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INTERCONNECTING GRAVITY MEASUREMENTS BETWEEN THE AUSTRIAN AND THE HUNGARIAN NETWORK

Géza CSAPÓ*, Bruno MEURERS**, Diethard RUESS***, Gábor SZATMÁRI*

An account is given of the comparative measurements carried out on the Hungarian and Austrian gravity base networks in the period of 1991-1993. This work includes absolute and relative gravity measurements. The absolute measurements were performed with the JILAG-6 absolute gravimeter, the relative measurements with 5 LCR gravimeters on 24 ties between selected points of the base networks along the border of the two countries.

It has been established that 40 μGal difference exists between the gravity datum of Austria and that of Hungary. To determine the source of this deviation further investigations and readjustment of the Hungarian gravity network are needed.

Keywords: gravity surveys, Austria, Hungary, network

1. Introduction

In the wake of the rapid progress in instrument design and measuring techniques the Earth sciences require the development of geodetical base networks covering as large areas as possible in order to solve the increasing numbers of theoretical and practical tasks.

For some years the gravimetric network of Austria has been connected to those of Germany, Switzerland and Italy (1985-1987), while the network of Hungary to that of former Czechoslovakia (1985-1988). Further cooperation was rendered possible by the countries of Central Eastern Europe lifting the secrecy on their base networks and striving to participate more and more intensively in joint projects initiated by international organizations. This re-

* Eötvös Loránd Geophysical Institute of Hungary, H-1145 Budapest, Kolumbusz u. 17-23
** Universität Wien, Institut für Meteorologie und Geophysik, A-1190 Wien, Hohe Warte 38
***Bundesamt für Eich- und Vermessungswesen, A-1025 Wien, Schiffamtgasse 1-3
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sulted in the conducting of connecting measurements between the Austrian and Czech, and the Slovakian gravity base networks in 1991. Similar work was performed in 1991-93 between Austria and Hungary. The framework for these projects was set up partly by bilateral agreements on scientific cooperation, partly by the 'DANREG' program started in 1989. The connecting measurements include absolute and relative gravity surveys.

2. Absolute gravity measurements

The Austrian Gravity Base Network (AGBN) contains 23 absolute stations, and at several selected points repeated determinations have been performed as well [RUESS et al. 1989]. On the basis of these measurements the AGBN point catalogue was up-dated for 1993 prior to the interconnecting measurements.

In 1989 at the time of the adjustment of Hungarian Gravity Network (HGN-80) the '*g*' values determined at five points with a GABL absolute gravimeter between 1978-80 were accepted as constraints, thus the datum level and scale of the network were determined by these values [CSAPÓ, SÁRHIDAI 1990]. In the period of 1991-93, using the JILAG-6 equipment, RUESS et al. repeated the earlier absolute measurements at four points. From data compiled in *Table I*, it is evident that the discrepancy of values determined by the two different type of instruments is substantially higher than the accuracy of absolute gravimeters [BOULANGER et al. 1991]. The examination of such conspicuous discrepancies goes beyond the scope of this paper. For the

absolute station	year	GABL JILAG-6 mGal	VG μGal/m	difference μGal	variation μGal/year
81 SIKLÓS	1978	678.291	339.4	+ 30	+ 2.3
	1991	678.321	339.4		
82 BUDAPEST	1980	824.328	250.2	- 22	- 1.9
	1991	824.307	250.0		
85 KŐSZEG	1980	784.748	267.2	- 33	- 2.5
	1993	784.715*	271.0		
86 SZERENCS	1980	872.816	290.6	- 31	- 2.2
	1993	872.785*	298.0		

* calculated with the corrected vertical gradient (VG)

Table I. Results of absolute measurements in Hungary
I. táblázat. A magyarországi abszolut mérések eredményei

comparison the Hungarian gravity data were reduced by the average of differences (15 μGal)* obtained on the four reobserved absolute stations. The repeated absolute measurements require the re-adjustment of HGN-80 as a necessity. In this respect, in 1993–94 several new absolute points have been measured in Hungary; re-adjustment of the network is due to be performed after these measurements have been completed.

The absolute measurements were processed by RUESS in the usual way, i. e. corrections with regard to systematic instrumental effects, air pressure, polar motion and height (reduction to ground level) were applied. The 'vertical gradient' measurements were performed by means of 2 LCR gravimeters with an accuracy of ±2μGal.

