

On Magnitude Determination by Using Macroseismic Data

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INTRODUCTION.

The time interval between two seismic periods in a given region may fluctuate within very wide limits. Quite often this interval takes over 50 years and not rarely over 1 and 2 centuries or more. This implies that the measure which determines the degree of the earthquake activity in a given region can not be reliable, if it is not based on data covering a period of at least 100 years.

It was already proved that the most reliable data for measuring the seismicity of a given region are the magnitudes. Since the magnitude determination is connected with the existence of seismic records, the magnitude of shocks having occurred before the operation of modern seismographs, i. e. before 1900, cannot be determined in a regular way. The need for magnitude data covering very large periods led several seismologists to relate the macroseismic data with the magnitude. However, the relations established between the magnitude and the macroseismic data all have the general form:

$$M = b I_0 + k \log h + c \quad [1]$$

In the formulae proposed the coefficients b , k , and c have values 0.5 to 0.8, 1.0 to 2.35 and -1.48 to 0.4 , respectively (Karnik, 1960). A

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simple analysis of the formulae proposed shows that a slight change of the depth, h , results in a significant change in the magnitude, M . Further, the depth is usually unknown and the depth determinations are not very accurate, especially when macroseismic data are used. In shallow shocks the error may be quite large. Even with instrumental data, for shocks at a depth of 16 km the error may well be ± 6 km, in favorable cases. At a depth of 50 km it may be as high as $+ 20$ km (Benioff-Gutenberg, 1955).

The relation of the intensity, I , to the acceleration of the shock, a , is given by different empirical formulae having the general form:

$$I = p \log a + q \quad [2]$$

where p and q have values 2 to 3 and 1.5 to 2.5, respectively (Karnik, 1956). These differences in the values of the coefficients p and q has an unfavorable influence on the macroseismic determination of the M . Moreover, most of the shocks have their epicentral tract in unpopulated areas or offshore. In these cases an error of 2 degrees in the estimation of the epicentral intensity is not rare. The corresponding error in the determination of the magnitude is therefore at least 1 magnitude unit.

EQUATION USED.

The present investigation is based on a simple empirical equation. According to B. Gutenberg and C. F. Richter, (1942):

$$\frac{a D^2}{h} = \text{const. } \sqrt{E} . \quad [3]$$

Since

$$a_0 h^2 = a D^2 = a_r R^2, \quad [4]$$

it can be written:

$$a_0 h = \text{const. } \sqrt{E} \quad [5]$$

$$\frac{a_r R^2}{h} = \text{const. } \sqrt{E} . \quad [6]$$

Combining [5] and [6], there results:

$$a_r a_0 R^2 = C E . \quad [7]$$

At the limit of perceptibility we may assume that the hypocentral distance R is approximately equal to the epicentral distance r . Thus we may put $\pi R^2 \cong \pi r^2 = A$ (= Area over which the shock was felt). From field observations we are convinced that the macroseismic effects "must correspond only to that level of acceleration which persisted long enough to produce permanent effects, which must be less than the maximum acceleration recorded on a complete seismogram" (Gutenberg-Richter, 1942; Byerley, 1942). Taking this into consideration and that the empirical relation

$$\log a = I/3 - 1/2 \quad [8]$$

"fails for higher intensities" (Gutenberg-Richter, 1956a), it may be assumed that the acceleration at the epicenter $a_0 \cong cI_0$. This assumption(*) is furthermore justified in view of other much larger uncertainties involved in the estimation of the macroseismic elements of the shocks, especially those of the past centuries, and more over it is well-substantiated by the results obtained. Assuming now that the acceleration at the limit of perceptibility $a_r \cong$ constant, and that $E = 10^{k_1 + k_2 M}$, we arrive at

$$M = C_1 \log AI_0 + C_2 \quad [9]$$

It was found by B. Gutenberg (1945), that the energies released in the longitudinal and transverse waves of an earthquake are about equal, regardless of focal depth. More recently, however, Gutenberg and Richter (1956b) assume the energy in P waves to be only half that in S waves. Later it was found by M. Båth (1958), that the energy ratio $E_S/E_P = 1.5 \pm 0.4$ is independent of magnitude and of epicentral intensity. Outside the meizoseismal area the macroseismic effects are not due to surface waves, but to body waves, and mostly to shear waves (Sieberg, 1932; Benioff-Gutenberg, 1955). Curves giving equal values of Q for S as a function of epicentral distance Δ and focal depth h show very little change with depth in the range of felt shaking (Gutenberg-Richter, 1956b). "With increasing focal depth, less energy arrives

(*) The assumption $a \cong cI_0$ differs from the basic relation $\log a \cong cI_0$ used in all macroseismic computations. However, this assumption is widely used in the standards for reducing the numerical values of the horizontal coefficient of the seismic force in the Building Codes in earthquake-prone countries, with reference to the class of the area or the kind of ground. ("Earthquake-Resistant Regulations of the World", compiled by Organizing Committee, SWCEE, 1960).

near the epicenter more at greater distance" (Gutenberg, 1945). It is well known that "A shallow shock may be heavily felt over a small area, but the effects do not extend very far. A deep shock gives a moderate shaking to a much greater area" (Eiby, 1957). From equations [5] and [6] it is obvious that the epicentral intensity, I_0 , is almost

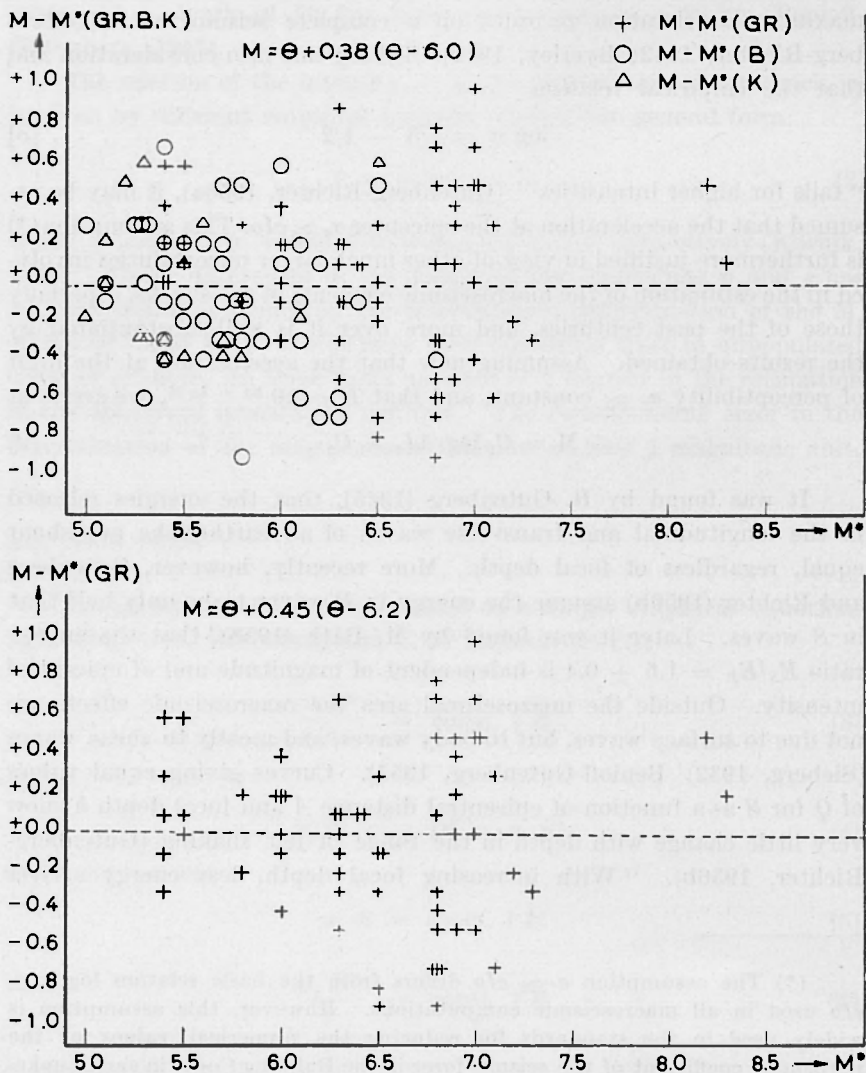


Fig. 1. - Variations with M^* of differences between macroseismic magnitudes computed from Eqs. [10] and [12] and instrumental magnitudes M^* (GR, B, K) and M^* (GR), respectively.

inversely proportional to h , but the area of perceptibility, A , is approximately proportional to h . As the wave velocity increases and the coefficient of absorption decreases with increasing depth, the distances up to which the earthquake energy is felt increase with the focal depth (Byerly-Denoyer, 1958; Sponheuer, 1960). Thus the product AI_0 of

