ATTENUATION OF INTENSITIES IN TURKEY

R. Yarar (I)
O. Ergünay (II)
M. Erdik (III)
K. Eren (IV)

Presenting Author : M. Erdik

SUMMARY

Earthquake intensities are subjective evaluations of earthquake effects and descriptions of the apparent severity of the destructions. In addition to the fact that they still remain as a valuable criterion on which the deterministic and probabilictic seismic hazard assessments are based, it has been a general practice in the profession to calculate accelerations from intensities, primarily in regions with inadequate strong motion data.

The study will involve : (1) Compilation and re-evaluation of the available iso-seismal maps, (2) Adoption of an appropriate attenuation model, (3) Regression analysis and (4) Comparison of the intensity attenuation relationships with others from similar geological regions.

COMPILATION OF ISOSEISMAL MAPS AND DATA

The isoseismal maps used in this study are based on several sources as compiled by Ergin et.al. (1967, 1971, 1978, 1982) and by Canıtez et.al.(1982). For past-1966 earthquakes, the field reports and the isoseismal maps prepared by the Earthquake Research Division of the Ministry of Reconstruction and Resettlement have been utilized. Several earthquake reports put out by the Istanbul Kandilli Observatory and the Mineral Research and Exploration Institute have also been consulted. To account for the non-isotropic characteristics of the intensity distributions, the attenuation of intensities for earthquakes associated with strike slip faulting and those associated with graben type are treated seperately. The isoseismal maps of the earthquakes associated with strike slip faulting (North and East Anatolian Faults) exhibit elliptic behaviour with major axis in the direction of the fault rupture, whereas those associated with graben systems (i.e. Aegean Grabens) are more or less circular in nature. Table 1 lists the earthquakes and their significant parameters utilized in this study. Fig.1 provides an epicentral map of these events. In Fig.2 some of the isoseismal maps are given for illustration purposes.

Since the original assessment of the isoseismal maps is based on the subjective evaluations of the investigator, discrepancies and data dispersion are unavoidable. Certain isoseismal maps assign the specific intensity values to the contours whereas others make these assignments to the regions

(I) Chairman, Turkish National Committee for Earthquake Engineering

(II) Director General, General Directorate of Building Materials, Ankara

(III,IV) Earthquake Engineering Research Center, Middle East Technical University, Ankara, Turkey

between contours. For the intensity assignments, various scales have been used depending on the date of the event. These include Rossi-Forrel (RF), Mercalli-Cancani-Sieberg (MCS), Modified Mercalli (MM) and Medvedev-Sponheur-Karnik (MSK-64) scales. Since 1965, the MSK-64 scale, and currently, an adaptation of this scale to regional construction practices (unpublished reports of the Earthquake Research Division of the Ministry of Reconstruction and Resettlement) are being employed. Another source of discrepancy is the assignment of epicentral intensities. Certain epicentral intensities have been assigned on the basis of specific damage observations, yet others are based only on the basis of topographical changes. These differences prompted a homogenization and re-evaluation process for further statistical treatment of the data. In this regard; (1) the epicentral intensities were reexamined and reassigned on the basis of the damage reports, (2) the intensities were assigned to the regions between contours and the upper contour is assumed to represent the fore-most extent of the assigned intensity and (3) where applicable, intensities were converted and re-assigned in terms of the MSK-64 scale.

For the derivation of intensity attenuation relationships associated with strike-slip events, four sets of intensity versus distance data are obtained for each isoseismal contour referring to the distances to the fault rupture along the perpendicular axis to the fault and to the center of the fault rupture along the fault axis. For distance determinations the isoseismal lines are smoothed to approximate ellipses. For graben type faulting associated events with more-or-less circular shaped isoseismal maps the intensity contours are converted to equi-area circles centered at the macroseismic epicenter and their radii are used as the distance parameter for each intensity.

