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Danube Region Environmental Geology Programme DANREG — Explanatory Notes | Editor: G. Császár

Geophysical results

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Magnetic anomalies

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Introduction

In the framework of the DANREG programme it was decided to combine the available magnetic data of the three participating countries. In Austria data from an aeromagnetic survey (GUTDEUTSCH & SEIBERL 1987) were available, whereas in Hungary a D*Z* map constructed from the data of a regional ground survey (HAÁZ & KOMÁROMI 1966) existed; the observation data were digitized in the framework of the DANREG programme. The Slovak part of the DANREG programme area was covered by ground (BÜRGL & KUNZ 1955) as well as by airborne measurements. The data sets were handed over to the team of Austrian geophysicists that supervised the magnetic project. The data set of the map shown in the attached map came into being at the Geophysics Department of Vienna University. The map was printed out in ELGI to ensure the unified format of the DANREG geophysical maps.

Theoretical basis for the construction of the unified map

Several obstacles had to be faced when constructing the unified map. The first and most important of these was that in some areas only D*T* values observed at different altitudes were available, while in other areas there were only ground D*Z* values. In addition, in calculating the anomalies different normal corrections were used in the three countries, the existing maps referred to different epochs, *etc.* Under such conditions no correct solution could be achieved. The unified maps could only be constructed by means of approximations and by neglecting certain factors.

It was decided that the unified common map would be a DT map (but a DZ map has also been constructed). In Hungary only DZ anomaly values were available, therefore these would have to have been transformed into DT data. The following relation exists between the relative changes in total field intensity (DT) and relative changes in the vertical magnetic component:

$$\Delta T = \sqrt{(\Delta H^2 + \Delta Z^2)}, \qquad (1)$$

where D*H* is the horizontal component of the changes in magnetic field.

The horizontal component can be expressed using the inclination (*I*) and the vertical component:

$$\Delta H = \Delta Z\,(\tan I)^{-1}, \qquad (2)$$

where *I* is the inclination of the total vector of the Earth's magnetic field.

Such transformation of the D*Z* component into D*T* assumes the existence of induced magnetization only (without any remanence).

Since the inclination values are not available at each station an approximation had to be used. Thus, the *I* values were determined for each station using the following normal equation:

$$I = 61°39.46' + 0.97448Dj + 0.04731Dl - 0.0004938Dj^2 + 0.0000252DjDl - 0.00003186Dl^2 \qquad (3)$$

where $Dj = j - 45°30'$ and $Dl = l - 16°\,00'$.

The above normal equation was based on 300 Hungarian stations and determined by ACZÉL & STOMFAI (1968).

After having transformed the D*Z* data into D*T* data, the determination of the unified D*T* anomaly system was the next step. To eliminate the distortion along the borders caused by the different normal fields used in the participating countries the equation determined in ELGI for the territories of Austria, Hungary and Slovakia (SZABÓ 1985) was used as the common normal field. In determination of the normal field for Hungary and Slovakia data of the magnetic base network measurements referring to the epoch of 1980.0 were used. Because in Austria only the data referring to the epoch of 1960.0 were available, the time variation between 1960 and 1980 had to be taken in correction. The determination of the time correction was carried out using a quadratic function calculated from the time series of the magnetic observatories in the nearby countries (Niemegk, Wien–Koblenz, Fürstenfeldbruck, Hurbanovo, Nagycenk, Surlari, Grocka, L'Aquila). Coefficients of the quadratic function most closely approximating the field were determined by means of adjustment of Slovak, Hungarian and corrected Austrian data.

To unify the DT data set established by the Austrian colleagues in the framework of the DANREG programme the difference between the common normal field mentioned above and the normal fields applied originally by the individual countries was calculated for each station in all the three countries. The common data set was corrected using the obtained differences; thus the distortions caused by the deviations between the originally applied normal fields were eliminated. Using the unified data set the D*T* map was constructed in ELGI by means of the contouring programme developed by A. SÁRHIDAI (see the attached map).

To check the reliability of the above transformation some profiles were measured in 1991 which traversed characteristic anomalies in all the three countries.

Description of the map

If we look at the map attached the immediate impression is that the magnetic pattern within the Carpathians differs considerably from that outside the mountains. The reason for this is not the fact that the measurements in Hungary and on a significant part of the Slovak territory were carried out about twenty years earlier than in Austria. Even so, it is, of course, true that the accuracy of the measurements performed in Austria in 1987 is by nearly two orders of magnitude higher than, for example, that of the earlier measurements in Hungary. But the real reason is that the Vienna Basin is not so abundant in magnetic anomalies as the region within the Carpathians.