Using three independent sets of measurements at Kőszeg, Hungary (*Fig. 1.*) the most probable value of gravity and its error can be calculated in two different ways:

a) each drop taken as an individual measurement

b) one set (containing 1200–1800 drops) taken as one measurement.

We regarded version b as a more realistic approximation, and these values are given in Table I.

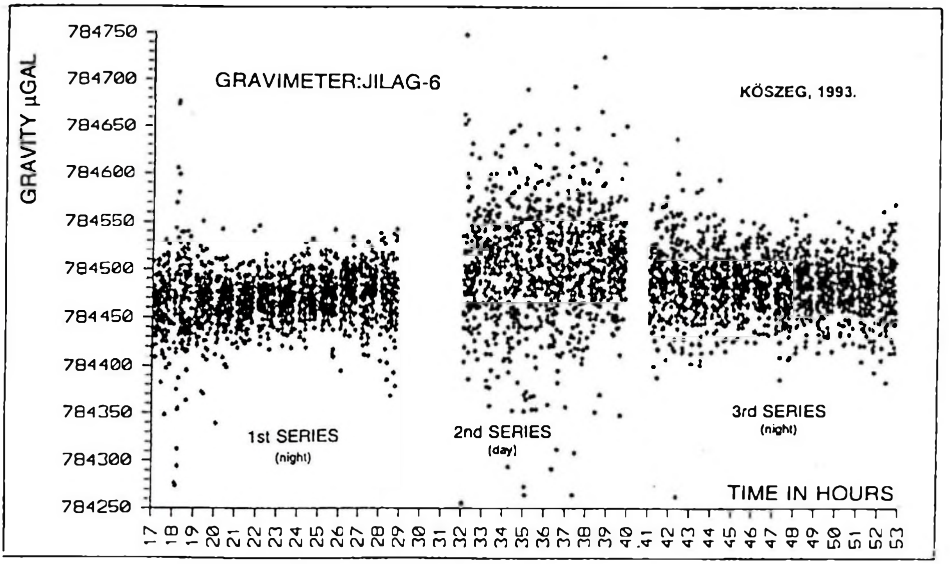

Fig. 1. Chart showing the results of absolute gravity measurements (4800 drops)

1. ábra. Abszolut módszerrel végzett nehézségi mérés eredményének diagramja (4800 ejtés)

* 1 μGal=1 × $10^{-8}ms^{-2}$

3. Relative gravity measurements

The relative gravity measurements were performed with LCR gravimeters by researchers of the institutes listed on the front page together with those of the Geophysical Department of the Mining University of Leoben on the 24 ties shown in *Fig. 2*. In *Tables II* and *III* the observed Δg values for each gravimeter and their simple arithmetic mean are compiled. The average of the latter is