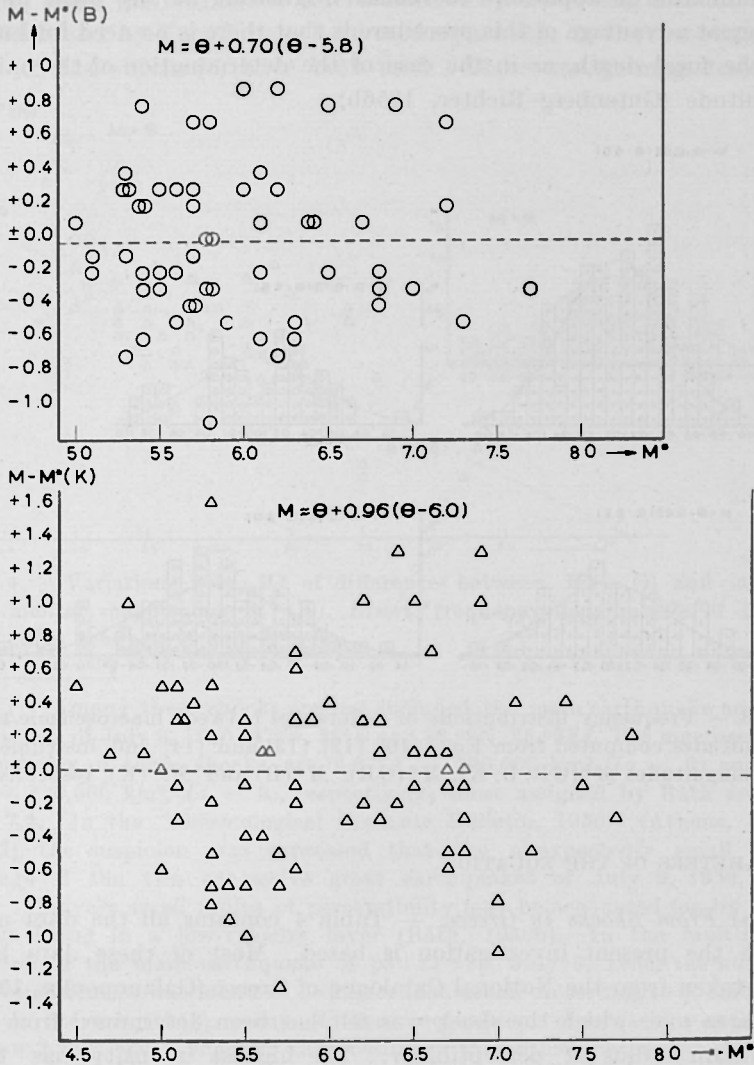


Fig. 2. - Variations with M^* of differences between macroseismic magnitudes computed from Eqs. [13] and [14] and instrumental magnitudes $M^*(B)$ and $M^*(K)$, respectively.

earthquakes with the same E remains practically constant for any focal depth (Toperczer, 1953, 1960). This means that the quantity $\log AI_0$, used for the determination of earthquake magnitudes, has the advantage of being the same for two shocks of the same magnitude originating at different depths. This explains why the proposed procedure for M -determination is applicable to shocks originating at any focal depth. The great advantage of this procedure is that there is no need for knowing the focal depth, as in the case of the determination of the unified magnitude (Gutenberg-Richter, 1956b).

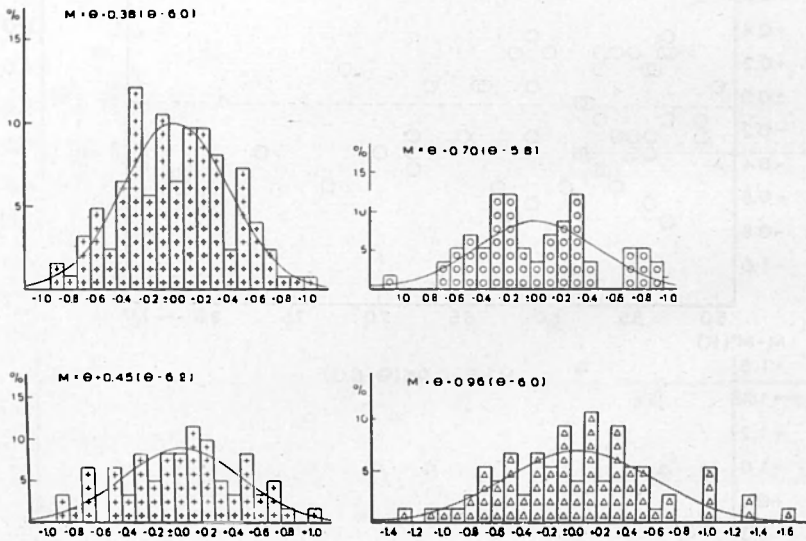


Fig. 3. — Frequency distributions of differences between macroseismic magnitudes computed from Eqs. [10], [12], [13] and [14] and instrumental magnitudes $M^*(GR, B, K)$, $M^*(GR)$, $M^*(B)$ and $M^*(K)$, respectively.

PARAMETERS OF THE EQUATION.

a) *From Shocks in Greece.* — Table 4 contains all the data upon which the present investigation is based. Most of these data have been taken from the National Catalogue of Greece (Galanopoulos, 1960). The area over which the shock was felt has been determined from the maximum radius of perceptibility. The highest intensity has been adopted as epicentral intensity. The magnitudes and the depths of the shocks have been taken from Gutenberg and Richter (1954), Gutenberg (1956, 1959), Richter (1958), Båth (1956a), Karnik (1956) and station bul-

letins. All the magnitudes assigned by Gutenberg and Richter have been used. The magnitudes computed by Karnik have been used for lack of magnitude determinations by Båth. Where no magnitude was available, the average of the magnitudes assigned by Båth (1956a) from both body waves and surface waves has been adopted as the value of M . In the second stage the magnitude determinations by Gutenberg and Richter, by Båth and by Karnik have been used separately. In the first stage the data of 124 shocks (*) have been used. There are 61 magnitude de-

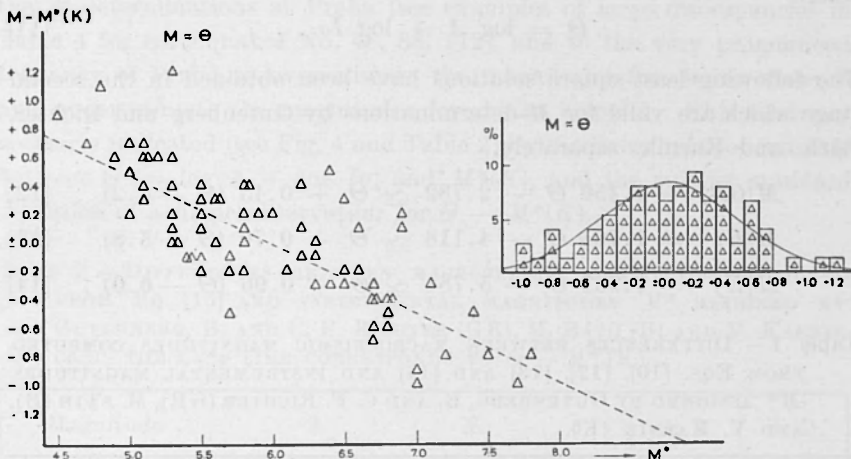


Fig. 4. — Variations with M^* of differences between $M (= \Theta)$ and instrumental magnitudes $M^*(K)$. Insert, frequency distributions of differences between M and $M^*(K)$.

(*) Among these shocks are not included the main earthquake and the aftershock of July 9, 1956 (37°N , 26°E and $36.^\circ 8\text{N}$, $25.^\circ 2\text{E}$). The macroseismic magnitudes of these shocks are 6.6 ($A = 300,000 \text{ km}^2$, $I_0 = 9$) and 6.3 ($A = 180,000 \text{ km}^2$, $I_0 = 9$), respectively; those assigned by Båth are 7.7 and 7.2. In the "Seismological Institute Bulletin, 1956" (Athens, 1957, p. 43), the suspicion was expressed that the unexpectedly small total damage of the two successive great earthquakes of July 9, 1956, and their relatively small radius of perceptibility may be accounted for by their source being in a low-velocity layer (Båth, 1956b). In the fault-plane solution of the main earthquake of 03 : 11 : 39, July 9, 1956, the number of inconsistencies was found to be higher than usual. According to J. Hodgson and A. Stevens (1958), many of these inconsistent observations are in a narrow band, which suggests the possibility that other mechanism may be operating. Such being the case, we have decided to exclude these shocks from the present investigation, although the discrepancies of their magnitudes (-1.1 and -0.9 , respectively) are within the limits of error of M -determinations from instrumental data (Båth, 1956a).

terminations by Gutenberg and Richter, 58 by B ath and 75 by Karnik.