Some details of the data acquisition and interpretation should be mentioned. In the eastern part of Austria the airborne magnetic measurements were carried out with a proton magnetometer (accuracy ±0.125 nT) mounted on a fixed-wing aircraft. The line separation was 2 km, the flight altitude 800 m above sea level. Thus the clearance above the ground surface varied between about 600 and 750 m in the Vienna Basin. To improve the data quality tielines were flown perpendicularly to the lines at every 10 km. The sampling rate of the magnetometer was 1 s (~50 m sampling interval along the line). Flight path recovery was made by means of 35 mm films. The daily variation of the magnetic field was measured at local base stations; their data were later tied to the main magnetic observatory in Austria (Wien–Koblenz). The epoch 1977.7 was used in processing.

The magnetic anomaly pattern in Austria can be characterized by relatively low amplitudes. In the NW part of the attached map traces of the SE portion of a very wide regional anomaly can be recognized. This is caused by a deep-seated body (10–20 km below the surface); in the strike direction it starts from S of Munich, then through Salzburg it runs along the N part of the Kalkalpen (Calcareous Alps). It joins via Vienna the complex magnetic anomalies around Brno (Moravian anomaly). The tectonic setting of this anomaly belt is still a controversial issue. This magnetic pattern is most likely caused by an old basement (Proto-Europe?) which has been conserved between the consolidated Hercynian Bohemian Massif and the Alpine–Carpathian Zone. Younger geological sources —remnants of a North Penninic oceanic crust— have also been considered for the western part of this anomaly (GNOJEK & HEINZ 1993).

There are no magnetic rocks on the surface that could cause the small magnetic anomalies W of Eisenstadt. They might be connected to the young Tertiary volcanic activity that can be observed along the whole eastern rim of the East-Alpine units.

An interesting magnetic anomaly can be found 6 km NE of Rust, right on the W side of Lake Neusiedl/Fertõ. The lateral extension of this anomaly is approximately 6˘5 km and its amplitude is 24 nT (Fig. 1). Using a Werner modelling algorithm a source depth somewhat greater than 2 km is obtained (HEINZ *et al.* 1987). If we consider an average flight altitude of 700 m then the magnetic body lies at a depth of 1.5 km. It is likely that this anomaly is also an evidence for the above mentioned Tertiary volcanism because sulphuric mineral waters occur at the nearby town of Rust.

The most significant magnetic anomaly belt in the area of the DANREG programme with a more than 100 km length in strike lies mainly on Hungarian and Slovak territory. Only some marginal parts of these anomalies can be observed in Austria, E of Lake Neusiedl/Fertõ and S of the town of Hainburg.

Considering its extension the most significant anomaly in the area is the positive anomaly arc which starts S of Mosonmagyaróvár, its strike direction is NE; it turns N of Dunajská Streda and via ˘urány, Dubnik and Karnenin, with a dominant strike of E–SE it terminates at the mouth of the River Ipoly/Ipel'. Taking into account geological and other geophysical data this anomaly is part of a multiple arc structure. The Leitha Hills and the Carpathian chains form the outermost arc. The next arc is the magnetic anomaly discussed here whose maximum zone coincides with the NW and N edges of the assumed source of the stripped gravity anomaly. The next arc is the stripped gravity anomaly itself; the innermost arc assumed by us is the SE–S edge of the stripped gravity anomaly, which coincides with the Rába–Hurbanovo Line detected by numerous methods. All these suggest that the tectonic events associated with the formation of the Leitha Hills and the Carpathians have affected the area of the arcs as well and determined fundamentally the present geological setting.

The spatial coincidence with the outer edge of the stripped gravity anomaly arc is so close that the magnetic anomaly follows the small bulge that can be seen N of Dunajská Streda and also the 15–20 km southward shift of

Fig. 1. Magnetic anomaly near Rust

the northern edge of the stripped gravity anomaly E of the Hurbanovo–Nové Zámky Line.

The spatial coincidence with the deep structural zone reflected by the stripped gravity anomaly suggests that the source of the magnetic anomaly arc is some magmatic rock intruded along the deep fracture. We have, however, no other direct information about these rocks and their spatial position. Within the basin sediments only smooth, parallel reflections can be recognized in the seismic section K–1, which was measured close and parallel to the Danube, over the Hungarian part of the Gabèíkovo anomaly that can be considered as part of the anomaly arc. Thus, within the sediments no volcanic structure of suitable size could be assumed which would be able to cause this anomaly. Based on the seismic data the assumable shallowest source of the magnetic anomaly is the volcanic rock directly overlying the basement at a depth of about 6 km (NEMESI *et al.* 1994). The magnetic susceptibility of the rocks penetrated by the well at ˇurány (S–1) is not high enough ($1.5ˇ10^{-3}$ SI) to explain the whole anomaly.

