# APPLICATION OF TERRAIN CORRECTION FOR MICROGRAVITY DATA

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## ABSTRACT

Microgravity measurements were carried out on a hill, which has relative elevation of about 30 m above the surroundings. The elevated area is located near the center of Sulaimaniyah city in the northeast of Iraq. The measurements were carried out for detecting any subsurface cavity and to delineate weakness zones, in comparison with the surroundings for engineering purposes.

One hundred and five microgravity stations were measured in this survey. Conventional corrections, Bouguer slab and free air in addition to terrain correction were applied to get Bouguer gravity values. The website Google earth was utilized to obtain elevations and topography of the hill for calculating the terrain correction. 3D contour maps were drawn to represent three cases of Bouguer gravity values: the first was without terrain correction, the second includes terrain correction, extending to 50 m around each microgravity station and the third one was with terrain correction extending to 100 m around each microgravity station. The comparison between the three maps showed that it is not preferable to calculate the huge mass of the surroundings, like the elevated hill, when the area under study is small and the anomaly is small too, but it is preferred to calculate terrain correction, when delineation of weakness zones for engineering geological purposes is dealt with.


# تطبيق تصحيح التضاريس على بيانات الجاذبية الدقيقة

**سمير رشدي حجاب**


**المستخلص**

أنجزت القياسات الجذبية الدقيقة على تل ذو ارتفاع نسبي، حوالي 30 متر عن المناطق المحيطة به، يقع هذا التل قرب مركز مدينة السليمانية في شمال شرق العراق. لقد أجريت القياسات بهدف التحسس لأي تكهفات تحت الأرض وتحديد مناطق الضعف بالمقارنة مع المناطق المحيطة، للأغراض الهندسية.

تم قياس مائة وخمسة محطات جذبية دقيقة وتطبيق التصحيحات التقليدية Bouguer slab و free air بالإضافة إلى terrain correction للحصول على قيم بوجير الجذبية. لقد تمت الاستفادة من موقع Google earth للحصول على ارتفاعات وشكل التل وذلك لحسابات terrain correction، حيث رسمت ثلاثة خرائط كنتورية بثلاثة أبعاد لتمثل ثلاثة حالات من قيم بوجير للجاذبية: الحالة الأولى بدون تطبيق terrain correction، الحالة الثانية مع تطبيق terrain correction لمدى 50 متر حول كل محطة جذبية دقيقة والحالة الثالثة مع تطبيق terrain correction لمدى 100 متر حول كل محطة جذبية دقيقة. أجريت مقارنة بين هذه النتائج وأظهرت النتائج بأنه ليس من المفضل حساب كتلة كبيرة من المناطق المحيطة، مثل تل مرتفع، عندما تكون منطقة الدراسة صغيرة والشواذ صغيرة أيضاً، لكن من المفضل حساب terrain correction عندما نتعامل مع تحديد مناطق الضعف للأغراض الجيولوجية الهندسية.


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## INTRODUCTION

Carrying out geophysical projects for detecting and delineating cavities and weakness zones sometimes face restricting circumstances, such as the assigned period, absence of topographic map of convenient scale, and absence of GPS instrument in the field to read the elevations around the studied area. All these aspects form obstacle to measure the terrain correction.


Fig.1: Location map

A hotel of 15 floors is to be built in the studied area, which is located near the center of Sulaimanyiah city in the northeast of Iraq (Fig.1). Two boreholes were located in the area (Borehole 1 and 2); one hundred and five gravity stations were prepared to be measured just before drilling (Fig.2). Microgravity measurements were conducted by Hijab (2005), with the aim of delineating cavities, fractures, weakness zones and other features affecting the construction of the proposed hotel. The building is cited on an area, which represents a small portion of that hill. The accuracy of the method depends on the corrections applied; terrain correction has vital importance in producing accurate results. Since the shape of the hill is irregular in its elevation, it was found that it is necessary to construct a topographic map of the surroundings. The data was obtained from Google earth Website then the topographic map was constructed by means of SURFER software.

## GEOLOGICAL SETTING

Geologically, only upper part of Shiranish Formation is exposed in the site, it is composed of light grey, fine crystalline, and well bedded limestone. The beds dip about $25^{o}$ NW wards in the studied area. Generally, the lithologic column starts with soil with fragments of limestone as Quaternary sediments, with thicknesses ranging from (0.3 – 0.5) m, followed downward to depth of about 20 m by slightly to moderately weathered, fine crystalline limestone (Kapigian *et al*., 2005). Borehole 1, shows bedded limestone highly jointed and fractured with calcite and iron oxide fillings the bores. Borehole 2 shows limestone, light grey thinly bedded and fine crystalline.