Plotting $\Theta - M^*$ as a function of M^* (= magnitude computed from instrumental data) gives a straight line passing through the axis of zero residuals around $M^* = 6.0$. The data are very well represented by the resulting, purely empirical equation:

$$M(GR, B, K) = 1.385 \Theta - 2.315 \cong \Theta + 0.38 (\Theta - 6.0), \quad [10]$$

where

$$\Theta = \log A + \log I_0. \quad [11]$$

The following least-square solutions have been obtained in the second stage which are valid for M -determinations by Gutenberg and Richter, B ath, and Karnik, separately,

$$M(GR) = 1.450 \Theta - 2.782 \cong \Theta + 0.45 (\Theta - 6.2) \quad [12]$$

$$M(B) = 1.704 \Theta - 4.118 \cong \Theta + 0.70 (\Theta - 5.8) \quad [13]$$

$$M(K) = 1.961 \Theta - 5.784 \cong \Theta + 0.96 (\Theta - 6.0). \quad [14]$$

Table 1 - DIFFERENCES BETWEEN MACROSEISMIC MAGNITUDES COMPUTED FROM EQS. [10], [12], [13] AND [14] AND INSTRUMENTAL MAGNITUDES M^* ASSIGNED BY GUTENBERG, B. AND C. F. RICHTER (GR), M. B ATH (B), AND V. KARNIK (K).

Magnitudes	h	N	$\bar{\delta}$	S. E.	S. D.
$M^*(GR, B, K)$	$n, (n), > n$	124	- 0.01	± 0.04	± 0.40
$M^*(GR)$	$n, (n), > n$	61	+ 0.01	± 0.06	± 0.45
$M^*(B)$	$n, > n$	58	- 0.01	± 0.06	± 0.46
$M^*(K)$	$n, (n) >, n$	75	+ 0.01	± 0.07	± 0.58

h = depth of foci of earthquakes used (n = normal, (n) = slightly below normal, $> n$ = deep);
 N = number of earthquakes used;
 $\bar{\delta}$ = mean difference;
 S. E. = standard error of the mean;
 S. D. = standard deviation of a single observation.

Table 1 gives the results of the computations of the differences between macroseismic and instrumental magnitudes. The macroseismic magnitudes were computed from equations [10], [12], [13] and [14], respectively.

The magnitudes computed from Eq. [10] are given in Table 4. Variations with M^* of differences between macroseismic and instrumental magnitudes and percentage frequency distributions of the various magnitude differences are shown in Figures 1, 2 and 3, respectively.

Table 1 shows that the standard deviations in all cases but one are around ± 0.4 to ± 0.5 . The larger standard deviation of a single observation found from the M -determinations by V. Karnik are partly due to large discrepancies (sometimes amounting to one magnitude unit) in the M -determinations at Praha (see examples of large discrepancies in Table 4 for earthquakes No. 48, 88, 112), and to the very pronounced tendency of Praha to overestimate the magnitudes for shocks above 6 and underestimate the magnitudes for shocks below 6. This tendency is clearly indicated (see Fig. 4 and Table 2) by the linear relation existing between Θ ($= \log A + \log I_0$) and $M^*(K)$, and the smaller standard deviation of a single observation for $\Theta - M^*(K)$.

Table 2 - DIFFERENCES BETWEEN MACROSEISMIC MAGNITUDES COMPUTED FROM EQ. [15] AND INSTRUMENTAL MAGNITUDES M^* ASSIGNED BY GUTENBERG, B. AND C. F. RICHTER (GR), M. BÄTH (B) AND V. KARNIK (K). THE LAST LINE CORRESPONDS TO $\Theta - M^*(K)$.

Magnitude	h	N	δ	S. E.	S. D.
$M^*(GR, B, K)$	$n, (n), > n$	124	- 0.01	± 0.03	± 0.36
$M^*(GR)$	$n, (n), > n$	61	- 0.01	± 0.05	± 0.39
$M^*(B)$	$n, > n$	58	- 0.07	± 0.05	± 0.37
$M^*(K)$	$n, (n), > n$	75	+ 0.03	± 0.05	± 0.47
$M = \Theta$	$n, (n), > n$	75	+ 0.02	± 0.06	± 0.48

If we apply the very simple formula

$$M = \Theta + 0.2 (\Theta - 6) \tag{15}$$

the corresponding standard deviations become much smaller (see Table 2). This result may be explained by the following reasoning. By adding the term $0.2 (\Theta - 6)$ to Θ , the slope of the line we get by plotting $\Theta - M^*(GR, B, K)$ as a function of $M^*(GR, B, K)$ becomes smaller. By adding the term deduced by the least square method to Θ we minimize the slope of the line, but the standard deviations become relatively greater (see Table 1). This shows that the magnitudes computed from

Eq. [15] correspond more closely to the magnitudes determined from body waves. This is clearly indicated by the fact that the slope of the line we get by plotting $\Theta - M^*(GR)$ or $\Theta - M^*(B)$ against $M^*(GR)$, i. e. $M^*(B)$, mostly based on body waves, is much smaller than that of the line we get by plotting $\Theta - M^*(K)$ against $M^*(K)$, which is based on surface waves.

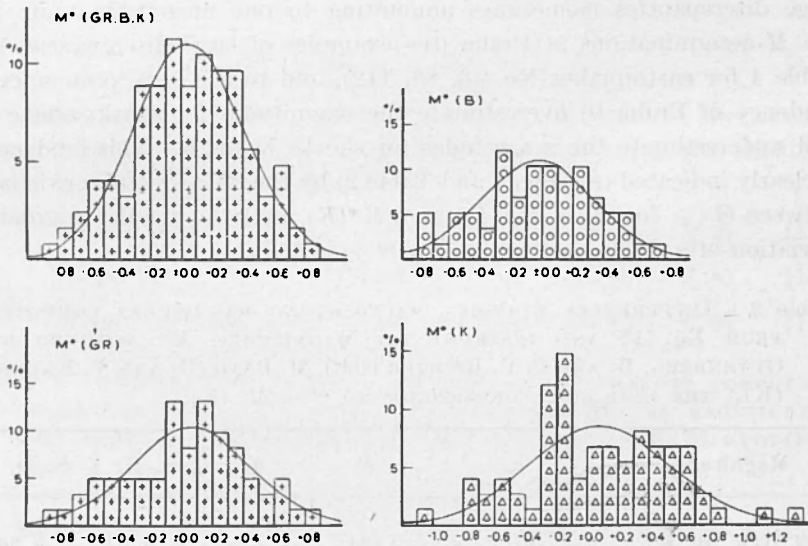


Fig. 5. — Frequency distributions of differences between macroseismic magnitudes computed from Eq. [15] and instrumental magnitudes $M^*(GR)$, $M^*(B)$, $M^*(K)$, $M^*(GR)$, $M^*(B)$ and $M^*(K)$.

The percentage frequency distributions of the various magnitude differences which have resulted by applying the formula [15] are shown in Fig. 5. As the limit of an individual M -determination from instrumental data is approx. ± 0.3 , the accuracy of determining earthquake magnitudes from macroseismic data by the proposed method is very satisfactory. An error of 100% in the assignment either of the epicentral intensity or of the area of perceptibility corresponds to 0.3 units of the magnitude scale.

b) *From Californian Shocks.* — In view of the relative reliability of the instrumental and macroseismic data available for shocks in Greece, an attempt was made to apply the proposed method for the M -determi-

nation of California shocks. Data used (see Table 5) were the very reliable elements of California shocks taken from Tables 12 and 15 of the first and second papers on "Earthquake Magnitude, Intensity, Energy, and Acceleration" by B. Gutenberg and C. F. Richter (1942, 1956a).

