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Georg-August-Universität Göttingen
Platz der Göttinger Sieben 1
37073 Göttingen
Germany
Email: gdz@sub.uni-goettingen.de

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Results of Height Measurements in Northern Iceland 1965/1977

H. Spickernagel
Institut für Markscheide- und Bergschadenkunde, Montan-Universität Leoben, Franz-Josef-Straße 18, A-8700 Leoben, Austria

Abstract. Results of repeated height measurements in NE Iceland are reported. In 1965 a 142 km levelling line was set up from Akureyri towards east to Jökulsá á Fjöllum. It crosses the entire young volcanic zone of Northern Iceland in WE direction. The observed changes in height should answer the question of the width of the zone of vertical movements related to the volcanic and rifting activity. The results show this width to be 35 km W-E. It is, however, possible that the zone is wider, because the levelling line was too short in the east.

Key words: Iceland rift zone – Changes of height – Precise levelling.

1. Introduction

Niemczyk (1943) and Emschermann made the first geodetic measurements in Northern Iceland in 1938. When in 1965 the measurements could be repeated, and simultaneously expanded, the Institut für Markscheide- und Bergschadenkunde, Montan-Universität, Leoben, Austria, carried out the height measurements. The program for 1965 included also a new 142-km-long-levelling line extending from the port of Akureyri along Eyjafjördur across Vadlaheidi, Másvatn, Mývatn, and Námaskard toward the east to Jökulsá á Fjöllum. The line consisted of more than 150 bench marks. In 1977 the line was remeasured by precision levellings.

2. Conditions and Methods of Measurements

The height measurements involved considerable problems partly from climatic, partly from morphological factors (H. Spickernagel, 1966). The measurements were performed with automatic levelling instruments (Ni 2, Ni 002, KONI 007) equipped with optical micrometers and invar rods with 0.5-cm intervals. The coast stations were stabilized by heavy 7-kg-levelling supports. With the exception of the Ni 002 which was first used in 1977, the same instruments and measuring equipment were employed in all field seasons. The rods had been checked by the Austrian Federal Office of Measures and Weights. The correction for the rod pair between 1965 and 1977 was only ± 0.005 mm/m, a negligible value.

Reading the rods, we followed the recommended change of reading and levelling the instruments when using levels with automatic setting of the sight line. For each instrument the readings were done in the sequence R F F R or F R R F (R=Rear rod reading, F=Forward rod reading). In difficult conditions the sequence of measurements was occasionally disregarded. To counteract this possible source of error, all height measurements were carried out with two instruments resulting in eight values measured per station. The simultaneous use of two instruments represents a safeguard against possible mistakes in reading or writing. Both instruments were positioned symmetrically between the two rods with an accuracy of about ± 0.1 m. The distance between rod positions was, depending on surface conditions, kept at 40 to 60 m. This resulted in sight line distances of 20 to 30 m. However, when crossing ridges or cliffs this had to be reduced to 3 or 6 m occasionally.

3. Evaluation of the Results

The height measurements were evaluated as follows: first, the height differences measured by the two instruments in both directions were compared. Then the mean error per kilometer was calculated in conventional manner, in spite of the disadvantage for instruments with automatic levelling of the sight line. Invariably there are remaining errors which become manifest as systematic errors.

The mean kilometer-errors calculated for the above observational procedure amounted to ± 0.78 mm/km and for the KONI 007 to ± 0.79 mm/km. The height differences and the mean kilometer errors calculated for 14 levelling sections of about 10-km length and for each instrument show no expectional values (Table 1).

The observed height differences between all bench marks are given in the Annex. The mean values of the two-way measurements of the sum of the height differences along the line Akureyri to Jökulsá á Fjöllum amount to

Ni 2/Ni 002 = +364.499 m
KONI 007 = +364.489 m.

The differences over the total distance of 142 km is only 10 mm. Height measurements conducted in 1965 had also shown good agreement of the height differences obtained by both instruments (only 5 mm difference). The mean kilometer-errors in 1965, 0.8 mm/km and 0.7 mm/km, also agree well with those in 1977. Differences between forward and backward levelling of 10 mm (1977) and 5 mm (1965) correspond to 0.84 mm $\sqrt{R}$ and 0.4 mm $\sqrt{R}$ where R is the simple levelling distance in km. The differences are therefore very satisfactory in view of the demands on this kind of precise levelling.

