On Magnitude Determination by Using Macroseismic Data

(Second Paper)

A. G. Galanopoulos (*)

Ricevuto il 27 Novembre 1961

In the first paper (Galanopoulos, 1961), it was assumed that there is a linear relation of the earthquake intensity to the acceleration at the epicenter. On this assumption the magnitude formula:

$$M = C_1 \log I_o r^2 + C_2 \quad [1]$$

was derived from the empirical equation:

$$a_r a_o \; R^2 = CE \quad [2]$$

found by Gutenberg and Richter (1942). The formula [1] was proved to be appropriate for M-determination from macroseismic data.

By using the basic relation:

$$I = p \log a + q \quad [3]$$

applied in all macroseismic computations, the magnitude formula:

$$M = K_1 \log r^2 + \frac{I_o}{K_2} + K_3 \quad [4]$$

is derived from the equation [2] on the same assumptions.

The results obtained from the equations [1] and [4] with the proper parameters derived from shocks in Greece ($N = 124$) and from Californian shocks ($N = 36$) by the least-square method are presented in the table below. For reasons of comparison the results obtained from the corresponding equations set up by Gutenberg and Richter (1956) are given in the same table. Data used are those contained in the tables (4) and (5) of the first paper. Notation is the same.

(*) Acknowledgment. The author is much indebted to Dr. V. Karnik for suggesting this investigation.

The comparison shows that there is no difference in the M-determination if a linear or logarithmic relation of the intensity to the acceleration at the epicenter is assumed. The same is true if a linear or logarithmic relation of the earthquake magnitude to the epicentral intensity is applied for determining the magnitude.

Table 1 – DIFFERENCES BETWEEN MACROSEISMIC MAGNITUDES COMPUTED FROM THE CORRESPONDING EQUATIONS AND INSTRUMENTAL MAGNITUDES M^* ASSIGNED BY GUTENBERG AND RICHTER (GR), M. BÅTH (B) AND V. KARNIK (K).

Magnitude	h	N	δ	S. E.	S. D.
$M = 1.38 \log I_o r^2 - 1.63$	n, (n), $>n$	124	—0.01	±0.04	±0.40
$M = 0.83 \log r^2 + \frac{I_o}{3.62} + 0.14$	n, (n), $>n$	124	—0.02	±0.04	±0.42
$M = 1.58 \log r^2 - 1.38$	n, (n), $>n$	124	—0.01	±0.04	±0.48
$M = 1.79 \log I_o r^2 - 3.97$	n	36	—0.02	±0.05	±0.28
$M = 1.02 \log r^2 + \frac{I_o}{2.92} - 1.45$	n	36	—0.03	±0.05	±0.31
$M = 2.12 \log r^2 - 3.98$	n	36	—0.03	±0.05	±0.32
$M = -3.0 + 3.8 \log r$ (GR)	n	36	—0.05	±0.05	±0.29
$M = 1 + \frac{2}{3} I_o$ (GR)	n	36	+0.05	±0.08	±0.50
$M = 0.7\ I_o + 0.7$	n	36	+0.01	±0.09	±0.52
$M = 12.53 \log I_o - 4.89$	n	36	+0.03	±0.09	±0.57

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

More important is the fact that in either relationship the epicentral intensity in itself alone is rather unreliable for determining earthquake magnitudes. This is due to the fact that the relation of the intensity to the acceleration at the epicenter is neither logarithmic nor linear. Moreover, in estimating the earthquake intensity the personal factor of the field investigator is inevitably involved.

