P-129

Depth to the bottom of magnetic sources in Germany – analysis of anomalies of the Earth's magnetic total field

A.R. Bansal[1*], G. Gabriel[2] and V. P. Dimri[1]
[1]. National Geophysical Research Institute, Council of Scientific and Industrial Research
[2]. Leibniz Institute for Applied Geophysics

Summary

The depth to the bottom of magnetic sources (DBMS) is calculated from 31 overlapping blocks in Germany using Centoid method. The depth to the top of magnetic bodies varies from 1.49 km to 5.25 km in the region. The centroid depth and DBMS varies from 9.82 to 19.03 km and 19.9 to 33.98 km, respectively. The deeper DBMS are found corresponding to the North German Basin having lower heat flow values in the region. The inverse relation between the heat flow and DBMS is found. In general Moho depth is deeper than the DBMS except for the blocks 24, 25, 27 and 28 lying in the lower heat flow region of North German Basin. The thermal conductivity values in the region varies from 2.4 to 4.0 Wm^{-1} *℃*$^{-1}$ *based on the constant temperature at the DBMS.*

Introduction

The DBMS is an important parameter to understand the temperature distribution in the crust and the rheology of the Earth's lithosphere (Ravat et al., 2007). Some authors assume that the DBMS is equivalent to the Curie point depth of the magnetic minerals, where rocks loose their ferromagnetic properties due to an increase of the temperature in the crust. Curie temperature depends strongly on the magnetic minerals and in general 580 °C is considered as Curie temperature in the continental crust (e.g. Ross et al. 2006). As the basal depth of the magnetic sources can be caused by contrasts in lithology also, the DBMS and Curie point depths might not coincide. To avoid the complication of the Curie point depth and the DBMS, we are using the DBMS in our study for greater transparency, as depths are derived from aeromagnetic data. Nevertheless, the DBMS can be used as a proxy for temperature at depth and therefore to estimate heat flow density and geothermal gradient. Nevertheless, the more precise and direct way to measure heat flow is geophysical logging in boreholes (Pollack et al., 1993). So far these measurements are very sparse and often insufficient to define the regional thermal structures.

Ravat et al. (2007) presented a comparison of different spectral methods for computing the DBMS, e.g. the spectral peak method (Spector & Grant, 1970), forward modeling of the spectral peak (Finn & Ravat, 2004), centroid method (Bhattacharyya & Leu 1975, 1977), and power-law correction method or scaling spectral method (Pilkington and Todoeschuck, 1993; Maus and Dimri,

Uppal Raod, Hyderabad – 500 606, email: abhey_bansal@ngri.res.in (ARB), director@ngri.res.in (VPD),
gerald.gabriel@liaghannover.de (GG)

1995). Ravat et al. (2007) also suggested the use of aeromagnetic without filtering and avoiding the calculation of the DBMS from the exponential low wavenumber part of the spectra.

In this study, for the first time the DBMS's are calculated for entire Germany and the northeastern part of Austria. For many years no homogenous data set of the anomalies of the Earth's magnetic total field was available. Several studies have shown a correlation between the DBMS and average crustal temperatures in a number of regions around the world: California (Ross et al., 2006), Central – Southern Europe (Chiozzi et al., 2005), African – Eurasian convergence zone, SW Turkey (Dolmaz et al., 2005), Island of Kyushu and surrounding area (Okubo et al., 1985), Northeast Japan (Okubo and Matsunaga, 1994), Yellowstone National Park (Bhattacharyya and Leu, 1975), East and Southeast Asia (Tanaka et al., 1999), Bulgaria (Trifonova et al., 2009), India (Rajaram et al., 2009), Cerro Prieto geothermal area, Baja California, Mexico (Espinosa-Cardeña and Campos-Enriquez, 2008) etc.

