INVESTIGATION BY LEVELLING ERRORS OF CLOSURE OF RELIABILITY OF VELOCITY VALUES OF THE RECENT VERTICAL CRUSTAL MOVEMENTS OF HUNGARY

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Trueness of the purport of the map of velocity values of the recent vertical crustal movements is usually proved or disproved by geology-geomorphology data. KOROKINA, T. P. (1973) suggests an estimate method applying geodetic data, and she qualifies the map with measures of accuracy usual in geodesy.

Essentially, the method relies on the fact that the measurements of levelling networks have different durations, several years or even decades, so that closed polygons are usually put together from measurements made in different years.

If bench marks move vertically during measurements, then levelling misclosure comprises also vertical movements rather than measurement errors alone.

Reduction of measurement results of the levelling network for a chosen epoch is expected to reduce the misclosures, namely reduction exempts the network from the effect of vertical movements of bench marks during all the measurement period. Calculating the reduction by means of the recent crustal movement map, then confronting original errors of closure with those reduced for an epoch reflects the velocity map reliability. The qualification of velocity maps is especially satisfactory in regions where the investigated polygons don't belong to the network of relevellings used to the movements map.

Our investigations were carried out on the Hungarian part of movements maps of the *East-European* and *Carpatho-Balkan* regions. Both movements maps have been described in detail in e.g. [2], [5], [6], [7], [1], [10].

Hungarian parts of both movements maps were based on levellings in 1921 to 1944 (II) and in 1948 to 1964 (III). Common lines of both levellings were combined to 17 levelling loops [2], data representing Hungarian movement values in both international movements networks.

For the present investigation, it was attempted to select polygons from levelling networks II and III which weren't identical with those used in the international movements networks. Our ideas were about matched by polygons

Table 1

Polygon No.	Levelling misclosures			Errors of closure of velocities	Levelling misclosures		
	Levelling II (1921 to 1944)				Levelling III (1948 to 1964)		
	$\Sigma \Delta h_{II}$ [mm]	$\Sigma \Delta h_{II}$ reduced by		$\Sigma \Delta v = \Sigma \frac{\Delta h_{III} - \Delta h_{II}}{\Delta T}$ (mm/year)	$\Sigma \Delta h_{III}$ (mm)	$\Sigma \Delta h_{III}$ reduced by	
		East-European map (mm)	Carpatho-Balkan map (mm)			East-European map (mm)	Carpatho-Balkan map (mm)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.	−1.71	−2.51	−2.51	−0.10	−4.69	−4.99	−4.99
2.	−7.79	−7.49	−7.79	+1.03	+17.27	+17.07	+17.27
3.	−4.01	−2.21	−2.71	−0.30	−10.19	−8.69	−9.09
4.	+1.04	+1.24	+1.44	−0.96	−24.07	−23.07	−22.77
5.	+24.55	+23.65	+23.65	−0.63	+10.14	+8.54	+8.44
6.	−22.28	−23.08	−21.68	+1.01	+3.42	+3.42	+3.42
7.	−15.35	−15.45	−15.35	+1.24	+14.22	+14.72	+14.22
8.	+8.00	+9.20	+11.20	+0.32	+16.40	+16.40	+16.40
9.	+10.92	+12.62	+20.32	−0.84	+0.90	+1.60	+2.50
10.	−4.28	−5.18	−4.88	+0.28	+0.33	+1.73	+2.13
11.	+11.67	+10.07	+10.27	−0.12	+4.20	+5.90	+6.60
12.	+0.70	+1.70	+0.90	−0.69	−17.46	−17.96	−17.66
13.	−3.40	0	+0.80	+0.82	+29.31	+24.71	+23.91
14.	+21.13	+22.23	+20.93	−0.12	+16.75	+15.55	+15.55
15.	+0.18	+2.28	+1.78	−0.81	−22.10	−20.90	−20.30
16.	+35.42	+39.62	+37.72	−1.27	−2.08	+1.72	+1.72
17.	−14.47	−14.97	−15.17	−0.63	−36.23	−37.53	−36.63
18.	+11.04	+6.24	+9.04	+0.43	−6.57	−5.37	−6.37
19.	−13.55	−20.35	−18.75	+0.85	−6.40	−7.10	−6.60
20.	+5.83	+2.93	+8.83	−0.50	+3.65	+3.05	+4.35
21.	+5.93	+6.33	+5.93	−0.61	−4.71	−6.41	−5.71
22.	−3.06	−0.96	−1.96	+0.13	+0.51	+1.91	+0.81
23.	+12.42	+12.42	+13.02	−0.43	−1.87	−1.67	−1.17
24	−28.50	−27.90	−28.20	+1.40	+14.65	+15.75	+15.55
25.	−9.02	−10.72	−13.02	+0.38	+4.06	+0.66	+0.26
26.	+1.29	+2.69	+4.29	+0.52	+20.81	+21.81	+20.81
27.	−9.66	−5.96	−8.46	+0.65	+11.90	+11.90	+15.50
28.	−1.49	−2.09	−1.29	+0.46	+10.74	+14.14	+13.94
29.	+11.58	+10.78	+11.18	−1.07	−16.44	−16.84	−16.64
30.	+17.80	+14.30	+12.80	−0.63	−0.22	−0.22	−0.82
31.	+2.87	+4.97	+11.77	−0.75	−13.36	−13.06	−15.66
32.	+12.51	+13.41	+12.71	−0.20	+6.86	+8.06	+6.86
33.	−3.10	−2.40	−1.10	+0.03	−2.26	−2.86	−2.06
34.	+6.09	+4.99	+5.19	+0.01	+7.58	+7.08	+7.38
35.	−1.41	−2.01	−1.31	−0.26	−6.54	−7.04	−6.44