PHYSICAL REGRESSION MODELS

In most general terms the attenuation of the ground motion can be given by an equation of the following form (Savarenskii, 1975)

$$y = k\ R^{-n} \exp(-qR) \quad (1)$$

where y is the amplitude of a given harmonic of the ground motion, R is the distance from the source, q is the damping term and k and n are, respectively, the amplitude and geometric damping parameters. The damping term q can be further given as $q = \Pi f/Q\beta$ where f is the frequency of the ground motion harmonic, Q^{-1} is the so called specific attenuation and β is the shear wave propagation velocity.

Following the definition of Richter's Local Magnitude the amplitude parameter k can be expressed by $k = \exp(k_1 M + k_2)$ in terms of the local magnitude (M), where k_1 and k_2 are constants. Accordingly, Eq.1 can be expressed as :

$$y = R^{-n} \exp(k_1 M + k_2 - qR) \quad \text{or} \quad \ln y = k_1 M + k_2 - qR - n \ln R \quad (2)$$

It has been a standard practice of the profession to linearly correlate the intensity (I) with the logarithm of the peak ground acceleration, and the epicentral intensity (I_o) with the magnitude. Such correlations substituted in Eq.2 will yield the following regression equations in terms of (I_o-I) versus R, and I versus M and R as follows :

$$I_o - I = c_o + c_1 \ \ln R + c_2 R \qquad (3)$$

and

$$I = c_3 + c_4 M + c_5 \ \ln R + c_6 R \qquad (4)$$

where c_o, c_1, c_2, c_3, c_4, c_5 and c_6 are the regression constants

These regression models are basically the same as the following so-called "general equations of seismic field", widely used in the U.S.S.R. literature (Shebalin, 1968) :

$$I = bM - k \log \sqrt{\Delta^2 + h^2} - p \sqrt{\Delta^2 + h^2} + d_1 \qquad (5)$$

and

$$I = bM - s \log \sqrt{\Delta^2 + h^2} + d_2 \qquad (6)$$

where Δ is the average distance from the epicenter (mean radius) of the isoseismal line for the intensity I and b, k, p, s, d_1, d_2 and h are regression parameters.

RESULTS

Denoting the approximate and the adjusted values of parameters respectively by X_o and X_a, the observations by L_b, the adjusted observations by L_a and the residuals by V, the mathematical model can be taken to be as :

$$L_a = L_b + V = F(X_a) \qquad (7)$$

where

$$\Phi = V^T V \quad \text{is minimum when}$$

$$\hat{X} = X_a - X_o = -(A^T A)^{-1} A^T L \qquad (8)$$

and where $L = F(X_o) - L_b$ and $A = \partial F / \partial X_a$ at $X_a = X_o$

Thus X_a, can be computed by Eq.8 and can be substituted in Eq.7 to obtain the adjusted observations.

Following results are obtained for the attenuation of intensities in transverse direction to the strike slip faults on the basis of the regression equations given in Eqs 3 and 4 :

$$I - I_o = 1.237 + 1.216 \ \ln R + 0.004R \ ; \ \sigma(I-I_o) = 0.53 \qquad (9)$$

and

$$I = 0.34 + 1.54 \ M - 1.27 \ \ln R - 0.001R \ ; \ \sigma_I = 0.60 \qquad (10)$$

The attenuation of the intensity in parallel direction to the strike slip faults are closely related to the amount of fault rupture. For the strike-slip type earthquakes, the relationship between the fault rupture (L) and the magnitude (M) can be given by the following equation :

$$\ln L = 2.53 \ M - 14.04 \ ; \ \sigma_{\ln L} = 0.27 \ ; \ (M \geq 6.8) \qquad (11)$$

Experience with the strike slip faults in Turkey indicates that the earthquakes with surface magnitudes greater than MS 6.8 have been associated with surface fault ruptures and the intensity VIII contours have always encompassed the fault rupture area. The following mean end-to-end distances of intensity contours in parallel direction to the strike slip faults can be given on the basis of the regression analysis of the pertinent data.

