3 EARTH PHYSICS RESEARCH

3.1 INVESTIGATION OF THE GEOMAGNETIC FIELD*

Following the practice of previous years, the determination of the absolute value of the geomagnetic elements and the recording of their variation in time continued at Tihany Observatory.

Data obtained from processing the records were sent to users at home and to international data banks.

In order to check the geomagnetic datum of the Observatory comparative measurements were carried out during the year at Niemegk Observatory (GDR). Researchers of Hurbanovo Observatory (Czechoslovakia) performed similar measurements at Tihany Observatory.

Final processing of the national magnetic base network for the epoch 1980.0 has been completed in the course of which we determined coefficients of second and third order functions describing the horizontal component, the vertical component, total field intensity and the normal field of declination. Presented here as an example is the contour map of the normal field of total field intensity *(Fig. 98)*.

The digital magnetic recording system operated for many years at Tihany Observatory furnished a great deal of useful experience. On the basis of this experience we started the reconstruction of the obsolete data acquisition unit of the recording system in cooperation with the Department for Microwave Telecommunication of the Technical University of Budapest. Our purpose was to create a special digital magnetic recording system (DIMARS) capable of recording the total values and components of the geomagnetic field within the range of slow variations for a long time with high reliability, capable of working under as little supervision as possible and of furnishing the greatest possible amount of data observed or deduced from measured data by geomagnetic observatories.

A system designed with due consideration of the above purposes, the block-diagram of which is presented in *Fig. 99*, is characterized by the following main features:

— it measures signals proportional to variations of the three components

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which arrive from the variometers with electric outputs (MTV–2), as well as the temperature of the variometer room every 10 seconds;
- it calls in values measured by the proton magnetometer every 10 seconds;
- it averages measured data every minute and records the result on a digital cassette-type recorder;
- it continuously monitors the input data and gives a warning of any abnormality;
- if an abrupt change in magnetic field (magnetic storm) occurs—as determined in advance by the operator—it commences rapid recording on a second digital magnetic tape recorder until stopped by the operator.

In addition to the above mentioned basic functions the apparatus provides data, which are calculated usually by the staff of observatories while processing the records. Thus, for example, starting from any preprogrammed moment it records field characteristics every 10 minutes for field crews. These data are stored in the inner memory of the apparatus and at the operator's command are printed out or punched on punched tape. The values of daily maximum and minimum for each component with corresponding time data are also collected and stored. The hourly and daily average values are calculated and stored and printed out or recorded on magnetic tape at the end of the month at the command of the operator.

The recording system requires replacement of magnetic tape cassettes by the operator every 48 hours. On such occasions the operator is able to check the operation of the system with the aid of a keyboard, perform various tests, and modify or reprogram individual characteristics.

If a data recording apparatus of higher capacity is connected to the system, then remote control of the instrument is possible with the help of a telex attached to the equipment. Measured data cannot be entered directly to the telex, but there is no basic obstacle to such data being stored in the memory and transmitted if needed. In such instances there is no need to monitor the equipment at the site since it can be operated by remote control.

In the field of ionosphere-magnetosphere investigations the analog recording of whistlers and the processing of measured data continued. The signal detecting unit of an automatic whistler detecting and preprocessing apparatus has been completed. In its present state it is able to recognize whistlers with a reliability of 80% and to record the arriving signals in digital form.

3.2 GEODYNAMIC INVESTIGATIONS*

Within the framework of our geodynamic investigations, observations with the Model LCR ET–16 recording gravimeter of Darmstadt Technical University have been concluded. In the course of this cooperation a nearly two and a half years long continuous series of good quality data has successfully been recorded. The measurements are now being processed.