Structurally, the studied area is located within an anticline, within Sulaimaniyah Subzone (Al-Kadhimi *et al*., 1996), it is affected by tectonic movements during Alpine Orogeny, faulted strata were observed along the newly road cut in the southwestern part of the hill.

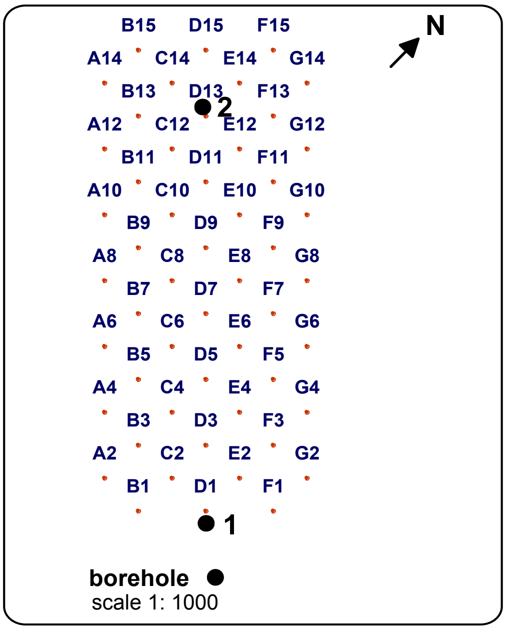


Fig.2: Distribution of gravity stations in the studied area

**MICROGRAVITY METHOD**

Microgravity is the most promising surface geophysical method that can detect cavities and weakness zones. It depends on the physical parameter, the density of rocks. The increase of density of rocks means positive anomalies in Bouguer gravity values, while the decrease of the density means negative anomalies in the Bouguer gravity values. The increase of density contrast among rocks gives the best results in distinguishing the anomaly (Jakosky, 1961).

Topographic works included measuring the elevations of one hundred and five stations distributed on seven parallel profiles (A, B, C, D, E, F, and G) as shown in Fig. (2), the distance between each adjacent profiles is 5 m. Each profile contains 15 stations; the distance between adjacent stations is 5 m. Elevations of the stations were measured relative to the base station, using leveling instrument Wild A2 that has an accuracy of 2 mm/ Km.

The gravity measurements were conducted using Lacoste and Romberg model D-198 gravimeter. The measurements included twenty three control stations, which were used to determine the standard deviation of the measurements. The results were found to be equal to ± 6 μ Gal; this represents the accuracy of the measurements. Twenty three stations were taken into consideration in addition to twenty eight repeated base stations taken during the period of the survey to establish the drift curves**.** Nettleton's method was applied to estimate the mean density of the rocks. The density deduced was 1.95 gm/ $cm^3$. The conventional gravity corrections (Free air, Bouguer slab) were carried out to eliminate elevation variation effects of gravity measurements in order to obtain the relative Bouguer values. The used density was 1.95 gm/ $cm^3$ too. Latitude correction has no effect, since we are dealing with a small area of 70 m length and has a deviation of 45 degree from the north, as shown in Fig. (2).

**TERRAIN CORRECTION**

The website Google earth was used in introducing the shape and the elevation of the hill for calculating the latitude correction. There are good facilities in the website that can be utilized, such as elevation acquirement for each point on the area under study, and measurement of the distance between any proposed points in addition to acquire the general shape of the whole area. The limitation in utilizing this website is, it should have a good marker on the studied area that could coincide with that in the website and the direction of the profiles of the gravity stations must be corrected according to the north.

Regular distribution of the points around the microgravity stations were carried out on the view of the studied area at that website (Fig.3). By recording the elevation at any chosen point, many readings were acquired, consequently a contour map was drawn (Fig.4), then the terrain correction was applied. The hill is gently slopping to the north and there is a moderate slope to both sides of the hill. It shows a relative elevation of about 30 m above the surroundings. The width of the studied area is 30 m (Fig.3).

Hammer chart of scale 1: 500 for calculating terrain correction was applied for recording the elevations around each station. The density of 1.95 gm/ $cm^3$ was used. Software Gravpac was used to calculate terrain corrected values, the program, depends on the hammer chart or sloping wedges methods, it can calculate terrain corrected values to any given distance. Two distances around each gravity station were chosen, they represent a radius of 50 and 100 m, respectively. The effect of terrain corrected values, which exceed more than 100 m may give equal regional effect on the microgravity stations.