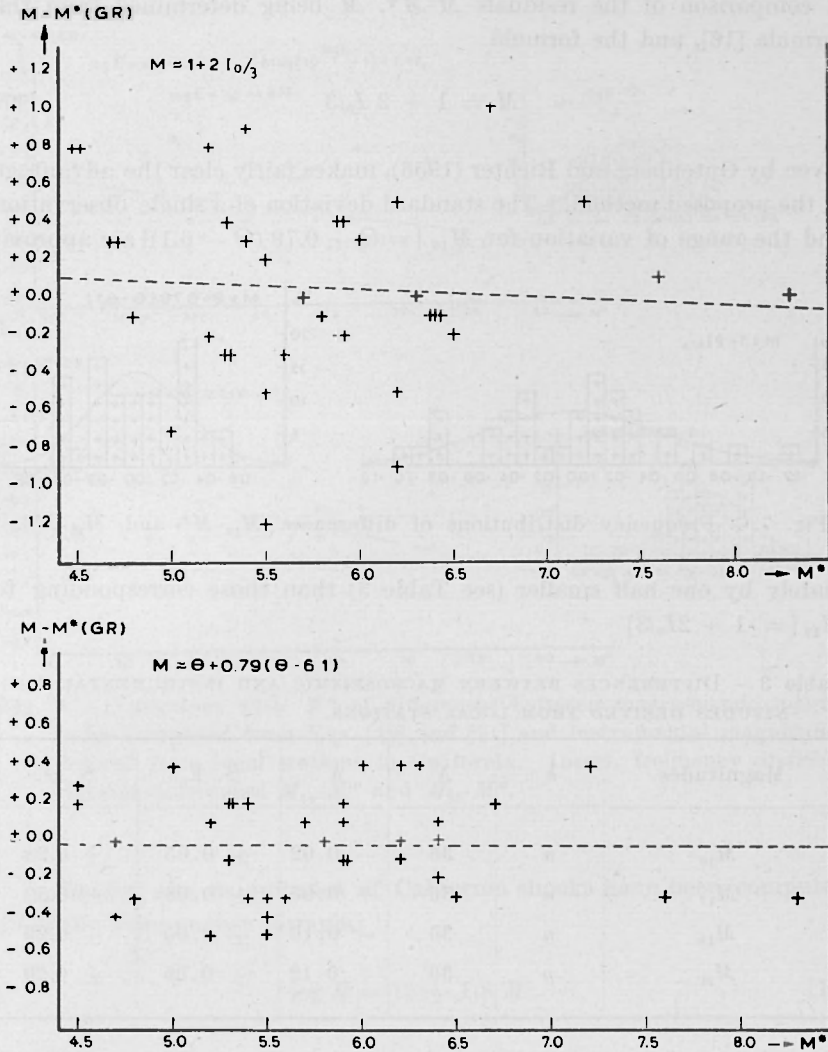


Fig. 6. - Variations with M^* of differences between macroseismic magnitudes computed from Eqs. [17] and [16], and instrumental magnitudes derived from local stations in California.

As shown in Figures 6 and 7, the macroseismic data of California shocks used for M -determination are much better represented by the equation:

$$M = 1.795 \Theta - 4.863 \cong \Theta + 0.79 (\Theta - 6.1). \quad [16]$$

A comparison of the residuals $M-M^*$, M being determined from the formula [16], and the formula

$$M = 1 + 2 I_0/3 \quad [17]$$

given by Gutenberg and Richter (1956), makes fairly clear the advantage of the proposed method. The standard deviation of a single observation and the range of variation for M_{16} [$= \Theta + 0.79 (\Theta - 6.1)$] are approxi-

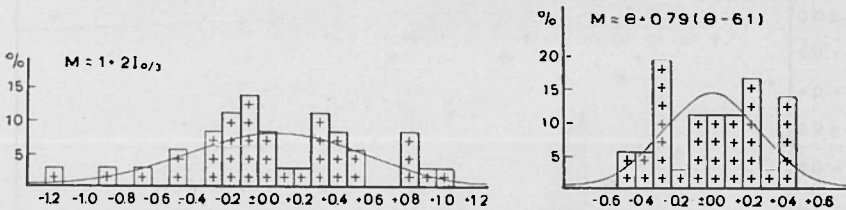


Fig. 7. - Frequency distributions of differences $M_{17}-M^*$ and $M_{16}-M^*$.

mately by one half smaller (see Table 3) than those corresponding to M_{17} [$= 1 + 2I_0/3$]

Table 3 - DIFFERENCES BETWEEN MACROSEISMIC AND INSTRUMENTAL MAGNITUDES DERIVED FROM LOCAL STATIONS.

Magnitudes	h	N	δ	S. E.	S. D.
M_{16}	n	36	- 0.02	± 0.05	± 0.28
M_{17}	n	36	+ 0.05	± 0.08	± 0.50
M_{19}	n	36	- 0.16	± 0.05	± 0.29
M_{21}	n	36	+ 0.12	± 0.05	± 0.29

From the equation

$$M_L - M_B = 0.4 (M_B - 6), \quad [18]$$

found by Gutenberg and Richter (1956a), it is seen that the formula [16] gives approximately the magnitude M_L , derived from local stations, and that Θ is nearly equal to the M_B determined from body waves. It is therefore confirmed independently that the magnitudes above 6 which were determined from local stations have been overestimated, while those below 6 have been underestimated.

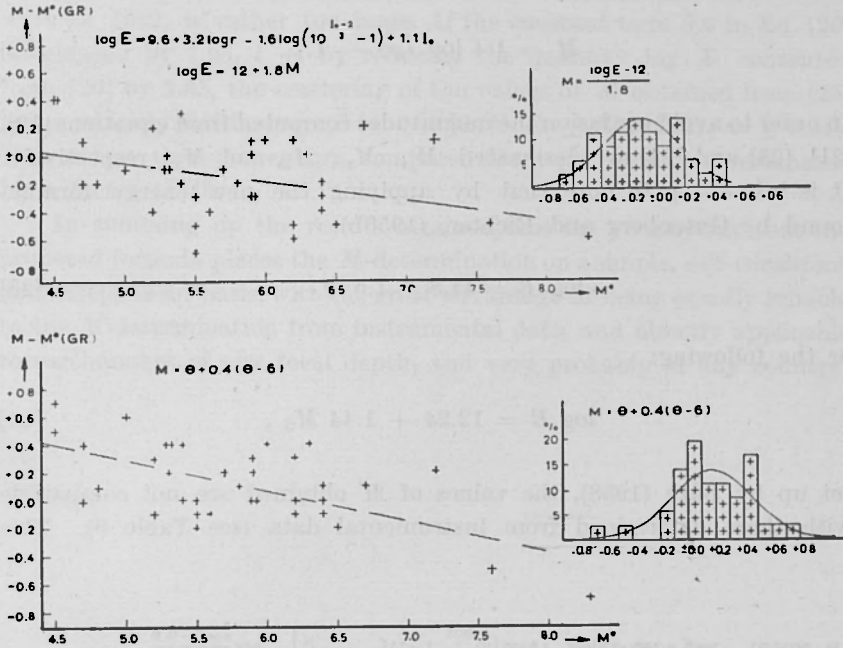


Fig. 8. - Variations with M^* of differences between macroseismic magnitudes computed from Eqs. [19] and [21] and instrumental magnitudes derived from local stations in California. Insert, frequency distributions of differences $M_{19} - M^*$ and $M_{21} - M^*$.

Finally, the magnitudes of California shocks have been computed from the older energy formula:

$$\log E = 12 + 1.8 M . \tag{19}$$

The quantity $\log E$ has been computed from the equation:

$$\log E = 9.6 + 3.2 \log r - 1.6 \log \left(10^{\frac{I_0 - 2}{3}} - 1 \right) + 1.1 I_0 \tag{20}$$

found by M. Báth (1953). As we see from Table 3 and Fig. 8, the values of M obtained from [19] and [20] are equally reliable as those found by using the very simple formula:

$$M = \Theta + 0.4 (\Theta - 6), \quad [21]$$

or the equivalent:

$$M = 1.4 \log I_0 r^2 - 1.7. \quad [22]$$

In order to avoid confusion the magnitudes computed from equations [19], [21], [23] and [24] are designated M_{19} , M_{21} , M_{23} and M_{24} , respectively. It is interesting to note that by applying the new energy formula found by Gutenberg and Richter, (1956b):

$$\log E = 11.8 + 1.5 M_S, \quad [23]$$

or the following:

$$\log E = 12.24 + 1.44 M_S, \quad [24]$$

set up by Báth (1958), the values of M obtained are not compatible with those determined from instrumental data (see Table 6). This

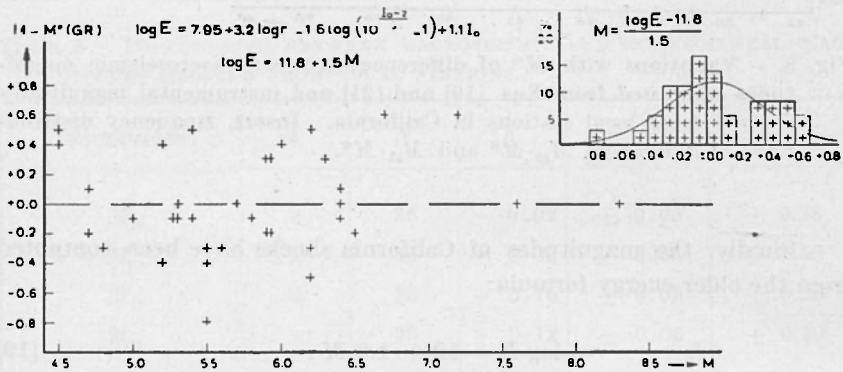


Fig. 9. — Variations with M^* of differences between macroseismic magnitudes computed from Eq. [23] and instrumental magnitudes derived from local stations in California. Insert, frequency distributions of differences $M_{23} - M^*$.

means, either the quantity $\log E$ computed from equation [20] is probably too large, or the factor of M_S in the new energy formula is too small.