At the Budapest geodynamic station (Mátyás-hill) the recording of the vertical and horizontal components of earth tides as well as the extensometer observations were continued. The extensometer observations show that the horizontal crust movement is characterized by a long period variation of 30 μm/year. Since variations of such order are usually related not to instrument drift but to movements in the surroundings of the instrument, we attempted to give this value a geophysical explanation. The relative yearly variation of 30 $\mu m/21\ m = 1.5 \cdot 10^{-6}$ recorded in our case was compared with the data of other stations all over the world. It has been established that independently of the type, azimuth and site of the extensometers the recorded variations are in the same order of magnitude as observed at our station meaning that the order of magnitude of horizontal crust movements is 0.01 mm/year. Theoretically it is also possible to estimate the stresses or, to put it more accurately, the stress changes on the basis of deformations. If relative displacements of 10^{-6}/year are accepted, a change in stress of 10^5 N/m^2/year is received. Such a change, however, is too great. By way of example: the value of stress experienced in the course of strong earthquakes amounts to 10^6 N/m^2, or when the value of 10^{-6} is applied to earth tides then 10^3 N/m^2 is received (whereas according to model calculations such a lunisolar stress can be reckoned with for the middle parts of the mantle only). In all probability the deformation variations observed by us are related to processes taking place at such depths.

Investigations were also carried out to determine whether stresses caused by meteorological and hydrological phenomena can be related to earthquakes. Such external influences may affect the triggering of earthquakes—when all other tectonic preliminary conditions are present—if they are able to create

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a correspondingly big change in stress at the surface or near it and the stresses have also a lateral gradient along the surface. The value of the highest possible elastic stress is 10^7 N/m^2. Under the influence of stress in excess of this value unelastic deformations will take place. This probably explains why the geoid anomalies do not exceed 100 m, since at the bottom of such anomalies stresses over 10^7 N/m^2 come into being leading to a viscous flow of substance off the bottom of anomalies to localities of lower pressure.

The stress caused by earth tides reaches the value of 10^3 N/m^2 at great depths only; at the surface there is no stress, not to speak of lateral gradient. Thus no mention can be made of the earthquake triggering effects of body tides. In spite of this many authors have published results of statistical investigations indicating that there exists a relationship between the outburst of earthquakes and changes in earth tide potential. This phenomenon may be attributable to the indirect effect of ocean tides, exerting a load on the earth's surface; stresses of the order of 10^4–10^5 N/m^2 appear in coastal areas decreasing rapidly departing from the coast (a high lateral gradient exists). Stresses due to oceanic load that appear at the earth's surface may trigger earthquakes if tectonic conditions are favourable.

The effect of barometric variations also exceeds the effect of earth tides. Such variations may cause stresses over 10^3 N/m^2 and if a significant lateral gradient exists they may influence earthquakes.

The depth of water reservoirs is often more than 100 m. The arising stresses during filling up these artificial lakes—in the case of fault structures—are more than enough to initiate an earthquake.

The load calculations rely on model *A* of Gutenberg–Bullen. Stresses caused by loads were calculated on the basis of Molodensky's theory. It could be established that the effect of external loads decreases rapidly with increasing depth, hence they may exercise some influence—if any—on shallow earthquakes only, Stresses originate only if the extent of the loaded area exceeds a critical value (0.25–0.7 km^2). At the margin of the area subjected to external load the stress falls abruptly, thus the maximal shear stress generated by surface load can influence earthquake occurences in the surroundings.

3.3 PALAEOMAGNETIC INVESTIGATIONS*

Palaeomagnetic investigation of geological basic sections

In the framework of this topic three themes were studied:

A) We have continued the investigation of the middle Triassic basic section of the Malom valley at Felsőörs started in 1981. Attempts were made to determine the polarity of characteristic remanent magnetization for odd number beds in 1981 and for even number beds in 1982. Of the even number beds 2–3 samples were taken from each one in order to see variations in direction and eventually in polarity within individual layers. For parts of the section suitable for sampling an approximate polarity scale was determined *(Fig. 100)*. Samples should also be taken from the omitted parts to complete the polarity scale.

B) The following exposures of red sandstones of the Balaton highland have been studied:

- *a)* Balatonalmádi, Vadvirág Street, exposure of the basic section: fine grained red sandstone and white Triassic limestone (dip: 310/41);
- *b)* Balatonalmádi, quarry: red sandstone (dip: 278/22);
- *c)* Balatonarács, exposure of the basic section in a railway cutting: fine grained red sandstone (dip: 228/37.5);
- *d)* Balatonfüred, exposure in front of the shipyard: fine grained red sandstone (dip: 240/56);
- *e)* Kővágóörs: red sandstone directly underlying the Triassic conglomerate (dip: 314/23).

