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THE CALCULATION OF PSEUDO-BOUGUER ANOMALIES FROM TOTAL-INTENSITY DATA USING TWO-DIMENSIONAL FILTERS

Abstract. A method based on Baranov's Reduction to the Pole, transformation is presented to calculate pseudo-Bouguer anomalies from total-intensity (T) measurements using Fourier's Theorem. The data transformation is performed via a two-dimensional convolution in which precalculated coefficient-matrices are used. The latter are dependent on both the induced and remanent magnetization of certain geological structures. By means of theoretical examples and real field measurements, obtained over a small volcano, the practical application of this method is examined. Quite good results can be obtained if additional information (e.g.: direction of the remanent magnetization or the density) of the disturbing body is available.

INTRODUCTION

In applied geophysics, one sometimes faces the problem of interpreting gravimetric and magnetic anomalies, both being caused by the same disturbing body. Under certain circumstances - homogeneous density (σ) and unifor magnetization (M) of the body - one can apply Poissons's Theorem to obtain a formal relationship between the gravimetric and magnetic data. This theorem can be simplified if the vector of the magnetization is vertical, as in this case, the second vertical derivative of the gravity potential (U) is directly proportional to the first vertical derivative of the magnetic potential (V). The Bouguer gravity (g), which is identical to the first vertical derivative of the gravity potential, and the total-intensity (T) of the Earth's magnetic field are usually obtained from field observations. To compare both, Baranov (1957) has developed a field transformation method called "reduction to the pole". In this method, total-intensity measurements, which are a function of the direction of the magnetization-vector, are transformed for a vertical direction of M. After calculating the vertical derivative of the Bouguer-gravity, this quantity can be related directly with the magnetic data (T_{90}).

Based on Baranov's method, a transformation is discussed in this paper which makes it possible to obtain pseudo-gravity values from magnetic field data. Lourenço (1973) has already discussed a similar transformation in his thesis.

THE METHOD

Starting off with Poissons's Theorem for a gravitating and magnetized body (where σ is the density, M the vertical dipping magnetization),

$$-\frac{\partial g}{\partial z} = \frac{f\sigma}{M} T_{90} \qquad \text{(where f is the gravitational constant),} \qquad (1)$$

Manuscript received September 2, 1989; accepted October 1, 1990.

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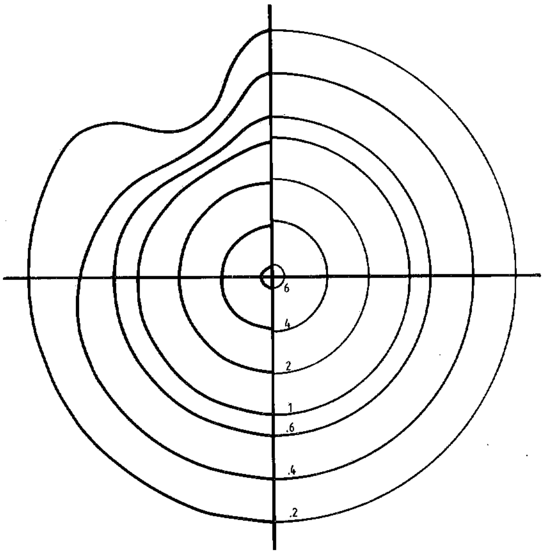

Fig. 1 - Pseudo-Bouguer anomaly (lefthand portion) and theoretical Bouguer anomaly (righthand portion) of a buried sphere (depth... z = two length units, radius... r = one length unit, density = 1 SI-unit, D = 0°, I = 63°), isolines in mGal.

and using Baranov's equation (9.14) (Baranov, 1975) for the reduction to the pole

$$T_{90}(x, y, z) = \frac{1}{4\pi^2} \int_{-\pi}^{\pi} \int_{-\pi}^{\pi} \tilde{T}(\alpha, \beta)\, e^{-\gamma z - i\alpha x - i\beta y} \frac{\gamma^2}{AB}\, d\alpha d\beta,$$

as well as equation (10.2) for the vertical gradient of the Bouguer gravity,

$$-\frac{\partial g(x, y, z)}{\partial z} = \frac{1}{4\pi^2} \int_{-\pi}^{\pi} \int_{-\pi}^{\pi} \tilde{g}(\alpha, \beta)\, e^{-\gamma z - i\alpha x - i\beta y} \gamma\, d\alpha d\beta,$$

one can show after integrating over α and β that

$$\tilde{g}(\alpha, \beta) = \frac{f\sigma}{M} \tilde{T}(\alpha, \beta) \frac{\gamma}{AB} \tag{2}$$