of the 35-polygon network composed earlier for national investigations (columns 1, 2, 5 and 6 in Table 1) although level lines of the denser network are about the same as some lines of the 17-polygon network (columns 1, 2, 6 and 7 of Table 2).

In our investigations, each line of the 35-polygon network was reduced to a chosen epoch. By means of isolines in movements maps, the velocity values of junction points were read off, then relative velocities between adjacent junction points calculated. Multiplying them by the number of years

Table 2

Polygon No.	Levelling misclosures — Levelling II (1921 to 1944)				Errors of closure of velocities	Levelling misclosures — Levelling III (1948 to 1964)			
		Reduced by					Reduced by		
	$\Sigma\Delta h_{II}$ (mm)	East-European map (mm)	Carpatho-Balkan map (mm)	Rigorous adjustment (mm)	$\Sigma\Delta v$ (mm)	$\Sigma\Delta h_{III}$ (mm)	East-European map (mm)	Carpatho-Balkan map (mm)	Rigorous adjustment (mm)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1.	−1.71	−2.51	−2.51	−2.55	−0.10	−4.69	−4.99	−4.99	−5.02
2.	+2.27	+0.57	+1.97	+0.46	+0.38	+13.56	+11.96	+11.86	+11.67
3.	−26.11	−23.91	−24.41	−23.77	+1.01	−2.77	+0.06	−0.37	+0.66
4.	+14.64	+16.64	+26.64		−0.24	+17.63	+19.73	+21.03	
4/a.	+6.64			+7.07	−0.56	+1.23			+5.37
5.	+11.67	+10.07	+10.27	+10.38	−0.12	+4.20	+5.90	+6.60	+1.38
6.	−2.70	+1.70	+1.70	+2.03	+0.13	+11.85	+6.75	+6.25	+6.52
7.	−14.47	−14.97	−15.17	−15.59	−0.63	−36.23	−37.53	−36.63	−36.22
8.	+21.31	+24.51	+22.71		−0.93	−5.35	−5.35	−4.75	
8/a.	+0.18			+0.69	−0.81	−22.10			−21.80
9.	+46.46	+45.86	+46.76	+43.90	−1.70	−8.65	−3.65	−4.65	−6.08
10.	−4.85	−12.05	−5.95		−0.13	−6.95	−8.55	−7.15	
10/a.	+2.87			+3.97	−0.48	−4.20			−7.52
11.	−28.50	−27.90	−28.20	−28.41	+1.40	+14.65	+15.75	+15.55	+15.63
12.	−10.51	−12.81	−14.31	−8.61	+0.85	+14.80	+14.80	+14.20	+15.24
13.	+13.71	+15.11	+17.31	+14.30	+0.09	+18.94	+20.14	+19.64	+19.41
14.	−6.79	−0.99	+3.31	+2.28	−0.10	−1.46	−1.16	−0.16	−0.53
15.	+11.58	+10.78	+11.18	+11.53	−1.07	−16.44	−16.84	−16.64	−16.42
16.	+23.89	+19.29	+17.99	+18.33	−0.63	+7.36	+6.86	+6.56	+5.97
17.	+9.41	+11.01	+11.61	+8.67	−0.17	+4.60	+5.20	+4.80	+5.84

between the measuring point of time of each line and the chosen epoch resulted in the differences in elevation of lines reduced to the epoch. These reduced values were applied again to compose the misclosures of levelling loops (columns 3, 4, 7 and 8 in Table 1).

