*J. Univ. Kuwait (Sci.)* **14**, 1987

# Gravity traverses in the State of Kuwait

W. E. K. WARSI AND HAMID O. ALI

*Department of Geology, University of Kuwait, P.O. Box 5969, Safat 13060, Kuwait*

## ABSTRACT

A programme of regional gravity measurements has been initiated in the State of Kuwait and three preliminary traverses have been made. These traverses describe the characteristics of the regional field. Variations in the upper crustal geological structure are indicated by the presence of 10–15 mGal anomalies. Systematic gravity measurements can be useful in mapping the orientation and extent of such anomalous structures.

## INTRODUCTION

Measurement of the Earth's gravity field has many applications. Among its various uses, gravity data can provide a valuable insight into the subsurface structure. Mass distributions associated with tectonic structures often show prominent gravity anomalies, and gravity surveys can provide independent data control in tectonic mapping. Surveys have become simpler and relatively inexpensive since the advent of high sensitivity portable gravimeters. Unfortunately, gravity data are not available for the State of Kuwait. Although gravity surveys were conducted in Kuwait during 1936–37 in connection with oil exploration (Milton 1967), the data are confidential and unpublished. In order to fill this basic data gap and make the information available in the public domain, a programme of regional gravity measurements has been initiated by the Department of Geology of the University of Kuwait. As a first step, traverses have been made to establish the characteristics of the regional gravity field. This paper is a preliminary report of the first phase of the project of comprehensive regional gravity measurements in the State of Kuwait.

In May 1984, about 50 gravity stations were measured along the highways in Kuwait (Fig. 1). The data from these stations provide information on gravity variations in north-south and east-west directions. A maximum variation of about 25 mGal is observed in Bouguer anomalies (BA). Free-air anomaly (FA) values show a similar variation. BA values generally decrease in all directions away from Kuwait City. Bouguer anomalies have a larger negative gravity gradient towards the west, which may be associated with the regional configuration of the Moho. A positive anomaly of limited extent in Dibdibah region indicates a shallow intra-crustal source.