The results of the height measurements in 1977 are compared with those of 1965. Apart of the influence of the current tectonic activity the following points are important:

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Table 1. Subsections of levelling line: height differences and mean kilometer-errors

Sub sections	Pt.-Pt.	Length	Height differences Ni 2/Ni 002	KONI 007	Mean	Mean kilometer errors Ni 2/Ni 002	KONI 007
		(km)	(m)	(m)	(m)	(mm/km)	(mm/km)
I	Adalstr. Nr. 5–5	9.6	+149.934	+149.932	+149.933	0.63	0.73
II	5–22	10.1	+383.646	+383.644	+383.645	0.43	0.46
III	22–N2097	9.3	−397.952	−397.951	−397.952	0.96	0.84
IV	N2097–61	12.9	− 3.089	− 3.088	− 3.088	0.42	0.42
V	61–73	11.3	− 9.888	− 9.888	− 9.888	0.60	0.50
VI	73–311	9.4	− 84.222	− 84.218	− 84.220	0.91	1.12
VII	311–95	10.0	+136.178	+136.178	+136.178	1.12	1.37
VIII	95–105	10.3	+151.220	+151.218	−151.219	1.09	1.13
IX	105–114	10.2	− 51.206	− 51.208	− 51.207	0.61	0.51
X	114–124	10.6	+ 0.865	+ 0.866	+ 0.866	0.73	0.92
XI	124–304	11.7	+ 80.330	+ 80.329	+ 80.329	0.37	0.32
XII	304–136	9.4	+ 36.856	+ 36.849	+ 36.852	0.18	0.53
XIII	136–143	10.2	− 38.254	− 38.250	− 38.252	1.08	0.86
XIV	143–151	11.7	+ 10.120	+ 10.118	+ 10.119	0.93	0.39

