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Interpretation of a Gravity Profile across the Southern Part of the Hon Graben, Libya

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Abstract. A 90 km long profile with 251 gravity stations was measured across the southern part of the Hon Graben. From a combination of a previously published ΔT anomaly (Schult, 1974) and the Bouguer anomaly $\Delta g''$, both measured along the same profile, a probable density structure for the southern part of the Hon Graben has been derived. The models show a sharp increase of thickness of Upper Cretaceous and Tertiary sediments at the graben borders. The thickness of 1 800 m of these sediments, which has been obtained from geological observations, is compatible with the gravity models assuming a density contrast of 0.2 g/cm^3 with respect to older sediments. In the central part of the graben a rise of the Pre Upper Cretaceous rocks, reaching up to about 300 m below the surface, divides the Hon Graben, at least in the southern part, into two separate troughs. In the western part of the graben border basic intrusions seem to exist, which are probably connected with the adjacent Jebel Soda volcanism.

Key words: Gravimetry – Hon Graben – Libya.

1. Introduction

The tectonic structure of the Sirte Basin in Libya is characterized by a number of troughs striking NNW-SSE. They extend from the Djebel Harudji in the southeast towards the northwest into the area between Malta and Tunesia which is now covered by the Mediterranean Sea. A detailed description of the tectonic development of the Sirte Basin has been given by Klitzsch (1970). It is assumed that the formation of the troughs and rises in the Sirte Basin started in Upper Cretaceous as a consequence of east-west directed tensions. The Hon Graben, about 260 km long and between 40 and 60 km wide, is one of the most dominant structures in the western part of the Sirte Basin. It was described for the first time by Knetsch (1950). Results of field magnetic measurements in the Hon Graben were published by Schult and Soffel (1971) and Schult (1974).

The present gravity survey was made in order to obtain more detailed information about the structure of the Hon Graben.

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* Now with Mobil Oil, Celle.

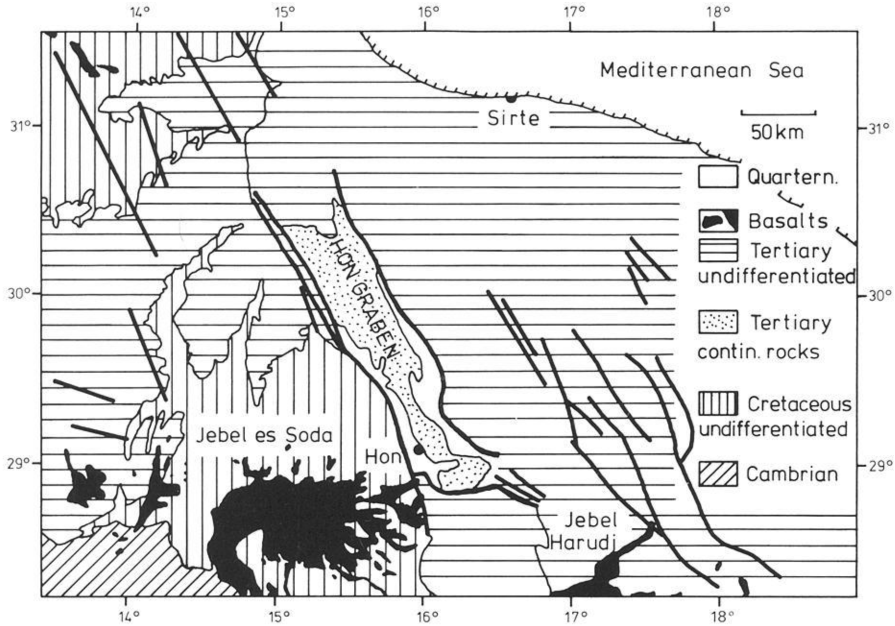

Fig. 1. Simplified geological map of the western part of the Sirte Basin in Libya. (Redrawn from the Geological map of Libya, scale 1:2000000)

