INTERPRETATION OF CHAMP MAGNETIC ANOMALY DATA OVER THE PANNONIAN BASIN REGION USING LOWER ALTITUDE HORIZONTAL GRADIENT DATA

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The ESA SWARM mission will have three earth orbiting magnetometer bearing satellites one in a high orbit and two side-by-side in lower orbits. These latter satellites will record a horizontal magnetic gradient. In order to determine how we can use these gradient measurements for interpretation of large geologic units we used ten years of CHAMP data to compute a horizontal gradient map over a section of southeastern Europe with our goal to interpret these data over the Pannonian Basin of Hungary.

Keywords: SWARM, horizontal gradient, CHAMP, Pannonian Basin

1 Introduction

Since CHAMP flew for ten years there are a large number satellite orbits. Using relatively lower orbit magnetic profiles (Fig. 1), a total field magnetic anomaly map was made from these data (Fig. 2). We then constructed a horizontal magnetic anomaly gradient map (Fig. 3). This was done in anticipation of the SWARM mission which will comprise three magnetometer bearing satellites, two at a low altitude (initially 460 km to 300 km) and one at a higher altitude (530 km) and with a different orbital inclination (initially near polar) but moving to a 90^{o} separation (Haagmans et al. 2012). Our preliminary study of computing a horizontal magnetic gradient map over the period of a decade of CHAMP data will simulate the SWARM measurements and show the value to be gained by simultaneously measuring the horizontal magnetic gradient. Long-wavelength magnetic anomaly data may result from a contrast in magnetization , heat flow or crustal thickness. Based on results from an earlier study (Taylor et al., 2005), however we chose to chose to interpret these computed CHAMP gradient data with the crustal thickness map of Hungary (Bielik et al., 2004), particularly the Pannonian Basin.

The Pannonian Basin is a deep intra-continental basin that formed as part of the Alpine orogeny. It is some 600 by 500 km in area and centered on Hungary. This area was chosen since it has one of the thinnest continental crusts in Europe (<25 km, Bielik et al., 2004) and is the region of complex tectonic structures. In order to study the nature of the crustal basement we used the long-wavelength magnetic anomalies acquired by the CHAMP satellite. CHAMP satellite has obtained an extensive amount of data with a dense coverage vertical and horizontal distribution. There is a large enough data base to compute the horizontal magnetic gradients over the Pannonian Basin region using a data set from a rather restricted altitude range (Fig. 1).

2 Data Processing

Employing the latest and lowest (310 to 339 km) altitude CHAMP data. We recomputed a satellite total- field magnetic anomaly map (Fig. 2), using the spherical-cap method of Haines (1985), the technique of Alsdorf et al. (1994) and from spherical harmonic coefficients of MF6 (Maus et al. 2008). We selected a number of CHAMP orbits that had a relatively limited variation in orbital altitude, with the average being 324 km altitude (Fig. 1) and with a $K_p \leq 1$. In addition differences in magnetic secular variation were largely reduced by processing after Alsdorf et al. (1994). The horizontal magnetic anomaly gradient map (Fig. 3) was computed from these data (Fig. 2) using the methods of Kis and Puszta (2006) and Kis (2009, page 233-243). The grid size is 500 m. This gradient map was made in order to preview what the SWARM mission will record and to determine how horizontal gradient data will aid in our geologic and tectonic interpretation of crustal units. The numerically determined horizontal gradient has a very small error in this model calculation it is less than 0.001 nT/km. The total field magnetic anomaly along a 1000 km northeast-southwest profile (Figs. 3 and 4) varies from -4 nT to 2 nT. The horizontal gradient along this profile (Fig. 5, solid line) was computed from this total magnetic anomaly data (Fig. 4) and used to produce our two dimensional model interpretation of the gradient profile (Fig. 5, dashed line).

3 Conclusions

A horizontal magnetic gradient map (Fig. 3) was computed from these anomalous total magnetic field data (Fig. 2). Horizontal magnetic gradients indicate significant magnetization boundaries in the crust (Dole and Jordan 1978, Cordell and Grauch 1985). A horizontal gradient anomaly profile, computed from Figure 3 and plotted in Figure 5 (solid line) varied from 0 to 0.025 nT/km with twin positive anomalies (0.025 and 0.023 nT/km, Figure 5, solid line) separated by a sharp anomaly negative reaching 0 nT/km. A two dimensional model (Talwani and Heirtzler, 1964) was made from this horizontal gradient anomaly profile across the Pannonian Basin (Fig. 5, dashed line) it was computed using the method of Kis and Puszta (2006) and required three bodies (Fig. 5, figure plotted using Grapher-6 software). The model parameters are given in Fig. 5. Our model indicates a two-step variation of the lithosphere of some 20 km this feature correlates with a 200 km area of crustal thinning in the southwestern Pannonian Basin (Bielik et al. 2004 and Fig. 6, elongated gray oval). As with all potential field methods, our results are not unique. We anticipate that with the SWARM data from the two lower orbiting satellites it will be possible to compute the horizontal gradient magnetic anomalies on a global basis. These gradient data will be very useful in interpreting crustal anomalies over large regions of the crust.

