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DETERMINATION OF THE UNIFIED MAGNITUDES OF EARTHQUAKES FROM THE RECORDS OF NURMIJÄRVI STATION

by

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Abstract

Unified magnitudes calculated from the vertical P waves of the short-period records of Nurmijärvi station have been compared with the magnitudes reported by USCGS. It has been found that the values of Nurmijärvi for shallow earthquakes are as a mean 0.2 unit of magnitude greater and the values of deep and intermediate earthquakes 0.1 unit greater than the values of USCGS. The correction, however, changes with the distance. For this reason the shallow earthquakes have been divided into ten groups according to epicentral distance, and the station corrections computed for each group.

1. *Introduction*

The unified magnitude of an earthquake is calculated from GUTENBERG and RICHTER's [1] formula

$$m = q + Q + s ,$$

where q is $\log_{10} u/T$ and $\log_{10} w/T$ for the vertical and horizontal components respectively. Q is a quantity which depends upon epicentral distance and focal depth. The values of Q are available from the charts in [1]. There are different charts for P, PP and S waves and for vertical and horizontal components. In this work only the vertical component and only short periodic P waves have been investigated. s is the station correction. Some scientists divide s into regional corrections, station correction, correction after azimuth, etc. In the present paper the correction has been made as simple as possible. It has been found, however, that the correction depends upon the epicentral distance. Therefore the shallow earthquakes are divided into ten groups according to distance and s is calculated as a mean for each group from differences m (USCGS) — m (NUR), where the first term is a magnitude given by USCGS and the second term the corresponding magnitude computed from the records of Nurmijärvi.

2. *Material*

The Nurmijärvi station (NUR) is located in southern Finland ($\lambda = 60°30'32''$ N, $\varphi = 24°39'05''$ E). Records of a short-period Benioff

Table 1. Data and corrected magnitudes of earthquakes, which had incorrect magnitudes for station NUR.

Data of USCGS								m(NUR) correct
Date	Epicenter		Origin time			m	m (NUR)	
1964, Nov 10	59.8 N,	144.3 W	06	07	49.6	5.0	4.2*	5.5
Nov 11	59.4 N,	144.6 W	08	01	26.1	5.2	4.4*	5.8
Nov 16	49.7 N,	78.0 E	05	59	57.4	6.0	4.4*	5.5
1965, Feb 4	52.0 N,	173.1 E	16	32	36.0	5.4	4.2*	5.2
	51.8 N,	176.4 E	16	51	33.9	4.8	3.7*	5.2
	51.3 N,	176.9 E	17	04	35.4	5.2	4.3*	5.6
	51.7 N,	174.9 E	17	17	29.4	4.7	4.0*	5.1
	51.9 N,	172.9 E	17	30	36.8	4.5	3.7*	4.8
	51.9 N,	175.2 E	17	50	43.4	5.0	3.8*	5.1
	51.9 N,	173.3 E	18	13	50.9	5.0	3.8*	5.1
	51.2 N,	176,7 E	18	34	07.3	5.3	4.7*	6.0
	51.5 N,	174.8 E	18	39	47.2	5.1	4.1*	5.2
	52.0 N,	174.9 E	18	48	11.0	5.3	4.3*	5.5
	52.2 N,	171.9 E	18	51	49.0	4.5	3.8	5.1
May 22	14.1 S,	13.8 W	16	09	29.5	5.5	7.1*	5.2
Jun 18	25.0 N,	93.8 E	08	17	37.6	5.9	6.9*	5.2
Jul 1	50.0 N,	158.9 E	17	41	34.3	5.0	6.0*	5.3
Jul 15	7.7 N,	123.8 E	18	33	29.9	5.8	4.9*	5.9
Jul 18	51.0 N,	177.9 E	17	49	10.6	4.8	4.3	5.0
Jul 19	9.2 N,	70.4 W	04	13	20.4	5.4	4.8	5.3
Oct 7	12.6 N,	114.5 E	03	35	59.6	5.9	8.0*	6.0

* omitted in determination of m (USCGS)

seismograph ($T_s = 1.0$ sec, $T_g = 0.75$ sec) have been used for the present work.