It should be noted that the anomaly arc bypasses the Kolárovo gravity anomaly, *i.e.* only non-magnetic rock can be assumed as the source of the gravity anomaly.

It is possible that the source of the positive anomaly E of Kapuvár is similar to that of the anomaly arc. However considering the location of this anomaly it is associated rather with the Rába–Hurbanovo Line, *i.e.* with the inner edge of the stripped gravity anomaly arc. In the area of this anomaly Miocene volcanic rocks are known from several wells; however, lava plays only a very limited role among them, thus the directly known formations certainly cannot be considered the source of the regional magnetic anomaly. It is possible that the rocks penetrated by the wells represent the uppermost level of a larger volcanic-subvolcanic complex (NEMESI *et al.* 1994).

East of the regional anomaly arc, mainly on Hungarian territory two further zones of different magnetic anomaly pattern can be distinguished. Between Esztergom and Diósjenõ, on both sides of the Danube (Börzsöny and Dunazug/Visegrád mountains) dense alternation of positive and negative anomalies of small extent is observed. This is caused by the Miocene volcanites making up the two mountains. The reason for the negative anomalies is the strong negative remanent magnetization of some of these volcanites a feature verified by paleomagnetic measurements (BALLA & MÁRTON 1980).

South of Diósjenõ starts an anomaly zone of E–NE strike and a width of about 5 km; it continues E of the area and having a strike length 100 km it terminates on Slovak territory. The scale of the map does not allow to show that this zone actually consists of two parallel positive anomalies. The anomaly zone is associated with the so called Diósjenõ dislocation belt. According to the geological interpretation the source of the southern anomaly may be a Mesozoic greenschist of Meliata type or some weakly metamorphosed basic rock, while the northern source is primarily a Paleozoic basic rock of Gemeric type, metamorphosed up to the greenschist–amphibolite facies (BALLA 1989).

Finally, there are magnetic anomalies of small amplitude and extent on the original magnetic maps of the Hungarian and Slovak territories that cannot be seen on the unified map due to the 25 nT contour line interval. Such small anomalies can be found at the edges of the large isometric anomaly S of Kapuvár. Their source is a Pliocene basalt lying close to the surface; this is an evidence that the crust structure has not come to rest even in recent times.

Some words about the magnetic modelling

The research has been focused on the sources of the large magnetic anomaly belt within the Carpathians, on their depth, age and origin since the coming into being of the first observation results. POSGAY performed the first modelling of the anomaly at the Danube (Gabèíkovo anomaly) thirty years ago (POSGAY 1967). His conclusion was that a source of Palaeozoic age should be sought for at a depth of 4 km. Twenty years later FILO & ˇEFARA obtained very similar results. In the framework of the DANREG programme ARNDT got also a depth of 4 km for the same source, using an up-to-date 3D computer modelling programme. Nevertheless, as we have already described, the seismic and magnetotelluric measurements certainly preclude this depth —at least if we assume that the source of the anomaly is a basic volcanic rock, as it could be demonstrated in each case within the Carpathians. Based on the velocity and resistivity data of the seismic and magnetotelluric measurements performed both in the Hungarian and the Slovak parts of the area, on the reflection image and the 2D geolelectric model (without evidence from wells) we might beyond doubt deduce say that there is a Lower Pannonian sedimentary sequence in this depth interval. Therefore —although there are results demonstrating the possibility of enrichment of magnetite in sedimentary environment and this might cause an anomaly— we have not found an explanation for the origin of this material. Our idea is that the magnetic modelling is simply not unambiguous and in all probability the superimposed effect of several sources has been encountered. In possession of all geophysical data measured in this region our view is that these sources should be located within the pre-Tertiary basement. NEMESI *et al.* (1994) succeeded in carrying out modelling in which the source was at a depth of at least 6 km, *i.e.* really within the basement. ˇEFARA assumes a complex body as the source of the anomaly, which consists of parts with normal and reverse magnetization or several bodies with normal magnetization but various dippings. PAπTEKA (1996) obtained by means of Werner deconvolution 7–7.5 km for the upper boundary of the source.

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