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Inversion of magnetic measurements of the *CHAMP* satellite over the Pannonian Basin

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ABSTRACT

The Pannonian Basin is a deep intra-continental basin that formed as part of the Alpine orogeny. In order to study the nature of the crustal basement we used the long-wavelength magnetic anomalies acquired by the *CHAMP* satellite. The anomalies were distributed in a spherical shell, some 107,927 data recorded between January 1 and December 31 of 2008. They covered the Pannonian Basin and its vicinity. These anomaly data were interpolated into a spherical grid of 0.5°×0.5°, at the elevation of 324 km by the Gaussian weight function. The vertical gradient of these total magnetic anomalies was also computed and mapped to the surface of a sphere at 324 km elevation. The former spherical anomaly data at 425 km altitude continued downward to 324 km. To interpret these data at the elevation of 324 km we used an inversion method. A polygonal prism forward model was used for the inversion. The minimum problem was solved numerically by the Simplex and Simulated annealing methods; a L_2 norm in the case of Gaussian distribution parameters and a L_1 norm was used in the case of Laplace distribution parameters. We interpret that the magnetic anomaly was produced by several sources and the effect of the sable magnetization of the exsolution of hemo-ilmenite minerals in the upper crustal metamorphic rocks.

1. Introduction

The Pannonian Basin extends some 800 by 500 km in a generally east–northeast direction with depths extending to 7 km. Large crustal features produce long wavelength magnetic anomalies. These anomalies are sufficiently resolved by satellite altitude observations. The German satellite *CHAMP* was launched on July 15, 2000 (Reigber et al., 2003, 2005) and it finished its mission on September 19, 2010. This satellite measured the gravity and magnetic field of the Earth with high accuracy. The total magnetic data are obtained by a scalar Overhauser magnetometer developed by the Laboratorie d'Electronique de Technologie et d'Instrumentation in Grenoble, France. The accuracy of the scalar magnetic measurements was ±0.5 nT and these magnetic field data were recorded every second (Rother et al., 2003).

CHAMP had a nearly circular, polar orbit. Its initial elevation of 456 km decreased due to upper atmospheric drag and it was boosted several times. The elevation interval of the orbit was between 319 and 340 km in 2008. The magnetic anomalies used in the present paper had been derived by the *NASA/GSFC* using *CHAOS2* model (Olsen et al., 2009).

2. Interpolation and coordinate transformation

The aim of our calculations is the reduction and interpretation of the magnetic anomalies over the Pannonian Basin and its vicinity (latitude, 38°–52° North; longitude, 14°–28° East). The magnetic measurements are mapped on a spherical shell at 319–340 km elevation, and these data are given as a function of the latitude, longitude and elevation. The experimental frequencies of the latitude, longitude and elevation distributions of the recorded locations are plotted in Fig. 1. As shown, they generally cover our study area. Data whose *Kp* index was less than or equal to 1_- were selected for further processing. Using this criterion we obtained 107,927 data points. These data are interpolated into a spherical grid of 0.5°×0.5° at the elevation of 324 km.

The Gaussian weight function of the 3D interpolation is

$$w(\Delta_i, k) = \frac{\pi^{3/2}}{k^3}\exp\left(-\frac{\pi^2}{k^2}\Delta_i^2\right), \quad (1)$$

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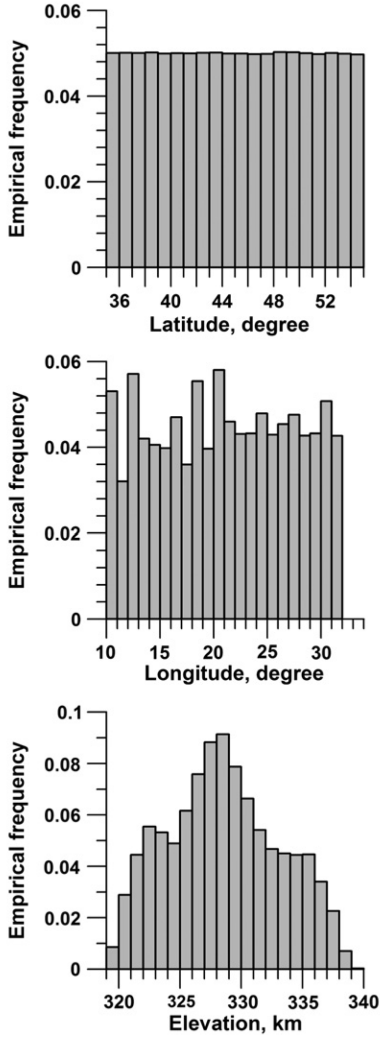

Fig. 1. Experimental frequency of the *CHAMP* magnetic anomalies *versus* latitude, longitude and altitude over the Pannonian Basin and vicinity.

where k is the parameter of the weight function, Δ_i is the distance between the ith data observed and the single reference point of the spherical grid details is given by Véges (1971), Kis and Wittmann (1998, 2002). The interpolated value is normalized by the following:

$$T^{\text{interpolated}} = \frac{1}{\sum_{i=1}^{n} w_i} \sum_{i=1}^{n} T_i w_i, \tag{2}$$

where n is the number of data taken into consideration and T_i is the ith total magnetic anomaly value. The interpolated total magnetic anomalies are plotted in Fig. 2.