Calculation of the DBMS

For this study 31 half overlapping blocks of 200 km x 200 km are selected and the centers of these blocks marked as 1-31 in the tectonic map of the region (Figure 1). The centers of these blocks lie in different tectonic units: 1 (northern part of Alps), 2-4 (Molasse Basin), 5-8 (Moldanubian Region), 9-12 (Saxo-Thuringian Zone), 13-15 (Mid German Crystalline High), 16-18 (Rhenish Massif a part of the Rheno-Hercynian Zone), 19-22 (Rheno-Hercynian Zone), 23 -31 (North German Basin). The DBMS is calculated by the Centroid depth method (Bhattacharyya & Leu 1975, 1977; Okubu et al., 1985; Tanaka et al. 1999). The centroid depth is calculated from the low wavenumber part of the scaled power spectrum as

$$\ln(P(k)^{1/2} / k) = A - |k| Z_o \ , \qquad (1)$$

where ln is the natural logarithm, P(k) is the radially average power spectrum, k is the wavenumber (2π/km), A is a constant depending on the properties of magnetisation and its orientation, and Z_o is the centroid depth of magnetic sources (Tarnaka et al., 1999). For the high wavenumber part, the power spectrum can be related to the top of magnetic sources by a similar equation:

$$\ln(P(k)^{1/2}) = B - |k| Z_t \ , \qquad (2)$$

where B is a constant; Z_t is the depth to the top of the magnetic sources. The depth of the bottom of magnetization (Z_b) is:

$$Z_b = 2Z_o - Z_t \ . \qquad (3)$$

The above mentioned methodology is applied to all 31 overlapping blocks selected in the region. The calculated depth to the top of magnetic body, centroid depths of magnetic body and the DBMs for all blocks are summarised in Figure 2. The depth values vary from 1.49 to 5.25 km (tops of the magnetic bodies), 9.82 to 19.03 km (centroid depths), and 19.9 to 33.98 km (DBM). The calculated DBMS are further compared to the Moho depth and heat flow density in the region (Figure 3). Further we explore the inverse relation between the heat flow densities and depth to the bottom of magnetic source by following relation (Tanaka et al., 1999; Ross et al., 2006).

$$Z_b = \frac{KT}{H}$$ (4)

where Z_b is the depth to the bottom of magnetic sources, K the coefficient of thermal conductivity, T the Curie temperature, and H the heat flux. Thermal conductivity of rocks is generally measured from the rock sample and its value varies from 0.8 to 6.0 $Wm^{-1\circ}C^{-1}$ depending on the physical properties of the rocks. By assuming the Curie temperature of 580 °C at the DBMS, the thermal conductivity values in the region are between 2.4 to 4.0 $Wm^{-1\circ}C^{-1}$.

Conclusion

The depth to the top of magnetic varies from 1.49 to 5.25 km for the region. The Centroid depth and the DBMS varies 9.82 to 19.03 km and 19.9 to 33.98 km, respectively. The deeper DBMS are found in the North German Basin and shallower in Northern Calcareous Alps, Molasse Basin, Moldanubian region and portion of Upper Rhine Graben. The deeper DBMS corresponds to the low heat flow. The Moho depths are deeper than the DBMS except for few blocks (24, 25, 27 and 28) lying in the North German Basin corresponds to lower heat flow values. The thermal conductivity values in the region varies from 2.4 to 4.0 $Wm^{-1\circ}C^{-1}$ based on the constant temperature at the DBMS for whole region.

Acknowledgements

We are thankful to the Council of Scientific and Industrial Research (CSIR), New Delhi, and the International Buero of BMBF, Project Management Agency DLR, Germany, for financial support**.** ARB and VPD are also thankful to the management of NGRI for granting permission for presenting this paper at SPG, India.

References

Berthelsen, A., Burollet, P., Dal Piaz, G. V., Franke, W. and Trumpy, R., 1992. Tectonics. In: D. Blundell, R. Freeman and St. Mueller (eds), A continet Revealed: The European Geotraverse, Cambridge University Press.

Bhattacharya, B. K. & Leu, L. K., 1975, Analysis of magnetic anomalies over Yellowstone National Park: mapping of curie point isothermal surface for geothermal reconnaissance, J. Geophys. Res., 80, 4461-4465.

Bhattacharyya, B. K. & Leu, L. K., 1977, Spectral analysis of gravity and magnetic anomalies due to rectangular prismatic bodies, Geophysics, 41, 41-50.

Chiozzi, P., Matsushima, J., Y. Okubo, V. Pasquale, M. Verdoya, 2005, Curie- point depth from spectral analysis of magnetic data in central-southern Europe, Physics of the Earth and Planetary Interiors, 152, 267-276.

Dolmaz, M. N., UstaÖmer, T., Hisarli, Z. M. and Orbay, N., 2005, Curie point depth variations to infer thermal structure of the crust at the African-Eurasian converengence zone, SW Turkey, Earth Planets Space, 57, 373-383.

