3 EARTH PHYSICS RESEARCH

3.1 INVESTIGATION OF THE GEOMAGNETIC FIELD*

Tihany Observatory recorded the time variations of the geomagnetic field as in previous years. The recorded data were regularly sent to the World Data Centre. According to the preliminary base-line adjustment and evaluation of the hourly mean values the geomagnetic components in Tihany for the epoch of 1986.5 were the following:

$$D = 1°34.8'$$
$$H = 21{,}454 \text{ nT}$$
$$Z = 42{,}358 \text{ nT}$$
$$F = 47{,}479 \text{ nT}$$

To check the standards of the Observatory, comparative measurements were carried out in the observatories of Belsk (Poland) and Grocka (Yugoslavia). Scientist of Hurbanovo Observatory (Czechoslovakia) carried out observations for the same purpose in Tihany. The observed differences in the intensity components were within an interval of 2–5 nT. It means the stability of the observatory standards is of the 2–5 nT interval.

Analysis of the hourly mean values of the horizontal intensity for the time interval of 1973–75 has been continued *(Fig. 100)*. Attempts have been made to determine the regular daily variation by computer filtering, the results were correlated to the quiet days' variation obtained empirically. The daily variation of the disturbed days was investigated as well. The results can be summarized as follows:

— the regular daily variation can be determined by computer filtering *(Fig. 101)*;

— the regular 24 hour period of the *Sq* variation can be recognized mainly near the summer and winter solstices *(Fig. 102)*;

— the residual component shows the regular daily variation of the disturbed periods as well and can be applied to the investigation of the *Sq–Ds* transitions *(Fig. 103)*.

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The observations of the magnetic base network have been recalculated using the coefficients of the IGRF–85 model. The compilation and interpretation of the secular variation map of Hungary and Slovakia has been started in cooperation with scientists of Hurbanovo Observatory.

Revision and resurveying of the secular network has been started. Our intention is to increase the number of base points because, for a number of reasons, many of our original points were destroyed or became disturbed by industrial noise during the last decades.

3.2 GEODYNAMIC INVESTIGATIONS*

Concerning instrumentation, in the first quarter of 1986 a second, 12 m long, extensometer was completed and put into operation in the geodynamic station of Mátyás hill (Budapest). The reconstruction of our old Askania gravimeter has been started in the Institute of Theoretical Geodesy, Bonn University. The planned modification of its thermostat is based on theoretical considerations. To increase the accuracy of the instrument, a new electrostatic calibration device will be built into it. The reconstruction of the Askania gravimeter is being financed by the Humboldt Foundation.

Statistical analysis of the data obtained from the International Centre for Earth Tides has been started. For the calculations only the data recorded in Europe were utilized. The results can be summarized as follows:

— the noise level of observations in the case of O_1, K_1, M_2 waves is 0.1–0.2‰. To reach this optimal noise level a series of observations for more than a year is required;

— the cryogenic and LaCoste–Romberg gravimeters have higher inner accuracy (lower noise level) than the Askania and Geodynamics gravimeters;

— the differences between the results of different instruments are higher than their noise level. This phenomenon hinders the interpretation of the earth tide observations because the possible regional variations of the tidal parameters based on three-dimensional model calculations are less than 1.2‰;

— the M_2 is the most accurately determined earth tidal wave, the noise level of O_1 is much higher. Unfortunately the comparisons of the various instruments were based formerly on wave O_1. *Figure 104* presents the noise levels of O_1, K_1, M_2 and S_2 waves.

Over the past years, differences—which are so far unexplained—have been experienced between the theoretical results of MOLODENSKY and KRAMER [1961] and WAHR [1981]. Based on model calculations it was pointed out that only apparent differences existed. While Molodensky used a simplified earth

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model, Wahr's calculations were performed with the PREM (Preliminary Earth Model) model. If we apply the inhomogeneous differential equations of Molodensky to the PREM we get results similar to those obtained by Wahr. Applying the mathematical arsenal of Molodensky to the new earth model the dependence of Love numbers and their combinations ($\delta = 1 + h - 3/2k$ and $\gamma = 1 + k - h$) on the structure of the mantle was studied. In the first phase the effects of the P- and S-wave velocity (α and β, respectively) variations in the mantle on these numbers, were calculated.

Similar studies were carried out in the case of compressional ($\varkappa$) and shear (μ) moduli *(Fig. 105)*. It can be seen that the effects of α, β, $\varkappa$ and μ on k, h and l values are significant. The dependence of δ and γ on the elastic constants of the mantle is not so characteristic. The obtained variations are non-linear and asymmetric, with larger changes in α and $\varkappa$ than in β and μ.