$n = 14$

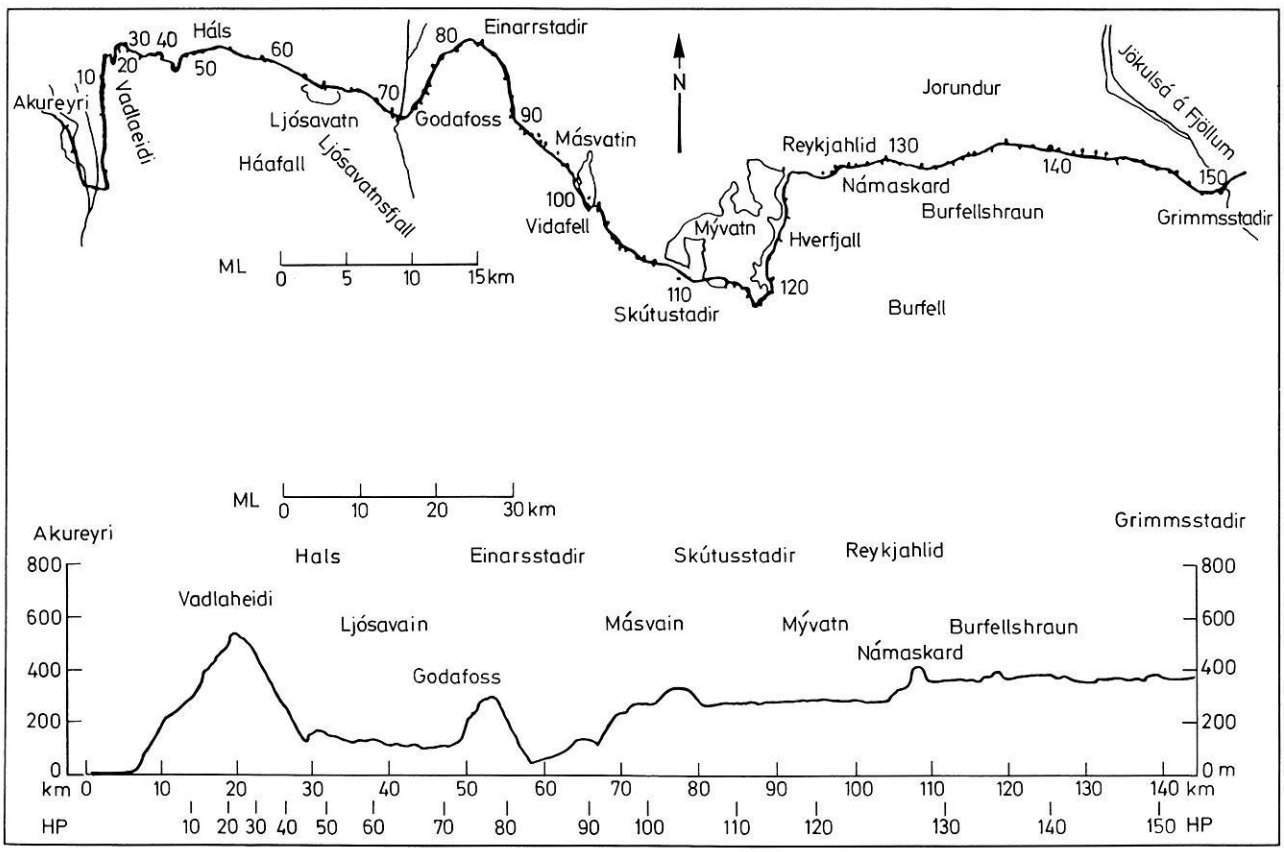

Fig. 1. The levelling line Akureyri-Jökulsá á Fjöllum; location and height profile

- The height change between Akureyri and the bench mark 142 km to the east in the bridge over Jökulsá á Fjöllum is 103 mm.
- Far to the west of the young volcanic zone, the Vadlaheidi area has been uplifted by as much as 65 mm, depending on the interpretation. This cannot be explained by measurement errors.

The levelling line Akureyri – Jökulsá á Fjöllum had been planned in 1965 with the intention to cross the young volcanic zone, and to make certain that the end points could be assumed con-

