SOME METHODOLOGICAL CONSIDERATIONS ON THE DETERMINATION OF MACROSEISMIC PARAMETERS AND THEIR RELATIONS IN THE STUDY OF EARTHQUAKES OF ALBANIA

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A B S T R A C T

The analysis of 156 isoseismal maps of earthquakes occurred in Albania and nearby, for the period 1800-1988 reveal a dependence relation between seismic intensities and epicentral distance of type proposed by Blake (1941). Based on this model a methodology proposed by Bottari A. et al., (1979) was applied for the determination of hypocentral depth h and attenuation coefficient, γ.

The application of this methodology in the case of shallow earthquakes as those of Albania and nearby regions gives very good results; the calculated seismic intensity corresponds very well to the observed one.

Based on statistical analysis, for the territory of Albania and nearby, we have found relations between M_{LH}, I_o, I_i and h.

ΜΕΘΟΔΟΛΟΓΙΚΕΣ ΘΕΩΡΗΣΕΙΣ ΠΑΝΩ ΣΤΟΝ ΠΡΟΣΔΙΟΡΙΣΜΟ ΤΩΝ ΜΑΚΡΟΣΕΙΣΜΙΚΩΝ ΠΑΡΑΜΕΤΡΩΝ ΚΑΙ ΤΩΝ ΣΥΣΧΕΤΙΣΜΩΝ ΤΟΥΣ ΣΤΗΝ ΜΕΛΕΤΗ ΤΩΝ ΣΕΙΣΜΩΝ ΤΗΣ ΑΛΒΑΝΙΑΣ

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Π Ε Ρ Ι Λ Η Ψ Η

Η ανάλυση 156 χαρτών ισοσείστων καμπυλών από σεισμούς της Αλβανίας και των γύρω περιοχών της περιόδου 1800-1988 αποκάλυψε μιά σχέση εξάρτησης τύπου Blake (1941) ανάμεσα στις εντάσεις και τις επικεντρικές αποστάσεις. Η τεχνική που προτάχθηκε από τον Bottari et al., (1979) βασίζεται στο παραπάνω μοντέλο και χρησιμοποιήθηκε για τον προσδιορισμό του εστιακού βάθους h και του συντελεστή απόσβεσης, γ.

Η εφαρμογή αυτής της μεθόδου στους επιφανειακούς σεισμούς της Αλβανίας και των γύρω περιοχών δίνει πολύ καλά αποτελέσματα: η υπολογισθείσα σεισμική ένταση αντιστοιχεί πολύ καλά με την παρατηρούμενη.

Με βάση την στατιστική ανάλυση, για την Αλβανία και τις γύρω περιοχές, βρήκαμε σχέσεις μεταξύ M_{LH}, I_o, I_i και h.

INTRODUCTION

The analysis of 156 isoseismal maps of earthquakes occurred in Albania and nearby, for the period 1800-1988 reveal a dependence relation between seismic intensities and epicentral

distance of type proposed by Blake (1941). Based on this model a methodology proposed by Bottari et al.(1979) was applied for the determination of hypocentral depth h and attenuation coefficient γ. The calculation of those two parameters are made following two steps: In the first step both the focal depth h and γ coefficient are roughly estimated from a comparison with some master curves. In the second step the final values of h and γ are obtained by using an analytical method.

In this procedure the accurate evaluation of the γ coefficients plays an important role on the accuracy of the determination of hypocentral depth h, epicentral intensity I_o and coefficient of seismic energy absorption.

By analysing macroseismic data for Albania and nearby regions it was found γ=3.06 for earthquakes with h<10km and γ=4.55 for earthquakes with h>10 km. γ=4.0 was accepted as a mean value. The mean value of absorption coefficient was found γ=0.0095.

Based on those parameters, for earthquakes of Albania and nearby regions, it was found the relation between epicentral seismic intensity I_o, seismic intensity I_i, magnitude M_{LH}, focal depth h, and the epicentral distance Δ_i or hypocentral distance D_i.

The determination of the parameters of macroseismic field and their relations with the instrumental ones is of a great interest for the seismic hazard assessment and seismic risk analysis.