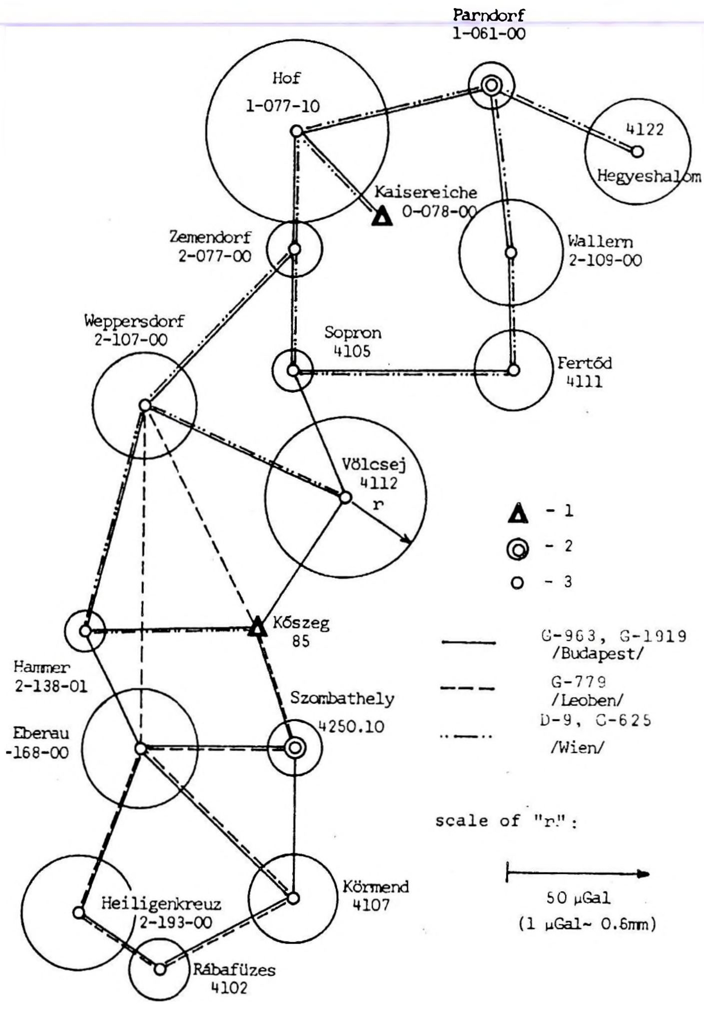

Fig. 2. Sketch of comparative measurements on the Austrian and the Hungarian gravity base networks and the 'error circles' of the measurements. 1—absolute station; 2—base point of the 1st order network; 3—base point of the 2nd order network

2. ábra. Az osztrák és a magyar gravimetriai alaphálózat összehasonlító méréseinek vázlata és a mérések „hibakörei". 1—abszolut állomás; 2—I. rendű bázispont; 3—II. rendű bázispont

TIE	GRAVIMETER				mean and error	
	D-9	G-625	G-963	G-1919	mGal	± μGal
KAISEREICHE - HOF	42.530	42.543	42.611	42.578	42.566	36
ZEMENDORF - HOF	37.173	37.196	37.196	37.179	37.186	12
HOF - PARNDORF	13.718	13.738	13.716	13.728	13.725	10
HEGYESHALOM - PARNDORF	7.223	7.251	7.240	7.264	7.245*	17
WALLERN - PARNDORF	18.463	18.482	18.440	18.440	18.456	20
FERTŐD - WALLERN	8.993	9.003	9.034	9.032	9.016	21
SOPRON - FERTŐD	15.864	15.892	15.877	15.871	15.876	12
ZEMENDORF - SOPRON	7.563	7.549	7.551	7.544	7.552	8
WEPPERSDORF - ZEMENDORF	24.519	24.512	24.545	24.527	24.526	14
WEPPERSDORF - VÖLCSEJ	25.919	25.911	25.960	25.913	25.926	23
HAMMER - WEPPERSDORF	3.915	3.906	3.895	3.920	3.909	11
HAMMER - KÖSZEG	12.341	12.333	12.313	12.326	12.328	12

* high seismic noise during the observations

Table II. Results of gravimetric measurements (northern part)
II. táblázat. A graviméteres mérések eredményei (északi rész)

±15 μGal. The ties were measured once in the order A-B-A-B-A or A-B-C-B-A-B-C-B-A (with the exception of the Sopron-Völcsej-Kőszeg part, which was observed twice with the instruments G-963 and G-1919). The readings of gravimeters G-625, G-779, G-963 and G-1919 were taken by CPI techniques, gravimeter D-9 was equipped with a feedback system. The results were reduced to the benchmark of each point and corrected for drift, Earth tides, barometric effect and scale factor. The scale factors were determined by comparison on national calibration lines. After the comparative measurements a calibration campaign was performed using the gravimeters of Wien and Budapest on the earlier established Göstling-Hochkar vertical calibration line [MEURERS, RUESS 1985]. Results of the measurements are compiled in *Table IV*, the calculated correction factors for scale constant in *Table V*.

TIE	GRAVIMETER			mean and error	
	G-779	G-969	G-1919	mGal	± μGal
EBERAU - WEPPERSDORF	11.001	—	—	11.001	
WEPPERSDORF - KŐSZEG	8.400	—	—	8.400	
SZOMBATHELY - KŐSZEG	8.565	8.545	8.561	8.557	11
KŐSZEG - VÖLCSEJ	—	17.517	17.482	17.500	25
VÖLCSEJ - SOPRON	—	6.147	6.175	6.161	20
EBERAU - SZOMBATHELY	10.860	10.831	10.844	10.845	15
EBERAU - HAMMER	—	7.076	7.067	7.072	6
KÖRMEND - EBERAU	19.532	19.578	19.548	19.553	23
KÖRMEND - SZOMBATHELY	—	30.415	30.419	30.417	2
KÖRMEND - RÁBAFÜZES	17.236	17.257	17.259	17.251	13
HEILIGENKREUZ - EBERAU	10.325	10.371	10.356	10.351	23
HEILIGENKREUZ - RÁBAFÜZES	8.030	8.056	8.055	8.047*	15