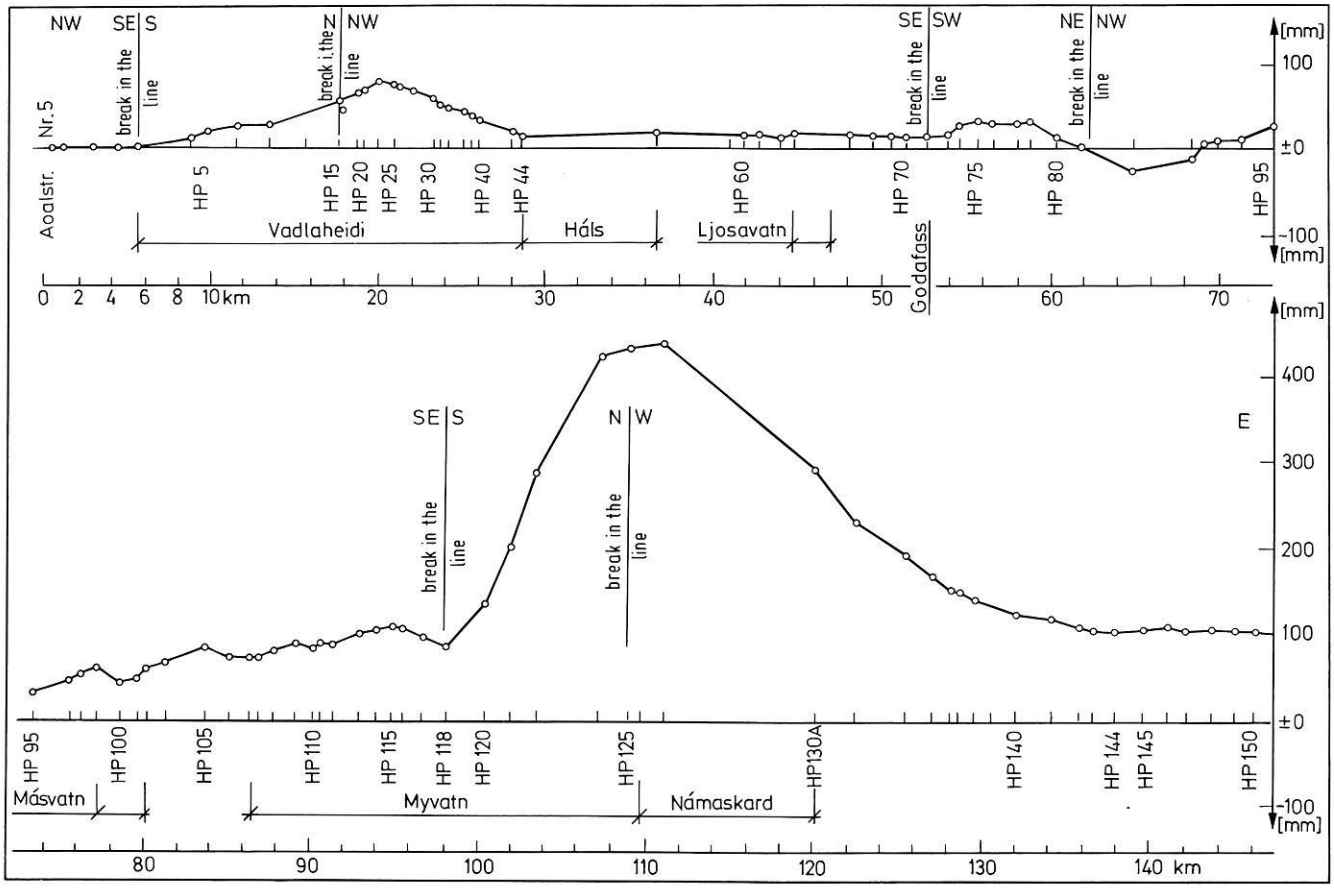

Fig. 2. Levelling line Akureyri-Jökulsá á Fjöllum; uplifts and subsidences between 1965 and 1977

stant; the stations were not to be affected by the recent events in the young volcanic zone. Even in 1965 it had been doubted that the bench marks in the large concrete bridge across Jökulsá á Fjöllum were realy stable. The large canyon through which the river flows represents a major tectonic structure. At the time, however, we were not able to continue our measurements further east because of the early advent of winter.

We then thought that the fix point at Akureyri was sufficiently west of the young volcanic zone to be considered constant. This assumption may require correction: the Vadlaheidi area is not stable in height. Measurements in 1977 revealed uplift of up to 60 mm compared with those of 1965. Only at Bench Mark 2 in a great bolder east of Eyjafjördur and at bench marks on the west side of Eyjafjördur no changes of altitude were observed. This is, of course, true only with respect to the reference station, i.e., bench mark at Adalstraeti No. 5 and must be kept in mind in the geotectonic discussion of northwest Iceland.

The height change between the endpoints of the levelling line by 103 mm is remarkable. Therefore the possibility of systematic errors, has to be investigated. First of all it has to be stated, that the measurements of 1965 and 1977 have been performed under comparable conditions by using the same methods and the same equipment (with the exception of the Ni 002 which has been used only in 1977). Even one of the two observers had been the same. Thus, the systematic errors were probably comparable.

If the heights were referred to the bench marks in the bridge over Jökulsá á Fjöllum a subsidence of 103 mm at the western end of the line would be the result. It is possible that the Akureyri district has changed its vertical position since 1965; but such changes should not be as large as 103 mm. The Akureyri district is assumed to be much more stable than the district of Jökulsá á Fjöllum; therefore the height measurements have been referred to the bench marks in Akureyri.

The levelling profile passes the Mývatn – Námaskard region (Fig. 1), which was affected by the rifting activity centered at Krafla to the north. Figure 2 shows the influence of the volcanic and rifting activity. It is best seen in the stations from HP 87 to HP 142. The maximum amount of 420 mm uplift may not be the final maximum. Movements still took place in September 1977 after our measurements (E. Tryggvason, personal communication). It must also be mentioned, that 6 bench marks had been destroyed between 1965 and 1977 between HP 127 and HP 130a.