We have studied the Love numbers and their combinations when α, β, $\varkappa$ and μ elastic constants are changing vertically in the mantle. *Figure 106* presents the effect of a layer of 0.05 relative earth radius thickness ($\sim$320 km) placed in different depths. The horizontal axis represents the depth of the layer in relative earth radius units: $r/R = 1.00$ means that the layer is on the surface; $r/R = 0.60$ means the layer is on the core–mantle boundary. The elastic constants of the anomalous layer are 10% higher than those of the surrounding medium. It can be seen that the effect of α and $\varkappa$ on the Love numbers and their combinations is the greatest if the anomalous layer is in the 0.95–0.85 depth interval. With β the relationship is more complicated: k and h decrease with increasing depth, while l decreases up to a relative depth of 0.9 then starts to increase. The variations of μ are similar to β.

In 1984 Woodhouse and Dziewonski studied the horizontal inhomogeneity of the upper mantle. Their investigations were based on S-wave velocity data. The result is a 3D upper mantle model down to 670 km ($r/R = 0.90$). The observed velocity anomalies are $\pm 8\%$ at 50 km, $\pm 2.5\%$ at 250 km and $\pm 2.0\%$ at 650 km depths. The horizontal velocity variations are about the same as experienced in the radial direction. With the PREM model there is a 15% jump in β at the Moho and 6%, 3% and 7% at depths of 220, 400 and 670 km, respectively. Elsewhere, Dziewonski [1984], published a 3D model based on P-wave velocities for the lower mantle. The P-velocity anomalies can reach about $\pm 3\%$ in the upper part of the lower mantle. The same is the situation at the core–mantle boundary. In other parts of the lower mantle anomalies of the order of $\pm 1\%$ can be found.

Based on the above mentioned data and the condition $\alpha \approx \sqrt{3}\,\beta$ the following variations were obtained compared with the radial model:

$$\Delta k = -1.80\%, \quad \Delta h = -2.67\%, \quad \Delta l = 0.82\%,$$

$$\Delta\delta = -0.72\% \quad \text{and} \quad \Delta\gamma = 1.59\%.$$

Taking it into consideration that the accuracy of the density function in the mantle is $\pm 2\%$ and modifying the density values of the PREM model by this 2% (taking a higher density for the inner core to keep constant the inertia moment of the Earth, which modification practically does not effect the Love numbers) we get the following values for the regional variations of Love numbers and δ and γ:

$$\Delta k = -1.16\%, \quad \Delta h = -1.42\%, \quad \Delta l = 1.76\%,$$

$$\Delta\delta = -1.23\% \quad \text{and} \quad \Delta\gamma = 1.80\%.$$

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Results of palaeomagnetic studies on the ophiolites from the Bükk Mts

A few outcrops of the Mesozoic ophiolites from the Bükk Mts were tested palaeomagnetically in the sixties [Márton and Márton, unpublished]. As a result of AF (alternating field) cleaning, up to a maximum of 0.05 Tesla, a relatively stable remanence was isolated with a reasonable but rather large scatter for each site. The mean magnetic directions exhibited northwesterly directed declinations with near-zero inclinations before tilt correction and very steep ones after. Meanwhile, the between-site scatter remained unchanged. These results did not fit any plausible tectonic model. Since the sixties both the instruments and methods have advanced. With the now available facilities the NRM (natural remanent magnetization) may be demagnetized in many steps till the meaningful signal is lost. In this way the whole spectrum of the NRM can be studied and very often its components of different origin can be recognized.

Samples from a number of ophiolite outcrops *(Fig. 107)* were recently subjected to such exhausting demagnetization. Each ophiolite specimen was treated first with AF sometimes up to 0.23 Tesla. Those having retained part of the NRM at 0.23 Tesla were further subjected to thermal demagnetization. These experiments revealed that the NRM of both the basalts and gabbros is extremely resistant to AF *(Fig. 108/a)*. This behaviour is difficult to explain since the carrier of the NRM seems to be basically magnetite *(Fig. 108/b)*. Moreover the NRM is complex in the sense that it is composed of two components with similar directions but opposite polarity. Overprint along the present-day field direction is very rare and is easily removed. Unfortunately a single component is not always easy to identify. The best studied in this respect is a gabbro sill (Fig. 107, locality 1) where samples were taken at six sites across the sill (maximum distance 45 m). Although full demagnetization of the NRM has been achieved, and the grouping of the remanence directions at most sites is reasonably good (*Table II*, the *k* value is large), there is no sense in computing an overall mean for the sill. After the removal of the overprint along the present-day field direction, the mean directions and

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some of the individual ones as well define a large circle joining counter-clockwise rotated directions with normal and reversed polarity, respectively *(Fig. 109)*.