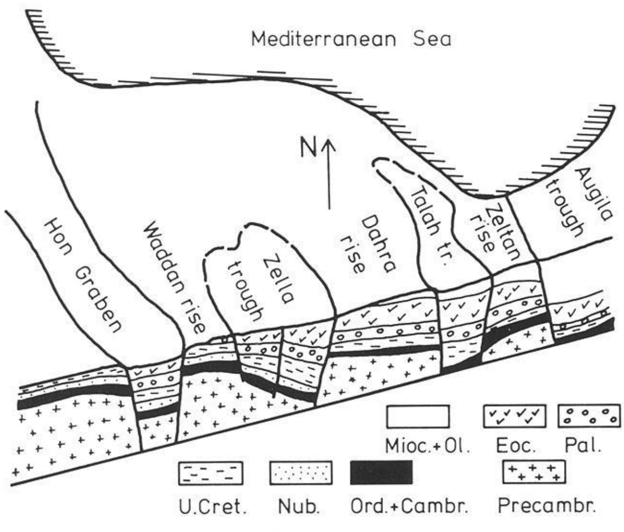

Fig. 2. Simplified cross section of the troughs and rises in the western part of the Sirte Basin. (Redrawn from Klitzsch 1970.) Conventional abbreviations for the formation names. *Nub:* Nubian sandstone, Mesozoic age

2. Geology of the Investigated Area

Fig. 1 shows the position of the Hon Graben on a simplified geological map of Libya (redrawn from the Geological map of Libya, scale 1:2000000). According to Klitzsch (1970), the formation of the Hon Graben was initiated in Upper Cretaceous. It has been shown by drilling about 50 km north of the profile that in the graben, at a depth of 1 800 m, the Upper Cretaceous sediments lie immediately on top of the Early Mesozoic Nubian Sandstone overlaying Paleozoic series. The Upper Cretaceous sediments are supposed to have a thickness of 550 m in the graben. In the southern part of the Hon Graben they are covered by Paleocene and Eocene sediments with a thickness of about 1 000 m. During the Oligocene vertical movements on both sides of the graben have continued ending in the Miocene as is revealed by further sedimentation of Oligocene and Miocene sediments. The total thickness of sediments of Upper Cretaceous and younger age is thought to be at least 1 800 m in the southern part of the Hon Graben. At present the graben borders consist of Upper Cretaceous sediments which are occasionally covered by thin layers of Lower Paleocene sediments.

Fig. 2 has been redrawn from Klitzsch (1970) and shows a simplified block diagram of the troughs and rises in the southern part of the Sirte Basin.

In its present from the Hon Graben shows a marked topographic depression between 100 and 300 m only in its southern part. The fault zones on both sides are between 1 and 2 km wide in the southern part of the graben, becoming wider towards the north.

The center of the volcanic area of Jebel Soda (volcanic activity between Miocene and Pliocene) is situated about 100 – 150 km southwest of the Hon Graben. Some flows reach very close to the southwestern margin of the Hon Graben. Field magnetic investigations by Schult (1974) indicate the presence of basic intrusions near the southwestern graben border.

3. Gravity Measurements

Fig. 3 shows the position of the measured profile across the southern part of the Hon Graben. It extends from the Jebel Waddan in the east along tracks and roads through Waddan, Hon and Sokna to the small oasis Bir el Machrigh in the west. It has a length of 90 km with 251 gravity stations at an average distance of 360 m.

Altitude differences and distances between measuring stations were determined by levelling. We estimate that the altitude differences between two stations are correct within ± 0.5 cm and the distance within ± 1 m. Gravity differences were measured with a Lacoste-Romberg gravity meter, model G. At each 5th or 6th station two or three repeated measurements were carried out at intervals of 2 to 3 hrs in order to eliminate the drift of the instrument and the effect of the earth's tides.

For interpretation, the topography and the gravity data were projected on a profile perpendicular to the graben. The projected profile has a length of 78 km and is also shown in Fig. 3. The topography along the projected profile is shown in the upper part of Fig. 4. The western graben border east of Sokna (hatched area) is only poorly recognizable while the eastern border (east of Waddan, hatched area) is much more pronounced. The plateau of Jebel Waddan lies about 300 m above the inner part of the Hon Graben.

