Proceedings of the 3rd Internátional Symposium on the Analysis of Seismicity and Seismic Risk
Liblice Castle, Czechoslovaquia, June 17-22, 1985

ISOSEISMAL MODEL FOR GREATER ANTILLES

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ABSTRACT

The macroseismic field of earthquakes in Greater Antilles is characterized by a wide variability, not only in shape but also in attenuation of macroseismic intensity. In this paper a theoretical model of elliptical isoseismals is presented. The model has been determined using parametric equations of an ellipse and intensitys attenuation law of Köveslígethian type. Comparing isoseismal maps of earthquakes in Greater Antilles with theoretical ones, model parameters were determined for different zones of these islands.

INTRODUCTION

It was pointed out by Alvarez and Bune (1977) that macroseismic field of greater earthquakes in Caribbean loop may be described in a first aproximation by the equation of Köveslígethian type:

$$I = 1.5\,M - 2.63\,\lg r - 0.0087\,r + 2.5 \qquad (1)$$

obtained by Fedotov and Shumilina (1973) for Kamchatka's region (r - hypocentral distance).

The deviations of observed macroseismic fields from circular isoseismals described by (1) were analized by Alvarez et al. (1983). These authors constructed a group of generalized isoseismals for different regions of Greater Antilles and showed the actual wide variability in shape and attenuation. The shape shown by isoseismals varies from circles to elonged ellipses, and actual attenuation may be higher or lesser than that obtained by formula (1) showing also an azimutal dependence. From region to region the changes are noticeable.

THEORETICAL MODEL OF ELLIPTICAL ISOSEISMALS

In order to describe the macroseismic field of earthquakes in Greater Antilles, a theoretical model of elliptical isoseismals was developed.

The shape of isoseismals is determined by the relation between ellipse semiaxes. Analytically it is expresed by means of parametric equations of an ellipse:

$$\Delta = A\ (\cos\theta / \cos\alpha) = B\ (\sin\theta / \sin\alpha) \qquad (2)$$

$$\theta = \mathrm{arc\ tg}\ (A/B\ \mathrm{tg}\,\alpha)$$

where: Δ - distance from ellipse centre to a point in its contour, A - major semiaxis, B - minor semiaxis, α - angle between major semiaxis and radius. In Fig. 1 all these parameters are shown graphically.

The intensity attenuation is determined by a macroseismic field equation of Köveslígethian type:

$$I = b\,M - k\,\lg r_e - p\,r_e + d \qquad (3)$$

which includes the r_e - effective radius

$$r_e = \sqrt{\Delta_e^2 + h^2}$$

being h - depth and Δ_e - epicentral distance.

The introduction of r_e is necessary because an ellipse has not constant radius and r_e corresponds to hypocentral distance measured along a direction between semiaxes which represents also a model parameter.

$$\bar{\Delta} = \frac{2}{\pi} \int_0^{\pi/2} \Delta \; d\alpha = \frac{2B}{\pi} K\,(m) \qquad (4)$$

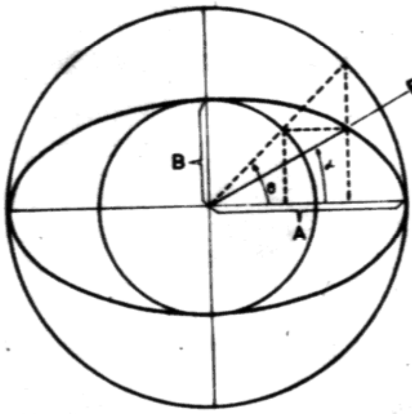


Fig.1 - Graphic representation of model parameters.