The current vertical movements raise the question, whether the uplift of 103 mm in the east may be explained by motion during the progress of measurements. A provisional evaluation was carried out in order to eliminate such possible errors. However, from observations made by the Nordic Volcanological Institute of the University of Iceland, it can be seen that during the time of our height measurements no noticeable vertical movements occurred near the levelling line (E. Tryggvason, personal communication).

Further, the elevation changes deduced from geometrical height measurements were compared with the gravity changes observed by A. Schleusener and W. Torge. Torge and Drewes (1977) confirm that in the Vadlaheidi district gravity decreases

between 1965 and 1975, and between 1975 and 1977. The corresponding elevation factor is about 0.15 mgal/m. In addition, we have noted new cracks of 1 to 3 cm width in the area around Peturskirkja in 1977. In spite of the considerable scatter of gravity values in general the gravity measurements concur with the geometric height measurements.

After all these checks, we can offer no other explanation for the 103 mm uplift at the east end of the profile than that it is real.

4. Conclusions

The evaluation of the height measurements performed in 1965 and 1977 between Akureyri and Jökulsá á Fjöllum has had the following results:

1. Uplift has occurred in the Vadlaheidi district, far to the west of the young volcanic zone of Northern Iceland. This is interpreted to be of tectonic nature.
2. The volcanic and rifting episode since 1975 (until August 1977) has influenced the profile Akureyri – Jökulsá á Fjöllum. This influence was particularly pronounced in the profile section between bench mark HP 100 and HP 140. The length of the section is 54 km, projected onto the east-west direction, 35 km.
3. Because of the loss of six bench marks in the Námaskard district the maximum uplift until the end of August 1977 could probably not be observed, for the same reason, subsidence in the central zone (e.g., Torge and Kanngieser, 1979) has not been seen. The location of the maximum uplift may not have been determined. Maximum uplifts amount to more than 420 mm. The direct distance to the Krafla volcano is about 7 km.
4. East of HP 143 an almost constant uplift of 103 mm has taken place with respect to Akureyri. This extends across about 10 km to Jökulsá á Fjöllum. A comparison with gravity observations appears to confirm the uplift.

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Annex

Akureyri to Jökulsá á Fjöllum: mean of the height differences 1977

Pt.	Ni 2/ Ni 002 m	KONI 007 m	Pt.	Ni 2/ Ni 002 m	KONI 007 m	Pt.	Ni 2/ Ni 002 m	KONI 007 m	Pt.	Ni 2/ Ni 002 m	KONI 007 m
Adalstr. Nr. 5	− 3.954	− 3.954	HP 61	− 25.127	− 25.127	HP 100	− 7.302	− 7.301	HP 139	+ 3.117	+ 3.116
Adalstr. Nr. 21	+ 0.435	+ 0.432	HP 62	+ 6.288	+ 6.288	HP 101	− 0.349	− 0.348	FM 320	+ 5.183	+ 5.183
HP 1	+ 0.916	+ 0.916	HP 63	− 0.165	− 0.166	HP 102	+39.858	+39.858	HP 140	−19.051	−19.053
HP 2	+ 90.402	+ 90.403	HP 64	+ 4.637	+ 4.638	HP 103	+14.950	+14.948	FM 107	− 0.502	− 0.503
HP 4	+ 62.136	+ 62.135	HP 66	−21.910	−21.910	HP 104	− 0.995	− 0.995	HP 141	− 0.310	− 0.307
HP 5	+ 68.080	+ 68.080	HP 67	+ 0.920	+ 0.920	HP 105	−38.257	−38.255	HP 142	− 8.634	− 8.634
HP 6	+ 6.377	+ 6.377	HP 68	+ 8.053	+ 8.053	HP 107	−33.856	−33.856	HP 143	− 1.730	− 1.728
HP 7	+ 15.764	+ 15.763	HP 69	+ 3.103	+ 3.104	FM 2	+ 1.368	+ 1.368	HP 144	+ 5.008	+ 5.006
HP 8	+ 10.815	+ 10.815	HP 70	− 3.728	− 3.726	HP 108	+ 5.681	+ 5.681	HP 145	+11.131	+11.129
HP 9	+ 50.580	+ 50.579	HP 71	− 0.018	− 0.018	HP 109	+10.770	+10.769	HP 146	−11.446	−11.449
HP 11	+ 31.868	+ 31.869	HP 72	+17.759	+17.759	FM 6415	+ 8.913	+ 8.913	HP 147	+ 5.853	+ 5.854
HP 13	+100.311	+100.312	HP 73A	+ 0.262	+ 0.262	HP 110	− 1.704	− 1 704	HP 148	+11.403	+11.403
HP 15	+ 1.890	+ 1.890	HP 73	+52.396	+52.396	HP 111	− 4.741	− 4.741	HP 149	+ 5.819	+ 5.818
HP 16	+ 39.232	+ 39.232	HP 74	+63.982	+63.984	HP 112	+ 7.721	+ 7.720	HP 150	−15.917	−15.918