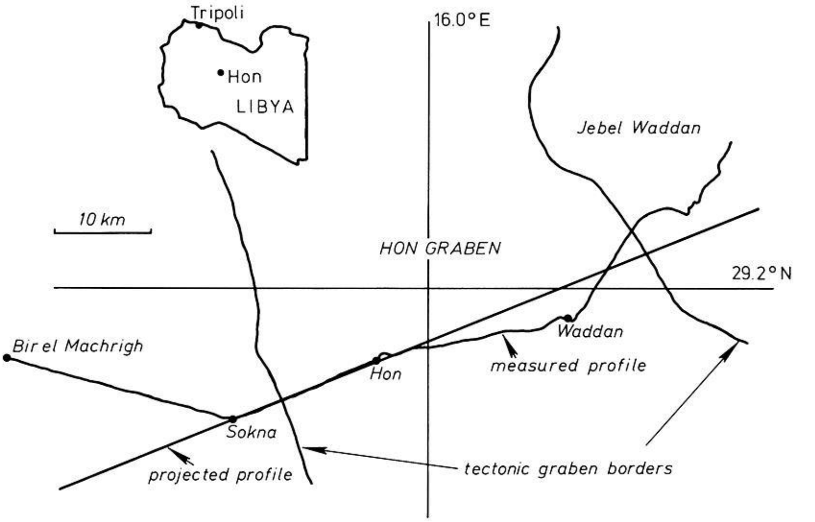

Fig. 3. Position of the measured and projected profile in the southern part of the Hon Graben

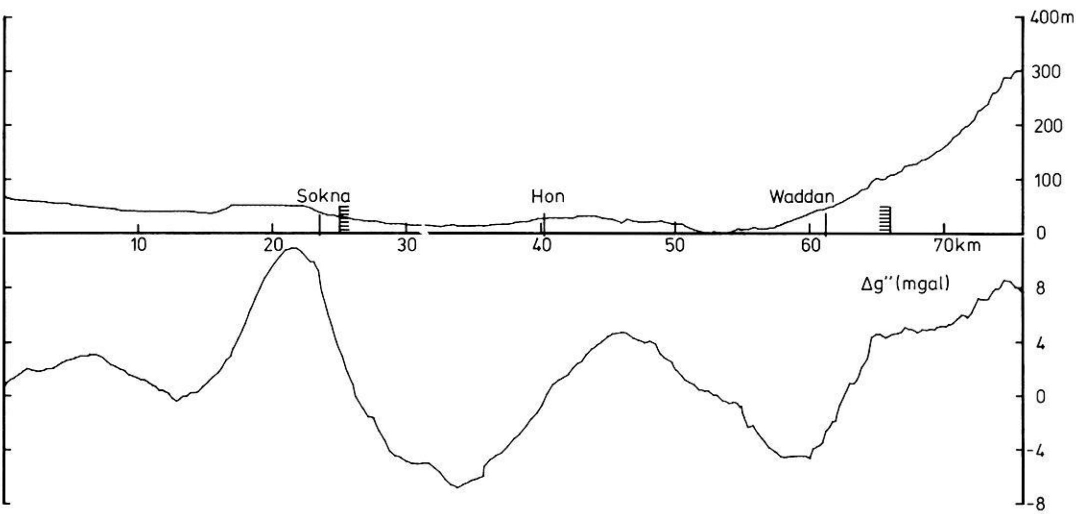

Fig. 4. Topography and Bouguer anomaly $\Delta g''$ along the projected profile

4. Determination of the Bouguer Anomaly along the Projected Profile

All gravity measurements have been referred to a base station near Waddan at the topographically lowest point of the profile. The north-south gradient of the earth's gravity field was computed from the international gravity formula. Topographic corrections, estimated on the basis of two-dimensional models (Jung, 1961), for stations within the Hon Graben were always smaller than 0.1 mgal and therefore neglected. The influence of the Jebel Soda southwest of the Hon Graben was also smaller than 0.2 mgal. Only in the eastern part of the profile approaching the Jebel Waddan topographic corrections became necessary. An accurate determination of the topographic corrections between km 70 and km 78 of the projected profile was not possible as an exact topographic map of the Jebel Waddan was not available. From the existing large-scale maps and from our own altitude determinations the topographic corrections were estimated with two-dimensional models. The Bouguer anomaly between km 70 and km 78 of the projected profile is therefore only reliable within ± 1 mgal, in contrast to the rest of the profile where the accuracy of the Bouguer anomaly is estimated to be ± 0.2 mgal. However this part of the profile is of minor importance for the interpretation of the gravity anomaly in the Hon Graben. Within the Hon Graben a density of 2.0 g/cm^3 for near surface rocks has been used for the calculation of the Bouguer correction. For the areas outside the graben a density of 2.3 g/cm^3 was taken. Due to the small altitude differences in the Hon Graben area the choice of the density of the near surface rocks has only little influence on the Bouguer anomaly.