Espinosa-Cardeña, J. M., and Campos-Enriquez, J. O., 2008, Curie point depth from spectral analysis of aeromagnetic data from Cerro Prieto geothermal area, Baja California, Mexico, Journal of Volcanology and geothermal Research, 176, 601-609.

Finn, C. A. and Ravat, D., Magnetic depth estimates and their potential for constraining crustal composition and Heat Flow in Antarctica, EOS, Trans. Am. Geophys. Un., 85(47), Fall Meet. Suppl., Abstract T11A-1236.

Maus, S. and Dimri, V. P., 1995, Potential field power spectrum inversion for scaling geology, J. Geophys. Res., 100, 12605-12616.

Okubo, Y., and Matsunaga, 1994, Curie point depth in northeast Japan and its correlation with regional thermal structure and seismicity, Journal of Geophysical Research, 99(11), 22363 - 22371.

Okubo, Y., Graf, R. J., Hansen, R. O., Ogawa, K., and Tsu, H., 1985, Curie point depths of the Island of Kyushu and surrounding area, Japan, Geophysics,53(3), 481-489.

Pollack, H. N., Hunter, S. J., Johnson, J. R., 1993, Heat flow from the earth's interior: analysis of the global data set. Rev. Geophys. 31, 267-280.

Pilkington, M. and Todoeschuck, J. P., 1993, Fractal magnetization of continental crust, Geophys. Res. Lett., 20, 627-630.

Rajaram, M., Anand, S. P., Hemant, K., Purucker, M. E., 2009, Curie isotherm map of Indian subcontinent from satellite and aeromagnetic data, Earth and Planetary Science Letters 281, 147–158.

Ravat, D., Pignatelli, A., Nicolosi, I., and Chiappini, M., 2007, A study of spectral methods of estimating the depth to the bottom of magnetic sources from near-surface magnetic anomaly data, Geophys. J. Int., 169, 421-434.

Ross, H. E., Blackely, R. J. and Zoback, M. D., 2006, Testing the use of aeromagnetic data for the determination of Curie depth in California, Geophysics,71(5), L51-L59.

Spector, A. & Grant, F. S., 1970, Statistical Model for interpreting aeromagnetic data, Geophysics, 35, 293-302.

Trifonova, P., Zhelev, Zh., Petrova, T., Bojadgieva, K., 2009, Curie point depths of Bulgarian territory inferred from geomagnetic observations and its correlation with regional thermal structure and seismicity, Tectonophysics, doi:10.1016/j.tecto.2009.03.014

Tanaka, A., Okubo, Y., Matsubayashi, O., 1999, Curie point depth based on spectrum analysis of the magnetic anomaly data in East and Southeast Asia, Tectonophysics, 306, 461-470.

Tesauro, M., Kaban, M. K., Cloetingh, S. A. P. L., 2009, A new thermal and rheological model of the European lithosphere, Tectonophysics, 476, 478-495.