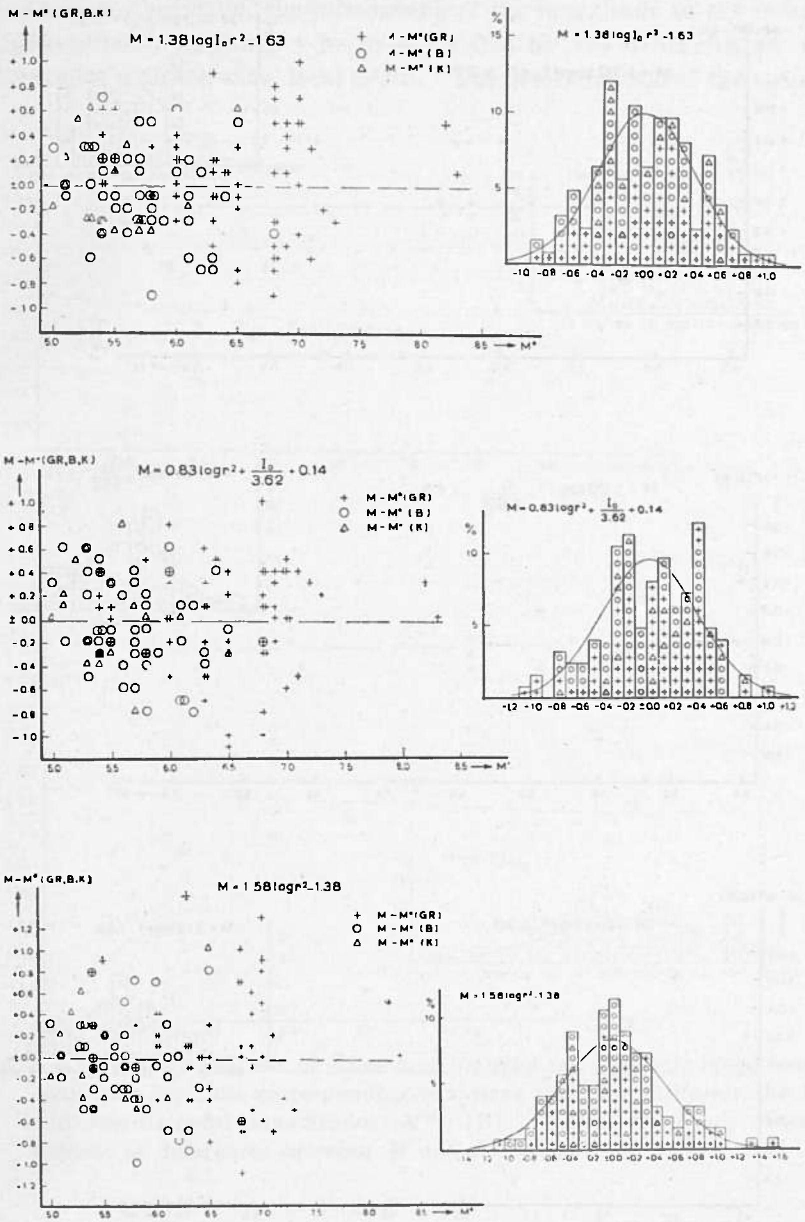

Fig. 1 – Variations with M^* of differences between macroseismic maguitudes computed from the correspondig equations valid for shocks in Greece and instrumental magnitudes M^* (GR, B, K). Insert, frequency distributions of differences between M and M^* (GR, B, K).