Since the equations [23] and [24] agree very well with each other, although they were derived independently by different methods and by different material, it appears reasonably certain that $\log E$ computed from [20], which was based on Gutenberg and Richter's work of 1942, is rather too large. If the constant term 9.6 in Eq. [20] is replaced by 7.95, i. e. by reducing the quantity $\log E$ computed from [20] by 1.65, the scattering of the values of M obtained from [23] becomes fairly satisfactory ($\delta = + 0.01$, S. E. ± 0.06 , S. D. $= \pm 0.34$). This means that the energy computed from [20] was overestimated by a factor of 45.

In summing up the results attained thus far we may say that the proposed formula places the M -determination on a simple, self-consistent and independent basis, with the great advantage of being equally reliable to the M -determination from instrumental data, and directly applicable to earthquakes of any focal depth, and very probably of any country.

Table 4 — THIS TABLE CONTAINS ALL THE DATA UPON WHICH THE PRESENT INVESTIGATION IS BASED. THE MAGNITUDES M WERE COMPUTED FROM EQUATION [10]. IN THE COLUMN HEADED "REMARKS" ARE GIVEN MAGNITUDE DETERMINATIONS ASSIGNED BY M. BÄTH OR V. KARNIK.

No	Origin time, θ G M T	Location φ, λ	h km	A km ²	I_0	M	M^*	$M-M^*$	Remarks
1	1903, Aug. 11 04 : 32.9	36°N 23°E	100-150	5,000,000	10-11	8.4	8.3 GR	+ 0.1	—
2	1905, Nov. 8 02 : 41	40° $\frac{1}{4}$ N 24° $\frac{1}{4}$ E	(n)	1,300,000	9-10	7.5	7 \pm GR	+ 0.5	—
3	1908, May 17 12 : 30 : 09	35°N 24°E	100	2,000,000	6-7	7.6	6 $\frac{3}{4}$ GR	+ 0.8	—
4	1910, Febr. 18 05 : 09.3	36°N 24° $\frac{1}{2}$ E	150	2,000,000	8-9	7.7	7 GR	+ 0.7	—
5	1911, Apr. 4 15 : 43.9	36° $\frac{1}{2}$ N 25° $\frac{1}{2}$ E	140	2,600,000	4-5	7.5	7 GR	+ 0.5	—
6	1912, Jan. 24 16 : 23.1	38°N 20° $\frac{1}{2}$ E	60	210,000	10-11	6.5	6 $\frac{3}{4}$ GR	- 0.3	—
7	1912, Apr. 21 02 : 53.7	37° $\frac{1}{2}$ N 19° $\frac{1}{2}$ E	n	100,000	5-6	5.7	5 $\frac{3}{4}$ GR	- 0.1	—
8	1914, Oct. 17 06 : 22.5	38° $\frac{1}{4}$ N 23° $\frac{1}{2}$ E	n	180,000	7-8	6.2	6 GR	+ 0.2	—
9	1922, Aug. 13 00 : 09 : 53	36°N 28°E	40	220,000	5-6	6.1	6 $\frac{3}{4}$ GR	- 0.7	—
10	1925, Febr. 7 12 : 14 : 58	37°N 19°E	n	70,000	4-5	5.4	5 $\frac{1}{4}$ -5 $\frac{1}{2}$ GR	\pm 0.0	—
11	1925, Jul. 6 12 : 15 : 55	38° $\frac{1}{4}$ N 21° $\frac{3}{4}$ E	120	300,000	6-7	6.4	6 $\frac{1}{2}$ GR	- 0.1	—

Table 4 (cont.).

N ^o	Origin time, θ G M T	Location φ, λ	h km	A km ²	I_0	M	M^*	$M-M^*$	Remarks
12	1926, March 8 14 : 06 : 09	35°N 29°1/2°E	(n)	1,300,000	7-8	7.4	6.9 GR	+ 0.5	—
13	1926, Jun. 26 19 : 46 : 34	36°1/2°N 27°1/2°E	100	8,000,000	10-11	8.7	8.2 GR	+ 0.5	—
14	1926, Jul. 5 09 : 21 : 54	36°1/2°N 27°E	150	250,000	4-5	6.1	5 1/2 GR	+ 0.6	—
15	1926, Aug. 30 11 : 38 : 12	36°3/4°N 23°1/4°E	100	3,600,000	7-8	8.0	7.0 GR	+ 1.0	—
16	1927, Jul. 1 08 : 19 : 04	36°3/4°N 22°3/4°E	120	500,000	9-10	7.0	6.9 GR	+ 0.1	—
17	1930, Febr. 14 18 : 38 : 20	35°3/4°N 24°3/4°E	130	1,200,000	10-11	7.5	6 3/4 GR	+ 0.7	6.9K
18	1930, March 31 12 : 33 : 55	39°1/2°N 23°E	n	100,000	7-8	5.9	6.1 K	- 0.2	—
19	1930, Nov. 21 02 : 00 : 25	40°1/2°N 19°1/2°E	n	160,000	9-10	6.3	6 GR	+ 0.3	—
20	1931, Jan. 28 05 : 55 : 15	40°5'N 20°5'E	n	90,000	8-9	5.9	5.6 K	+ 0.3	—
21	1931, March 7 00 : 16 : 42	41°N 22°1/2°E	n	260,000	7-8	6.4	6 GR	+ 0.4	—
22	1931, March 8 01 : 50 : 19	41°N 22°1/2°E	n	480,000	9-10	6.9	6 3/4 GR	+ 0.1	6.6K
23	1932, March 9 10 : 16 : 48	38°N 20°1/2°E	n	100,000	6-7	5.8	5 1/4-5 1/2 GR	+ 0.4	—
24	1932, Aug. 15 04 : 34 : 10	39°1/4°N 22°E	100	100,000	5-6	5.7	5 1/2 GR	+ 0.2	—

Table 4 (cont.).

N ^o	Origin time, θ G M T	Location φ, λ	h km	A km ²	I_0	M	M^*	$M-M^*$	Remarks
25	1932, Sept. 26 19 : 20 : 37	40° 1/2 N 23° 3/4 E	n	700.000	9-10	7.2	6.9 GR	+ 0.3	—
26	1932, Sept 29 03 : 57 : 19	40° 1/2 N 23° 3/4 E	n	210.000	8-9	6.4	6 1/4 GR	+ 0.1	6.2K
27	1932, Sept. 30 06 : 12 : 09	36° N 22° 3/4 E	n	180.000	5-6	6.0	5 1/4-5 1/2 GR	+ 0.6	—
28	1932, Nov. 1 16 : 19 : 26	40° 1/2 N 23° 3/4 E	n	50.000	6-7	5.4	5 1/4-5 1/2 GR	± 0.0	—
29	1933, Apr. 23 05 : 57 : 35	36° 3/4 N 27° 1/4 E	50	90.000	9-10	5.9	6 3/4 GR	— 0.9	—
30	1933, May 11 19 : 09 : 44	40° 1/2 N 23° 3/4 E	n	280.000	7-8	6.5	6 1/4 GR	+ 0.2	6.3K
31	1934, Nov. 9 13 : 40 : 56	36° 3/4 N 25° 3/4 E	140	130.000	5-6	5.8	6 1/4 GR	— 0.5	—
32	1935, Jan. 4 14 : 41 : 23	40° 1/4 N 27° 1/2 E	n	250.000	5-6	6.2	6 1/4 GR	— 0.1	6 3/4 K
33	1935, Jan. 4 16 : 20 : 00	40° 1/4 N 27° 1/2 E	n	250.000	5-6	6.2	6 GR	+ 0.2	—
34	1935, Febr. 25 02 : 51 : 37	35° 3/4 N 25° E	80	1.200.000	7-8	7.3	6 3/4 GR	+ 0.5	6.9K
35	1935, March 18 08 : 40 : 41	35° 1/2 N 27° E	130	230.000	5-6	6.2	6 1/4 GR	— 0.1	6.7K
36	1937, Dec. 16 17 : 35 : 30	35° N 23° 1/2 E	100	150.000	4-5	5.8	6 1/2 GR	— 0.7	—
37	1938, March 11 14 : 50 : 55	38° 8 N 20° 6 E	n	50.000	7-8	5.4	5.8 K	— 0.4	—

Table 4 (cont.).