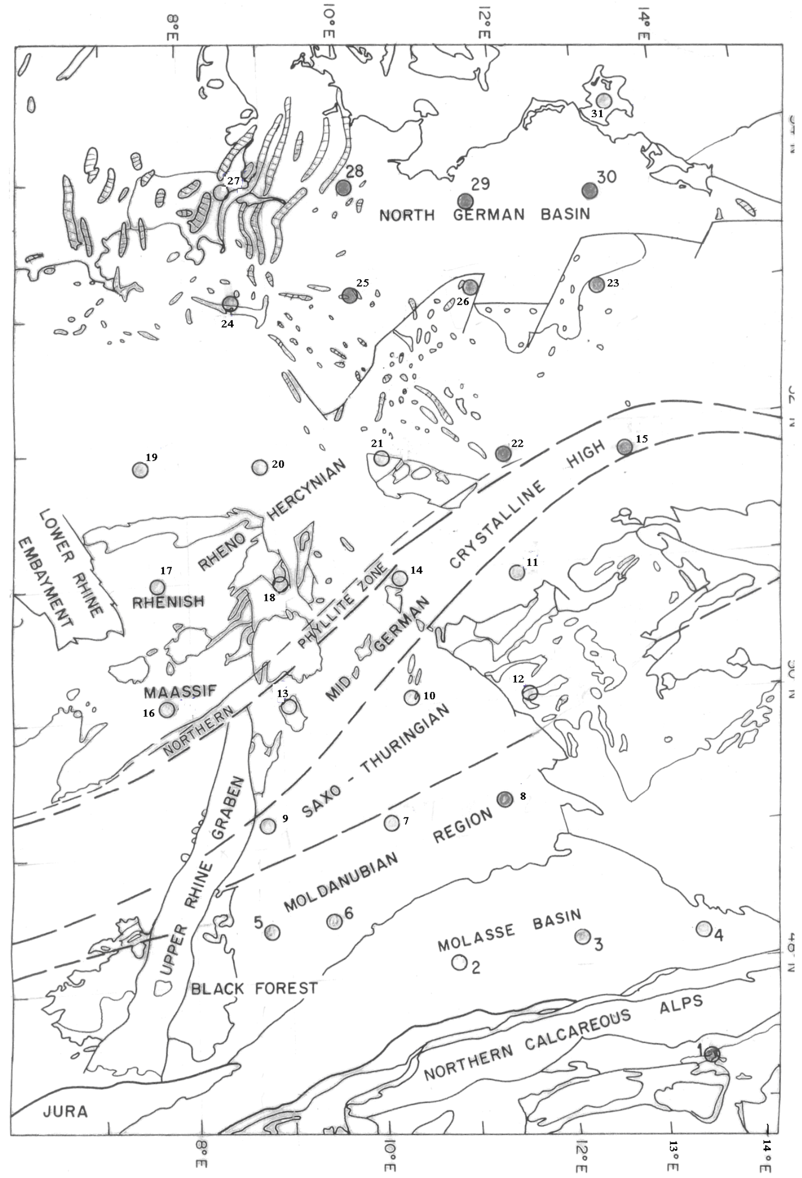

Fig. 1: Simplified tectonic map of Germany (Berthelsen et al., 1992). Numbers indicate centre locations of individual blocks that are analysed concerning Curie depth in this study.