Graphical method was used to separate the regional anomalies from the residual anomalies for the measured profiles A, B, C, D, E, F and G. Computer program Grav2dc 2.10 was used to interpret seven profiles. The program gives model, which may provide good information about the density contrast between the bodies and the surrounding rocks.


Fig.3: The studied area, as deduced from Google earth image

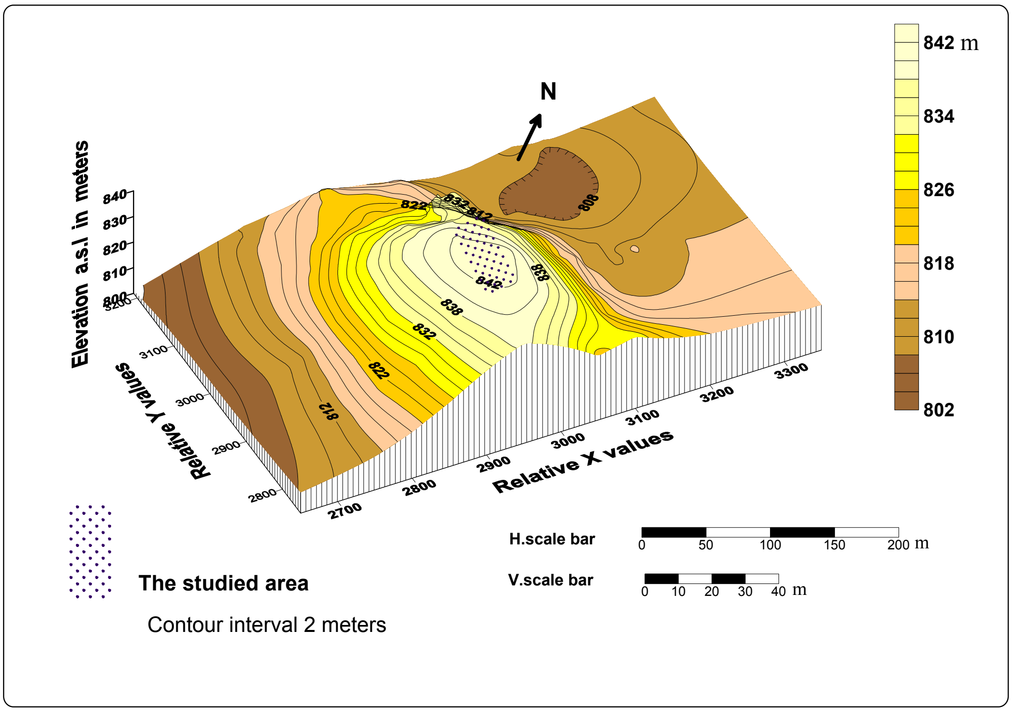


Fig.4: Topographic map of the hill derived from Google earth data

## THE RESULTS

In comparison of the acquired geophysical results with those of the boreholes, which were drilled in the studied area, a model of dipping beds of $25^{o}$ was drawn with Grav2dc 2.10 software indicating that a density contrast of about (0.1 – 0.2) gm/ $cm^3$ less than the surrounding rocks was found in the southern part of the studied area. A density contrast of about (0.08 – 0.18) gm/ $cm^3$ higher than the surrounding rocks in the northern part of the studied area was found too. The low density contrast was interpreted as a result of bedded limestone, highly jointed and highly fractured in the borehole 1. While the high density contrast was due to presence of thinly bedded and fine crystalline limestone, in the borehole 2.

3D Bouguer contour maps with interval of 20 microgals (which represent more than three times of the accuracy) were drawn using SURFER software, led to three cases of results. Figure (4A) represents Bouguer gravity values without terrain correction. The low values are obvious in the southern part of the area, which indicate that this part of the studied area may be jointed and fractured more than the northern part (Fig.5). Moreover, Fig. (4A) shows low Bouguer values in the northern part of the studied area (dark colored); it could be due to small areas of weakness zones. Figure (4B) represents Bouguer values included terrain correction values to a distance of 50 m, for each microgravity station. It shows that there is increase in Bouguer values due to addition of terrain correction, and the low values in the southern part of the studied area are still obvious. It was noticed the disappearance (almost) of small areas with weakness zones in the northern part of the studied area.