N ^o	Origin time, θ G M T	Location φ, λ	h km.	A km ²	I_0	M	M^*	$M-M^*$	Remarks
38	1938, March 13 17 : 45 : 32	38°8'N 20°6'E	n	50.000	7-8	5.4	5.7 K	- 0.3	—
39	1938, Jul. 20 00 : 23 : 35	38°1/4'N 23°3/4'E	n	150.000	7-8	6.1	5 3/4 GR	+ 0.3	6.2K
40	1938, Sept. 18 03 : 50 : 38	38°N 22°1/2'E	100	100.000	5-6	5.7	6 1/2 GR	- 0.8	—
41	1939, May 20 09 : 35 : 23	41°N 19°1/2'E	n	90.000	5-6	5.6	5 1/4-5 1/2 GR	+ 0.2	5.1K
42	1939, Sept. 22 00 : 36 : 32	39°N 27°E	n	250.000	8-9	6.5	6 1/2 GR	± 0.0	6.6K
43	1941, March 1 03 : 52 : 48	39°7'N 22°5'E	n	120.000	8-9	6.0	6 1/4 GR	- 0.3	6.3K
44	1941, May 23 19 : 51 : 53	37°1/4'N 28°E	n	80.000	7-8	5.7	6 GR	- 0.3	5.8K
45	1941, Dec. 13 06 : 16 : 05	37°N 28°E	100	160.000	6-7	6.0	6 GR	± 0.0	6.7K
46	1943, Oct. 16 13 : 08 : 53	36°1/2'N 27°1/2'E	110	1.800.000	3-4	7.2	6 1/4 GR	+ 0.9	6.4K
47	1947, Apr. 19 20 : 29 : 35	38°8'N 23°2'E	n	40.000	4-5	5.0	5.3 K	- 0.3	—
48	1947, Jun. 4 00 : 29 : 35	40°N 24°E	80	180.000	4-5	5.9	6 GR	- 0.1	7.0K
49	1947, Jul. 7 22 : 35 : 50	38°N 20°1/2'E	100 ±	100.000	4-5	5.6	5 1/2 ± GR	± 0.1	—
50	1947, Oct. 6 19 : 55 : 37	36°9'N 22°0'E	28	570.000	8-9	7.0	7 GR	± 0.0	7.5K

Table 4 (cont.).

N ^o	Origin time, θ G M T	Location φ, λ	h km	A km ²	I_0	M	M^*	$M-M^*$	Remarks
51	1948, Febr. 9 12 : 58 : 15	35° 1/2'N 27°E	40	250.000	8-9	6.5	7.1 GR	- 0.6	7.2K
52	1948, Apr. 22 10 : 42 : 41	38° 1/2'N 20° 1/4'E	n	250.000	9-10	6.5	6.4 GR	+ 0.1	6.8K
53	1948, Jun. 30 12 : 21 : 11	38° 1/2'N 20° 1/2'E	n	250.000	9-10	6.5	6.4 GR	+ 0.1	6.7K
54	1948, Aug. 27 10 : 44 : 06	42°0'N 19°4'E	n	45.000	4-5	5.1	5.4 K	- 0.3	—
55	1948, Sept. 11 08 : 52 : 32	37°N 23°E	80	1.200.000	4-5	7.1	6.5 K	+ 0.6	—
56	1949, Jan. 14 15 : 53 : 55	38°8'N 25°3'E	n	80.000	3-4	5.3	5.7 K	- 0.4	—
57	1949, Jul. 23 15 : 03 : 30	38°6'N 26°3'E	n	150.000	8-9	6.2	6.8 GR	- 0.6	7.0K
58	1949, Nov. 23 16 : 50 : 56	38°6'N 26°3'E	n	40.000	5-6	5.1	5.1 K	± 0.0	—
59	1951, Dec. 20 19 : 12 : 02	38°3'N 20°8'E	n	25.000	5-6	4.8	5.0 K	- 0.2	—
60	1952, Jun. 13 01 : 07 : 22	37°3'N 22°1'E	n	30.000	7-8	5.1	5.5 1/4 B	± 0.0	4.5K
61	1952, Oct. 5 10 : 54 : 56	37° 1/2'N 20° 1/2'E	n	80.000	4-5	5.4	5 1/2-5 3/4 B	- 0.2	5.6K
62	1952, Oct. 13 16 : 42 : 24	38°9'N 23°7'E	n	60.000	7-8	5.5	5 1/4-5 1/2 B	+ 0.1	5.1K
63	1952, Oct. 22 04 : 14 : 52	36°7'N 27°9'E	n	50.000	5-6	5.3	5 B	+ 0.3	5.0K

Table 4 (cont.)

N ^o	Origin time, θ G M T	Location φ, λ	h km	A km ²	I_0	M	M^*	$M-M^*$	Remarks
64	1952, Dec. 17 23 : 05 : 58	34°7N 24°7E	n	400.000	5-6	6.5	6 ³ / ₄ G	- 0.3	6 ¹ / ₂ -6 ³ / ₄ B; 6 ³ / ₄ K
65	1952, Dec. 31 17 : 18 : 42	35°5N 25°7E	n	50.000	5-6	5.3	5 ¹ / ₄ -5 ¹ / ₂ B	- 0.1	-
66	1953, Febr. 7 22 : 31 : 05	35°N 24° ¹ / ₂ E	n	360.000	7-8	6.6	6 B	+ 0.6	5.3K
67	1953, Febr. 14 08 : 43 : 13	35° ¹ / ₂ N 26° ¹ / ₂ E	100	60.000	5-6	5.4	5 ¹ / ₂ -5 ³ / ₄ B	- 0.3	-
68	1953, March 18 10 : 06 : 13	40°N 27° ¹ / ₄ E	n	500.000	10-11	7.0	7.2 GR	- 0.2	7.7B,K
69	1953, May 2 18 : 37 : 38	38°7N 26°5E	n	70.000	6-7	5.6	5 ³ / ₄ -6 B	- 0.3	-
70	1953, Jun. 18 05 : 44 : 06	41°7N 26°5E	n	40.000	5-6	5.1	5 ¹ / ₄ -5 ¹ / ₂ B	- 0.3	4.7K
71	1953, Aug. 9 07 : 41 : 06	38°1N 20°8E	n	150.000	8-9	6.2	6 ³ / ₄ GR	- 0.6	6.5B; 6.4K
72	1953, Aug. 11 03 : 32 : 30	38°1N 20°8E	n	180.000	9-10	6.3	6 ³ / ₄ GR	- 0.5	6.8B,K
73	1953, Aug. 12 09 : 23 : 49	38°1N 20°8E	n	530.000	10-11	7.0	7 ¹ / ₄ GR	- 0.3	7.2B; 7.1K
74	1953, Sept. 5 14 : 18 : 41	37°8N 23°0E	n	90.000	7-8	5.8	5.7 B	+ 0.1	5.6K
75	1953, Sept. 14 14 : 56 : 10	38°3N 21°0E	n	110.000	6-7	5.8	5.6 B	+ 0.2	5 ¹ / ₂ K
76	1953, Oct. 10 21 : 29 : 13	38°3N 21°0E	n	30.000	5-6	5.0	5.3 K	- 0.3	-

Table 4 (cont.).

N ^o	Origin time, θ G M T	Location φ, λ	h km	A km ²	I_0	M	M^*	$M-M^*$	Remarks
77	1953, Oct. 21 11 : 31 : 01	38°3N 20°8E	n	120.000	6-7	5.9	5.3 K	+ 0.6	—
78	1953, Oct. 21 18 : 39 : 51	38°3N 20°8E	n	210.000	7-8	6.3	6 1/2 GR	- 0.2	6.4B; 6.5K
79	1953, Nov. 28 20 : 17 : 31	37°3/4N 20°1/4E	n	60.000	4-5	5.3	5 1/4 B	± 0.0	4.9K
80	1953, Nov. 30 13 : 21 : 01	39°N 21°1/2E	n	70.000	8-9	5.7	5.2 K	+ 0.5	—
81	1953, Dec. 28 02 : 38 : 43	38°1/2N 21°E	n	50.000	5-6	5.3	5.1 K	+ 0.2	—
82	1954, March 8 08 : 17 : 21	38°2N 20°4E	n	30.000	5-6	5.0	5 1/4-5 1/2 B	- 0.4	5 1/2K
83	1954, April 30 13 : 02 : 36	39°3N 22°2E	n	260.000	9-10	6.6	7 GR	- 0.4	7 1/4B
84	1954, May 25 22 : 03 : 33	39°5N 22°2E	n	60.000	5-6	5.4	5 1/2 B	- 0.1	5 1/2K
85	1954, Aug. 3 18 : 18 : 10	40°2N 25°0E	n	150.000	4-5	5.8	6-6 1/4 B	- 0.3	5 3/4K
86	1954, Dec. 23 16 : 27 : 17	37°9N 21°3E	n	140.000	7-8	6.0	6-6 1/4 B	- 0.1	5 3/4K
87	1955, March 28 14 : 45 : 45	37°6N 21°1E	n	60.000	7-8	5.6	5 3/4 B	- 0.2	—
88	1955, Apr. 13 20 : 45 : 45	37°1/4N 22°1/4E	n	70.000	7-8	5.6	6 1/4 B	- 0.7	5 1/4K
89	1955, Apr. 19 16 : 47 : 19	39°3N 23°1E	n	170.000	9-10	6.3	6 1/4-6 1/2 B	- 0.1	6 1/4K

Table 4 (cont.).