is valid (A similar relationship was used by Cordell and Taylor (1971) to investigate the magnetization and density of a North Atlantic seamount). $\tilde{T}(\alpha, \beta)$ and $\tilde{g}(\alpha, \beta)$ are the Fourier transforms of the T-data and g-data respectively. α and β are the parameters of the spectral plane, and the quantities γ, A and B have been defined by Baranov (1975) as follows:

$$\gamma = \sqrt{\alpha^2 + \beta^2}$$

$$A = \lambda_1 \alpha_i + \lambda_2 \beta_i + \lambda_3 \gamma$$

$$B = \nu_1 \alpha_i + \nu_2 \beta_i + \nu_3 \gamma,$$

where λ_1, λ_2 and λ_3 are the direction cosines of the inducing magnetic field vector and the

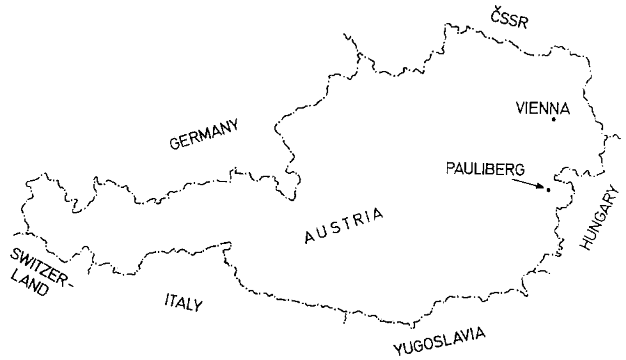

Fig. 2 - Location of the area under investigation.