The third case (Fig.4C) represents Bouguer values included terrain correction to a distance of 100 m, for each microgravity station, this distance may cover the entire hill and reaches its feet in three directions, north, east and west. This case shows that there is an increase in contrast of Bouguer values, although Bouguer values have been increased by addition of terrain correction, but the low Bouguer values were not changed. The small weakness zones in the northern part of the studied area disappeared completely.

## DISCUSSION

Terrain correction is often an essential correction in the calculation of Bouguer gravity values. When computing terrain correction, it is necessary to estimate the mass of the surrounding terrain and the dimensions of a given mass. To perform this correction, it is necessary to have information about the locations of microgravity stations and the shape of the topography surrounding the studied area. Sometimes, microgravity survey is carried out in a small area, the calculated terrain correction may not go far from the microgravity stations; it could be a few tens of meters, the distance beyond this extent will give regional effect or same values on the microgravity stations. Thus, there will be a need for a topographic map of large scale like 1: 500 or 1: 200 in order to use Hammer chart for calculating terrain correction. These scales of maps are most often not available. The alternative solution is either using digital topographic databases, which are recently available, or using GPS instrument. But, sometimes Google earth website may be the alternative when is available. On the other hand, when the area under study is small, the computation of terrain correction of the surroundings should be in close distance. It may be a few meters away from the microgravity station, especially if the measurements are in a rugged area.