THE MACROSEISMIC FIELD MODEL

For modelling the dependence of seismic energy attenuation on hypocentral distance many authors have proposed relations between epicentral intensity I_o, hypocentral distance D_i and hypocentral depth h (Shebalin et al.a. 1974, Chrometskaya and Shebalin 1978, Evenden et al. 1974, Fu Cen and Liu 1960, Gutenberg and Richter 1956, Howell and Schultz 1975, Karnik 1956, Karnik 1969a,b, Neuman 1954, Sulstarova and Kociaj 1975, Sulstarova 1986)

The classical relation which represents the attenuation of energy from hypocentral distance is:

$$E=\frac{E_o}{4\pi}D_i^{-n}\exp(-cD_i) \qquad (1)$$

E_o - total seismic energy release at the focus of earthquake
D_i - hypocentral distance
n - constant of the rhythm of energy attenuation from the hypocentral distance
c - constant of the rhythm of energy absorbtion

If it is supposed that the seismic intensity I_i is proportional to the seismic Energy E, then:

$$I_i=a+b\log E \qquad (2)$$

Replacing the equation (2) to equation (1) we will obtain:

$$I_i=a+b\log\frac{E}{4\pi}-bn\log D_i-bcD_i\log e \qquad (3)$$

In the case when the observation point is the epicentre of earthquake (D_i=h) we obtain:

$$I_o=a+b\log\left(\frac{E}{4\pi}\right)-bn\ \log h-bch\ \log e \qquad (4)$$

Subtracting the equation (3) from the equation (4) we will obtain:

$$I_o-I_i=bn\ \log D_i-bn\ \log h+bcD_i\ \log e-bch\log e \qquad (5)$$

replacing:

$$\gamma = bn$$

$$D_i=\sqrt{\Delta_i^2-h^2}$$

$$p = bc\ \log e$$

in the equation (5) we obtain:

$$I_o-I_i=\gamma\log\sqrt{\left(1+\frac{\Delta_i^2}{h^2}\right)}+p\left(\sqrt{(\Delta_i^2+h^2)}-h\right) \qquad (6)$$

Equation (6) represents the model of macroseismic field of Kovesligeth type. The seismic energy attenuation with distance can be expressed by a simpler equation:

$$E=E_oD^{-n} \qquad (7)$$

Substituting the equation (7) to the equation (2) and following the above simplification we obtain the following equation:

$$I_o-I_i=\gamma\log\sqrt{\left(1+\frac{\Delta_i^2}{h^2}\right)} \qquad (8)$$

This equation represent the model of macroseismic field proposed by Blake(1941).

The equation (6) is of Kovesligethy form and represents more accurately the macroseismic field, especially in the case of large earthquakes. Blake's equation (8) is simple but, in case of distant strong earthquakes it can't model accurately the macroseismic field. For studying the macroseismic field of earthquakes in Albania and nearby regions, since the maximum expected magnitude of earthquakes is M_{max}= 7.2+/-0.3 and the epicentral distance is relatively small, we have applied the model proposed by Blake.

By analysing the isoseismal maps of 156 earthquakes occured in Albania and nearby (Shebalin et al. b. 1974, Hadzievski 1971, Sulstarova and Kociaj 1975, Sulstarova 1986), it is clearly seen that for equal intensity intervals the corresponding interval for the epicentral distances increases as I decrease. Consequently the ratio between the first interval to the second one results linearly proportional to the intensity I, and is always negative, given that I decreases as increases. Based on this conclusion and differentiating equation (8) we obtain:

$$\frac{dI_i}{d\Delta_i} = -\frac{\gamma}{2.303} \qquad \frac{\Delta_i}{D_i^2} = -\alpha I_i \tag{9}$$

Using equation (9) we can calculate the coefficient of absorption:

$$\alpha = \frac{\gamma}{2.303} \frac{\Delta_i}{D_i^2 I_i} \tag{10}$$

Equation (10) is used for the determination of the coefficient of energy absorption in respect to the epicentre and hypocentral distance.

The parameters of the equation (8) and (10) are determined using macroseismic observations. They depend on the effects of seismic wave propagation and the absorbing properties of the medium.

Knowing the coefficient of the seismic intensity attenuation γ and based on isoseismal map data, from the equation (8), we can determine the focal depth:

$$h = \frac{1}{N} \sum_{i=1}^{N} \frac{\Delta_i}{\sqrt{10^{\frac{[2I_o - I_i]}{\gamma}} - 1}} \tag{11}$$

By using equations (10) and (11), we can calculate respectively absorbtion coefficient γ and focal depth h. The intensity attenuation coefficient is an important parameter of the macroseismic field.

THE DETERMINATION OF THE INTENSITY ATTENUATION COEFFICIENT

Based on the theoretical model of the macroseismic field represented by equation (8) we constructed graphically the master curves for γ in the 2 to 8.0 interval and focal depths h in the 0 to 45 km interval, for every 5 km. In fig.1 is shown one of those master curves. The abscissa represent log and the ordinates represent $I_o - I_i$. The mean epicentral distances for each isoseist are calculated using the area within the isoseist.