* high seismic noise during the observations

Table III. Results of gravimetric measurements (southern part)
III. táblázat. A graviméteres mérések eredményei (déli rész)

4. Adjustment of measurements

The adjustment of the network shown in Fig. 2. was carried out as a constrained network in three versions (*A, B, C*). In version '*A*' the absolute gravity value of Kaisereiche and Kőszeg measured with the JILAG-6 gravimeter was taken as a constraint. In version '*B*' in addition to the two absolute values, the points of HGN-80, while in version '*C*' apart from the absolute values, the points of AGBN were taken as constraints as well. All measurements were assumed to be of the same reliability, and the Δg values observed by each gravimeter were taken as independent measurements. The results of adjustment are contained in *Table VI.* The errors of the adjusted Δg values are 6-12 μGal, which — on account of the limited number of measurements — can be regarded as satisfactory. To give a better illustration of the quality of measurements, 'error circles' were plotted in Fig. 2. The radius (r) of each circle was calculated by the following relationship:

$$r_i = \sum v_i^2 / n_{vi}$$

where v_i — residuals belonging to point i obtained from adjustment 'A' in μGal,
n_{vi} — number of residuals belonging to point i.

TIE	known Δg (mGal)	gravimeter	observed Δg 1st day	2nd day	3rd day	mean (mGal)	error (mGal)	scale factor
HOCHKAR - AIBLBODEN	71.447	G-963	.447	.465	.443	71.451	± 11	0.999 944
		G-1919	.381*	.410	.413	71.401	23	1.000 644
HOCHKAR - LASSING	157.184		.107	.124	.129	157.120	13	1.000 407
			.136	.142	.147	157.141	12	1.000 274
AIBLBODEN - GÖSTLING	126.892		.804	.783	.803	126.797	14	1.000 749
			.863	.857	.855	126.859	5	1.000 260
LASSING - GÖSTLING	41.155		.145	.129	.121	41.132	13	1.000 559
			.112	.126	.119	41.119	8	1.000 876
HOCHKAR - GÖSTLING	198.339	**	.252	.253	.250	198.251		1.000 444
			.248	.268	.266	198.261		1.000 393

* gross error due to carelessness of the observer

** total gravity difference (calculated from the above four observed Δg)

Table IV. Results of measurements on the Göstling-Hochkar vertical calibration line
IV. táblázat. Hitelesítő mérések eredményei a Göstling-Hochkar vertikális bázison

gravimeter	correction factors for the scale constant 1	2*	3
G-963	1.001434	1.000415	1.002993
G-1919	1.000532	1.000513	1.001434

* calculated from mean value of four ties

Table V. Calibration factors of gravimeters G-963 and G-1919
1—Hungarian Gravimetric Calibration Line; 2—Göstling-Hochkar vertical calibration line; 3—adjustment, version '*A*'
V. táblázat. A G-963 és G-1919 graviméter méretaránytényezői
1— Magyar Gravimetriai Hitelesítő Alapvonal; 2—Göstling-Hochkar vertikális hitelesítő vonal; 3—„*A*" kiegyenlítési változat

AGBN and HGN-80 base points	known gravity (mGal) (-980 000)	adjusted gravity (G) A	B	C	G_A-G_K	G_B-G_K	G_C-G_K
					(μGal)		
HOF	837.967	838.000	838.025		+ 33	+ 58	
PARNDORF	851.690	851.724	851.745		+ 34	+ 55	
ZEMENDORF	800.799	800.819	800.841		+ 20	+ 42	
WEPPERSDORF	776.279	776.296	776.298		+ 17	+ 19	
WALLERN	833.230	833.267	833.279		+ 37	+ 49	
HAMMER	772.366	772.385	772.385		+ 19	+ 19	
EBERAU	765.268	765.307	765.312		+ 39	+ 44	
HEILIGENKREUZ	754.927	754.955	754.949		+ 28	- 22	
HEGYESHALOM	844.486	844.451		844.446	- 35		- 40
FERTŐD	824.258	824.250		824.222	- 8		- 36
SOPRON	808.421	808.374		808.351	- 47		- 70
VÖLCSEJ	802.226	802.217		802.206	- 9		- 20
SZOMBATHELY	776.173	776.158		776.136	- 15		- 37
KÖRMEND	745.750	745.750		745.718	0		- 32
RÁBAFÜZES	762.995	763.001		762.971	+ 6		- 24
No of ties		24	24	24			
No of independent measurements		78	78	78			
No of unknowns		15	8	7			
M_0^* (μGal)		±17	±30	±21			