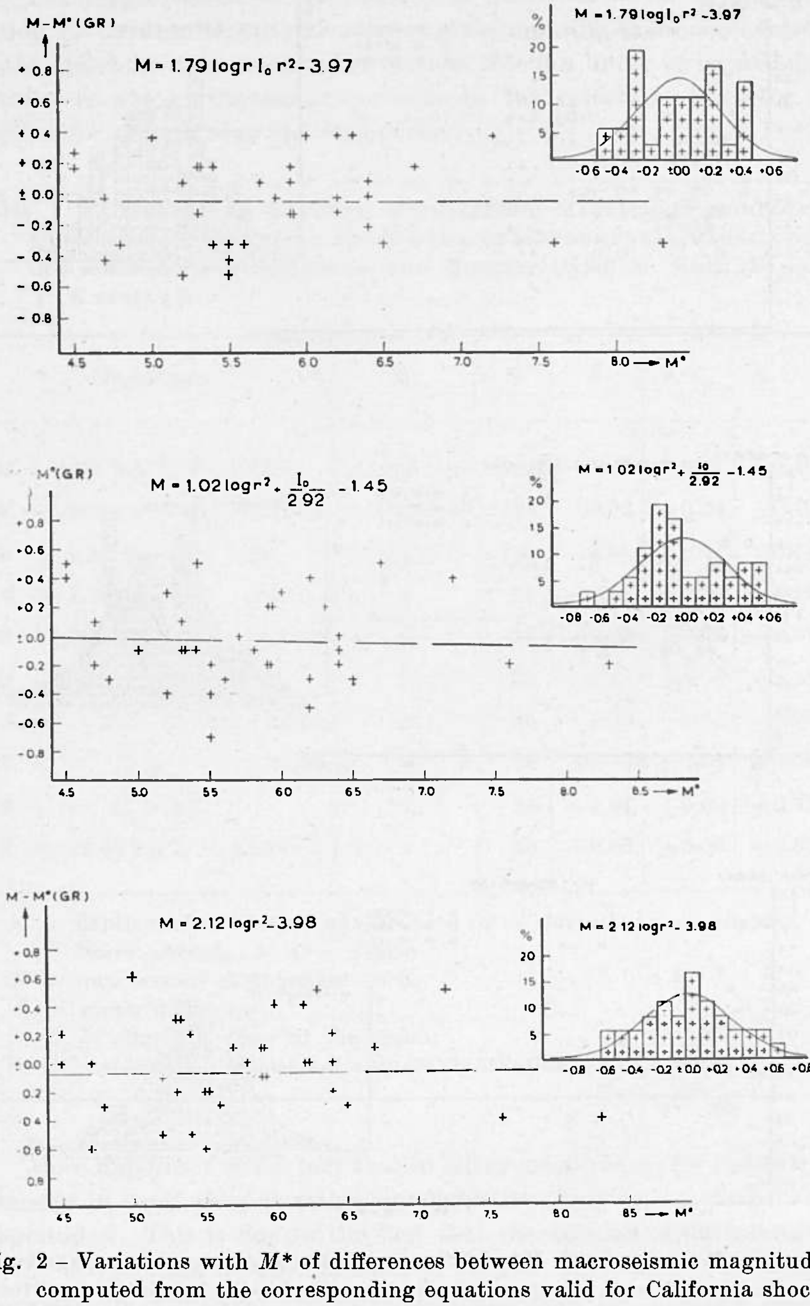

Fig. 2 – Variations with M^* of differences between macroseismic magnitudes computed from the corresponding equations valid for California shocks and instrumental magnitudes M^* (GR). Insert, frequency distributions of differences between M and M^* (GR).

On the other hand, the relationship of the magnitude to the radius of perceptibility appears to be most reliable for the determination of magnitudes with the same focal depth. The determination of the radius