No	Origin time, θ G M T	Location φ, λ	h km	A km ²	I_0	M	M^*	$M-M^*$	Remarks
90	1955, Apr. 21 07 : 18 : 18	39°3N 23°1E	n	140.000	8-9	6.1	6 B	+ 0.1	5.9K
91	1955, Jun. 2 23 : 34 : 33	40°N 25° $\frac{1}{4}$ E	n	80.000	5-6	5.6	5 $\frac{1}{4}$ B	+ 0.3	—
92	1955, Jul. 9 23 : 53 : 43	40°9N 22°1E	n	60.000	7-8	5.6	5 $\frac{1}{4}$ B	+ 0.3	—
93	1955, Jul. 16 07 : 07 : 12	37°9N 27°1E	n	230.000	8-9	6.4	6 $\frac{3}{4}$ / -7 GR	- 0.5	6 $\frac{3}{4}$ B; 6 $\frac{1}{2}$ - 6 $\frac{3}{4}$ K
94	1955, Aug. 28 13 : 39 : 17	37°N 27°E	n	25.000	4-5	4.7	5 $\frac{1}{4}$ B	- 0.6	—
95	1956, Jan. 13 20 : 00 : 34	37°6N 24°0E	n	40.000	5-6	5.1	5.5 K	- 0.4	—
96	1956, May 18 22 : 08 : 30	39° $\frac{1}{4}$ N 22° $\frac{1}{4}$ E	n	70.000	5-6	5.5	6.1 B	- 0.6	—
97	1956, Jul. 30 09 : 14 : 57	35° $\frac{3}{4}$ N 25° $\frac{3}{4}$ E	n	280.000	5-6	6.3	6.1 B	+ 0.2	5 $\frac{3}{4}$ K
98	1956, Jul. 30 10 : 39 : 57	35° $\frac{3}{4}$ N 25° $\frac{3}{4}$ E	n	100.000	4-5	5.6	5.4 B	+ 0.2	—
99	1956, Nov. 2 16 : 04 : 33	39°5N 23°0E	n	80.000	7-8	5.7	5 $\frac{3}{4}$ B	- 0.1	5.1K
100	1956, Nov. 20 23 : 20 : 52	39° $\frac{3}{4}$ N 26°E	n	50.000	5-6	5.3	5 $\frac{1}{2}$ B	- 0.2	—
101	1957, March 8 12 : 14 : 14	39°5N 22°8E	n	220.000	8-9	6.4	6.8 B	- 0.4	6 $\frac{1}{2}$ K
102	1957, March 8 12 : 21 : 14	39°4N 22°7E	n	220.000	9-10	6.5	6 $\frac{1}{4}$ GR	+ 0.2	7B; 6.7K

Table 4 (cont.).

N ^o	Origin time. θ G M T	Location φ, λ	h km	A km ²	I_0	M	M^*	$M-M^*$	Remarks
103	1957, March 8 20 : 38 : 02	39°5N 22°8E	n	70.000	5-6	5.5	5.8 B	- 0.3	—
104	1957, March 8 23 : 35 : 11	39°5N 22°8E	n	220.000	7-8	6.3	6.2 B	+ 0.1	5.8K
105	1957, March 28 22 : 26 : 00	39°1/2N 22°3/4E	n	25.000	5-6	4.9	5.8 B	- 0.9	5.7K
106	1957, Apr. 24 19 : 10 : 16	36°3N 29°1E	(n)	1.100.000	7-8	7.3	6 3/4-7 GR	+ 0.4	6.9B; 7.4K
107	1957, Apr. 25 02 : 25 : 36	36°1/2N 28°3/4E	(n)	1.100.000	9-10	7.4	7.1 GR	+ 0.3	7.2B; 7.8K
108	1957, Oct. 30 01 : 43 : 01	35°3N 27°2E	n	70.000	4-5	5.4	5.7 B	- 0.3	5 1/4K
109	1957, Nov. 9 23 : 55 : 52	38°4N 22°1E	n	30.000	5-6	5.0	5.4 K	- 0.4	—
110	1957, Nov. 26 08 : 15 : 22	39°5N 22°8E	n	70.000	5-6	5.5	6.2 B	- 0.7	—
111	1957, Nov. 26 11 : 50 : 02	39°5N 22°8E	n	110.000	5-6	5.7	5.8 B	- 0.1	—
112	1958, Jan. 2 02 : 08 : 14	36°0N 22°4E	n	140.000	5-6	5.9	5.7 B	+ 0.2	4.8K
113	1958, Jan. 16 04 : 18 : 13	39°1/2N 25°1/4E	n	50.000	4-5	5.2	5.6 B	- 0.4	5 1/4K
114	1958, March 15 06 : 27 : 08	40°9N 21°2E	n	80.000	6-7	5.6	5.3 B	+ 0.3	5K
115	1958, Apr. 3 02 : 23 : 40	41°N 20°E	n	80.000	5-6	5.6	5.7 B	- 0.1	5 1/2K

Table 4 (cont.).

No	Origin time, θ G M T	Location φ, λ	h km	A km ²	I_o	M	M^*	$M-M^*$	Remarks
116	1958, May 9 02 : 40 : 47	36° 1/2 N 27° 3/4 E	n	200.000	5-6	6.1	5.4 B	+ 0.7	—
117	1958, Jul. 17 05 : 37 : 08	40° 3/4 N 23° 1/4 E	n	100.000	6-7	5.6	5 1/2 K	+ 0.1	—
118	1958, Aug. 27 15 : 16 : 34	37° 8 N 20° 5 E	(n)	900.000	5-6	7.0	6.5 B	+ 0.5	—
119	1959, Apr. 25 00 : 26 : 41	37° 0 N 28° 5 E	n	80.000	7-8	5.7	6.3 B	— 0.6	—
120	1959, May 14 06 : 36 : 55	35° 1/4 N 24° 3/4 E	n	450.000	8-9	6.8	6 1/2 GR	+ 0.3	6.2B 6.6 1/4 K
121	1959, Jun. 10 04 : 16 : 03	35° 3/4 N 24° 1/4 E	n	210.000	6-7	6.2	5.7 B	+ 0.5	—
122	1959, Jul. 26 17 : 07 : 03	41° N 27° 1/2 E	n	40.000	4-5	5.0	5.1 B	— 0.1	—
123	1959, Aug. 16 18 : 42 : 00	37° 1/4 N 22° 0 E	n	90.000	6-7	5.7	5.5 B	+ 0.2	—
124	1959, Aug. 17 01 : 33 : 14	41° N 19° 1/2 E	n	330.000	4-5	6.3	5.8 B	+ 0.5	6K