M_0^* = standard error of unit weight

Table VI. Main parameters of adjustments
VI. táblázat. A kiegyenlítések főbb paraméterei

5. Evaluation of the results

Based on the evidence of the error circles the '*g*' values of different points have different reliability. This is explained by the fact that the number of residuals changes from point to point and that from the statistical point of view the radius of the error circles is uncertain owing to the limited number of measurements. For several ties (e.g. Kaisereiche-Hof) differences exceeding the reliability of measurement were observed between the readings of different gravimeters. It can be seen from Table VI that both networks deviate to a small extent from the scale determined by the absolute measurements. This deviation is $-3.5 \times 10^{-5} \pm 1.7 \times 10^{-5}$ for the Austrian Base Network, and $2.5 \times 10^{-5} \pm 2.6 \times 10^{-5}$ for the Hungarian one. According to versions *B* and *C* the datum of HGN-80 is higher by about 40 μGal than the datum of AGBN. The difference can be explained by changing gravity or by a more trivial reason, an inaccurate g value of Sopron, which even at the 90 % probability level cannot be regarded as having the same reliability as those of the rest, i.e. the standard error of unit weight (M_0) of version B adjustment is significantly higher than those of the other two versions.

Our supposition, that the changes obtained at the reobserved absolute points are due to some other reason than instrument error, is based on the monotonously decreasing value of g obtained during reobservations carried out six times in nearly regular time intervals between 1980 and 1993 with different types of absolute gravimeters (GABL, JILAG, AXIS). The rate of decrease is 1.9 μGal/year during the investigated time interval (Table I).

To clarify the reason for the 40 μGal discrepancy, further investigations are needed.

In conclusion the following can be established:

1) From the viewpoint of plotting common gravity maps for the territories of the two countries the difference revealed has no practical importance;
2) Due to causes discussed in this paper, HGN-80 requires readjusment;
3) For joint gravity projects requiring high accuracy it is essential that the gravimeters be calibrated on the same calibration line.

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ÖSSZEKAPCSOLÓ GRAVITÁCIÓS MÉRÉSEK AUSZTRIA ÉS MAGYARORSZÁG GRAVIMETRIAI ALAPHÁLÓZATAI KÖZÖTT

CSAPÓ Géza, Bruno MEURERS, Diethard RUESS, SZATMÁRI Gábor

A dolgozatban a magyar és osztrák gravimetriai alaphálózatok 1991-93 között végzett összekapcsoló méréseiről számolnak be a szerzők. Ez a munka abszolut és relatív graviméteres méréseket tartalmazott. Az abszolut méréseket JILAG-6, a relatív méréseket 5 db LCR graviméterrel végezték 24 mérési kapcsolaton, a két ország teljes közös határszakaszán kiválasztott bázishálózati pontok között.

Megállapították, hogy a két ország alaphálózatának referenciaszintje 40 μGal-lal különbözik. Ezen eltérés okainak felderítése további vizsgálatokat, illetve a magyarországi alaphálózat újrakiegyenlítését igényli.

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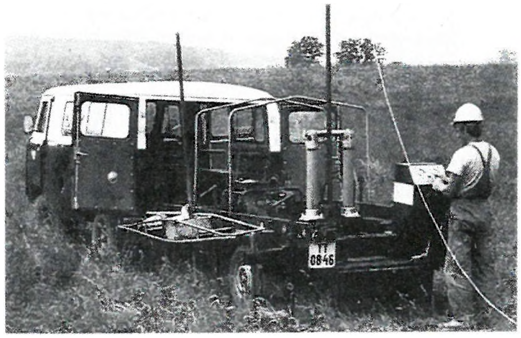

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