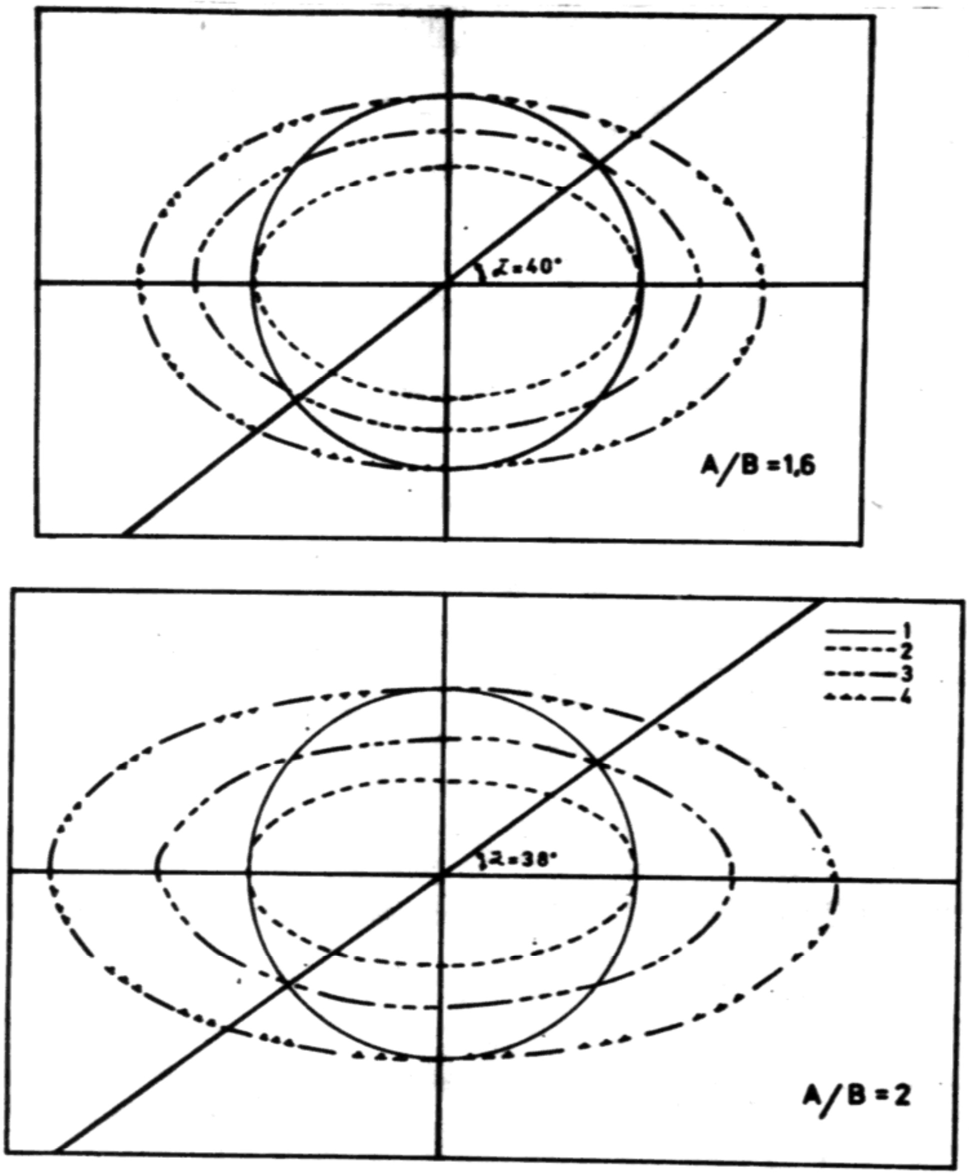


Fig.2 - Isoseismal of intensity V for different directions of measurement of Δ_e. 1- circular isoseismal, 2 - Δ_e = A, 3 - $\Delta_e = \bar{\Delta}$, 4 - Δ_e = B.

$$m = 1 - B^2 / A^2 \geqslant 0$$

k (m) - elliptical integral of first kind which values may be found in special tables. This radius is located in a direction that forms an angle $\bar{\alpha}$ with respect to major semiaxis:

$$\bar{\alpha} = \text{arc sin} \frac{1 - A^2 / B^2 (\pi/2\ K(m))^2}{1 - A^2 / B^2}$$

Fig.2 shows the isoseismals of intensity V obtained using coeficients of formula (1) for $\Delta_e = (A, \Delta, B)$ and different values of A / B, for an earthquake of $M_s = 6$ and h = 5 Km. From this fig. it is easily seen that developed model allows us to obtain very different theoretical isoseismals without any change in parameters of macroseismic field formula. This property is very important because it allows to use a general expression for differents attenua - tions in isoseismal maps.

PARAMETERS OF ISOSEISMAL MODEL FOR DIFFERENT ZONES OF GREATER ANTILLES

Initial data.

Isoseismal maps and macroseismic data were taken from (Alvarez et al.,1984, Chuy, 1984, Chuy and Alvarez, 1984, Chuy et al., 1980, Chuy et al., 1983, Chuy et al., 1984 a, Chuy et al., 1984 b, Pereira, 1978, Tomblin and Robson, 1977) and in some cases were constructed from macrosismic data doing the necessary corrections to include newly obtained information.