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References

Alsdorf D E, von Frese R R B, Arkani-Hamed J, Noltimier H C 1994: J. Geophys. Res., 99, 4655–4668.

Bielik, M, Šefara J, Kováč M, Bezák V, Plašienka D 2004: Tectonophysics., 393, 63–86.

Cordell L E, Grauch V J S 1985: Mapping basement magnetization zones from aeromagnetic data in the San Juan Basin, New Mexico, Society of Exploration Geophysicists, Utility of regional gravity and magnetic maps, 181–97.

Dole W E, Jordan N F 1978: Am. Assoc. Pet. Geolog. Bulletin, 62, 2427–2440.

Haagmans R, Bock R, Rider H 2012: ESA's Earth Explorer Mission, BR-302, 18p.

Haines G V 1995: J. Geophys. Res., 90, B3, 2583–2589.

Kis K I, Puszta S 2006: J. App. Geophys., 60, 13–26.

Kis K I 2009: Magnetic Methods of Applied Geophysics, Eötvös University Press, 410 pp.

Maus S et al. 2008: Geochem. Geophys. Geosyst. 10, Q08005,doi:10.1029/2009GC002471.

Talwani, M, Heirtzler J 1964: Computation of magnetic anomalies caused by two-dimensional structures of arbitrary shape. Computers in the mineral industries, Part 1, Stanford University Publication Geological Sciences, 9, 464-480.

Taylor PT, Kis KI, von Frese RB, Korhonen, JV, Wittmann, G, Kim HR, Potts, LV, 2005:Effect of varying Crustal Thickness on CHAMP Geopotential Data, Earth Observation with CHAMP Results from Three Years in Orbit, Springer, 279-286.

Captions

Fig. 1. Altitude distribution of CHAMP orbits used to produce the total intensity magnetic anomaly map of the greater Pannonian Basin region (Fig. 2). Total number of orbits divided into ascending (dusk) and descending (dawn) orbits.

Fig. 2. Regional total magnetic anomaly map of southeastern Europe computed from CHAMP satellite magnetic data (Fig.1). Note the large negative southeast-northwest low (< -12 nT) over

the Pannonian Basin. Total field anomaly map contour interval 1 nT. Anomaly gray scale varies from -13 to 2 nT.

Fig. 3. Horizontal gradient map computed from CHAMP magnetic anomaly data (Fig. 2). Data were selected that were approximately at the same elevation and had small horizontal separation. The location of the total magnetic anomaly profile (Fig. 4) is indicated by the northeast-southwest line and a horizontal magnetic anomaly gradient profile (Fig. 5 solid line) was made along this same line (Fig. 3). Contour interval 0.002 nT/km. The light areas are positive anomaly gradients and the dark are negative.

Fig. 4. Total magnetic anomaly profile (northeast-southwest line, Fig. 3) was made from the CHAMP magnetic anomaly data (Fig.2). The horizontal gradient of this profile computed (Fig. 5 solid line) and used to make our lithospheric model (Fig. 5 and dashed line).

Fig. 5. Two horizontal magnetic anomaly gradient profiles. The solid profile is from the observed data of Figures 3 and 4; while the dashed was computed from the model. Model blocks 1 and 2 represent relatively smaller regions of anomalous magnetization. Block 3 corresponds to the lithosphere across the Pannonian Basin. Gradient contour interval 0.00012 nT/km. Model body parameters: Magnetization: Body; 1 (-0.5); 2 (5.0); and 3 (6.5) A/m. Main field inclination 60 deg and declination 0 deg. azimuth 30 deg. Magnetization, inclination and declination,α and β, -60 deg and 60 deg.

Fig 6. Crustal thickness map of the Pannonian Basin region (Bielik et al. 2004). Northeast-southwest dashed line is from profile in Figure 3. The highlighted oval region indicates the horizontal extent of lithosphere thinning shown in Figure 5.