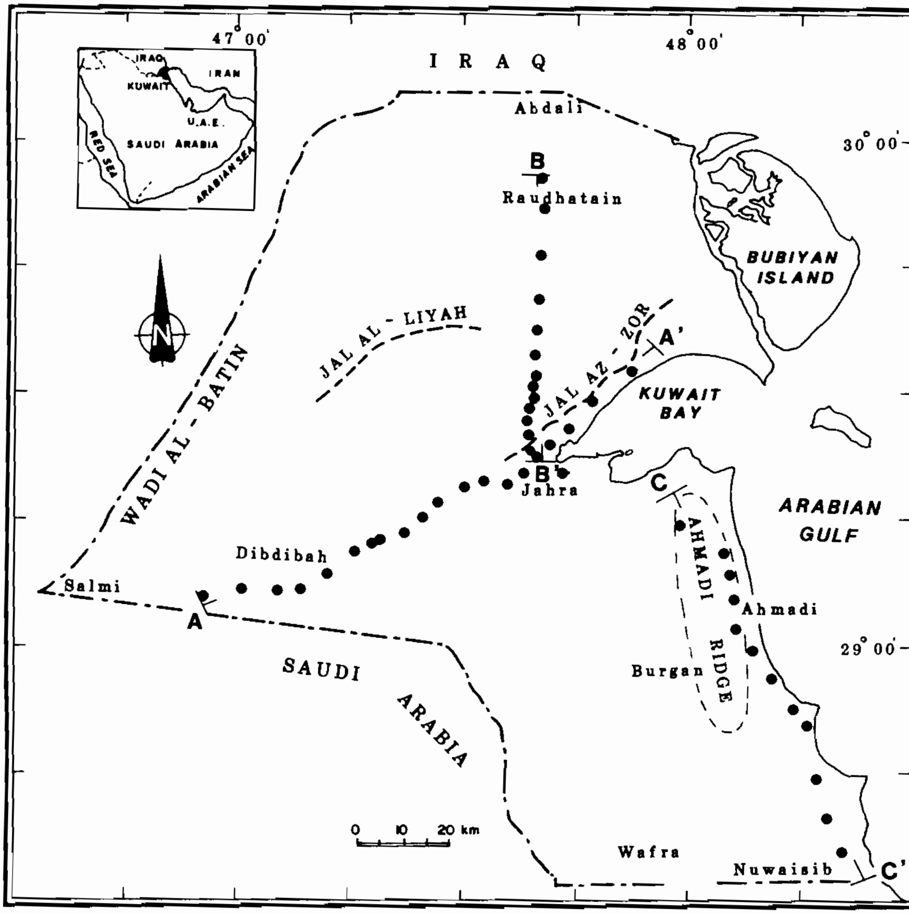


**Fig. 1.** Location map. Gravity stations are indicated by dots.

The gravity field across the Jal-Az-Zor escarpment, a prominent geomorphological feature in Kuwait, is only a topographic manifestation.

## THE DATA

Gravity surveying includes measurement of gravity, elevation and coordinates at observation points. These data are then used to define the anomalous gravity field. In this study gravity observations were made along the three main highways leaving from Kuwait to Abdali towards the north, Salmi towards the west and Nuwaisib towards the south. About 50 gravity stations were measured with a variable spacing of 2–8 km (Fig. 1). A Master Model Worden Gravimeter was used for gravity observations. The gravimeter drift was assumed to be linear within the loops which were 2–4 hours long.

Gravimeters measure only relative changes, so field measurements need to be tied to absolute gravity base stations. But absolute gravity values for the stations observed during this study could not be determined due to a lack of an absolute value base in Kuwait. The only international gravity base station WA2049 in Kuwait (ACIC, 1971) has been completely obliterated. Therefore, the anomalies are presented without an absolute scale and show only relative amplitudes.

Gravity anomalies are measures of variations in subsurface mass distribution, and are calculated by subtracting a theoretical gravity value for an assumed homogeneous earth model from the observed gravity value. Several theoretical formulae are available which describe gravity as a function of the station latitude. The most commonly used gravity anomalies are free-air and Bouguer anomalies, which are obtained by applying corrections based on station elevation. The free-air correction simply accounts for the effect of station height above the datum, usually mean sea level. Bouguer correction removes the effect of excess mass between the datum and the station. Free-air and simple Bouguer anomalies presented in this paper are based on the International Gravity Formula, 1967 (IGSN, 1971). A density value of 2·67 $g/cm^3$ has been used for the Bouguer correction. Perhaps a more appropriate value for the Bouguer slab density in this case would lie in the range 2·0–2·4 $g/cm^3$ as the near-surface rocks consist of lighter-density sediments. Bouguer anomalies based on such a value would be 0·02 mGal per meter more positive than those shown here. Since the topographic relief is flat and the elevations are small, curvature and terrain corrections have not been applied to the anomalies.

## REGIONAL GRAVITY VARIATIONS

The gravity data are presented as profiles. Three profiles have been projected along lines AB′A′, BB′ and CC′ (Figs 2–4) from the gravity station distribution shown in Fig. 1. In general, the gravity field in Kuwait varies smoothly, suggesting a largely homogeneous geological structure. A maximum variation of about 25 mGal is observed in Bouguer anomalies. Free-air anomalies exhibit a similar change. Bouguer anomalies show a general decrease north, west and south from Kuwait City. The maximum negative BA gradient of about −0·25 mGal/km is observed on profile AB′A′ trending in a NE–SW direction. Profiles BB′ and CC′, oriented in a northerly direction, exhibit a much smaller gradient, about −0·1 mGal/km. These observations