Table 5 - ELEMENTS OF CALIFORNIA SHOCKS FROM DATA OF U S C G S

No	Date	r(km)	I_0	M^*	M_{17}	M_{16}	$M_{17} - M^*$	$M_{16} - M^*$
1	1906, Apr. 18	650	11	8 $\frac{1}{4}$	8.3	8.0	± 0.0	- 0.3
2	1932, June 6	300	8	6.4	6.3	6.5	- 0.1	+ 0.1
3	Dec. 20	550	10	7.2	7.7	7.6	+ 0.5	+ 0.4
4	1933, Mar. 10	300	8 $\frac{1}{2}$	6.2	6.7	6.6	+ 0.5	+ 0.4
5	Oct. 2	140	7	5.3	5.7	5.2	+ 0.4	- 0.1
6	1934, June 7	280	8	6.0	6.3	6.4	+ 0.3	+ 0.4
7	1937, Mar. 8	110	6 $\frac{1}{2}$	4.5	5.3	4.8	+ 0.8	+ 0.3
8	1938 May 31	180	6	5.3	5.0	5.5	- 0.3	+ 0.2
9	1940 May 18	350	10	6.7	7.7	6.9	+ 1.0	+ 0.2
10	1941, June 30	230	8	5.9	6.3	6.1	+ 0.4	+ 0.2
11	Nov. 14	130	7	5.4	5.7	5.1	+ 0.3	- 0.3
12	1942, Oct. 21	250	8	6.4	6.3	6.2	- 0.1	- 0.2
13	1943, Aug. 29	150	6	5.5	5.0	5.2	- 0.5	- 0.3
14	1944, June 12	180	6	5.3	5.0	5.5	- 0.3	+ 0.2
15	1946, Mar. 15	350	8	6.3	6.3	6.7	± 0.0	+ 0.4
16	1947, Apr. 10	280	8	6.4	6.3	6.4	- 0.1	± 0.0
17	July 24	150	5	5.5	4.3	5.1	- 1.2	- 0.4
18	1948, Mar. 1	110	6	4.7	5.0	4.7	+ 0.3	± 0.0
19	Apr. 16	80	6	4.7	5.0	4.3	+ 0.3	- 0.4
20	Dec. 4	250	8	6.5	6.3	6.2	- 0.2	- 0.3
21	1949, May 2	200	7?	5.9	5.7	5.8	- 0.2	- 0.1
22	Nov. 4	200	?**	5.7	5.7	5.8	± 0.0	+ 0.1
23	1950, July 29	170	8	5.4	6.3	5.6	+ 0.9	+ 0.2
24	Sept. 5	100	5 $\frac{1}{2}$	4.8	4.7	4.5	- 0.1	- 0.3
25	1951, Jan. 23	150	6 $\frac{1}{2}$	5.6	5.3	5.3	- 0.3	- 0.3
26	Dec. 5	100	6 $\frac{1}{2}$	4.5	5.3	4.7	+ 0.8	+ 0.2
27	Dec. 25	200	?***	5.9	5.7	5.8	- 0.2	- 0.1
28	1952, July 21	450	10	7.6	7.7	7.3	+ 0.1	- 0.3
29	Aug. 22	200	7 +	5.8	5.7	5.8	- 0.1	± 0.0
30	Aug. 23	180	5	5.0	4.3	5.4	- 0.7	+ 0.4
31	Nov. 21	250	7 +	6.2	5.7	6.1	- 0.5	- 0.1
32	1953, June 13	120	7	5.5	5.7	5.0	+ 0.2	- 0.5
33	Sept. 25	110	6	5.2	5.0	4.7	- 0.2	- 0.5
34	1954, Jan. 12	220	8	5.9	6.3	6.0	+ 0.4	+ 0.1
35	Mar. 19	240	6 $\frac{1}{2}$	6.2	5.3	6.2	- 0.9	± 0.0
36	Apr. 25	140	7 $\frac{1}{2}$	5.2	6.0	5.3	+ 0.8	+ 0.1

** For the M -determinations the same intensity ($I_0 = 7$) was assumed for shocks No. 21, 22 and 27.

Table 6 - MAGNITUDES OF CALIFORNIA SHOCKS FROM DATA OF U S C G S*

No	M^*	M_{19}	M_{21}	M_{23}	M_{24}	$M_{19} - M^*$	$M_{21} - M^*$	$M_{23} - M^*$	$M_{24} - M^*$
1	8 1/4	7.7	7.6	9.4	9.5	-0.6	-0.7	+1.1	+1.2
2	6.4	6.2	6.5	7.6	7.6	-0.2	+0.1	+1.2	+1.2
3	7.2	7.3	7.4	8.9	8.9	+0.1	+0.2	+1.7	+1.7
4	6.2	6.3	6.5	7.8	7.8	+0.1	+0.3	+1.6	+1.6
5	5.3	5.3	5.5	6.4	6.4	± 0.0	+0.2	+1.1	+1.1
6	6.0	6.1	6.4	7.5	7.5	+0.1	+0.4	+1.5	+1.5
7	4.5	4.9	5.2	6.1	6.0	+0.4	+0.7	+1.6	+1.5
8	5.3	5.2	5.7	6.3	6.3	-0.1	+0.4	+1.0	+1.0
9	6.7	6.9	6.8	8.4	8.5	+0.2	+0.1	+1.7	+1.8
10	5.9	6.0	6.2	7.3	7.3	+0.1	+0.3	+1.4	+1.4
11	5.4	5.2	5.4	6.4	6.4	-0.2	± 0.0	+1.0	+1.0
12	6.4	6.0	6.3	7.4	7.4	-0.4	-0.1	+1.0	+1.0
13	5.5	5.0	5.5	6.2	6.1	-0.5	± 0.0	+0.7	+0.6
14	5.3	5.2	5.7	6.3	6.3	-0.1	+0.4	+1.0	+1.0
15	6.3	6.3	6.7	7.7	7.7	± 0.0	+0.4	+1.4	+1.4
16	6.4	6.1	6.4	7.5	7.5	-0.3	± 0.0	+1.1	+1.1
17	5.5	4.8	5.4	5.8	5.8	-0.7	-0.1	+0.3	+0.3
18	4.7	4.8	5.1	5.9	5.8	+0.1	+0.4	+1.2	+1.1
19	4.7	4.5	4.7	5.6	5.5	-0.2	± 0.0	+0.9	+0.8
20	6.5	6.0	6.3	7.4	7.4	-0.5	-0.2	+0.9	+0.9
21	5.9	5.6	5.9	6.8	6.8	-0.3	± 0.0	+0.9	+0.9
22	5.7	5.6	5.9	6.8	6.8	-0.1	+0.2	+1.1	+1.1
23	5.4	5.7	5.8	7.0	7.0	+0.3	+0.4	+1.6	+1.6
24	4.8	4.6	4.9	5.6	5.5	-0.2	+0.1	+0.8	+0.7
25	5.6	5.2	5.5	6.4	6.3	-0.4	-0.1	+0.8	+0.7
26	4.5	4.9	5.0	6.0	5.9	+0.4	+0.5	+1.5	+1.4
27	5.9	5.6	5.9	6.8	6.8	-0.3	± 0.0	+0.9	+0.9
28	7.6	7.1	7.1	8.7	8.7	-0.5	-0.5	+1.1	+1.1
29	5.8	5.6	5.9	6.8	6.8	-0.2	+0.1	+1.0	+1.0
30	5.0	4.9	5.6	6.0	5.9	-0.1	+0.6	+1.0	+0.9
31	6.2	5.7	6.2	7.0	7.0	-0.5	± 0.0	+0.8	+0.8
32	5.5	5.2	5.3	6.3	6.3	-0.3	-0.2	+0.8	+0.8
33	5.2	4.8	5.1	5.9	5.8	-0.4	-0.1	+0.7	+0.6
34	5.9	5.9	6.1	7.3	7.3	± 0.0	+0.2	+1.4	+1.4
35	6.2	5.6	6.1	6.8	6.8	-0.6	-0.1	+0.6	+0.6
36	5.2	5.4	5.5	6.7	6.6	+0.2	+0.3	+1.5	+1.4

* For the M -determinations the epicentral intensity I_0 and the radius of perceptibility r were taken from Table 5.

SUMMARY

A simple magnitude formula for macroseismic data is proposed which places the M -determination on a self-consistent and independent basis, with the great advantage of being equally reliable to the M -determination from instrumental data and directly applicable to shocks of any focal depth, and very probably of any country.

ZUSAMMENFASSUNG

Es wird eine einfache Magnitudengleichung für makroseismische Daten vorgeschlägt, wodurch die Magnitudenbestimmung auf einer selbskonsequenten und selbstständigen Grundlage gesetzt wird, mit dem grossen Vorteil diese Bestimmung mit derjenigen aus mikroseismischen Daten gleichermassen zuverlässig und geradeswegs auf Beben irgendeiner Herdtiefe und sehr wahrscheinlich irgendeines Gebietes anwendbar zu sein.

RESUME

On propose une formule simple pour la détermination de la magnitude des séismes par les données macroséismiques, qui est directement applicable aux séismes de toutes profondeurs et très probablement de toutes régions. La détermination macroséismique de M par cette méthode a le grand avantage d'être aussi valable que la détermination de M par les données des instruments.

RIASSUNTO

Viene proposta una formula semplice per la determinazione della magnitudine M dai dati macrosismici, la quale formula è direttamente applicabile ai terremoti di ogni profondità e molto probabilmente di ogni regione. La determinazione macrosismica dell' M con il metodo suddetto ha il grande vantaggio di essere talmente valevole quanto la determinazione dell' M dai dati degli strumenti.

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