Based on the mean radius of each isoseist and the intensity difference $I_o - I_i$, for each earthquake, we constructed a curve representing the seismic intensity decay with the epicentral distance. Those curves are compared with the master curves,

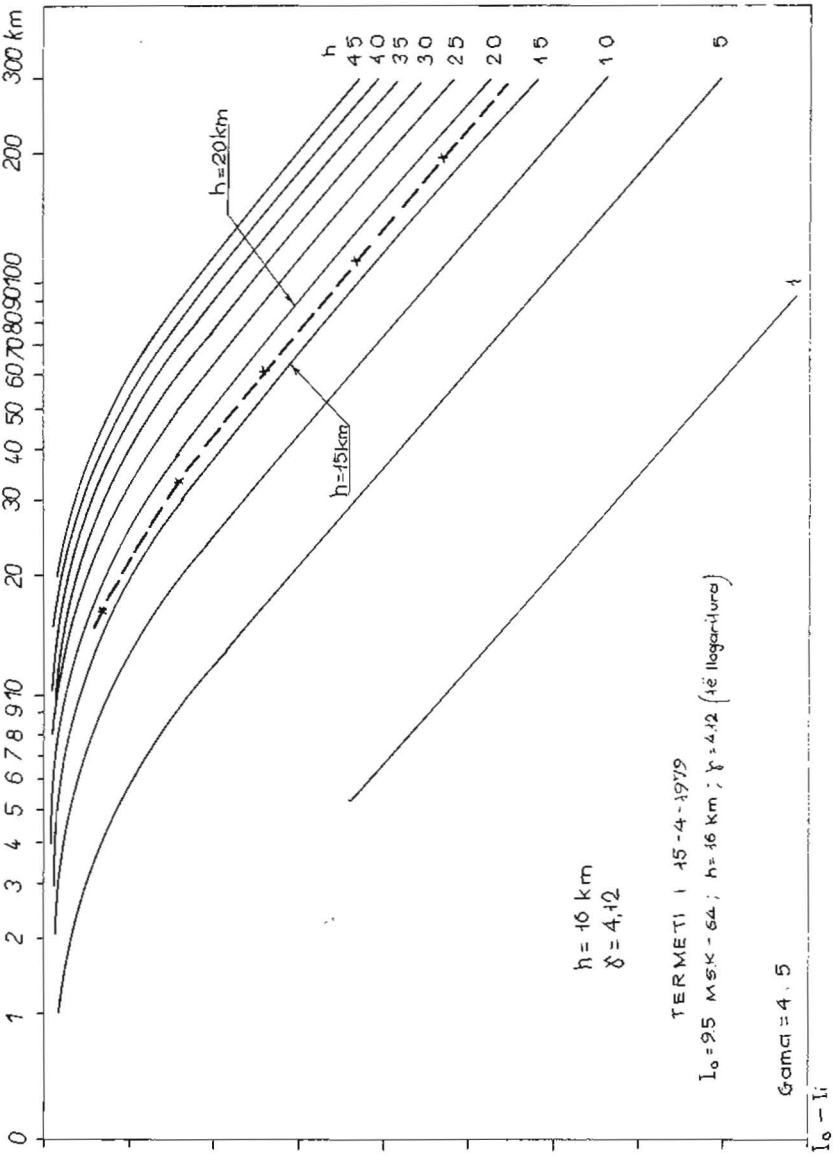

Fig.1. Master curves.

obtained by using equation (8). For each earthquake, the values of and h corresponding to that curve which fits better with the observed macroseismic data, are accepted as preliminary values and used for further calculations (see fig1).

The accurate values of γ, focal depth h and corrected epicentral seismic intensity I_{oc} are found using Least Square Method using equation (8). For each isoseist it is found the corresponding γ and I_o. Finally $\bar{\gamma}$ is calculated as mean value of found for each isoseist:

$$\bar{\gamma} = \frac{1}{N}\sum_{i=1}^{N} \frac{I_o - I_i}{\log\frac{D_i}{h}} \qquad (12)$$

The corrected epicentral intensity is calculated using the formula:

$$I_{oc} = \frac{\sum_{i=1}^{N} (I_i + \bar{\gamma}\frac{\log D_i}{h})}{N} \qquad (13)$$

The focal depth is finally evaluated using the equation (11) the corrected epicentral intensity I_{oc} and $\bar{\gamma}$. Then, we can calculate the theoretical radius of isoseists and the coefficient of absorption.

We applied the above method for the calculation of macroseismic parameters of earthquakes occurred in Albania for which isoseismal maps exist. In the tables 1 and 2 given two examples:

Examples:

Table 1. Earthquake of November 30, 1967, with magnitude M_{LH}=6.6
Intensity I_o=9 (MSK-1964 scale).