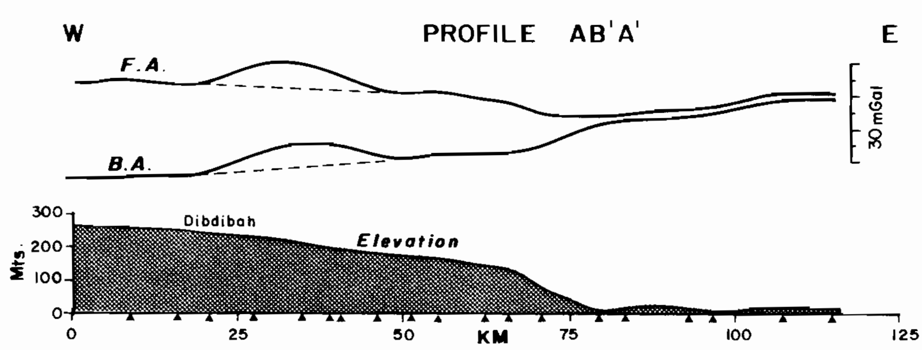


**Fig. 2.** Profile AB′A′. Free air (FA), Bouguer anomaly (BA) and elevation data have been projected along line AB′A′ from the station distribution shown in Fig. 1. The gravity scale is not absolute and shows only relative variations. Triangular symbol along the distance axis shows station control for the profile. Note the positive anomaly around Dibdibah.

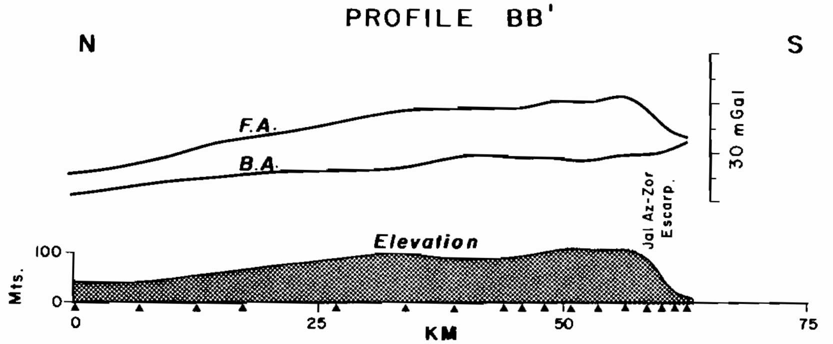


**Fig. 3.** Profile BB′. See Fig. 2 for explanation. Free-air anomaly across the Jal-Az-Zor escarpment arises primarily from topography.

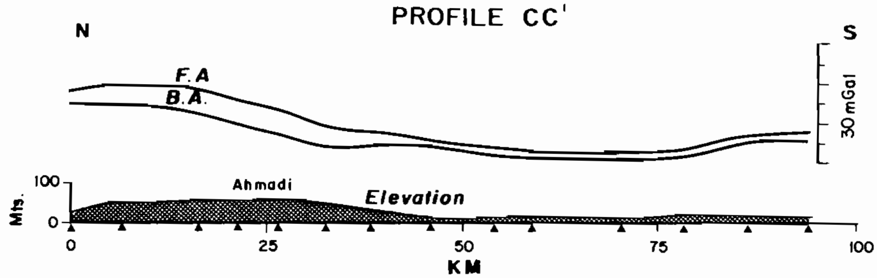


**Fig. 4.** Profile CC′. See Fig. 2 for exaplanation. The Ahmadi Ridge is associated with a positive anomaly.

are consistent with north-westerly regional tectonic trends of the Arabian foreland such that the maximum change would be observed in a NE–SW direction. Landward negative gravity gradients are typical of coastal regions. It is likely that the negative gradient in part reflects a general deepening of the Moho towards the west. The sediments overlying the basement are believed to thicken towards the east and should show a negative gradient seaward. The relatively small observed value of the BA gradient apparently results from the effect of platform sediments offsetting the gradient associated with Moho.