$$\ln D_{VIII} = 2.20\ M - 11.32\ ;\ \sigma_{\ln D_{VIII}} = 0.47 \qquad (12)$$

$$\ln D_{VIII} = 1.80\ M - 8.40\ ;\ \sigma_{\ln D_{VII}} = 0.34 \qquad (13)$$

$$\ln D_{VI} = 2.20\ M - 11.32\ ;\ \sigma_{\ln D_{VI}} = 0.45 \qquad (14)$$

Where the D distances refer to the end-to-end contour width. It should be noted that these relationships are associated with higher uncertainties than those corresponding to the transverse direction.

For earthquakes associated with graben type faulting, exhibiting more-or-less circular intensity distributions, the attenuation of intensities in radial directipn from the macroseismic epicenter can be given by :

$$I - I_o = 2.465 + 1.235\ \ln R + 0.0003\ R\ ;\ \sigma_{I-I_o} = 0.54 \qquad (15)$$

and

$$I = 0.568\ \ 1.534\ M - 1.235\ \ln R - 0.001\ R\ ;\ \sigma_I = 0.64 \qquad (16)$$

Where I_o and I denotes respectively, the mean epicentral intensity and the mean intensity at a distance R in transverse direction to the fault, and σ is the standard deviation of the dependent parameter.

In these equations R, in km's, refers to the radial distances from the macroseismic epicenter.

The attenuation relationships given be Eqs. 9, 10, 15 and 16 are plotted in Fig.3. Fig.4 depicts the mean theoretical shapes of the iso-seismal maps associated with strike-slip type earthquakes in Turkey on the basis of the investigations contained herein this report.

In Fig.5 the intensity attenuation relationships derived are compared with attenuation relationships based on geographically different iso-seismal data. Included in this comparison are the data related to Iran (Chandra et.al., 1979), California (Howell and Schultz, 1975) and San Andreas Fault (Chandra, 1979). Fig.5 indicates that while the average rates of decay exhibited by the different attenuation relationships between 30-100 km. are about the same, ($dI/dR \simeq 1.2/R$), there exist substantial differences in the near field decay rates and the epicentral intensities. It should be noted that the near field (less than 30 km to the fault) intensity decay rate for the Turkish earthquakes is about twice that of California earthquakes. This deviation may be partly due to the high frequency structures in Anatolia from which the intensity assessments are made. The damage of such high frequency structures is best correlated with the ground acceleration which has a higher decay rate than other ground motion quantities.

REFERENCES

Alsan, E.L., Tezucan and M.Bath (1975), An Earthquake Catalogue for Turkey for the Interval 1913-1930, Kandilli Observatory, Istanbul and Seismological Institute, Ipsala.

Canıtez, N., B.Büyükaşıkoğlu and U.Güçlü (1982), Seismicity of Sinop and Trakya Nuclear Power Plant Sites and their Vicinity: Trakya Area, Progress Report No.2 Submitted to Turkish Electricity Authority.

Chandra, U. (1979), Attenuation of Intensities in the United States, Bull. Seism.Soc.Am., 69,2003.

Chandra, U., J.G. McWhorter and A.A.Nowroozi (1979), Attenuation of Intensities in Iran, Bull.Seism.Soc.Am., 69, 237.

Dewey, J.W. (1976), Seismicity of Northern Anatolia, Bull.Seism.Soc.Am., 66,843.

Ergin, K., U.Güçlü and Z.Uz (1967), A Catalogue of Earthquakes for Turkey and Surrounding Area (11 A.D. to 1964 A.D.), Istanbul Technical University, Pub.No.24, Istanbul, Turkey)

Ergin, K., U.Güçlü and G.Aksay (1971), A Catalogue of Earthquakes of Turkey and Surrounding Area (1965-1970), Istanbul Technical University, Pub. No.28, Istanbul, Turkey.