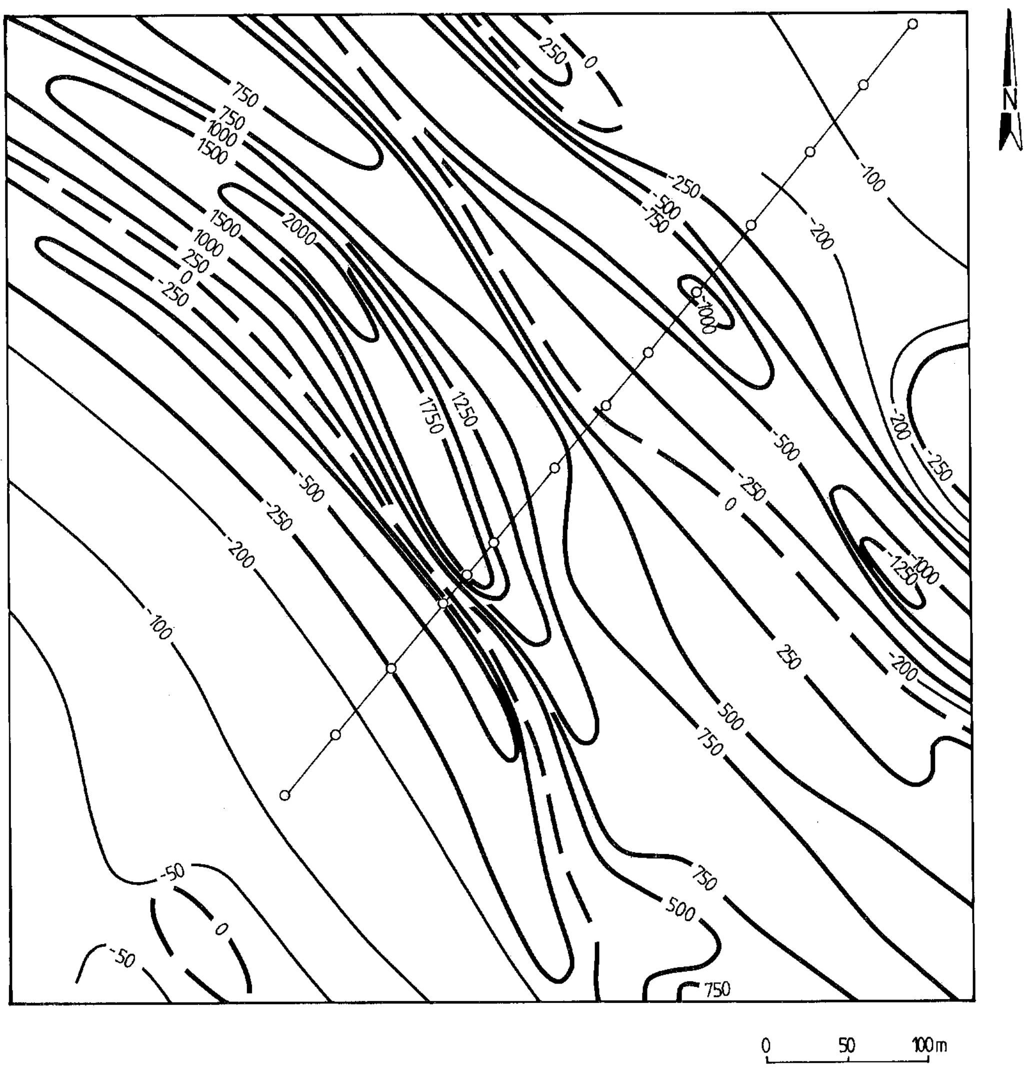

Fig. 3 - Portion of the total-intensity map of the Pauliberg area (Seiberl, 1978), epoch 1975. 0, Observatory Wien-Kobenzl, 47000 nT have been deducted from the reduced T-data.

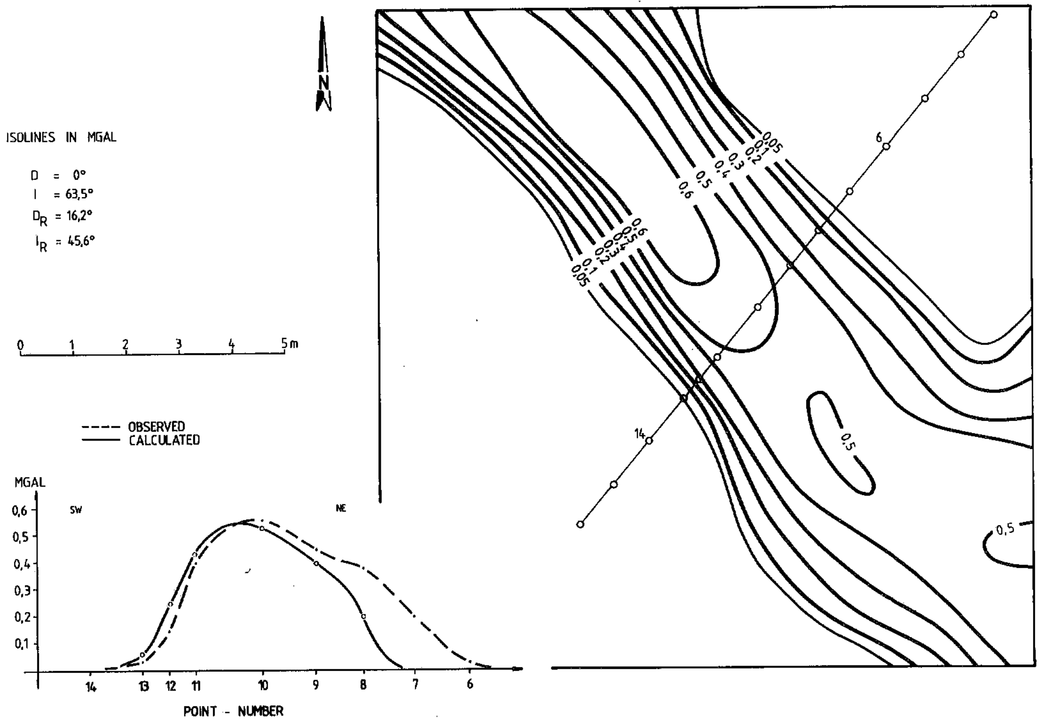

Fig. 4 - Pseudo-Bouguer anomaly map of the Pauliberg area.

remanent magnetization vector has the direction cosines of ν_1, ν_2 and ν_3.

From equation (2), one is also able to obtain pseudo-total magnetic field intensities from gravity observations:

$$\tilde{T}(\alpha, \beta) = \frac{M}{f\sigma} \tilde{g}(\alpha, \beta) \frac{AB}{\gamma} . \tag{2a}$$

This field transformation has already been discussed by Robinson (1971).
After applying Fourier's transformation theorem to the Bouguer-gravity data.

$$g(x, y, z) = \frac{1}{4\pi^2} \int_{-\pi}^{\pi} \int_{-\pi}^{\pi} \tilde{g}(\alpha, \beta)\, e^{-\gamma z - i\alpha x - i\beta y}\, d\alpha d\beta, \tag{3}$$

and using the identity in equation (2), a relationship between g and T,

$$g(x, y, z) = \frac{f\sigma}{4\pi^2 M} \int_{-\pi}^{\pi} \int_{-\pi}^{\pi} \tilde{T}(\alpha, \beta)\, e^{-\gamma z - i\alpha\chi - i\beta y} \frac{\gamma}{AB}\, d\alpha d\beta, \tag{4}$$

is obtained.