Superimposed upon the smoothly varying gravity field are some anomalies caused by shallower sources. A positive anomaly of about 10 mGal and a width of about 25 km is observed in the vicinity of Dibdibah (Fig. 2). Limited data distribution does not provide sufficient information on the orientation and extent of the anomaly. It falls over the Dibdibah Formation, which is of late Miocene–Pleistocene age and consists primarily of coarse-grained sandstones with pebble, cobble gravel and conglomerates. Local concentration of gravel and conglomerates can give rise to positive gravity anomalies. It is not likely that this anomaly is caused by such concentrations in the Dibdibah Formation. Accumulations of the order of 500–600 m would be needed to generate the observed anomaly, and the thickness of the Dibdibah Formation is considerably smaller than this.

The source of this anomaly appears to be located at shallow depths below the Dibdibah Formation. Maximum depth to the source of the anomaly has been estimated using the method of Skeels (1963). If a density contrast of 0·25 to 0·30 g/cm$^3$

is assumed, then this anomaly can be caused by a body lying shallower than 3 km and having a maximum thickness of 1 km.

The Jal-Az-Zor escarpment shows a 10 mGal free-air anomaly (Fig. 3). This anomaly is probably topographic in nature as there is no BA associated with it. Had there been a fault here, the Bouguer anomaly profile would be expected to show a step across it. The amplitude of such an anomaly depends on the fault offset, thicknesses and densities of the layers involved. It has been suggested that the Jal-Az-Zor escarpment has formed along a fault extending to depth (e.g. Salman 1979). A lack of anomaly could result from insignificant density contrast between rocks on either side of the fault. Gravity alone, however, is insufficient to determine if the escarpment has a deeper tectonic control.

Profile CC′ is oriented along the regional strike and shows a generally flat gravity field to the south of Ahmadi (Fig. 4). A notable feature on this profile is a broad positive anomaly between Kuwait City and Ahmadi. This anomaly falls on the eastern flank of the Ahmadi Ridge which is a broad topographic features, striking in a NNW–SSE direction. The profile crosses the ridge obliquely and a maximum anomaly of about + 15 mGal is observed towards the northern end of the ridge. The gravity field shows that the ridge is not merely a topographic feature. Positive BA and FA are consistent with the anticlinal structure of the ridge suggested by seismic data (Milton 1967).

## BOUGUER ANOMALIES VERSUS ELEVATIONS

Generally older geologic provinces such as the Arabian Shield and the Arabian Platform exhibit complete isostatic compensation. In regions of isostatic equilibrium Bouguer anomaly change with height is found to be in the neighbourhood of − 112 mGal/km (Woollard 1959). Bouguer anomalies in Kuwait decrease rather slowly with increasing elevations. A linear regression between the BA values and elevations yields a slope of − 55 mGal/km (Fig. 5). There may be some uncertainty due

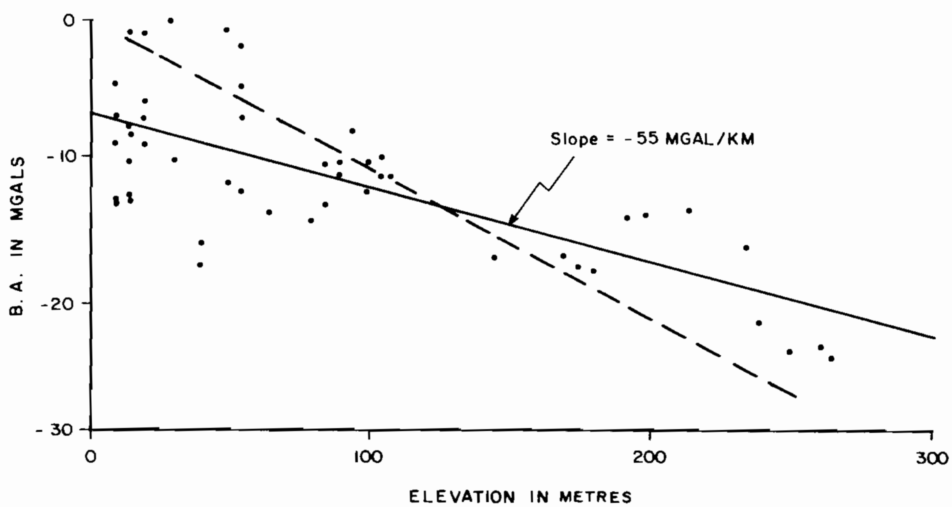


**Fig. 5.** Plot of Bouguer (BA) anomalies versus elevation. Solid line is the least square fit to the observed data. Broken line represents the relationship for isostatically-compensated regions.

