Sino-Korean 지괴에서의 진도감쇠

Intensity Attenuation in the Sino-Korean Craton

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요 약

진도의 거리에 따른 감쇠양상은 두 가지 측면에서 중요하다. 첫째는 역사지진의 크기를 평가하는데 사용되고 둘째는 역사지진 자료를 이용하여 지진위험도를 평가하는데 이용된다.

한반도의 경우 대부분의 지진활동 자료가 역사지진이므로 이 지진들의 크기를 결정하고 이들을 이용하여 지진위험도를 평가하기 위하여 합리적인 진도감쇠양상의 결정은 매우 중요한 과제라 할 수 있다. 진도의 감쇠양상은 진앙진도와 진앙거리 등 두 요소에 같이 의존함이 알려져 있으므로 한반도에서 MMI VIII만의 지진자료를 이용하여 결정된 Lee(1)의 기존의 감쇠공식은 그 사용범위에 한계가 불가피하므로 상기 두 가지 요소를 함께 고려한 새로운 감쇠공식의 유도가 요구되어 진다.

지체구조적으로 Sino-Korean 지괴라고 불리우는 중국 북동부와 한반도에서 발생한 MMI VIII-X 지진들의 자료를 이용하여 한반도에서 발생하는 MMI VIII-X의 강진들에 대한 새로운 진도감쇠양상을 결정하였다.

1. Introduction

Intensity attenuation with distance is important in seismic risk evaluation as well as size estimation of historical earthquakes. Since most of the Korean seismic data consist of historical earthquakes, determination of intensity attenuation pattern is a very important problem for seismological researches in

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Korea. We have about 1900 historical earthquakes in Korea. However, it is impossible to obtain a reasonable intensity attenuation formula from the Korean historical seismic data.

In the 20th century, there occurred two destructive earthquakes of MMI VIII : the 1936 Saangge-Sa earthquake and 1978 Honsung earthquake, Lee[1] derived a intensity attenuation formula for the Korean Peninsular from these earthquakes. It is observed that intensity attenuation depends on distance as well as epicentral intensity (Grandori *et al.*[2]). Therefore, it is desired to derive new intensity attenuation formulas covering a wide range of intensity. It is known that the northeastern part of China and the Korean Peninsula are similar in geotectonics and they are referred to as the Sino-Korean Craton or the North China Block, collectively (Fitches *et al.*[3]).

In this study we intend to derive intensity attenuation formulas appropriate for the Sino-Korean Craton using macroseismic data of strong earthquakes occurred in the Craton during the 20th century.

2. Intensity Attenuation Relation

Most of intensity attenuation laws are either equivalent to or special cases of the following two formulas (Howell and Schultz[4]).

$$I_0 - I = a_1 + b_1 \ln D + c_1 D \qquad (1)$$

$$\ln I_0 - \ln I = a_2 + b_2 \ln D + c_2 D \qquad (2)$$

where I_0 is the epicentral intensity, I is the attenuated intensity at an epicentral distance D, and $a_1, b_{1,}, c_1, a_2, b_2$ and c_2 are constants.

These constants differ from area to area due to different velocity and attenuation structures (for instance, Howell and Schultz[4], Vanmarcke and Lai[5]). For the Korean Peninsular Lee[1] derived the following formula by using the Ssangge-sa and Hongsung earthquakes.

$$I - I_0 = 0.191 - 0.834 \ln D - 0.0068D \qquad (3)$$

Formula (1) indicate intensity attenuation depends on epicentral distance only. In actuality, however, intensity attenuation depends not only on distance but also on epicentral intensity. Generally, it is observed that intensity attenuates more rapidly as epicentral intensity grows smaller (Grandori *et al.*[2]).

According to formula (2), intensity attenuation is proportional to epicentral intensity. But this attenuation pattern is contrary to actual observations, too.

It is clear that a reasonable intensity attenuation formula must accomodate these two observations.

Based on the macroseismic data of strong earthquakes during the 20th century in Italy, Grandori *et al.*[2] proposed the following new intensity attenuation formula.

$$I_0 - I_i = \frac{1}{\ln \psi} \ln\left[1 + \frac{\psi - 1}{\psi_0}\left(\frac{D_i}{D_0} - 1\right)\right] \qquad (4)$$

where D_0 and D_i are mean radii of isoseismals for I_0 and I_i respectively, and ψ_0 and ψ are

$$\psi_0 = \frac{D_1 - D_0}{D_0} \qquad (5)$$

$$\psi = \overline{\psi_i} = \left(\frac{D_{i+1} - D_i}{D_i - D_{i-1}}\right) \qquad i \geq 1 \qquad (6)$$

Formula (4) allows the phenomena that intensity attenuation depends not only on epicentral distance but also on epicentral intensity and agrees better with observations in Italy than formulas (1) and (2).