Pt.	Ni 2/ Ni 002	KONI 007	Pt.	Ni 2/ Ni 002	KONI 007	Pt.	Ni 2/ Ni 002	KONI 007	Pt.	Ni 2/ Ni 002	KONI 007
	m	m		m	m		m	m		m	m
HP 19			HP 75			HP 113			HP 151		
	+ 20.566	+ 20.567		+ 8.130	+ 8.130		− 7.103	− 7.102			
HP 20			HP 76			HP 114					
	+ 38.162	+ 38.162		+26.142	+26.142		− 0.243	− 0.242			
HP 22			HP 77			HP 115					
	− 3.705	− 3.705		+24.679	+24.679		+ 0.922	+ 0.922			
HP 23			HP 78			HP 116					
	− 12.558	− 12.558		− 7.144	− 7.144		− 1.570	− 1.571			
HP 24			HP 79			HP 117					
	− 7.604	− 7.604		−90.380	−90.379		+ 0.678	+ 0.679			
HP 25			HP 80			HP 118					
	− 6.654	− 6.654		−83.842	−83.841		+ 2.100	+ 2.100			
HP 26			HP 81			HP 120					
	+ 1.477	+ 1.477		−26.092	−26.092		+ 8.384	+ 8.384			
HP 27			HP 82			HP 121					
	− 20.483	− 20.483		−32.222	−32.223		− 6.167	− 6.165			
HP 28			HP 84			HP 122					
	− 22.299	− 22.298		+40.686	+40.685		− 3.240	− 3.241			
HP 29			HP 86			HP 124					
	− 10.103	− 10.103		+30.601	+30.600		+ 4.754	+ 4.754			
HP 30			HP 87			HP 125					
	− 28.004	− 28.003		+ 9.561	+ 9.561		− 6.580	− 6.579			
HP 31			HP 88			Kongsp.					
	− 22.934	− 22.934		− 3.079	− 3.079		+15.686	+15.686			
HP 32			HP 89			FM 5604					
	− 21.987	− 21.987		+ 0.544	+ 0.544		+26.445	+26.446			
HP 33			HP 89A			HP 127					
	− 55.713	− 55.714		−10.483	−10.484		− 0.016	− 0.017			
HP 36			HP 91			FM 6412					
	− 24.113	− 24.113		−21.635	−21.634		+37.799	+37.795			
HP 37			HP 92			FM 115					
	− 16.240	− 16.239		+40.348	+40.348		+ 7.074	+ 7.072			
HP 38			HP 93			HP 130A					
	− 32.276	− 32.275		+ 9.839	+ 9.839		− 0.556	− 0.561			
HP 40			HP 94			HP 133					
	− 58.697	− 58.697		+19.924	+19.924		+18.093	+18.092			
HP 42			HP 95			HP 135					
	− 40.995	− 40.995		+65.542	+65.543		+14.487	+14.488			
HP 44			HP 97			HP 136					
	− 21.010	− 21.008		+23.748	+23.748		−24.140	−24.138			
HP 312			HP 98			HP 137					
	− 8.632	− 8.632		+ 7.508	+ 7.508		+ 2.794	+ 2.797			
HP 59			M 6			HP 138					
	+ 11.657	+ 11.656		+ 0.071	+0.071		− 0.002	− 0.002			
HP 60			HP 99			FM 109					
	− 0.170	− 0.170		+ 8.189	+ 8.187		+ 3.290	+ 3.292			
HP 61			HP 100			HP 139					

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