Were analysed 32 cases, distributed in the following way: Western Cuba (2), Central Cuba (5), Southeastern Cuba (6), Northeastern Cuba (1), Northern Hispaniola (4), Southern Hispaniola (6), Jamaica (7), Cayman Is. region (1). For Puerto Rico Is. there was not possible to obtain the corresponding data.

Method of analysis.

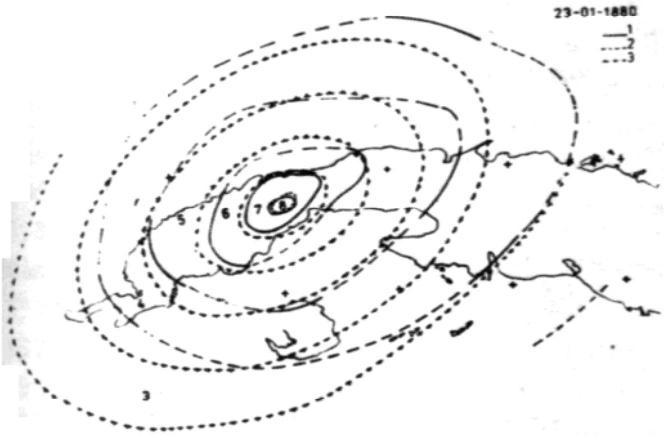
For Greater Antilles we used the coefficients of Köveslìgethian law given in formula (1). The parameters possible to be variated in the model are depth, magnitude, relation between semiaxes, A/B, and direction of measurement of Δe (A, B or $\bar{\Delta}$). For each isoseismal map an aproximate average ratio of semiaxes, A/B, is determined. With this value a set of theoretical isoseismal maps is constructed in the desired scale varying the others parameters with the aid of computing programs. A "try and error" method was used to determine parameters. Further proofs with other values of ratio A/B may be realized for fine adjustment.

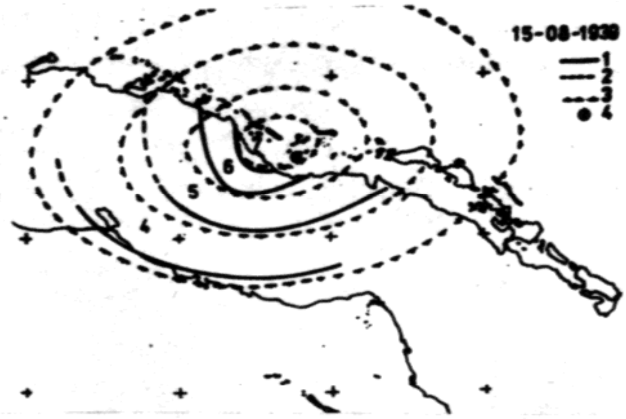
Obtained results.

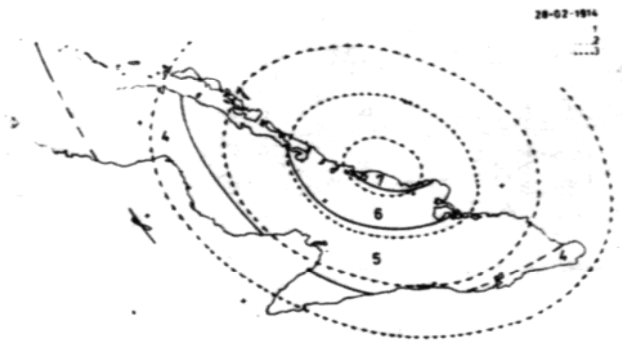
In table 1 are presented earthquake data and adjusted model parameters for every analysed case. Fig.3 shows some examples of model adjustment experimental isoseismal maps.

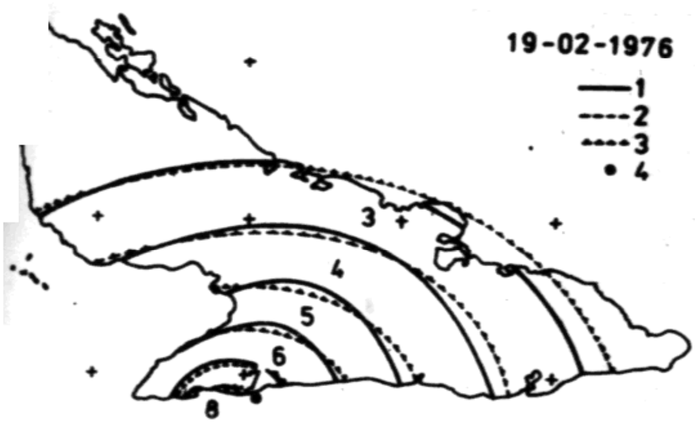
DISCUSSION

As it is seen in table 1, the models were adjusted not only for earthquakes with known magnitudes, but also for great historical earthquakes and for weak ones, without instrumental determination of M. In the cases of known instrumen-