3. Analysis of the Data in the Sino-Korean Craton

In view of the new intensity attenuation relation of equation (4), it is desired to derive a similar relation for the strong earthquakes in the Sino-Korean Craton.

To compensate for lack of strong earthquake data in the Korean Peninsula, we collected earthquake data over the northeastern part of China in the Sino-Korean Craton from Catalog of Chinese Earthquakes[6].

We used 2 earthquakes in the Korean Peninsula and 9 earthquakes in the northeastern part of China.

Each earthquake has epicentral intensity equal to or greater than MMI 8 and contains at least three isoseismal lines. Table 1 shows earthquakes used in this analysis.

First, we checked if formula (1) and (2) fit intensity attenuation patterns of strong earthquakes in the Sino-Korean Craton. We calculated mean radii of the isoseismals for each epicentral intensity and plotted intensity attenuations in Fig. 1. Then we calculated the constants of formula (1) and (2) by the least square method, plotted intensity attenuation using the formulas and compared the results with the observations in Fig. 2. It can be seen in Fig. 2 that formulas (1) and (2) do not fit the data satisfactorily.

In order to derive new attenuation relations, we calculated the constants ψ_0, $\psi(i \geq 1)$, Φ in equations (5), (6) and (7) and the reference value for D_0.

$$\Phi = \frac{D_i(I_0 = j+1)}{D_i(I_0 = j)} \quad (7)$$

The constants and the reference values computed are listed in Table 2. The constant Φ is a measure of the more rapid rate of attenuation of small earthquakes compared with large ones. The constant ψ shows that the distances between two successive isoseismal lines increases with i at a constant rate and the constant ψ_0 reveals that the rate of attenuation is more rapid for small than for large distances.

Thus, we obtain a new intensity attenuation

$$I_0 - I_i = \frac{1}{\ln \psi} \ln\left[1 + \frac{\psi - 1}{\psi_0}\left(\frac{D_i}{D_0} - 1\right)\right] \quad (8)$$

with

$$\psi_0 = 1.42$$

$$\psi(i \geq 1) = 1.77$$

$$\Phi = 1.31$$

$$D_0(I_0 = 10) = 9.3$$

Intensity decay through a new formula compared with the observations is shown in Fig. 3. Comparision of Fig. 2 and 3 clearly shows new formula fits the observations much better than formulas (1) and (2).

4. Conclusion and Discussion

In this study, we obtained a new intensity attenuation formula for epicentral intensity MMI VIII-X from macroseismic data in the Sino-Korean Craton. It appears that the seismic risk of the Korean Peninsula has been evaluated lower than reality because of inappropriate intensity formula independent of epicentral intensity. Thus, the formula derived in this study can be used to evaluate seismic risk of the Korean Peninsula more accurately.

5. References

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Table 1. Earthquakes in the Sino-Korean Craton

Place		Date	Epicenter	MMI
China	Diexi	1933. 8.25	31.9°, 103.4°	X
	Shandan	1954. 2.11	39.0°, 101.3°	X
	Ninjin	1966. 3.22	37.5°, 115.1°	X
	Kangle	1936. 2. 7	35.4°, 103.4°	IX
	Heze	1937. 8. 1	35.4°, 115.1°	IX
	Longyao	1966. 3. 8	37.4°, 114.9°	IX
	Macheng	1932. 4. 6	31.4°, 115.0°	VIII
	Tianshui	1936. 8. 1	34.2°, 105.7°	VIII
	Guosian	1952.10. 8	39.0°, 112.7°	VIII
Korea	Saangge-Sa	1936. 7. 4	36.2°, 127.7°	VIII
	Hongsung	1978.10. 7	36.6°, 126.6°	VIII

Table 2. Equivalent radii(km) and statistical evaluations

I_0=10	1933	1954	1966			mean D_i	Φ	ψ	D_0
D_0	11.0	13.2	7.4			10.6		1.11	
D_1	19.4	24.4	22.9			22.2		1.63	9.6
D_2	33.5	42.4	47.9			41.2			8.9
									$\overline{D_0}=9.3$
I_0=9	1936	1937	1966			mean D_i	Φ	ψ	D_0
D_0	5.7	5.7	10.0			7.1	1.48	1.03	
D_1	12.8	13.3	17.2			14.4	1.54	2.31	6.3
D_2	24.8	38.4	31.0			31.4	1.31		6.8
									$\overline{D_0}=6.5$
I_0=8	1932	1936	1952	1936	1978	mean D_i	Φ	ψ	D_0
D_0	5.3	4.0	6.0	3.8	3.1	4.4	1.61	1.79	
D_1	9.5	8.2	14.6	13.1	16.1	12.3	1.17	1.36	5.3
D_2	15.2	23.4	27.7	21.1	27.6	23.0	1.36		5.0
									$\overline{D_0}=5.2$