Ergin, K.and S.Büyükaşıkoğlu (1978), Seismicity of Akkuyu Nuclear Power Plant Site and its Vicinity, Final Report Submitted to Turkish Electricity Authority.

Ergin, K., N.Canıtez, S.Büyükaşıkoğlu and U.Güçlü (1982), Seismicity Progress Report No.2 submitted to Turkish Electricity Authority.

Howell, B.F, and T.R.Schultz (1975), Attenuation of Modified Mercalli Intensity with Distance from the Epicenter, Bull.Seism.Soc.Am., 65, 651-665.

Joyner, W.B. and D.M. Boore (1981), Peak Horizontal Acceleration and Velocity from Strong-Motion Records Including Records from the 1979 Imperial Valley, California Earthquake, Bull.Seism.Soc.Am., 71,2011-2039.

Karnik, V. (1968), Seismicity of the European Area, Czechoslovak Academy Sciences, Prague, Czechoslovakia.

Savarenskii, E.F. (1975) Seismic Wawes, English Translation, Printed in Jeussalem, Israel, TT 74-50021.

Shebalin, N.V. (1968) Methods of Using Engineering Seismology Data in Seismic Zoning, in Seismic Zoning of the USSR ed.by.S.V. Medvedev, Izdatel'stro "Nauka" , Moscow 1968.

Shebalin, N.V. (1969), Macroseismic Field and the Source of Strong Earthquakes, Institute of the Physics of the Earth, Moscow.

US/NOAA Data File and Preliminary Determination of Earthquakes (PDE) Bulletins of U.S.G.S. / N.E.I.S.

TABLE I EARTHQUAKES CONSIDERED IN THIS PAPER

STRIKE-SLIP TYPE EARTHQUAKES					GRABEN TYPE EARTHQUAKES			
Date	Name of the Event	Magnitude (MS)	Epicentral Intensity (MSK)	Fault Rupture (km)	Date	Name of the Event	Magnitude (MS)	Epicentral Intensity (MSK)
9. 8.1912	Şarköy - Mürefte	7.3(K)	X	(10)	31. 3.1928	Tepeköy - Torbalı	6.5(K)	VIII
26.12.1939	Erzincan	8.0(K)	XI	350	2. 5.1953	Karaburun	5.4(A)	VII
20.12.1942	Erbaa - Niksar	7.0(K)	IX	(36)	16. 7.1955	Söke - Balat	7.0(A)	IX
20. 6.1943	Adapazarı - Hendek	6.6(KE)	VIII	-	20. 2.1956	Eskişehir	6.5(KE)	VIII
26.11.1943	Ladik	7.6(KE)	X	265	25. 4.1957	Fethiye	7.1(A)	IX(Inferred)
1. 2.1944	Bolu - Gerede	7.6(KE)	X	190	13. 6.1965	Denizli	5.7(A)	VII
13. 8.1951	Kurşunlu	6.8(K)	IX	(40)	23. 3.1969	Demirci	5.6(NOAA)	VI
18. 3.1953	Gönen - Yenice	7.2(K)	IX	60	28. 3.1969	Alaşehir - Sarıgöl	6.4(NOAA)	VIII
26. 5.1957	Abant	7.0(D)	IX	40	28. 3.1970	Gediz	7.1(NOAA)	IX
6.10.1964	Manyas	7.0(D)	IX	-	12. 5.1971	Burdur	5.9(NOAA)	VII
19. 8.1966	Varto	6.8(D)	IX	(30)				
22. 7.1967	Mudurnu Vadisi	7.2(A)	IX-X	80				
22. 5.1971	Bingöl	6.7(NOAA)	VII	15				
24.11.1976	Çaldıran	7.3(NOAA)	IX	53				

KE : Ergin et.al. (1967), K: Karnik (1968), A: Alsan et.al. (1975),
NOAA : PDE Data File, D: Dewey (1976)