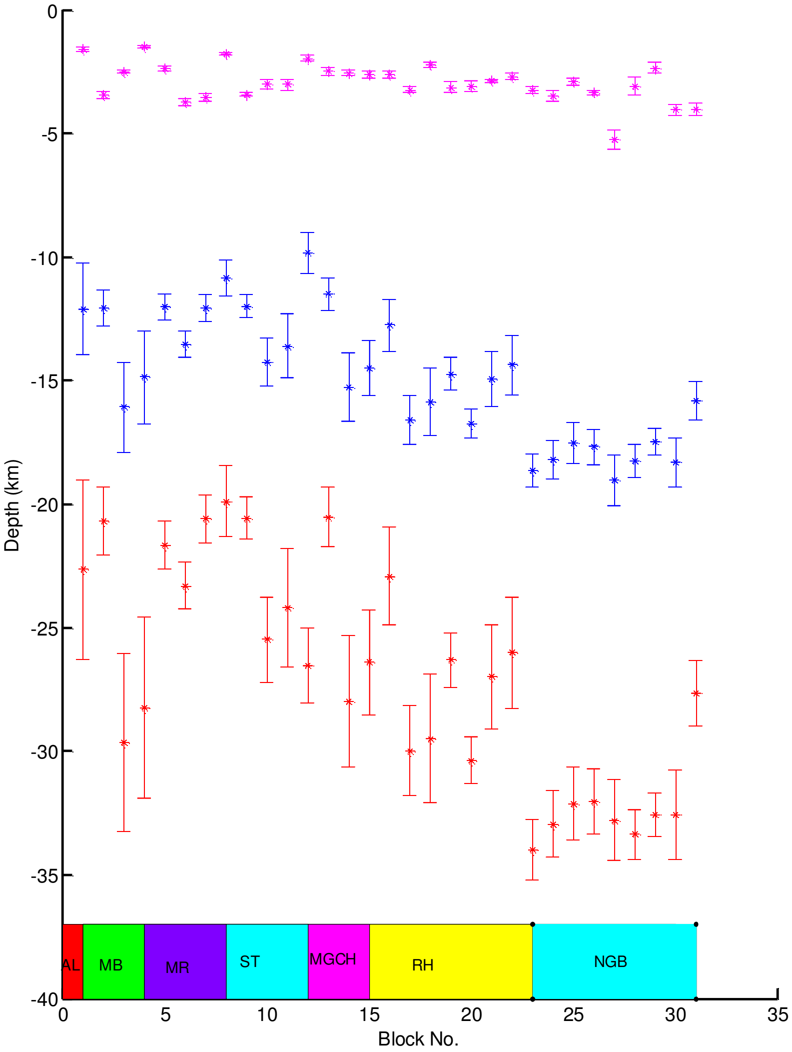

Fig. 2: Depths to the top, centroid, and DBMS with standard errors for the individual blocks, the different geological environments are also shown. AL- Northern Calcareous Alps, MB- Molasse Basin, MR- Moldanubian Region, ST- Saxo- Thuringian, MGCH- Mid German Crystalline High, RH- Rheno Hercynian, NGB- North German Basin.

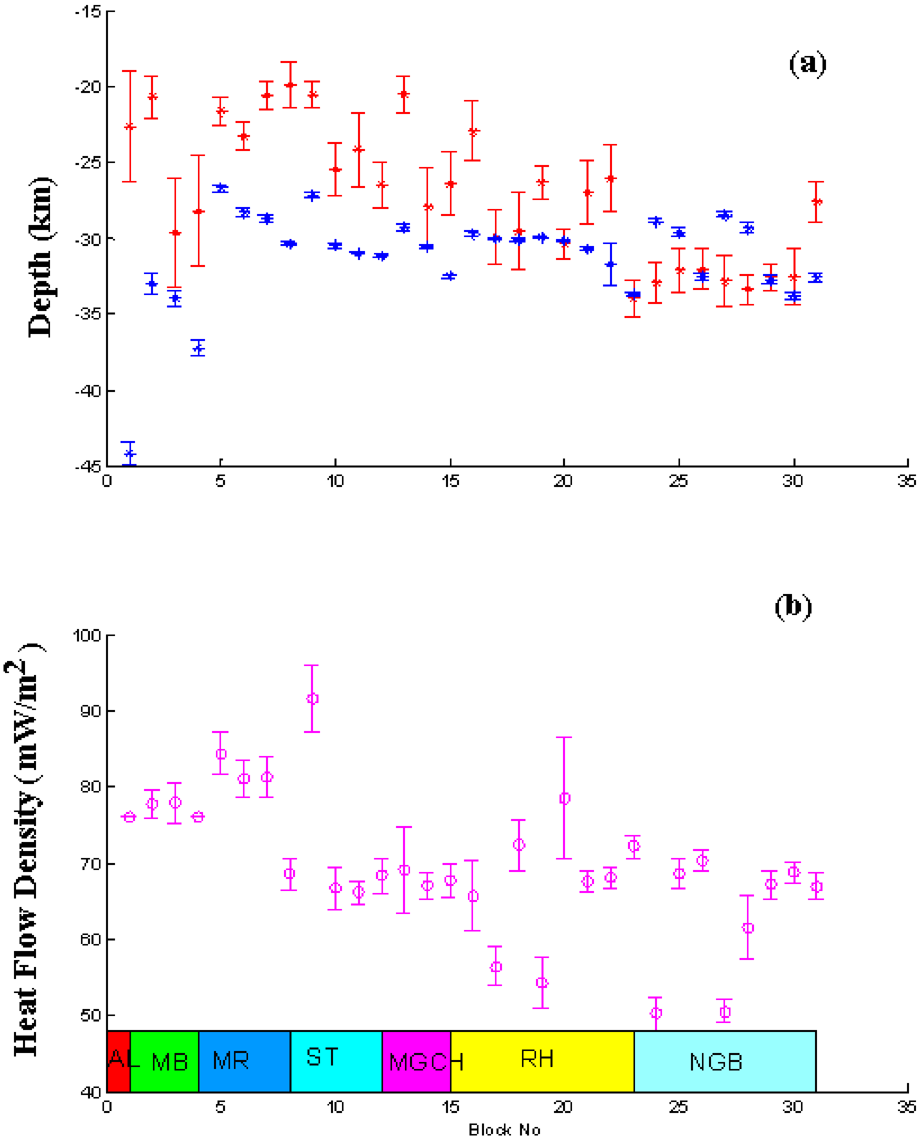

Fig. 3: (a) Comparison of the DBMS (red) with Moho depth (blue, after Tesauro et al. 2009); (b) heat flow densities for each block. Standard errors are shown as error bars.