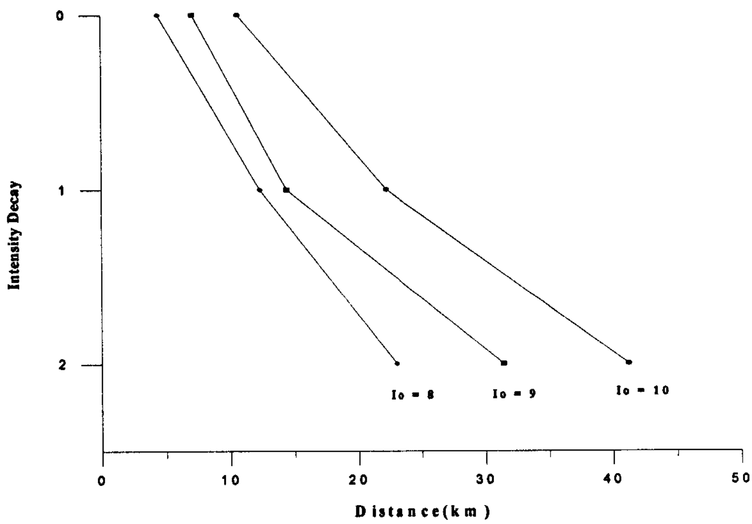

Fig. 1. Intensity decay versus epicentral distance. Mean values

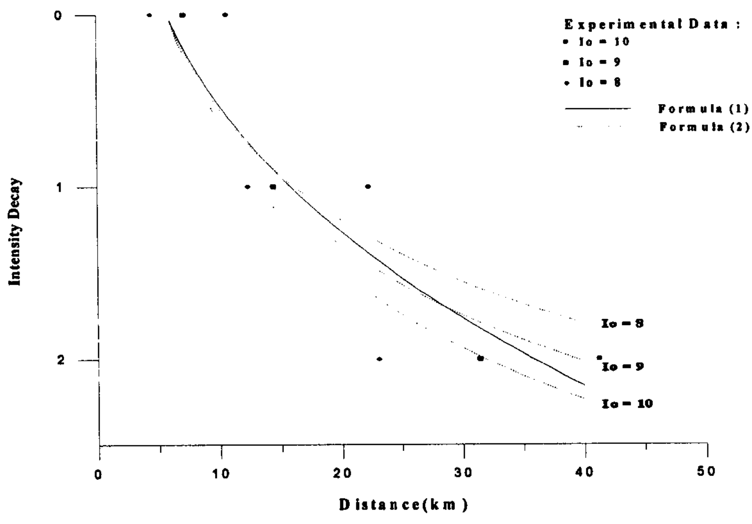

Fig. 2. Interpretation of observations of Fig. 1 with formulas (1) and (2)

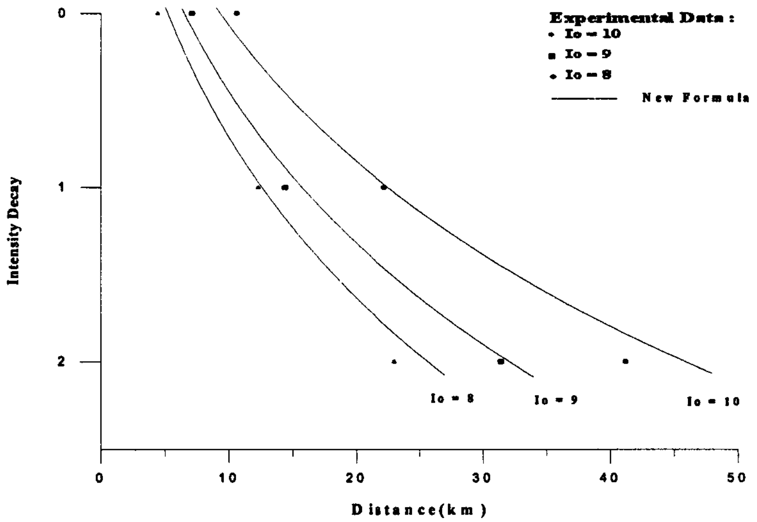

Fig. 3. Interpretation of observations of Fig. 1 with new formula