The same investigation was also made for the 17-polygon network (columns 3, 4, 8 and 9 of Table 2) although the same polygons were known to had been used to the movements maps. Namely, movements maps of both the *East-European* and the *Carpatho-Balkan* regions comprised the results of an international common adjustment of the movements networks of several countries, eventually it enables to draw conclusions from the development of errors of closure reduced to the epoch on the effect of international common adjustment constraints.

Our analyses on the 17-polygon network were completed compared to the 35-polygon one, namely in the meantime, an independent, rigorous adjustment of the 17-polygon network according to the original adjustment method of HAZAY, I. (1967) was achieved at the *Institute of Geodesy, Technical Univer-*

sity, Budapest. The rigorous adjustment resulted in velocity values at junction points and some line points of the 17-polygon network. (No isoline velocity map was made.) The obtained velocity values were used to reduce the 17-polygon network to the epoch. The errors of closure after reduction are seen in columns 5 and 10 of Table 2.

Statistical distributions of the levelling errors of closure reduced to the chosen epoch are presented in form of frequency histograms. The changes of errors of closure have been calculated both in mm units and in percentage of the given misclosure as well and the occurrence frequency plotted. The rate and frequency of decrease or increase of the original errors of closure reduced using the map of Eastern Europe are seen in Fig. 1. The same reduced using the map of the Carpatho-Balkan region is seen in Fig. 2. Results of a reduction using velocity values obtained from the rigorous adjustment have been plotted in Fig. 3.

The errors of closure are seen in the figures to have been decreased and increased by reduction to about the same proportion.

Velocity values deduced from error-free measurements would result in zero successively for the error of each closure reduced to the chosen epoch (taking no notice of theoretical levelling error of closure).

The tendency to zero of reduced errors of closure best appears from the type of frequency histograms with interval given in percent on abscissa (right-hand side figure set).

That map is rated the best where most of the frequency values are to the left of the ordinate and there they are the highest around the 100%. In our estimation the velocity values obtained by rigorous adjustment may be considered perhaps the best, followed by the Carpatho-Balkan movements map, last comes the East-European velocity map. It should be noted, however, that no considerable quality difference is seen between the analysed velocity maps and values.

In the left-hand side set of frequency histograms, intervals are shown in mm on abscissa. The velocity maps can also be qualified by comparing figures in this set, considering "increasing $\Sigma\Delta h$" sides of histograms. It can be stated that the highest value among increases of errors of closure is the least favourable one, and the map leading to the least of decrease of fewer errors of closure is the better. Also according to this qualification, velocity values deduced by rigorous adjustment prove to be the best, the second being perhaps the East-European map, and the last the map of the Carpatho-Balkan region. Neither in this case can be the qualities of the considered maps sharply differentiated.

The increase of the errors of closure for about half of the analysed polygons may show that either accuracy of the measurements or the used method of calculation and mapping was inadequate, or both. The increases of errors