23-01-1880
1
2
3


15-08-1939
1
2
3
4


28-02-1914
1
2
3


19-02-1976
1
2
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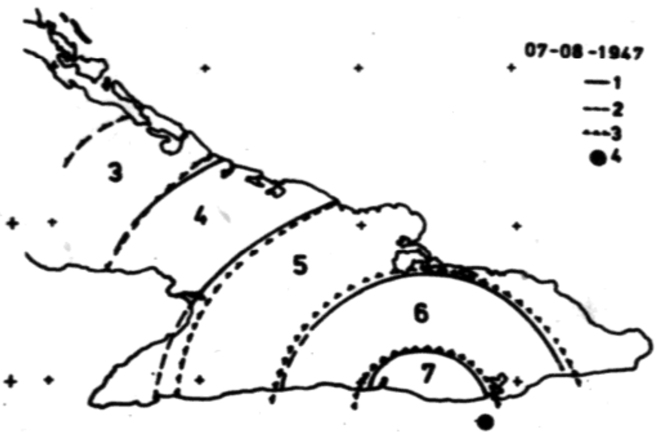
07-08-1947
1
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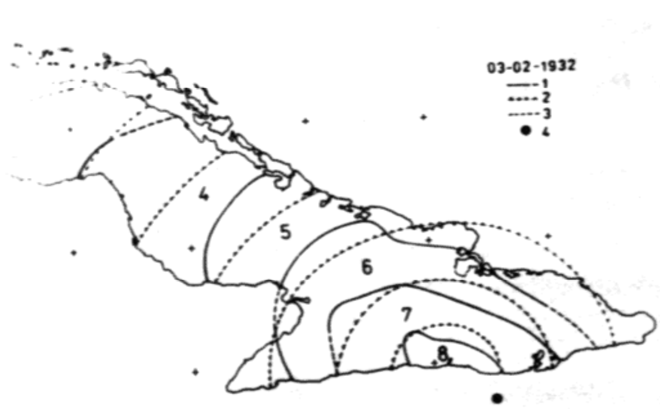
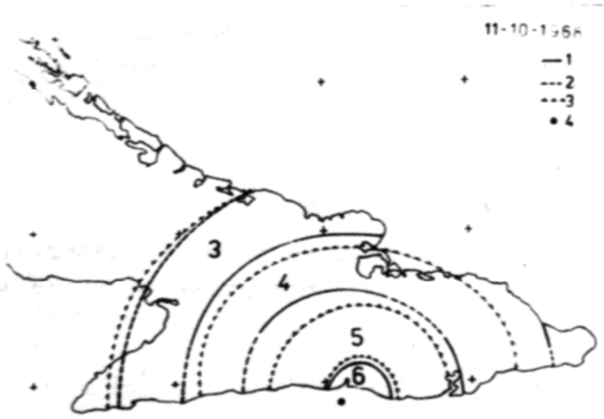