USCGS determines a unified magnitude of all earthquakes for which the requisite data are available. The magnitude is calculated only from readings of short-period vertical P waves for each station and a mean is taken. The mean, m (USCGS), and magnitude of each station are reported in the Earthquake Data Reports published by USCGS. Data of the Nurmijärvi station are often included in the calculations. The data for the present work have been taken from these lists. All the earthquakes for which the magnitude of NUR has been calculated are included from all lists of the year 1965 and from the lists 88—108 of the year 1964. In all, magnitudes of 748 shallow and 141 deep or intermediate earthquakes have been treated. Only the earthquakes for which a magnitude of NUR had been calculated erroneously by USCGS are listed here in Table 1 with the correct magnitudes. These magnitudes were incorrect because of an error in the data. Sometimes a trace amplitude reported by the station has been treated as a ground amplitude, sometimes a reported ground amplitude as a trace amplitude.

3. *Results*

Figure 1 shows the frequency distribution of differences m (USCGS)—m (NUR). 58 per cent of the magnitudes of NUR for deep and intermediate earthquakes and 46 per cent of the magnitudes for shallow earthquakes differ by less than 0.25 unit from the magnitudes of USCGS. The station correction can now be calculated as a mean of the differences. For shallow shocks it is —0.21 and for deep and intermediate shocks —0.10, with standard errors of 0.01 and 0.03 respectively. After correction of the magnitudes of NUR by these amounts we find that 64 per cent of the magnitudes of deep and intermediate earthquakes and 67 per cent of the magnitudes of shallow earthquakes now differ by less than 0.25 unit from the magnitudes of USCGS.

From Figure 2, however, where the differences m (USCGS)—m (NUR) of the shallow earthquakes are plotted against distance, one can see, that the difference is a function of distance. There is, for instance, a clear minimum about 65 degrees and a maximum about 74 degrees. A second maximum occurs after 30 degrees but unfortunately about 30 degrees there is a lack of observations, so that one can not see what really happens at that distance. There is another region for which data

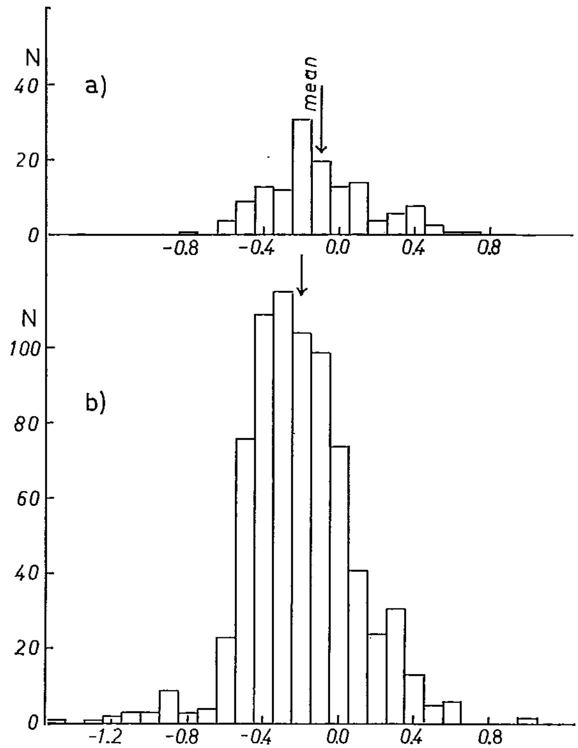

Fig. 1. Frequency distribution of differences *m* (USCGS) — *m* (NUR), a) of deep and intermediate b) of shallow earthquakes.

are lacking at about 42 degrees, but no special feature is expected here. The observations are now divided into ten groups according to epicentral distance. For instance, all the earthquakes with epicentral distances D for which the relation $54° \leqq D < 68°$ is valid fall into the interval from 54 to 68 degrees. The frequency distribution of the differences *m* (USCGS) — *m* (NUR) for each group is given in Figure 3. Only 8 observations fall between 13 and 16 degrees but their dispersion is small. Similarly, in the interval between 31 and 33 degrees there are only ten observations. The other groups consist of more than 20 observations. Most of the figures have a relatively normal distribution on both sides of the mean, which is marked in the figure with an arrow. The distribution in Figures 3h, 3i and 3j, however, is slightly bimodal in character. This is perhaps due to omission of regional corrections.