Fig. 4 shows the topography and the Bouguer anomaly $\Delta g''$ along the projected profile. At both margins of the graben (hatched areas) a decrease of the Bouguer anomaly of about 8 to 10 mgal with respect to the graben shoulders can be observed. In the inner part of the graben a Bouguer gravity maximum of about 8 mgal is present. The western margin of the Hon Graben is characterized by higher Bouguer anomaly values than the eastern graben border. No general trend in the Bouguer anomaly (especially no east-west trend) can be recognized which could be indicative of a strong gradient of the regional field in this direction.

5. Interpretation of the Bouguer Anomaly

The ratio between the length, width and expected depth of the Hon Graben permits to consider it as a two dimensional structure. This justifies also the projection of the gravity data on a profile perpendicular to the strike of the graben as shown in Fig. 3 and Fig. 4.

The maximum horizontal gravity gradients of 2 mgal/km (on the average 1 mgal/km) and the small half-width of the anomaly on the western margin of the graben indicate that the sources of the Bouguer anomaly are located at rather shallow depth. The good correlation between the geologically known graben borders and the Bouguer anomaly $\Delta g''$ is obvious.

Two different two dimensional models for the density distribution in the Hon Graben are discussed. It is assumed in all models that $\Delta g''$ is caused by density differences within the top 2 km of the subsurface between the Upper Cretaceous and Tertiary sediments and the Lower Mesozoic and older rocks.

For model A (Fig. 5) a density contrast of 0.2 g/cm^3 is assumed between the Upper Cretaceous and Tertiary sediments and the older rocks. In this model the graben borders are in good agreement with the fracture zones (hatched areas). For the adopted density contrast the thickness of the Upper Cretaceous and younger sediments (1.8 km) is in good agreement with geological observations. A central rise must be assumed for the explanation of the central anomaly. However a discrepancy exists on the western graben border between the model

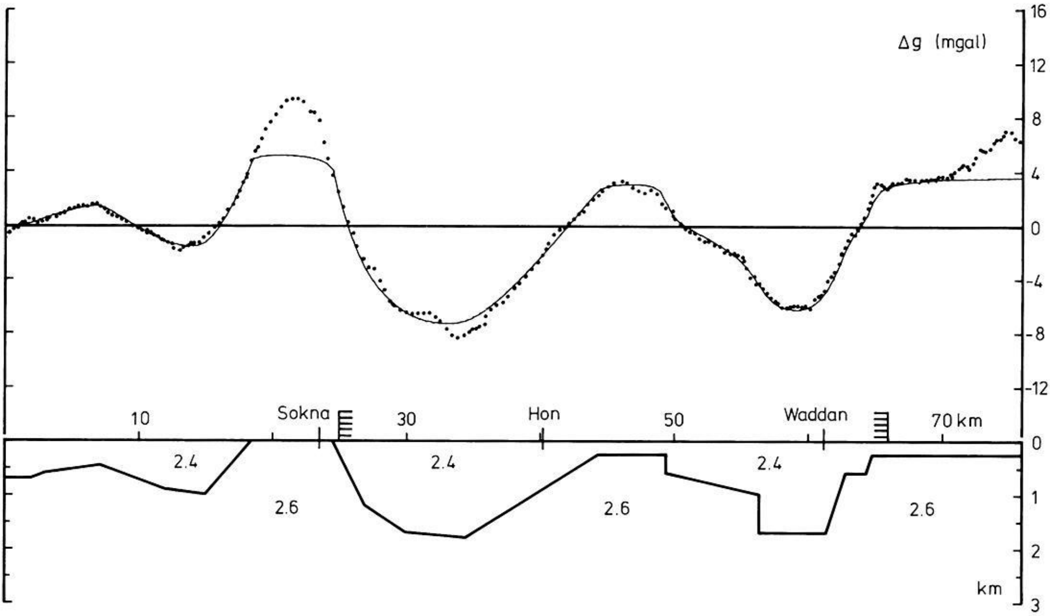

Fig. 5. Model A for the density distribution. Full line: model anomaly. Dotted line: measured $\Delta g''$

anomaly and the observed $\Delta g''$ values. Even Pre Upper Cretaceous rocks reaching to the surface (which is not in agreement with geological observation) cannot explain the observed high $\Delta g''$ values.