Due to the orthogonality-properties of the trigonometric functions, the T-field data have to be digitized on a square grid. By choosing the distances $D_x = D_y = 1$ between the grid points, one can use Baranov's equation (9.15) (Baranov, 1975),

$$\widetilde{T}(\alpha, \beta) = \sum_k \sum_n T(k, n)\, e^{k\alpha i + n\beta i},$$

to calculate the Fourier-transform of the T-data. In this equation, k and n are the indices of the T-field grid-points. After setting x=y=z=0

$$g(0, 0, 0) = \frac{f\sigma}{M} \sum_k \sum_n T(k, n) \frac{1}{4\pi^2} \int_{-\pi}^{\pi} \int_{-\pi}^{\pi} e^{k\alpha i + n\beta i} \frac{\gamma}{AB}\, d\alpha d\beta$$

$$= \frac{f\sigma}{M} \sum_k \sum_n T(k, n)\, C(k, n), \tag{5}$$

the transformation of the T-data into pseudo-gravity values can be performed by means of a two-dimensioonal convolution. To calculate the filter coefficients sets C (k, n), a similar procedure, which has been published by Baranov (1975), is used.

EXAMPLES

To get an idea of the errors one might expect in the transformation of T-data into pseudo-gravity values, numerous theoretical examples using a buried sphere were evaluated. In the investigations, the inclination (I) of the magnetization and the depht (Z) of the centre of the sphere were varied. As an example, the pseudo-gravity over a magnetized sphere is shown in the lefthand portion of Fig. 1 using a 15x15 coefficient-matrix. In this case, the declination and inclination of the magnetization are $D=0°$ and $I=60°$, respectively. If one compares this result with the theoretical Bouger-gravity over the same sphere, which is shown on the right in Fig. 1, it can be seen that the southern part of the T-data is transformed quite well, whereas the northern part of the transformed T-field is somewhat distorted due to the inclination of the magnetization-vector.

To examine the practical applications of the above discussed transformation method, total-intensity measurements (T) (Seiberl, 1978) and gravity observations using a LaCost-Romberg gravimeter were carried out near the Austro-Hungarian border (Fig. 2) over a sheet-like volcano (called Pauliberg) of Tertiary age. The geology of Pauliberg and the surrounding area has been described by numerous authors (e.g.: Kümel, 1936). The basalts of Pauliberg lie on top of different types of gneisses and mica shists. The mean geological strike-direction is NW-SE.

In Fig. 3, a portion of the total-intensity map (Seiberl, 1978) over Pauliberg, and the profile along which the gravity measurements were carried out, are shown. After digitizing the T-data to a 50mx50m square grid, the transformation according to equation (5) was performed. Originally, only an inducing magnetic field with a declination of $D=0°$ and an inclination of $I=63.5°$, typical of the Pauliberg area, was assumed. By comparing the measured Bouguer-gravity data (shown as a data-profile in the insert of Fig. 4), with the pseudo -Bouguer-gravity data, it was obvious that during the data-transformation, some contributions due to a remanent magnetization of the Pauliberg-basalts had to be considered. From rock samples, the declination ($D_R=16.2°$) and the Inclination ($I_R=45.6°$) of the remanent magnetization were determined with the aid of a spinner-type magnetometer (Seiberl et al., 1979). Using both magnetization directions and by varying the scaling-factor $f\sigma/M$, a rather good fit between the observed Bouguer anomaly (full line in the insert of Fig. 4) and the calculated pseudo-Bouguer anomaly (dashed line in the insert of Fig. 4) can be recognized. The small discrepancy at the northeastern end of the profile may be due to certain demagnetization effects since the basalts are rather thin here. Finally, in Fig. 4, the pseudo-Bouguer anomaly-map of the area under the consideration, obtained by using the transformation method discussed above and the total-intensity data from the Pauliberg area, is shown.

CONCLUSION

By applying certain two-dimensional filters to total-intensity data, one is able to calculate pseudo-Bouguer anomalies. To obtain reasonable results, the geological structure under investigation has to be characterisized by both a magnetization and density contrast with the surrounding rocks. Additionally, information such as the direction of the remanent magnetization or the density of the investigated body may help to improve the results.

Acknowledgements. This work has been supported by the Austrian national program "Geophysik der Erdkruste". The authors take the opportunity to express their appreciation and thanks to the Federal Ministery of Science and Research.

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