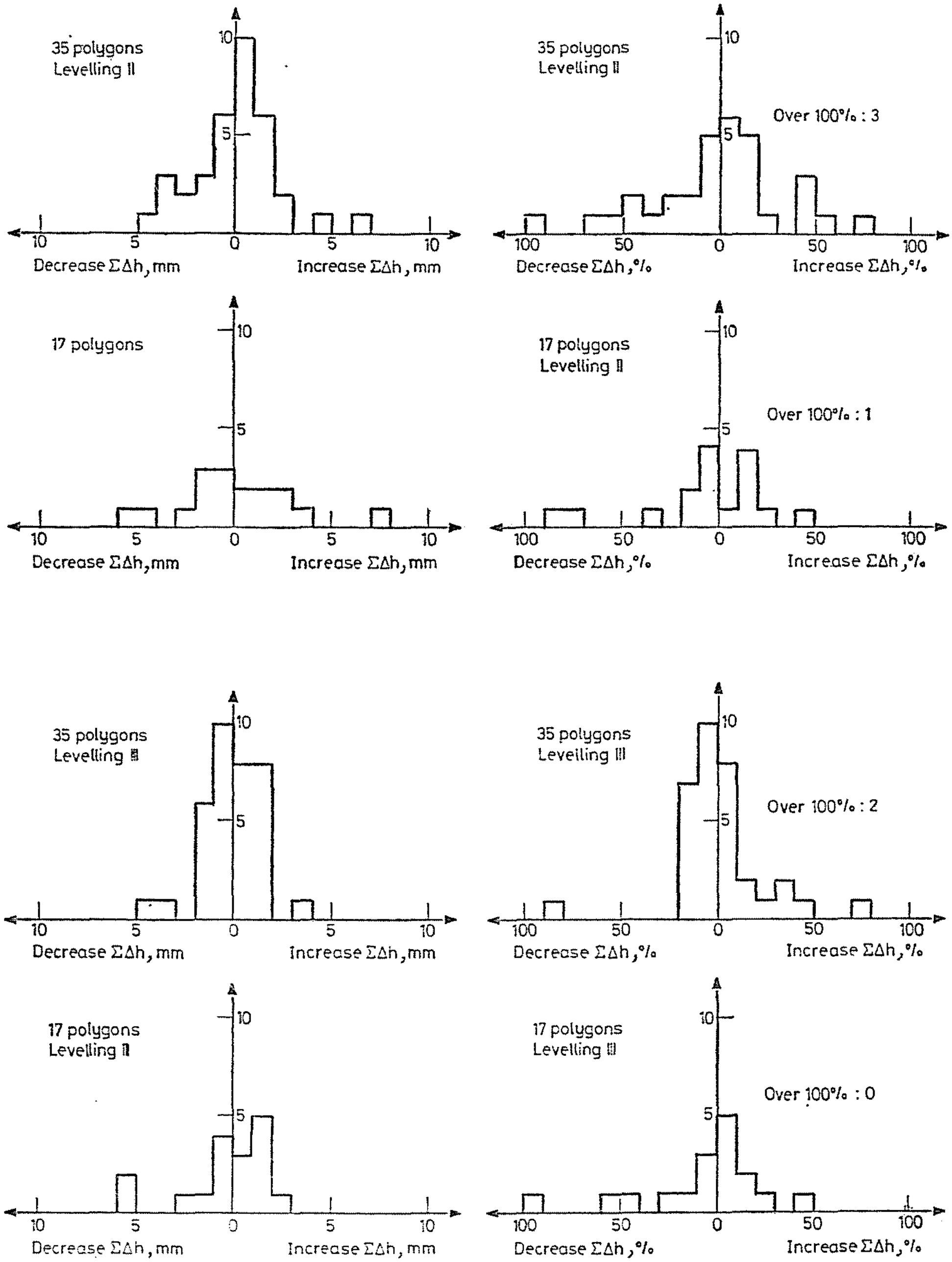

Fig. 1. **Frequency histograms for the map of Eastern Europe**

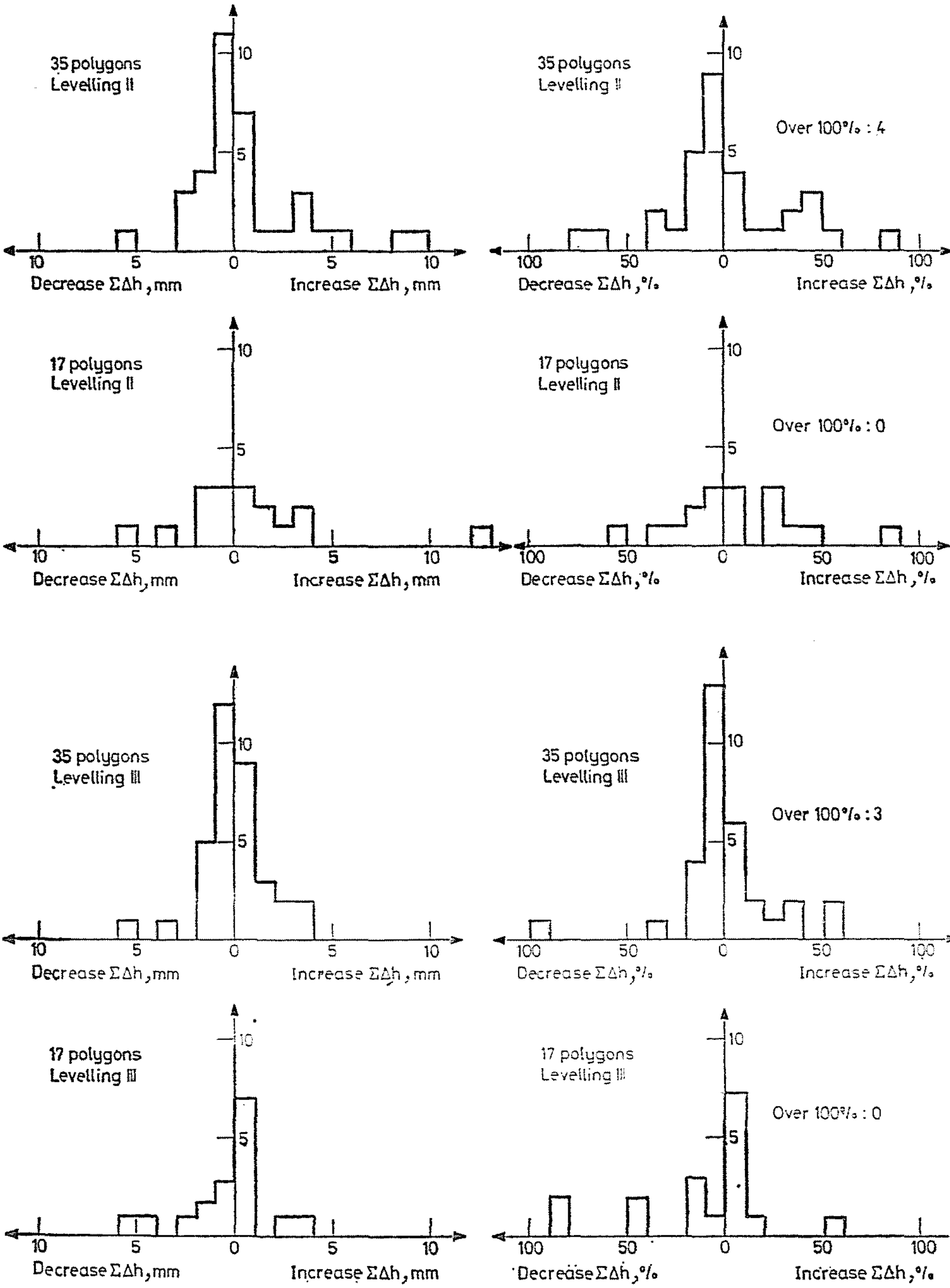

Fig. 2. Frequency histograms for the map of the Carpatho-Balkan region

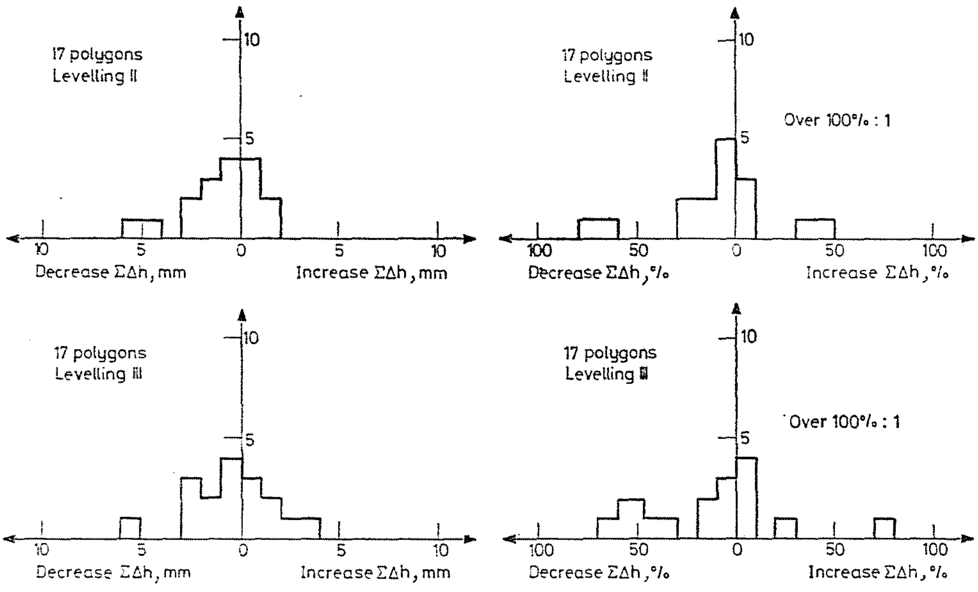

Fig. 3. Frequency histograms for rigorous adjustment

of closure over 2 mm may be results of reduction for an epoch having used a sort of velocity values, which imply disproportion in time or even opposite sign of movement values.

Summary

A geodetic method is applied to investigate the reliability of the Hungarian part of the international vertical crustal movement maps prepared to now. The accuracy is investigated by reducing the measurements of levelling lines measured at different times to a chosen epoch by velocity values read off the movements maps, then polygons are put together from reduced values and their errors of closure computed. Reliability of velocity maps is concluded on from the changes of original errors of closure.

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