This discrepancy is removed by model B, shown in Fig. 6, which is the same as model A except the density distribution on the western graben border. The upper model curve (curve 1) represents Pre Upper Cretaceous rocks not reaching to the surface plus an intrusive body with a density of 2.9 g/cm^3. The presence of basic intrusives in this area has been discussed by Schult (1974). The lower model curve (curve 2) refers to the model without the intrusive body. The density distribution of model B is very probable from the presently available gravity and field magnetic data.

The presence of a central rise of the Pre Upper Cretaceous rocks not reaching to the surface has not yet been discussed in literature according to our knowledge. It implies that the Hon Graben is divided into two separate troughs at least in its southern part.

6. Comparison between Models of the Hon Graben Derived from Gravimetric and Magnetic Anomalies and Conclusion

For the same profile, Schult (1974) has published a model derived from a ΔT anomaly assuming an induced magnetization of $J_i = 1.3 \cdot 10^{-3}$ Gauss for the magnetic basement and $J_i = 0$ for the overlaying sediments. The model of the magnetic

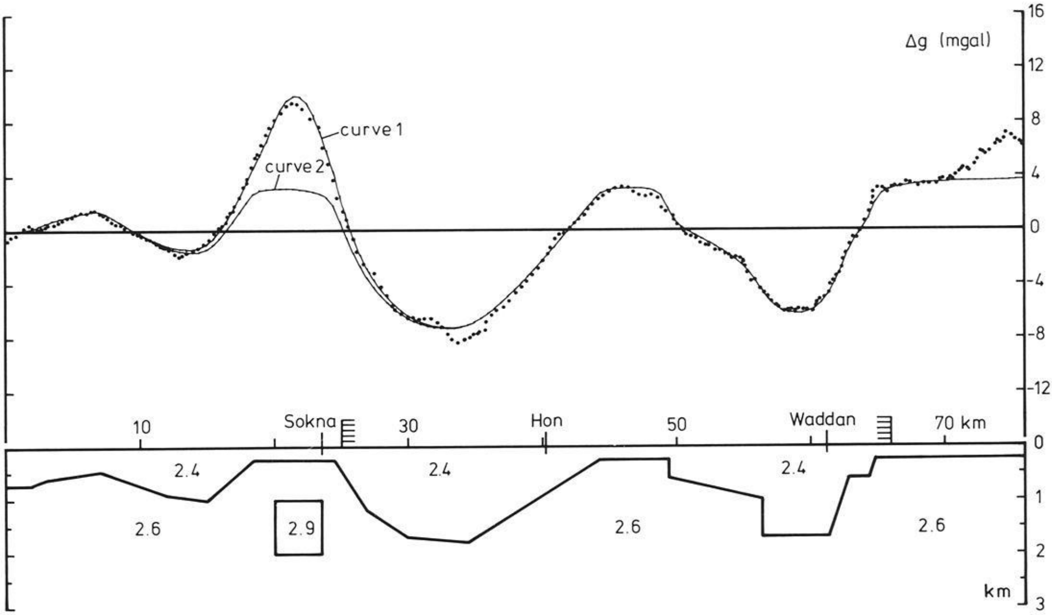

Fig. 6. Model B for the density distribution. Full lines: model anomalies. Dotted line: measured $\Delta g''$. Curve 1: whole model. Curve 2: basement alone without additional intrusive body