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The directions of characteristic magnetization for the individual sample groups are as follows:

Prior to tectonic correction	After tectonic correction
a) $N=18$ $D=323^\circ$ $I=49^\circ$ $k=21$ $\alpha_{95}=7.8^\circ$	$D=319^\circ$ $I=9^\circ$ $k=21$ $\alpha_{95}=7.8^\circ$
b) no characteristic magnetization	
c) $N=16$ $D=316^\circ$ $I=46^\circ$ $k=12$ $\alpha_{95}=10.9^\circ$	$D=285^\circ$ $I=34^\circ$ $k=12$ $\alpha_{95}=10.9^\circ$
d) $N=9$ $D=308^\circ$ $I=29^\circ$ $k=15$ $\alpha_{95}=13.8^\circ$	$D=295^\circ$ $I=0^\circ$ $k=15$ $\alpha_{95}=13.8^\circ$
e) $N=9$ $D=317^\circ$ $I=52^\circ$ $k=16$ $\alpha_{95}=13.4^\circ$	$D=316^\circ$ $I=29^\circ$ $k=16$ $\alpha_{95}=13.4^\circ$

From the mean direction of sample groups *a)*, *c)*, *d)* and *e)* having a characteristic magnetization a new mean direction was calculated prior to and after tectonic correction:

Prior to tectonic correction	After tectonic correction
$N=4$ $D=316^\circ$ $I=44^\circ$ $k=51$ $\alpha_{95}=13^\circ$	$D=304^\circ$ $I=18^\circ$ $k=13$ $\alpha_{95}=26^\circ$

where

D = average declination
I = average inclination
k and α_{95} = statistical parameters
N = number of samples

The statistical parameters deteriorate after the beds have been adjusted to the horizontal position (after tectonic correction). This phenomenon seems to indicate that the rocks obtained their magnetization in their present tectonic positions. Sampling of further exposures is needed to decide whether the magnetization of each type (or of certain types only) of red sandstone of the Balaton highland originated after folding.

C) Investigation of Jurassic and Cretaceous limestones around Úrkút and Városlőd.

The purpose of this investigation was to decide whether the deviation in strikes of units characterized by structural axes running in different directions (N–S or NE-SW) might be due to tectonic movements after the lower Cretaceous.

Samples were collected at the following sites:

a) Úrkút, manganese mine, shaft 3, western gallery: Dogger grey limestone, bottom of the manganese complex. 10 samples, N–S structure;

b) Városlőd, Gombáspuszta: thin banks of white limestone without level indicating fossils, a Bajocian formation exists beneath it thus it is thought to be of Bathonian age. 6 samples, N–S structure.

c) Városlőd, Gombáspuszta, railway cutting: light-grey Dogger limestone, 5 samples, NE–SW structure;

d) Úrkút, Csingervölgy: folded light Dogger limestone. 4 samples, N–S structure;

e) Úrkút: Albian pink fractured limestone in thick banks. 10 samples, N-S structure.

Groups *a)*, *b)* and *e)* show a characteristic magnetization. From investigations performed in 1982 it can be established that there is no significant deviation in magnetic directions of sample groups obtained from structures with axes running N–S and NE–SW, but the limited number of sampling sites giving results does not permit one to draw final conclusions.

Palaeomagnetic investigation of bauxites and their embedding rock

Within the framework of this topic we have continued investigating the Gánt and Szőc bauxite areas started in 1981.

A) At Szőc, samples were collected from bauxite beds overlying and underlying the red zone characterized by iron accumulation, from the iron-containing zone itself and the overlying Eocene limestone. Similarly to previous observations the Eocene limestone has not revealed any characteristic magnetization in this instance, either. The direction of magnetization within the iron-containing zone indicates a total remagnetization in the recent magnetic field. The directions of typical magnetization for bauxites underlying the ironcontaining zone are as follows:

$$D=114.2^\circ \quad I=-23.4^\circ \quad k=9 \quad \alpha_{95}=19.3^\circ \quad N=8.$$

The bauxites over the iron-containing zone has no characteristic magnetization.