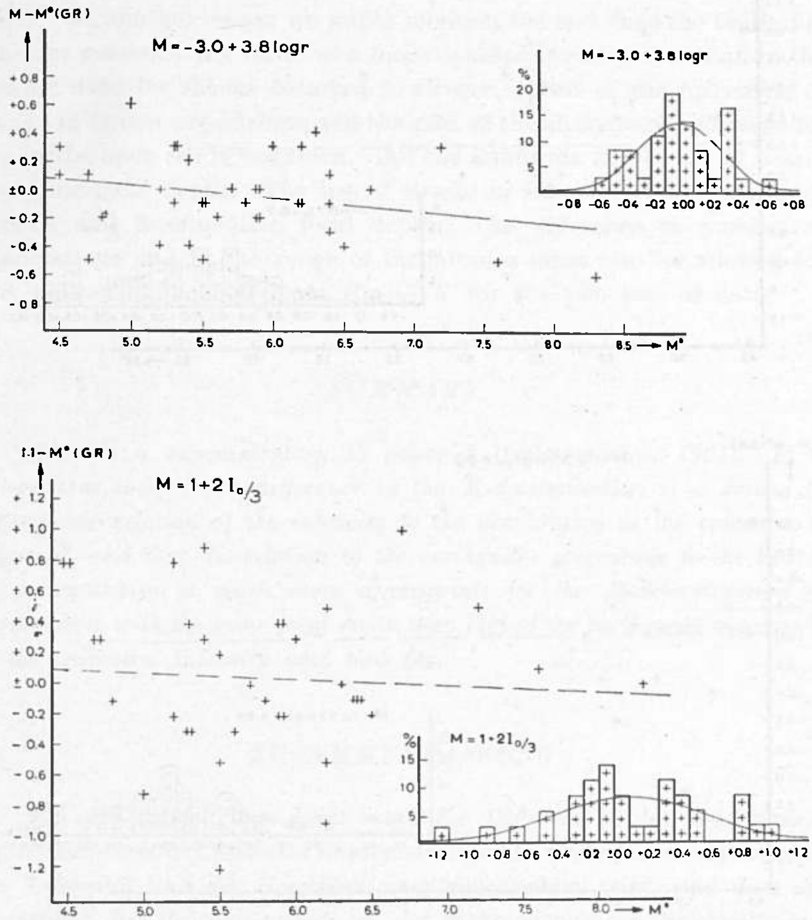

Fig. 3 – Variations with M^* of differences between macroseismic magnitudes computed from the corresponding equations valid for California shocks and instrumental magnitudes M^* (GR). Insert, frequency distributions of differences between M and M^* (GR).

of perceptibility is not influenced appreciably by personal factors, and the errors involved are negligeable.

Variations in differences between macroseismic and instrumental magnitudes and percentage frequency distributions of the various magnitude differences versus instrumental magnitude, M^*, presented in Figures 1 to 4, show clearly the relative superiority of the

