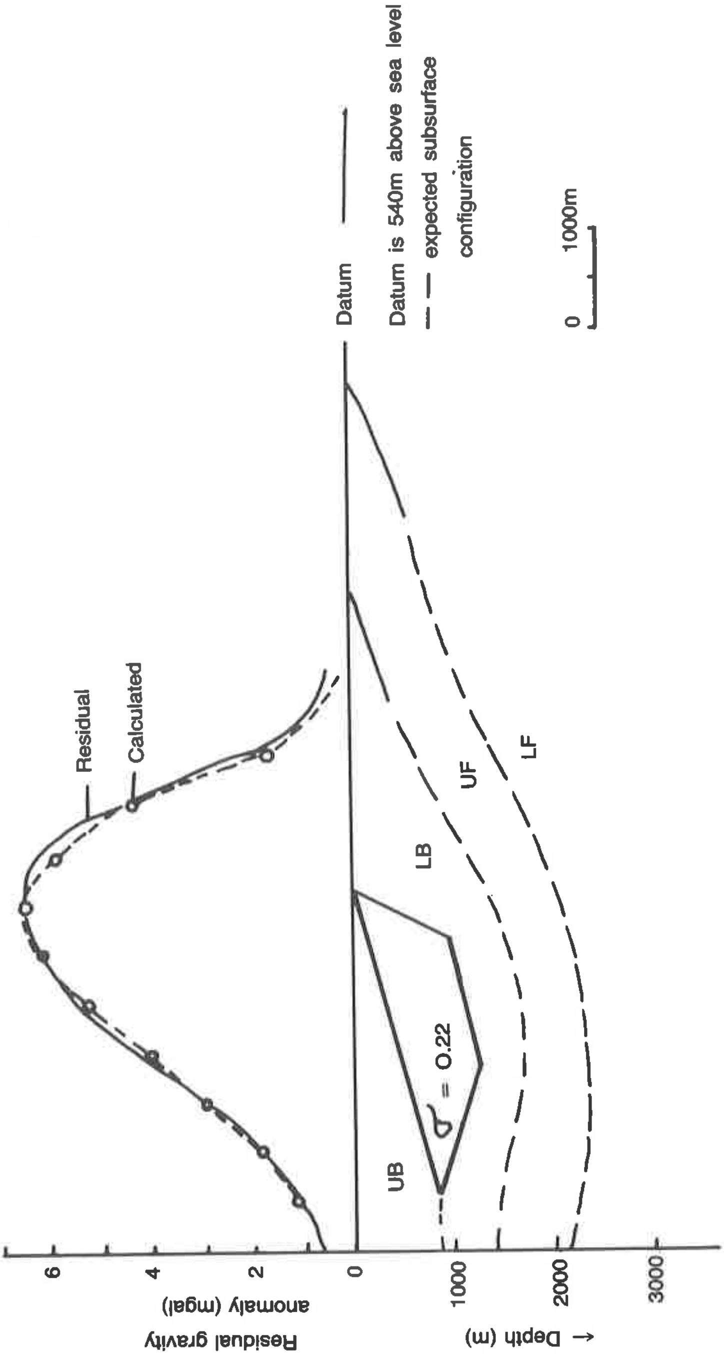

Fig. (3). Geological Model of Mulla Omar Anomaly

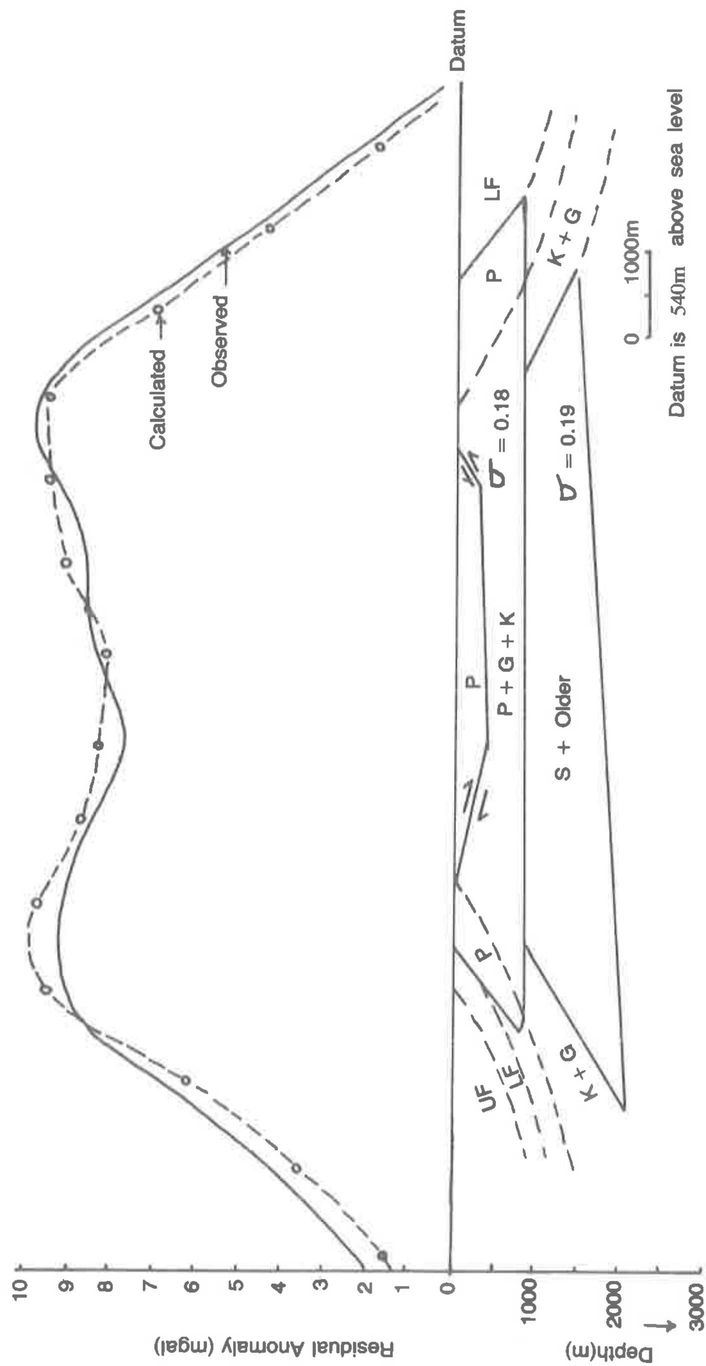

Fig. (4). Geolgical Model of Salahaddin Anomaly

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تحري جذبي ومغناطيسي إستطلاعي بين أربيل ـ شقلاوة، شمال شرق العراق

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تم القيام بدراسة جذبية ومغناطيسية إستطلاعية على طول الطريق الذي يربط بين مدينتي أربيل وشقلاوة في شمال شرق العراق وذلك في محاولة لتسليط الضوء على التراكيب الجيولوجية تحت السطحية وبالأخص وضعية صخور القاعدة. المنطقة تتميز بغطاء رسوبي سميك وطيات واضحة المعالم وإن أول سلسلة من الطيات المرتفعة بصورة حادة والتي يتكون لبها من الباليوجين الأسفل أو الكريتاسي المتأخر فإنها تمثل أول سلسلة من تراكيب منطقة الطيات العالية. ولذلك فإن منطقة الدراسة هذه تمثل المنطقة الإنتقالية بين منطقة أقدام التلال ومنطقة الطيات العالية، حيث يعتقد بأن هذا الإنتقال ربما له علاقة بوضعية صخور القاعدة.

المعلومات الجيوفيزيائية غير متوفرة في هذا الجزء من العراق ماعدا دراسة جذبية أجريت في منطقة طية حرير. كما أن الخريطة الجذبية للعراق والتي أعدت من قبل شركة النفط الوطنية العراقية عام ١٩٦٠ لم تغط هذا