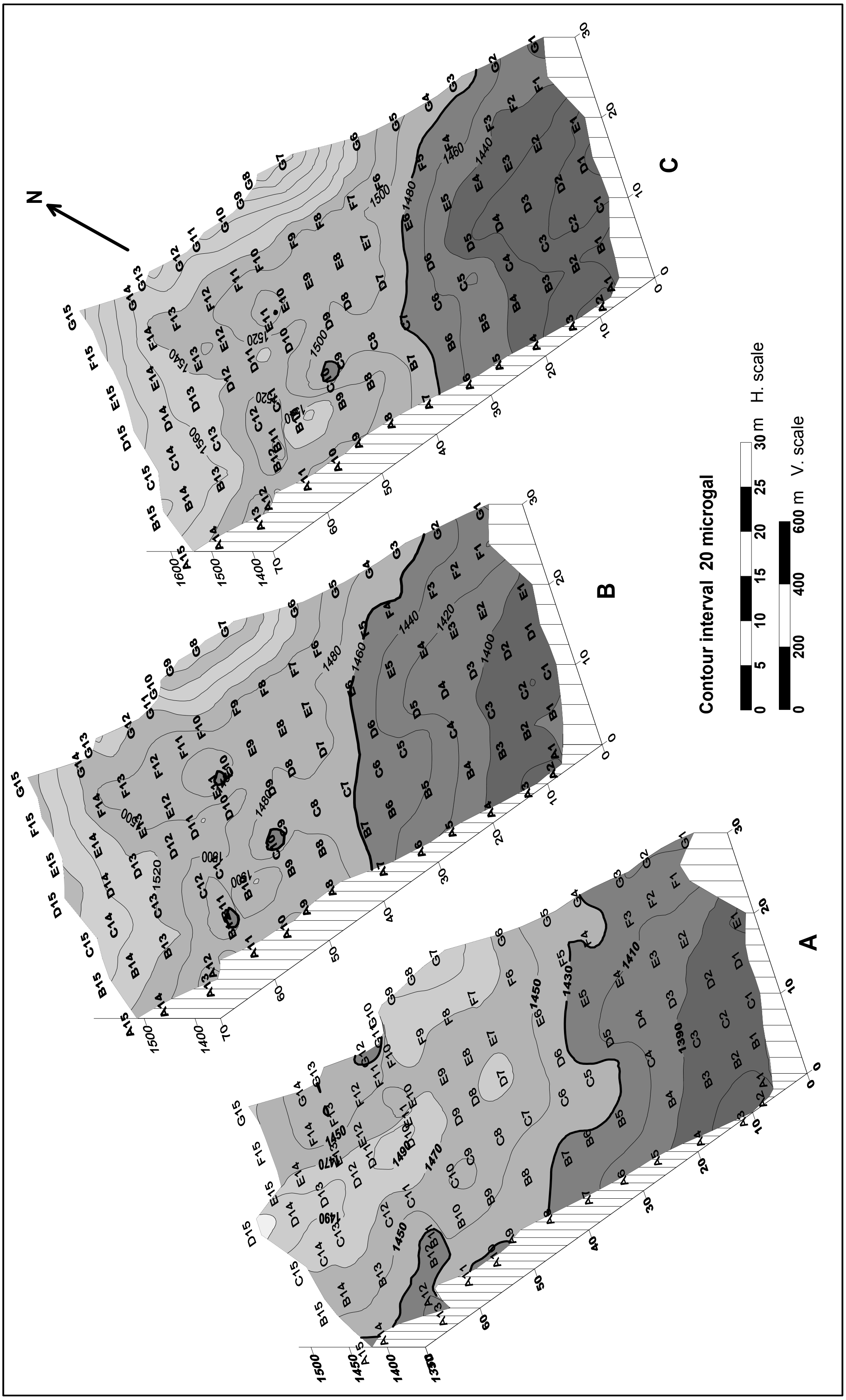


Fig.5: Comparison between 3D Bouguer values, A) without terrain correction, B) Bouguer values with terrain correction to a distance of 50 m and C) Bouguer values with terrain correction to a distance of 100 m

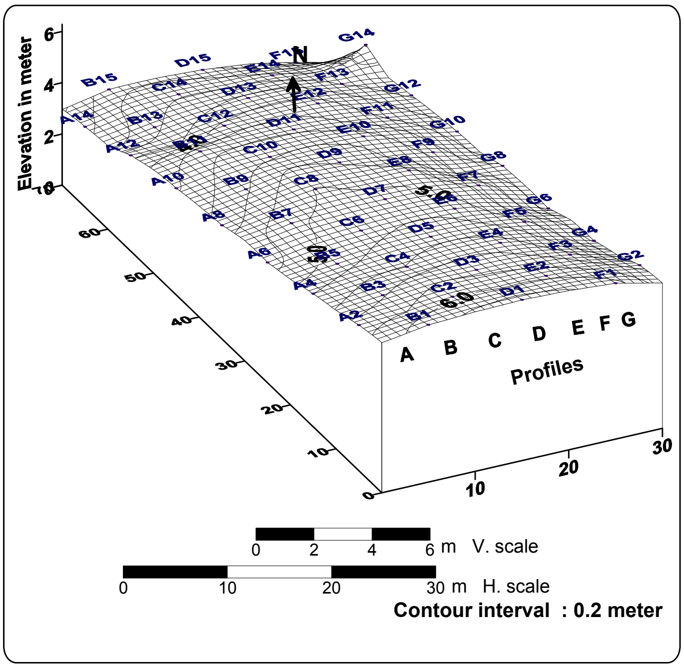


Fig.6: Contour map measured by microgravity (relative elevations)

Figure (6) shows the topography of the studied area, which was drawn by using the elevations of the microgravity stations. It exposes nearly smooth area. It coincides with the elevations obtained from Google earth website and this shows that there is an acceptable accuracy in the elevations of this website.

The residual microgravity map was put aside in this study. The residual gravity had used only in drawing a model of 2D, as stated before. The obtained three cases of the results could be explained as follow: In the **first case** (Fig.4A), the small anomalies in the northern part of the studied area were obvious with the details, since no terrain correction was used in small smooth area. In the **second case** (Fig.4B), terrain correction was used with distance of about 50 m. The small and detailed anomalies were affected in opposite direction. In the **third case** (Fig.4C), terrain correction was used with a distance of about 100 m. The small and other details are hardly distinguishable, but the low Bouguer values at the lower part of the studied area are now more obvious. As mentioned, the distance of 100 m that was used to calculate the terrain correction, almost covered the entire hill.

## CONCLUSIONS

- Terrain correction on microgravity measurements should not always be calculated. It depends on the circumstances of the area under study, and the purpose of the survey.
- If the purpose of the study is searching for local anomalies within small smooth area, it is not preferable to calculate the huge mass of the surroundings like an elevated hill and adding it as a terrain correction, it will mislead the small details.
- If the studied area is examined to delineate weakness and competent zones for engineering purposes, then it is preferable to calculate the terrain correction, it will make the results more obvious, and especially if the area is relatively large, then terrain correction should be performed, this is obvious from increasing Bouguer values contrast.
- In multi purpose microgravity surveying, it is preferable to get two results of terrain correction, for close and far distances around microgravity stations.
- The rugged areas are considered as a basic requirement to achieve terrain correction, even if they were small areas.
- The results showed that it could delineate the weakness and competent zones in comparison with the three mentioned cases.
- There is a good coincidence with the physical properties as acquired from the samples of borehole 1 and borehole 2 with the three cases.

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