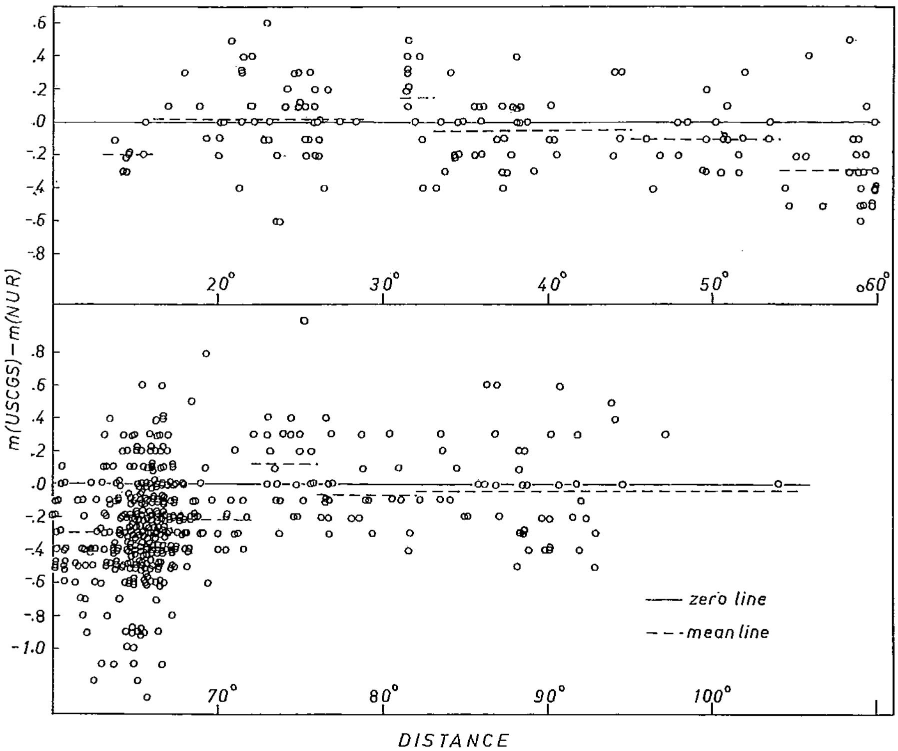

Fig. 2. Differences m (USCGS) — m (NUR) of shallow earthquakes versus distance.

In Table 2 the distance intervals are listed in column 1 and the number of observations in each interval in column 2. In column 3 is represented as a percentage the number of these magnitudes of NUR which differ by less than 0.25 unit from the magnitude of USCGS. Column 4 gives the means of the differences m (USCGS) — m (NUR) and column 5 the standard error of the mean. The recommended correction s is given in column 6. If the standard error is greater than the absolute value of the mean, no correction is recommended. Column 7 indicates in percentages the number of magnitudes which deviate by less than 1/4 unit from the magnitudes of USCGS after correcting the magnitudes of NUR with s. One can see by comparing columns 3 and 7 that a remarkable advantage is gained by the operation. The advantage is, of course, greater at greater values of s, i.e. in the interval between 54 and 68 degrees or in the interval between 68 and 72 degrees.

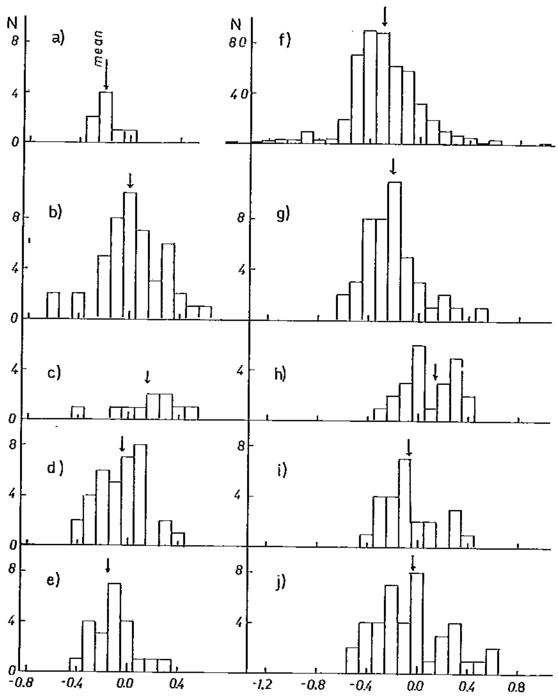

Fig. 3. Frequency distributions of differences m (USCGS) — m (NUR) of shallow earthquakes for various distance intervals: a) 13—16, b) 16—29, c) 31—33, d) 33—45, e) 45—54, f) 54—68, g) 68—72, h) 72—76, i) 76—82, j) 82—110 degrees.

Table 2.