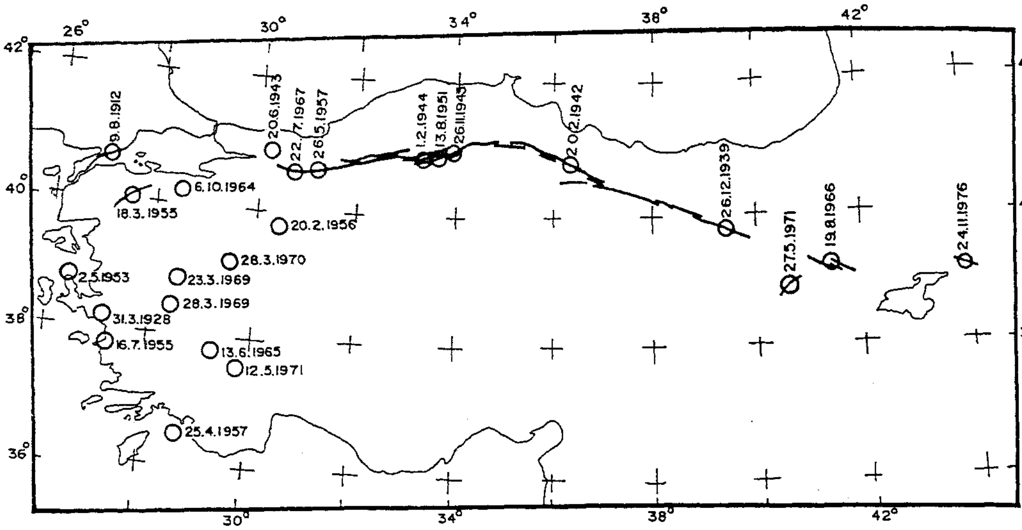
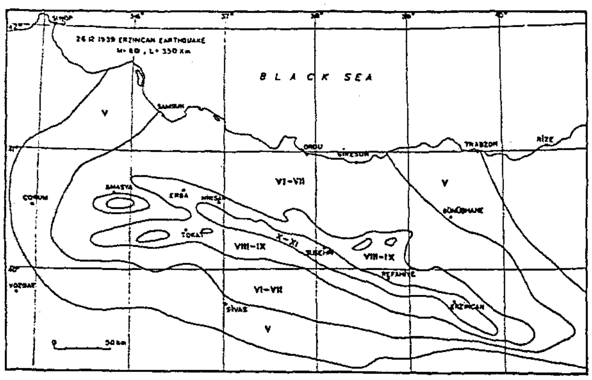
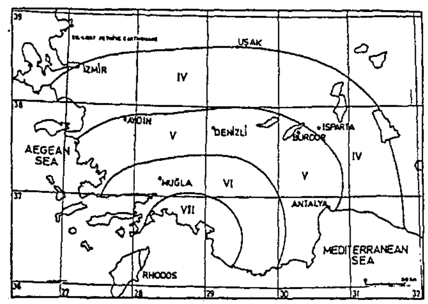


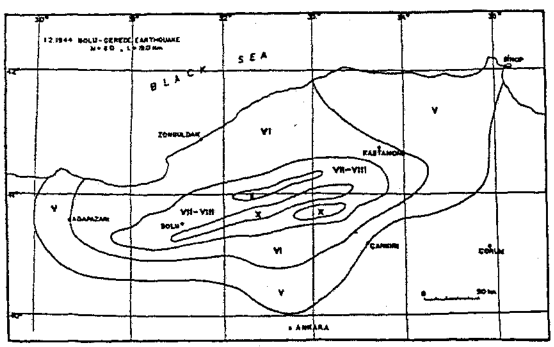
FIGURE 1. Epicentral Map of Earthquakes Considered