03-02-1932
1
2
3
4


1
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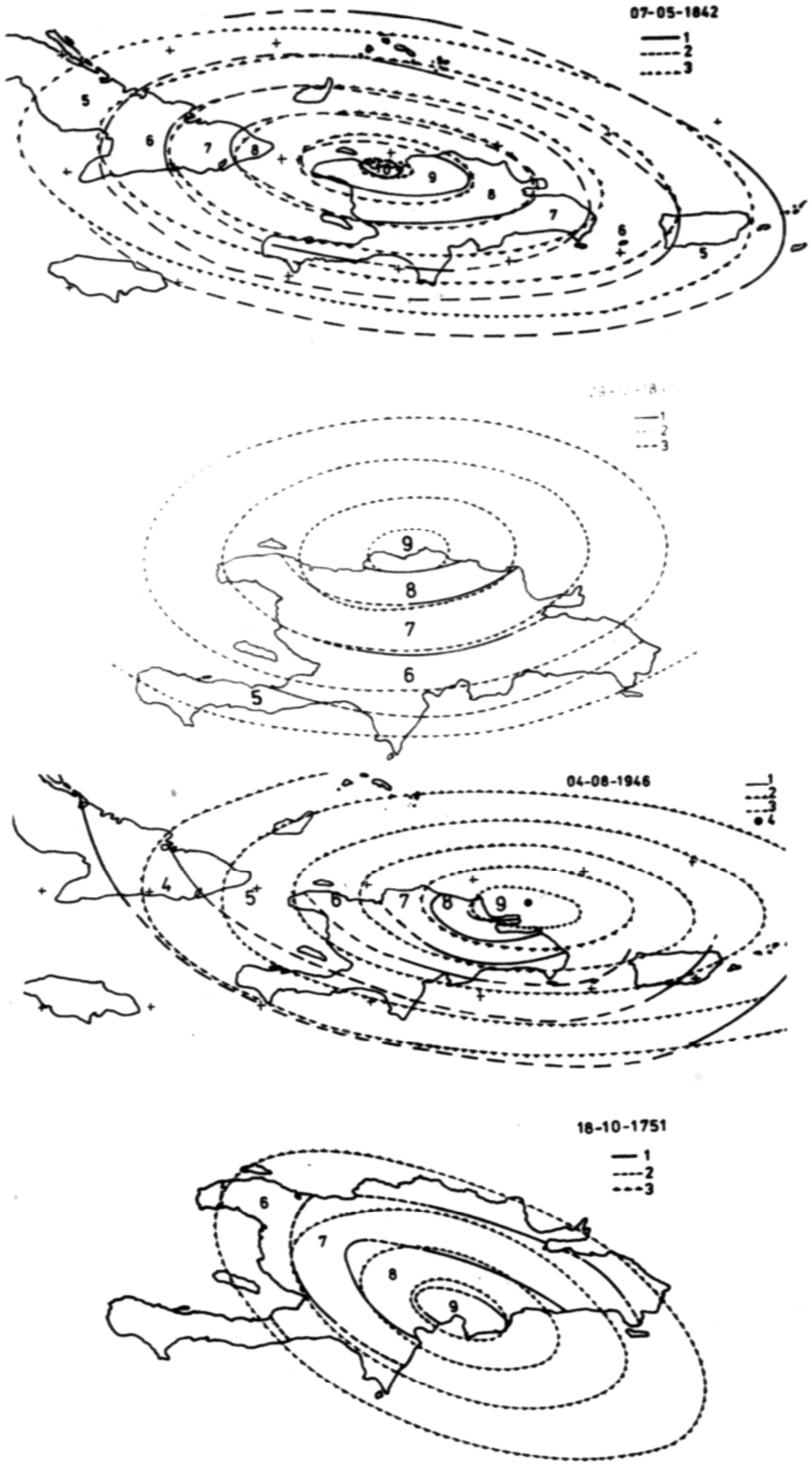

Fig. Some examples of model adjustment. 1- Real isoseismal. 2- Supposed. 3- Theoretical model. 4- Instrumental epicenter.