الجزء من العراق، بالإضافة إلى ذلك فإن عدم وجود آبار عميقة في المنطقة جعل وضعية ونوعية صخور القاعدة غير معروفة. ولهذا فإن الدراسة الحالية تمثل دراسة إستطلاعية لمعرفة جيولوجية تحت السطح للمنطقة.

أظهرت الدراسة أن المجالين الإقليميين الجذبي والمغناطيسي يزدادان بمعدل ٤٨, ٠ملي كال/كم و٢٠٢ كاما/كم بإتجاه الشمال الشرقي (بإتجاه مدينة شقلاوة). وهذا يدل على أن عمق القاعدة يقل بهذا الإتجاه. حيث وجد أن عمق القاعدة

في أربيل ١٢,٧كم بينما قرب شقلاوة١٠,٧ كم تحت مستوى سطح البحر، كما وجد أن سمك القشرة الأرضية بالقرب من أربيل ٣٨,١ كم تحت مستوى سطح البحر. إن هذا التغير في عمق صخور القاعدة ربما يمثل إرتفاع موضعي في القاعدة أو ربما يمثل الطرف الجنوبي الغربي لطية سفين الأقليمية. غير أن الدراسة لم تظهر أي علاقة مميزة بين وضعية صخور القاعدة والإنتقال من منطقة أقدام التلال إلى منطقة الطيات العالية.

أظهرت الدراسة أيضاً وجود إثنان من الشواذ الجذبية المحلية الموجبة والتي فسرت على أنها تراكيب ضمن الغطاء الرسوبي. الشذوذ الجذبي الموضعي قرب قرية ملا عمر فسر على أنه تركيب منخفض ضمن تكوين البختياري الأسفل والذي ملىء في ما بعد بترسبات من تكوين البختياري الأعلى، بينما الشذوذ الجذبي الموضعي في منطقة صلاح الدين وجد بأنه نتيجة طية بيرمام داغ المحدبة.