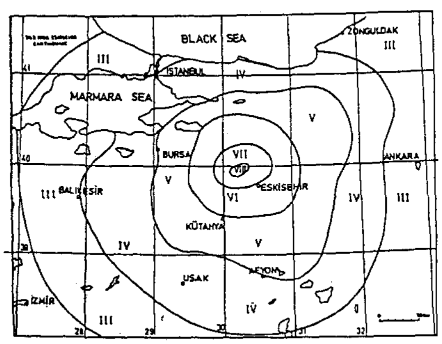
(1.2.1944 Earthquake)



(25.4.1957 Earthquake)



(26.12.1939 Earthquake)



(20.2.1956 Earthquake)

FIGURE 2. Illustrative Isoseismal Maps

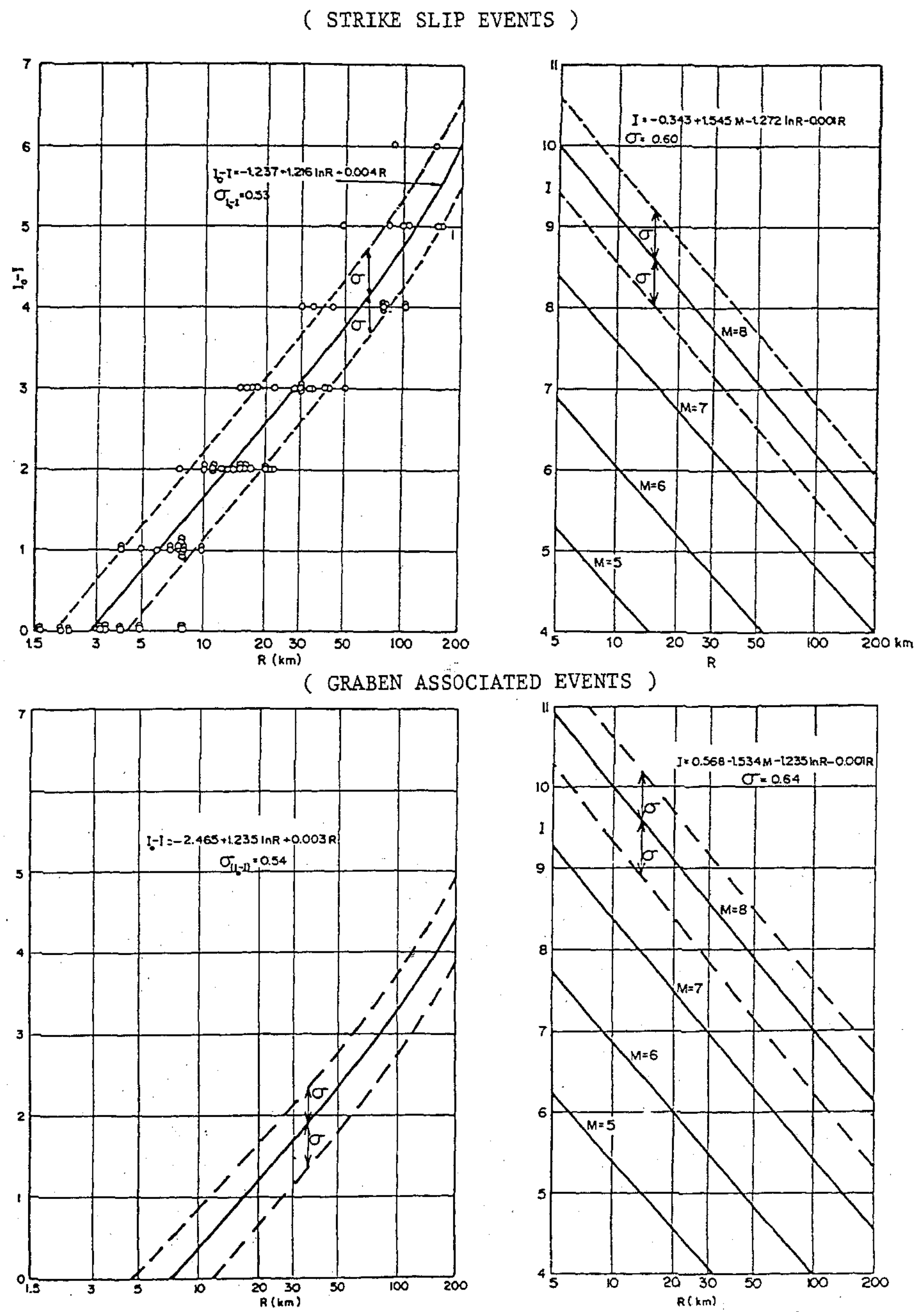


FIGURE 3. Theoretical Shape of the Intensity Attenuation Relationships for Strike Slip Type and Graben Faulting Associated Earthquakes.

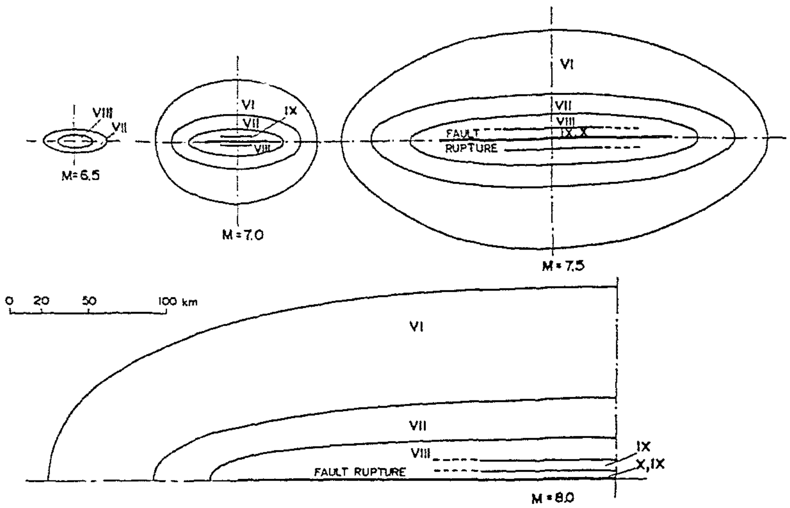
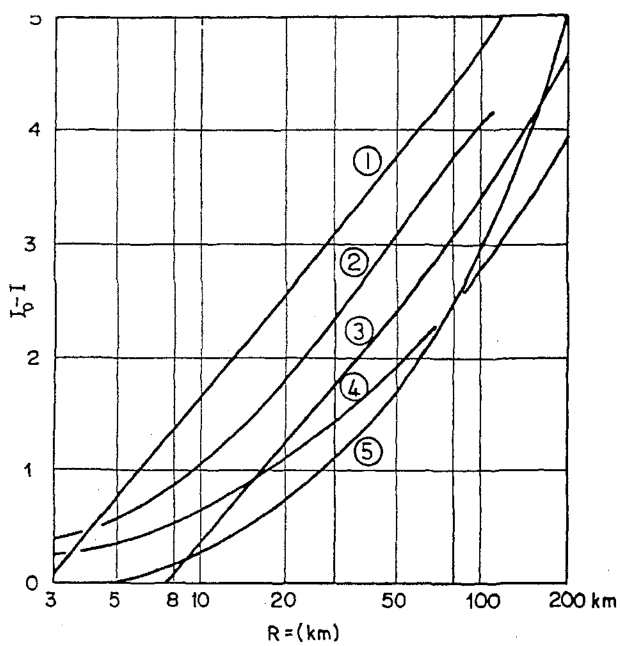


FIGURE 4. Mean Theoretical Shapes of Isoseismal Maps Associated with Strike Slip Earthquakes



1 Strike Slip Type Earthquakes, This Study
2 Iranian Data, Transverse to Isoseismals, Chandra, et al.,(1979)
3 Graben Faulting Type Earthquakes, This Study
4 California Data, Howell and Schultz (1975)
5 California-San Andreas Fault Data, Chandra (1979)

FIGURE 5. Comparison of Intensity Attenuation Relationships