Intens.	Mean Radius of Isoseist		Parameters
	Observed	Theoretical	
IX	5.3	4.81	
VIII	17.4	17.94	
VII	39.0	36.25	$\bar{\gamma}$ = 3.8384±0.2402 (6.25%)
VI	73.7	67.87	I_{oc} = 9.1651±0.2413 (2.72%)
V	130.0	124.65	h = 10.282 ±1.4676 (14.27%)
IV	165.0	227.65	$\gamma = 51\cdot10^{-4}$

Table 2. Earthquake of April 15, 1979 with magnitude M_{LH}=7.2, intensity I_o=9.5 (MSK-1964 scale)

Intens.	Mean Radius of Isoseist		Parameters
	Observed	Theoretical	
IX	13.6	13.58	
VIII	36.6	33.09	
VII	62.8	62.26	$\bar{\gamma}$ = 4.1241±0.1808 (4.36%)
VI	105.1	111.23	I_{oc}= 9.4827±0.9150 (0.96%)
V	184.8	195.77	h = 16.0795±0.9509 (5.91%)
IV	341.6	342.94	$\gamma = 35 \cdot 10^{-4}$

In almost all 156 earthquakes analysed by applying the Blake model we have obtained a very good fitting between the empirical relation and observed data. We can conclude that Blake's model is a good tool for studying the macroseismic field of earthquakes of Albania territory and nearby, where the earthquakes are shallow and maximum magnitude is M_{max}=7.5.

In this study we have also analysed the relation between focal depth h, γ and epicentral seismic intensity I_o. The results obtained show a clear dependence of γ on focal depth and in contrary, no depend ence on I_o . Because of the effect of wave propagation, in γ in creases when focal depth increases.

For Albania and the regions nearby it is found γ=3.06 for earthquakes with h < 10 km and γ=4.55 for earthquakes with h>10 km. γ=4.0 is accepted as a mean value and the corresponded value of the absorbtion coefficient is found α=0.0095.

RELATIONS BETWEEN MAGNITUDE (M_{LH}), SEISMIC INTENSITY (I) AND FOCAL DEPTH (h)

For the evaluation of seismic intensity, in this study we have applied the MSK-1964 scale (Medvedev et al. 1964). This scale is based on the evaluation of damage of structures which are builded without any aseismic design criteria. For buildings where such criteria are applied we have used a revised appropriate scale. In dense populated areas, where macroseismic data were sufficient, and for earthquakes with intensity greater than 5 degrees (MSK-1964), the evaluation of seismic intesity was carried out based on a statistical approach (Sulstarova,E., 1986). For each type of building the mean degree of damage and corresponding intensity (I_i) is evaluated.

Based on statistical analysis, for the territory of Albania and nearby, we found the following relations between M_{LH}, I_o, I_i

and h:

$$M=0.53(\pm 0.01)I_o+1.46(\pm 0.12) \qquad (14)$$

$$I_o=1.75M_{LH}-3.06\log h-0.61; \quad h<10Km; \quad 4.0\leq M\leq 7.5 \qquad (15)$$

$$I_o=1.75M_{LH}-4.55\log h+3.45; \quad h>10Km; \quad 4.0\leq M\leq 7.5 \qquad (16)$$

The mean relation:

$$I_o=2.1M_{LH}-4.0\log h+0.44: \quad 4.0\leq M\leq 7.5 \qquad (17)$$

In the cases of historical earthquakes where macroseismic data exist, the following formula is adopted for the calculation of macroseismic magnitude:

$$M_{max}=\frac{1}{b}(I_i+\gamma\log D_i+c); \quad for\ i>2 \qquad (18)$$

where:

D_i- hypocentral distance; I_i- seismic intensity based on MSK-1964 scale; γ- coefficient of seismic intensity attenuation; b, c- coefficients .

When $\Delta i>>h$ and the seismic intensity of the corresponding isoseist is 2 degree and more smaller than epicentral intensity, $D_i\approx\Delta_i$ is a good approximation.

It is observed that in the cases when accurate values of b,c,γ coefficients are obtained the instrumental magnitude M_{LH} is equal to the macroseismic one, calculated following the formula (18). For example in the case of April 15,1979 earthquake, with I_o=9.5 (MSK-964 degree), the macroseismic magnitudes correspondig to the isoseistes 7,6,5 degree with respective average radius 63,105,185 km are found respectively 7.29,7.20,7.23. The mean value of magnitude M_{max}=7.24 is very close to the instrumental magnitude M_{LH}=7.2

CONCLUSIONS

The macroseismic field model proposed by Blake can be applied with very good results in the case of shallow earthquakes as those of Albania and nearby regions. The calculated seismic intensity following this model corresponds very well to the observed one.

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