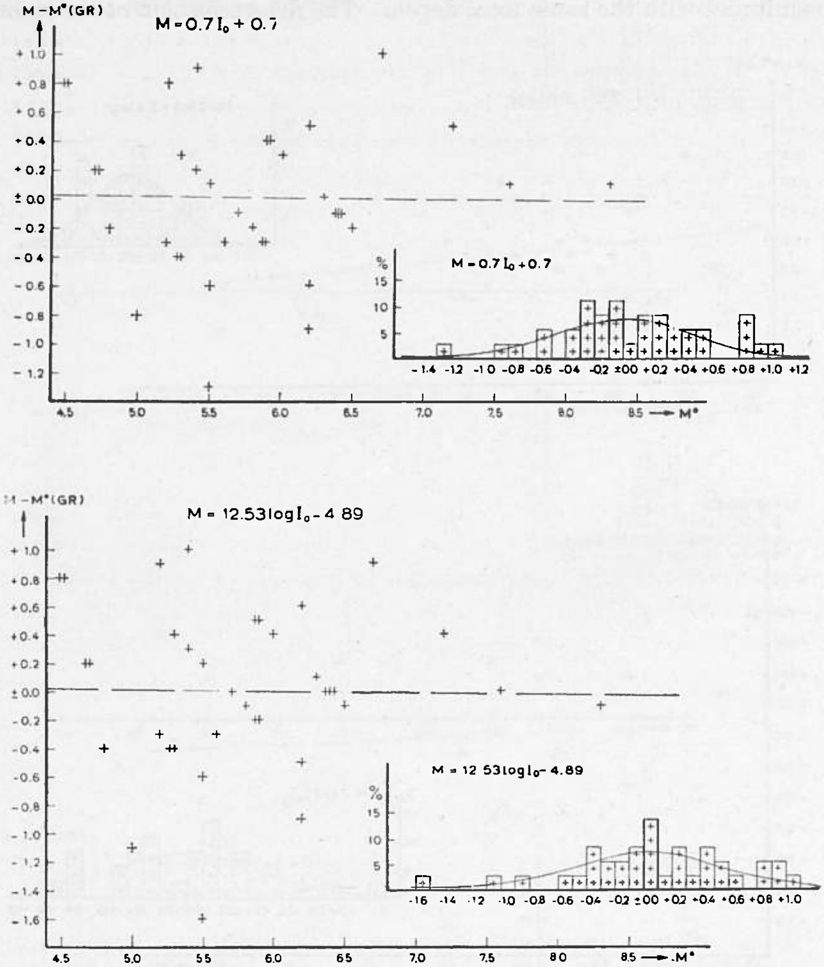

Fig. 4 – Variations with M^* of differences between macroseismic magnitudes computed from the corresponding equations valid for California shocks and instrumental magnitudes M^* (GR). Insert, frequency distributions of differences between M and M^* (GR).

formula [1] for M-determination of earthquakes originating at any focal depth.

The differences in coefficients C and K for the two sets of data are due primarily to the difference in r used. It was stated in the first paper that r denotes the maximum radius of perceptibility for the shocks in Greece and the mean radius for the California shocks. Owing to the existing differences in the building-civilization in the two countries, the same picture of damages does not correspond to the same earthquake-force. As another reason we might mention the fact that the California data are generally the result of a more detailed investigation than in the case of data for shocks occurred in Greece. Most of the epicenters of shocks in Greece are offshore and the part of the shaken area corresponding to the open sea is unknown. All the California shocks are of nearly the same focal depth. The list of shocks in Greece includes shocks of normal and intermediate focal depth. The difference in number of observations and in the range of magnitudes must also be allowed for the differences in coefficients C and K for the two sets of data.

SUMMARY

This is a supplementary to paper 1 (Galanopoulos, 1961). It is shown that there is no difference in the M-determination if a linear or logarithmic relation of the intensity to the acceleration at the epicenter is assumed, and that the relation of the earthquake magnitude to the radius of perceptibility is much more appropriate for the M-determination of earthquakes with the same focal depth than that of the earthquake magnitude to the epicentral intensity used thus far.

ZUSAMMENFASSUNG

Es wird gezeigt, dass keine merkliche Differenz in der Magnitudenbestimmung existiert, falls eine lineare oder logarithmische Beziehung zwischen der Intensität und der Beschleunigung angenommen wird, und dass die Beziehung der Bebenmagnitude zu der makroseismischen Reichweite viel mehr geeignet ist für die Magnitudenbestimmung von Erdbeben derselben Herdtiefe als diejenige zwischen der Bebenmagnitude und der grössten Stärke im Schüttergebiet, die bisher dafür benutzt wird.

RIASSUNTO

Questa nota fa seguito alla prima pubblicata nella Rivista « Annali di Geofisica » Vol. XIV, Fasc. 3 (Anno 1961).

L'Autore dimostra che nella determinazione della Magnitudo dei terremoti, non esiste alcuna differenza se, anzichè usare una relazione lineare fra intensità e accelerazione all'epicentro, ci si serve di una relazione logaritmica. E inoltre molto più appropriato, sempre per la determinazione della Magnitudo di terremoti con la stessa profondità ipocentrale, servirsi della relazione fra la Magnitudo del terremoto ed il raggio di percettibilità macrosismica dello stesso, che usare la relazione fra Magnitudo del terremoto e la sua massima intensità epicentrale, finora applicata.

REFERENCES

GALANOPOULOS, A., *On Magnitude Determination by Using Macroseismic data*, in " Ann. di Geof. ", **14**, 3, (1961).

GUTENBERG B. – RICHTER C., *Earthquake Magnitude, Intensity Energy and Aceeleration*, in " Bull. Seism. Soc. Am. ". **32**, 3, 163-191, (1942).

— — *Earthquake Magnitude, Intensity, Energy, and Acceleration*, in " Bull. Seism. Soc. Am. ", **46**, 2, 105-145, (1956).