Table 1. Earthquake Parameters and Adjusted Models for all analized cases

EARTHQUAKE PARAMETERS						MODEL PARAMETERS			
DATE	TIME	N	W	h	MAGNITUDE	A/B	h	Ms	e
Western Cuba									
1880.01.23	04:10	(22.8	83.0)+			1.6	20	5.9	A
1982.12.16	20:6	22.6	81.25		4.5b	1.8	20	4.7	A
Central Cuba									
1939.08.15	03:52	22.5	79.25		5.3-5.9s	1.6	15	5.5	A
1970.11.11	14:24	(21.85	79.2)			1.5	5	2.4	A
1971.07.26	15:26	(21.85	79.2)			1.7	5	2.5	A
1972.06.27	00:12	(21.8	78.05)			2.9	5	3.0	A
1974.04.08	03:18	(21.8	78.05)			1.8	5	3.7	A
Northeastern Cuba									
1914.02.28	04:50	(21.3	76.2)			1.4	50	6.2	$\bar{\Delta}$
Southeastern Cuba									
1932.02.03	06:16	19.7	75.5		6.75s	1.2	30	6.75	A
1947.08.07	00:40	19.75	75.2	50	6.75s	1.1	50	6.3	A
1968.10.11	02:38	19.85	75.95	33	4.2b	1.2	30	5.0	A
1976.02.19	13:59	19.87	76.87	15	5.7s	1.6	15	5.7	A
1983.12.01	00:09	19.9	75.9		3.6s	1.1	15	3.8	A
1984.05.03	17:47	19.85	75.30			1.0	10	3.0	A
Cayman Is. Region									
1852.07.07	12:25	(19.3	79.5)			1.2	30	7.8	A
Northern Hispaniola									
1852.05.07	22:25	(20.0	72.2)			2.7	60	8.2	$\bar{\Delta}$
1887.09.23	11:55	(19.5	74.2)			2.7	60	7.9	$\bar{\Delta}$
1897.12.29	11:32	(20.1	71.2)			1.9	50	7.5	$\bar{\Delta}$
1946.08.04	17:51	19.25	69.0		8.1s	2.7	50	7.75	$\bar{\Delta}$
Southern Hispaniola									
1751.10.18	20:00	(18.4	70.6)			2.1	30	7.25	$\bar{\Delta}$
1751.11.21	13:00	(18.6	72.3)			2.1	30	6.5	$\bar{\Delta}$
1770.06.04	00:15	(18.5	72.3)			1.6	70	7.9	$\bar{\Delta}$
1860.04.09	03:30	(18.6	73.2)			2.1	50	6.7	$\bar{\Delta}$
1910.05.11	-	(18.5	70.8)			2.1	30	6.5	$\bar{\Delta}$
1911.10.06	10:16	19.0	70.5		7.0s	2.5	50	7.2	$\bar{\Delta}$
Jamaica									
1907.03.22	23:12	(17.8	76.8)			1.6	30	5.0	A
1908.01.02	13:09	(18.1	77.7)			1.6	20	5.5	A
1914.08.03	11:25	(18.0	76.3)			1.8	20	5.5	A
1914.10.14	07:15	(17.9	76.7)			1.6	30	4.8	A
1915.09.11	11:37	(18.0	76.7)			1.6	30	4.8	A
1916.01.30	08:34	(18.1	76.5)			1.9	10	4.5	A
1978.02.26	05:07	18.17	76.45	15	4.5b,3.9s	2.2	5	4.0	A

+- Coordinates in parenthesis correspond to determination by macroseismic data.

tal magnitudes, the differences between them and model magnitudes are not noticeable, with the exception of the earthquake of August 7, 1947 in Southern Cuba. Nevertheless, the comparison between isoseismal maps of this earthquake an of the earthquake of February 3, 1932, with the same instrumental magnitude, enables us to consider that the instrumental magnitude of the 1947 earthquake was overestimated, and that the model magnitude is more reasonable.

The quality of adjustment of models to experimental isoseismals maps is easily seen in the different cases presented in fig. 3. In some cases there is practically no difference between the real and the model isoseismals maps. In other cases, the differences between them may be associated to regional geological characteristics, as is the presence of faults, that may act either as wave guides or as screens. Chuy et al. (1983) described such a situation on their discussion of the December 16, 1982 earthquake. In general, it may be considered that the proposed model of isoseismals is a very good aproximation to the macroseismic field of earthquakes in the Greater Antilles.

The cases analized were grouped in table 1 by zones, in which its parameters were similar, the same direction of measurement of Δ_e and not very different semiaxes relations A/B in particular. This allows us to establish a zoning of model parameters (table 2) which characterizes regional behaviour of the macroseismic field of earthquakes in the Greater Antilles.

Table 2. Regional behaviour of model parameters.

Region	e	A/B
W Cuba	A	1.6-1.8
Central Cuba	A	1.5-2.9
NE Cuba	$\bar{\Delta}$	1.4*
SE Cuba	A	1.0-1.6
Cayman Is.	A	1.2*
N. Hispaniola	$\bar{\Delta}$	1.9-2.7
S Hispaniola	$\bar{\Delta}$	1.6-2.5
Jamaica	A	1.6-2.2

* - only one case

This model of isoseismals may be applied to any region. For this, it is only necessary to know the regional coefficients of the Köveslighetian formula (3) and to get a set of isoseismal maps or information about the shape of the isoseismals. For example, for earthquakes of the Vrancea's deep seismic source zone, Radu and Apopei (1978) published data about the shape of the isoseismals and the intensities attenuation that was used by Alvarez and Bune (these proceedings) to obtain the parameters of a model of this kind for seismic hazard estimation purposes of the eastern Balcanian region.

The wide applicability of the developed model of isoseismals and the quality of adjustment to experimental isoseismal maps allow us to affirm it's use in seismic hazard estimation problems and guarantees the obtention of trustworthy results.

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