The magnetic investigation of minerals which carry the magnetization, as well as the analysis of natural remanent magnetization make it evident that the magnetization of bauxites is complex from both points of view. Since further demagnetization is not possible any improvement of statistical parameters related to the given direction should come from an increasing number of samples.

B) The bauxite at Gánt is subject to similar comments. The direction of characteristic magnetization is:

$$D=112.9^\circ \quad I=-36.8^\circ \quad k=9 \quad \alpha_{95}=17.1^\circ \quad N=10.$$

The magnetization of the overlying grey marl is very well defined (however, its geological age is uncertain):

$$D=109.0^\circ \quad I=-57.4^\circ \quad k=101 \quad \alpha_{95}=4.6^\circ \quad N=11.$$

The overlying Eocene limestone does not show any typical magnetization.

Palaeomagnetic investigation in the Velence hills

The investigation of all andesite exposures suitable for palaeomagnetic sampling in the Velence hills has been concluded. The original magnetization of andesites has been completely overprinted by subsequent magnetization acquired in recent magnetic field. This subsequent magnetization can be completely removed by demagnetization in an alternate field with an intensity of 31,83 A/m (400 mOersted), or by thermal demagnetization at 400 °C *(Fig. 101)*. On the basis of 8 sampling sites the direction of the magnetic field at the time of the andesite volcanism was as follows:

$$D=153^\circ \quad I=-45^\circ \quad k=28 \qquad \alpha_{95}=10.6^\circ \quad N=8.$$

The magnetization of all andesite bodies is of reversed polarity.

The bulk of the investigated granites was completely or partly remagnetized at the time of the andesite volcanism. The materials of five separate granite exposures have independent magnetization. The direction of characteristic magnetization—maybe of upper Carboniferous age—is as follows:

$$D=144^\circ \quad I=31^\circ \quad k=9 \qquad \alpha_{95}=8.0^\circ \quad N=91.$$

International cooperation in palaeomagnetic investigations

Within the framework of cooperation between Yugoslavia and Hungary, Austria and Hungary, USA and Hungary, samples were taken of sedimentary exposures of the Dinarides, several magmatic exposures of the Mecsek Mts and Balaton highland, four metamorphic exposures in the Rohonc Mts and individual exposures of red sandstones of Permian age in Hungary and of Jurassic—Cretaceous age in the United States. Palaeomagnetic investigation of these rock samples is in progress.

3.4 GEODETIC GRAVIMETRY*

Gravimeter measurements over the Central and East European Gravity Standardizarion Net (CEEGSN) covering the territories of the socialist countries started in 1982. An initial condition concerning this network was that the standard deviation of individual ties (μ_0) should not be more than $3 \cdot 10^2$ nms^{-2} (=0.03 mgal)**. To meet this extremely rigorous requirement absolute gravity meters, relative pendulums and various types of relative gravimeters are used for measurements on the network.

To make the CEEGSN a high precision basis for the Gravity Base Networks of individual countries, each country designed an optimal network configuration which guarantees the fulfilment of the initial condition with regard to the available instruments.

When further planning of this network took place one of the conditions was the selection of a version—by choosing corresponding weights of measurement—which would furnish a network with an error distribution satisfying the planners' purposes to the greatest extent at minimum costs.

One method to determine the weight of a measurement is to minimize the scalar target function which is characteristic of the accuracy of the network. We elaborated several procedures for minimizing the scalar target function. Judging by our experience, the weight strongly depends on the choice of the target function and of the optimization process, as well as on the free or constrained nature of the network to be designed.