to limited data distribution but this value appears to be significantly different suggesting an isostatic undercompensation. It is possible that this undercompensation is local in nature and could result from thinner than normal crust, or higher crust-mantle density contrast. Additional data control on regional crustal structure would be necessary to resolve the nature of isostasy in Kuwait.

## CONCLUDING REMARKS

The subsurface structure in Kuwait is uniform and uncomplicated. The region has been a locus of sedimentation since the Paleozoic time and has been subjected to only gentle tectonic movements. The small gravity gradients observed along the profiles are in agreement with the general geologic structure outlined above. However, the gravity field in Kuwait is not monotonic. Lateral variations in the shallower subsurface geological structure are suggested by the presence of 10–15 mGal anomalies. The data presented here demonstrate the potential of regional gravity measurements in mapping the orientation and extent of such upper crustal anomalous structures.

A systematic regional gravity survey is now projected and will provide a complete areal coverage of Kuwait. International gravity base ties will also be made to bring the measurements to the absolute datum. The gravity maps compiled from these measurements should provide a valuable insight into the tectonic framework of Kuwait.

## ACKNOWLEDGEMENTS

We are thankful to Professors Douglas Shearman and David Almond for their valuable suggestions and critical reading of the manuscript. This research was supported by the Research Council of the University of Kuwait Grant No. SDG 103.

## REFERENCES

**ACIC. 1971.** World relative gravity reference network: Asia, Australia, and Pacific Ocean. U.S. Air Force Reference Publication No. 25.

**IGSN. 1971.** Geodetic reference system 1967. Special Publication No. 3. International Union of Geodesy and Geophysics, Bureau Central de l'Association Internationale de Géodésie, Paris, 116 pp.

**Milton, D.I. 1967.** Geology of the Arabian Peninsula, Kuwait. USGS Professional Paper 560-F, 7 pp.

**Salman, A.M.S. 1979.** Geology of Jal-Az-Zor–Al Liyah area, Kuwait. Unpublished M.Sc. Thesis, Kuwait University, 128 pp.

**Skeels, D.C. 1963.** An approximate solution of the problem of maximum depth in gravity interpretation. Geophysics **27**: 724–35.

**Woollard, G.P. 1959.** Crustal structure from gravity and seismic measurements. Journal of Geophysical Research **64**: 1521–44.

(*Received 16 February 1985, revised 23 March 1986*)

# قياسات الجاذبية على مسارات مختارة عبر دولة الكويت

وارس وارسى وحامد علي
قسم الجيولوجيا بجامعة الكويت ،
ص . ب ٥٩٦٩ ، الصفاة ١٣٠٦٠ ، الكويت

**خلاصة**

تمشيا مع المبادرة الخاصة بقيام برنامج أقليمي لقياسات الجاذبية بدولة الكويت فقد تم أخذ القياسات بصفة مبدئية على طول ثلاثة مسارات عبر دولة الكويت . وقد أوضحت هذه القياسات سمات المجال الاقليمي للجاذبية ، حيث اتسمت البنية الجيولوجية للقشرة الأرضية العليا بشواذ ثقيلة تتراوح قيمتها بين ١٠ و ١٥ م جال ، ويستدل من الدراسة على أن وضع برنامج منتظم لقياسات الجاذبية قد يساعد في معرفة اتجاه وامتداد مثل هذه الشواذ في البنية الجيولوجية .