Distance interval (in degrees) (1)	No. of observ (2)	Percentage of differences under 1/4 (3)	Mean of differences (4)	S.E. of mean (5)	s (6)	Percentage of differences under 1/4 unit after correction (7)
13—16	8	75	—0.19	.04	—0.19	100
16—29	47	70	+0.03	.04	—	70
31—33	10	50	+0.15	.08	+0.15	60
33—45	35	74	—0.05	.03	—0.05	86
45—54	22	73	—0.10	.04	—0.10	86
54—68	492	37	—0.29	.01	—0.29	75
68—72	45	49	—0.22	.03	—0.22	78
72—76	24	62	+0.13	.06	+0.13	75
76—82	24	62	—0.07	.05	—0.07	79
82—110	41	56	—0.04	.05	—	56
13—110	748	46				75

4. *Discussion*

The considerable negative value of s between 54 and 68 degrees has a special interest. A difference of -0.3 unit of magnitude means, in fact, a twofold amplitude compared with that expected. One can see from Figures 2 and 3 that the value of s becomes continuously smaller after 40 degrees, whereas after 70 degrees it increases rapidly. These negative values of differences mean a remarkable excess of energy compared with GUTENBERG and RICHTER's [1] Q values.

Sometimes very great differences appear between the magnitudes of NUR and USCGS, as can be seen, for instance, in Figure 1b. This is, of course, a usual phenomenon when magnitudes are determined. Sometimes, however, the procedure of USCGS for computing magnitude yields a questionable result, because the magnitude is taken there as the mean of the magnitude values calculated for different stations, but omitting the values which deviate from the mean by the equivalent of 0.7 unit of magnitude *at any point in the computation*. For instance, for an earthquake on Oct. 10, 1964, ($\lambda = 44.8$ N, $\varphi = 111.6$ W, $H =$ 07:38:31.0) the calculated magnitude values for different stations are as follows: 5.0*, 6.0, 6.2, 5.5, 4.8*, 5.4, 5.8, 5.2, 4.8*, 4.9*, 4.9*, 5.3, 5.0*, from which the magnitude of USCGS was computed as 5.6, this being the mean of 7 values. The values marked with an asterisk were neglected. It is possible, however, to choose 10 values (5.0, 5.5, 4.8, 5.4, 5.2, 4.8, 4.9, 4.9, 5.3, 5.0) which deviate by less than 0.7 unit from the mean 5.1. The magnitude 5.0 is the value of NUR which devites 0.6 unit from the magnitude of USCGS but only 0.1 unit from the magnitude computed here. A second example is an earthquake on Nov. 12, 1965, ($\lambda = 30.5$ N, $\varphi = 140.2$ E, $H =$ 17:52:24.1). The magnitudes are now: 6.4, 5.2*, 5.6*, 5.7*, 6.8, 6.5, 5.8*, 6.6, 5.0* and m (USCGS) $= 6.6$, from four values. Five values 5.2, 5.6, 5.7, 5.8, 5.0, however, give as a mean 5.5. The difference m (USCGS) $-$ m (NUR) would as a result decrease from 1.0 to 0.1 unit. A third example is from June 23, 1965, ($\lambda = 56.6$ N, $\varphi = 152.8$ W, H $=$ 12:23:22.2). The magnitudes are now: 6.1, 4.5*, 5.1*, 4.6*, 5.0*, 4.7*, 4.6*, 4.9*, 5.9 and m (USCGS) is calculated as 6.0 from two values. Seven values marked with an asterisk give a value of 4.8 for magnitude.

As explained above, if the magnitude values are chosen in different ways it is possible to get obviously more satisfactory estimates for magnitudes in some cases. This is a fact which should be taken into consideration when developing the computer program.

Three-quarters of the magnitudes of NUR may have been determined with a precision of $\pm 1/4$ unit (see the last row in Table 2). This is quite a good result, because there are many factors which tend to render the results unsatisfactory when magnitudes are determined from short-period waves. For instance, the period which corresponds to the greatest amplitude is often difficult to measure exactly because of superposition of waves with different periods. Further, a record of an earthquake may begin with very weak waves and then increase continuously. According to the instructions of USCGS [2] P wave period and amplitude should be taken within the first few cycles after the P onset and so it is difficult to decide which of the cycles should be measured.

Acknowledgment. The financial assistance given by the Sohlberg Foundation of the Societas Scientiarum Fennica is gratefully acknowledged.

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