Another method to determine the weights of measurements is the approximation of the network having an error distribution defined a priori by mathematical programming. In the course of planning the variances of ties that build up the network were accepted as a function of station distances. Since the weight numbers obtained by linear programming are usually not whole numbers they have to be rounded upwards to determine the number of necessary repeat observations. As a second version we performed planning using a "programming with whole numbers". In many instances the repeat numbers

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** 0.01 mgal$=10^2$ nms^{-2}

obtained by the second version turned out to be lower than the rounded up numbers obtained by linear programming.

These methods permit one to plan a substantially more accurate, homogeneous network making more efficient use of the available material means. A program for an R–35 computer was developed for each method of planning.

In recent years the absolute value of gravity with a standard deviation of ±10–14 μgal was determined at four points (refer to Annual Report for 1980, Fig. 86). These points were located to cover the possible greatest part of the "*g*" range of the country. Eight points of the CEEGSN are located on Hungarian territory (12,000 km^2/point).

The instruments were transported by a Pilatus-Porter turbo aircraft at a height of 200–400 m. The survey was performed in cooperation between Hungary and Czechoslovakia with 8 gravimeters using an *A–B–A–B–A* observation system. The Hungarian section of the CEEGSN is presented in *Fig. 102*. The absolute points were connected to CEEGSN points located at airfields near them by car transported gravimeters. The standard deviations of these connections are $\pm 5-8$ μgal.

Preliminary evaluation of the survey

Values of absolute "*g*" deduced for CEEGSN stations at the nearest airfields were assumed to be correct and accepting them as known values we carried out the adjustment of the Network for each single instrument. This adjustment furnished the scale factor of individual gravimeters. The latter were employed to correct the measured Δg values for a common adjustment of the network, where the "*g*" values of the new points were regarded as unknowns (ten unknowns) and all measurements were accepted as having equal weight.

Two version were prepared: In version 1 each Δg value calculated from one series of observations (*A–B–A–B–A*) was taken for an individual measurement (4 values for each instrument per day). In this version 1,063 items of data were available to determine the ten unknowns. Taking it into account that in adjustment based on the least squares method one may work with mutually independent measurements only, in version 2, the average results of individual gravimeters in a day were taken for independent values only (244 values).

We have calculated the standard deviation of the unit weight (μ_0) characterizing the reliability of the network—prior to adjustment—and the standard deviation of the most probable value (μ_x). Results are presented in *Table VI.* We have determined also the closure error of closed polygons prior to adjustment and obtained $\omega_A = +22$ μgal, $\omega_B = -15$ μgal, and $\omega_C = +30$ μgal (Fig. 102).

On the basis of the analysis the initial condition seems to be realizable for the Hungarian section of the CEEGSN.

Within the scope of the modernization of gravimetric networks we have continued the measurements of the gravity network of the II*nd* order. In 1982, 145 connections of this network were determined.

Table VI.

Connection	Version 1			Version 2		
	n	μ_0	μ_x	n	μ_0	μ_x
		$\cdot 10^2$ nms^{-2}			$\cdot 10^2$ nms^{-2}	
1.	84	4.4	0.5	21	4.0	0.9
2.	64	3.5	0.4	16	3.0	0.7
3.	60	4.4	0.6	15	3.2	0.8
4.	64	2.6	0.3	16	2.1	0.5
5.	64	1.7	0.2	16	1.5	0.4
6.	64	2.7	0.3	16	1.4	0.4
7.	64	2.8	0.4	16	2.2	0.6
8.	64	2.3	0.3	16	2.0	0.5
9.	64	2.6	0.3	16	2.2	0.6
10.	71	3.2	0.4	16	1.7	0.4
11.	60	1.4	0.2	16	1.2	0.3
12.	68	2.1	0.2	16	1.9	0.5
13.	69	2.5	0.3	16	2.7	0.7
14.	75	2.5	0.3	16	1.7	0.4
15.	64	2.4	0.3	16	2.4	0.6
16.	64	3.0	0.4	16	2.6	0.6
Σ	1,063			244		
mean		2.8	0.34		2.2	0.56

n = number of Δg measurements

$$\mu_0 = \pm \sqrt{\frac{\Sigma vv}{n-1}} \qquad \mu_x = \pm \frac{\mu_0}{\sqrt{n}}$$