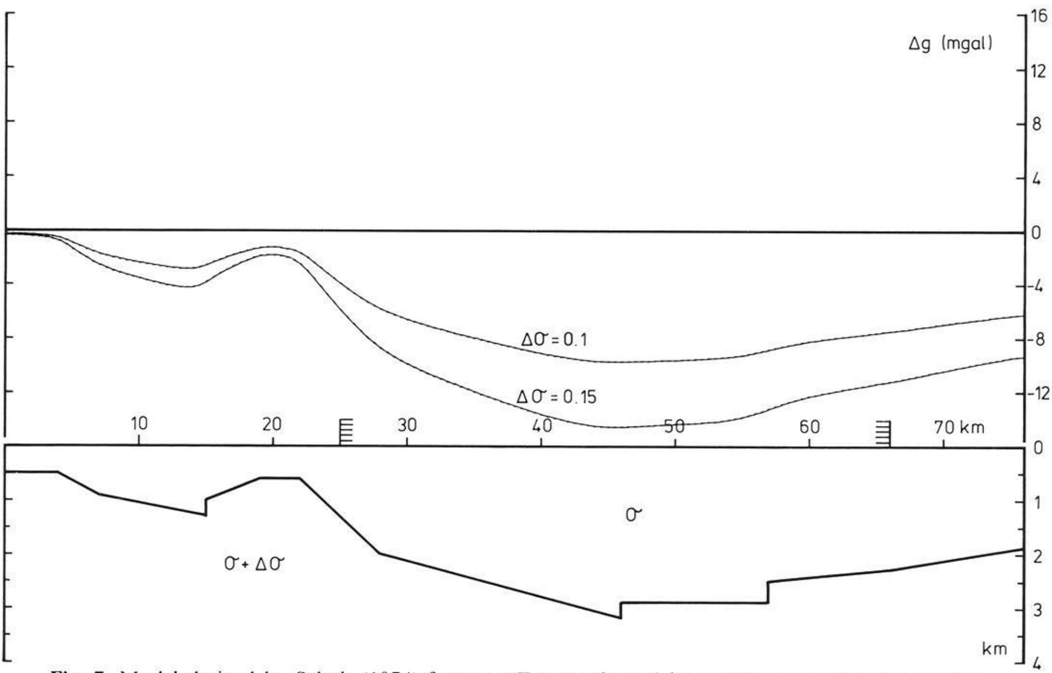

Fig. 7. Model derived by Schult (1974) from a ΔT anomaly and its gravity anomalies for density contrasts of 0.1 and 0.15 g/cm^3 respectively

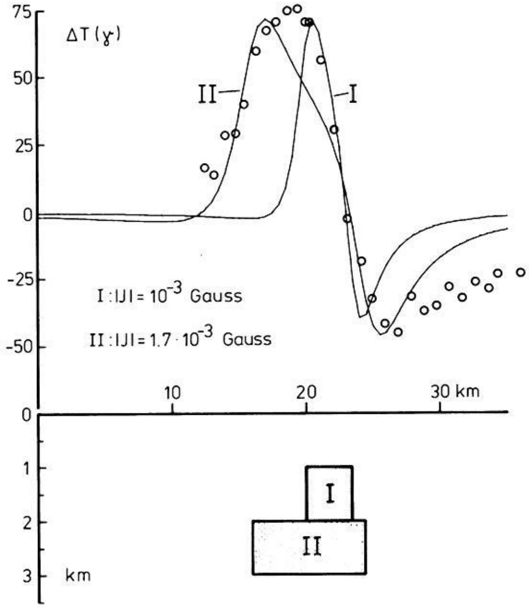

Fig. 8. ΔT anomalies of two basic intrusive bodies. Body I with an induced magnetization of 10^{-3} Gauss (curve I) corresponds to the high density body of model C (Fig. 7). Body II has an induced magnetization of $1.7 \cdot 10^{-3}$ Gauss (curve II). The strike of the two dimensional bodies is parallel to the graben borders. Dots are measured ΔT values

basement is shown in Fig. 8 together with its gravity anomaly assuming density differences between the magnetic basement and the sediments of 0.1 and 0.15 g/cm^3 respectively. A comparison of the gravity anomaly of this model with the observed $\Delta g''$ anomaly (see Fig. 4) shows a discrepancy indicating that the main sources of the gravity anomaly must be structures reaching close to the surface, as was assumed in the previous models A and B. The discrepancy favours an alternative model proposed by Schult (1974) for the interpretation of the ΔT anomaly on the western graben border. This model suggests a weakly magnetized basement with a strongly magnetized basic intrusion (in connection with the Jebel Soda volcanism) near the western margin of the Hon Graben. Fig. 8 shows that in principle intrusive bodies similar to the high density body of gravity model B (body I in Fig. 8) with plausible values for the magnetization can explain the measured ΔT anomaly on the western graben border. A complete accord between the magnetic and gravimetric interpretation in the western part of the profile cannot be expected as the western part of the magnetic profile ends a few km south of the gravity profile. The absence of a magnetic anomaly in the central part of the Hon Graben (due to the rise of the Pre Upper Cretaceous rocks as obtained from the gravimetric measurements) is a further indication for a weakly magnetized basement and also favors the interpretation of the ΔT anomaly on the western graben border by a basic intrusion.

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