At *site I*, the mean declination is close to 180°, the mean inclination has a low positive value; both remain unchanged on cleaning. For *site II*, the mean moves along a great circle on demagnetization. This great circle is defined by triangle 1 (direction measured from the natural state up to 0.05–0.11 Tesla) and triangle 2 (directions measured at 0.09–0.11 Tesla). One sample, represented by a small triangular symbol, exhibited different behaviour from the others —represented by the large triangles. At *site III*, the samples exhibit uniform behaviour and the direction changes along a great circle similar to that for site II (semi-circle 1 is for the natural state, 2 is for 0.08–0.11 Tesla cleaning steps, 3 is for 0.09–0.12 Tesla demagnetization field). At *site IV* the overprint in the present Earth's field is evident (circle 1, natural state), but this overprint is removed at 0.05 Tesla (2nd step). At higher AF fields and high temperatures (0.15 Tesla and 550 °C) the directions became scattered—as shown by the small circles labelled by 3. Samples from *site V* exhibit an overprint along the present-day field (square 1, natural state) which is removed at 0.04–0.05 Tesla. On cleaning, the direction shifts towards negative inclinations (square 3) with the exception of one sample. The initial behaviour of the samples from *site VI* is similar to those from site V, but the remanence direction stabilizes on the normal side of the sphere instead of cleaning further.

The reverse end of the great circle defined by samples of locality 1 seems to be reached by some samples, while the normal end is only extrapolated. At other localities, however, a similar direction is borne out from actual measurements (crossed circle). The extreme values on the reverse side might be taken to be a primary remanence at this locality (Table II, sites II, III, V.; cleaning stage 3) and the rest rejected on grounds of imperfect cleaning.

The example of locality 1 shows, therefore, that AF demagnetization in moderate peak fields, routinely applied to igneous rocks, is a complete failure for the Bükk ophiolites. It is only the complete demagnetization and analysis of the NRM that renders the palaeomagnetic information sealed in the ophiolites decipherable.

It is well known that the Bükk ophiolites were subjected to low-grade metamorphism. The question arose as to whether the metamorphism could deflect the direction of the remanence from the Earth's ambient magnetic field. The possible bias due to an oriented texture of metamorphic (or magmatic) origin is commonly estimated from the degree of magnetic susceptibility anisotropy and the grouping of the principal axes of the susceptibility ellipsoid. Locality 1 was studied for this effect, too. The results may be summarized as follows:

— the degree of anisotropy is surprisingly low for a metamorphosed rock: $\varkappa_{max}/\varkappa_{min}$ is close to 1.00, the degree of anisotropy does not exceed a few per cent and in some cases it is less than 1%;
— the grouping of at least one principal susceptibility axis (despite the low degree of anisotropy) is very good for each site except IV;
— the distribution of the principal susceptibility axes is far from being uniform across the sill and does not reflect the stress field that must have prevailed during regional metamorphism;
— no correlation seems to exist between the orientation of the susceptibility ellipsoids and the direction of the remanent magnetization (compare *Figs 109* and *110*).

3.4 GEODETIC GRAVIMETRY*

In 1986, absolute gravity measurements were carried out on the gravity base in the cave of Mátyás hill using a Soviet-made absolute gravimeter (GABL). This was the third occasion of the determination of the absolute gravity field at the point. In order to study the vertical gradient-height relationship, gravimeter measurements were carried out at different levels on the absolute point. Between the reference heights of 618 mm and 1672 mm a variation of 165 E was experienced in the vertical gradient *(Fig. 111)*.

So far as methodology is concerned, investigations were carried out to determine the gravity effect of varying atmospheric masses. A computer program was developed for the calculations based on different atmospheric models, isobar maps and radio-sonde data. Taking into account extreme atmospheric conditions for Middle Europe a gravity effect of $13 \cdot 10^{-8}$ ms^{-2} (13 μgal) was obtained, which value is higher than the accuracy of modern absolute gravity determinations.

The observations carried out on the Unified Gravity Net (UGN) between 1980 and 86 were adjusted by the least squares method and by other methods applying different target functions. The method of robust estimation proved to be very useful especially in the case of relatively high observation errors.

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