For the methods used in this study, the quantitative interpretation of the satellite measured magnetic anomalies requires the transformation from a spherical to Cartesian coordinates. The origin of the Cartesian coordinate system is $\varphi = 47°$ (latitude) and $\lambda = 21°$ (longitude) at an elevation of 324 km. In accordance with the general usage in geomagnetism, the coordinate axes x and y directed towards the North and East, respectively, while the z-axis points downwards. The details of these computations are given in Appendix A.

3. Vertical derivative and downward continuation

Vertical gradient anomalies show a good correlation with the shape of the geologic body (Blakely, 1995). They qualitatively

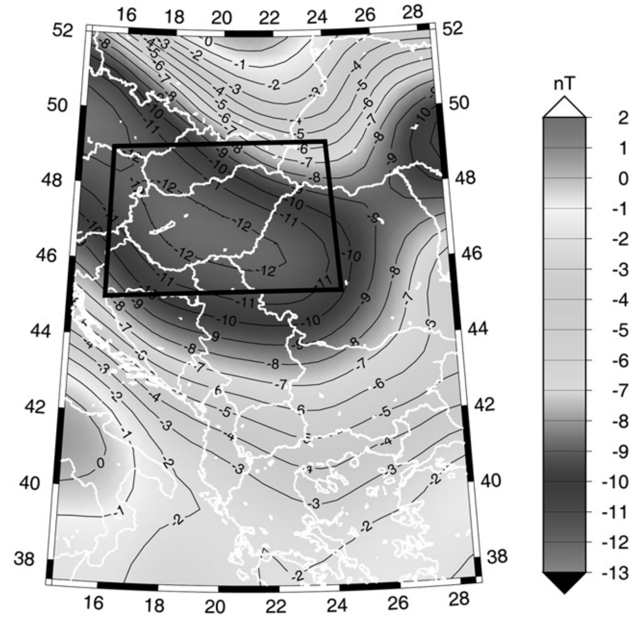

Fig. 2. The *CHAMP* total magnetic anomaly map determined by interpolation of data from the Pannonian Basin region, plotted on an Albers' projection at 324 km altitude; anomalies are in nT with a range of 22 grey levels and a contour interval of 1 nT, inner frame shows the investigated territory.

delineate the lateral extension of the magnetic source. The determination of the vertical gradients is a linear transform; its transfer function is given by:

$$S\left(f_x, f_y\right) = 2\pi\left(f_x^2 + f_y^2\right)^{1/2}, \tag{3}$$

where f_x and f_y are the spatial frequencies in the x and y axes (Blakely, 1995). It has long been recognized that high frequency amplification is undesirable, since these frequencies possess the lowest signal-to-noise level. In order to eliminate noise this transfer function is multiplied by a two-dimensional Gaussian low-pass window:

$$S_{LP}\left(f_x, f_y\right) = \exp\left(-k^2\left(f_x^2 + f_y^2\right)\right). \tag{4}$$

The parameter k controls the passed frequency range. The weight function of this transform is:

$$s(x, y) = \frac{\pi^{5/2}}{k^3} \exp\left(-\left(\frac{\pi^2\left(x^2 + y^2\right)}{k^2}\right)\right) \mathrm{M}\left(-\frac{1}{2}, 1, \left(\frac{\pi^2\left(x^2 + y^2\right)}{k^2}\right)\right), \tag{5}$$

where M means the confluent hyper-geometric function. The details of this transform are given by Kis and Puszta (2006). The vertical gradients of the total magnetic anomalies at the altitude of 324 km are plotted in Fig. 3. A negative anomaly, with a minimum gradient of 0.01 nT/km, covers the Pannonian Basin. The spatial shape of the vertical gradient anomaly determines the extension of our model in the inversion procedures.

The downward continuation of the magnetic anomalies can also be expressed as a linear transform. Its transfer function is:

$$S_{\text{downward}}\left(f_x, f_y\right) = \exp\left(2\pi h\left(f_x^2 + f_y^2\right)^{1/2}\right), \tag{6}$$

where h is the downward continuation value. Different authors (Bullard and Cooper, 1948; De Meyer, 1974) have suggested the