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Estimation of Regional Seismic Hazard in the Korean Peninsula Using Historical Earthquake Data between A.D. 2 and 1995

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Abstract Located between the very active Japan and Ryukyu subduction zones and the northern China plate, the Korea Peninsula has been considered a part of the stable Eurasia continent and is very quiet in seismic and tectonic activity. Although there were many significant damaging earthquakes reported in historical times, seismic hazard in Korea has long been overlooked. Modern earthquake activity in the Korean Peninsula is very low and is not well recorded, at least until 1998 when the modernization of the Korean National Seismic Network was implemented. Thus, modern earthquake data are not adequate for evaluating seismic hazard in the Korean Peninsula. On the other hand, the historical earthquake catalog, which includes documented earthquake information from around the Korean Peninsula and can be dated back to as early as A.D. 2, provides the only available long-term database for the investigation of temporal and spatial patterns of earthquake activity. The importance of seismic hazard assessment has significantly increased in modern times because of the recent construction of many critical facilities, such as nuclear power plants, supercomputer centers, large hospitals, and high-technology centers, throughout the entire Korean Peninsula. Although uncertainties on the historical earthquake locations and their magnitudes are expected to be large, information obtained from this historical earthquake catalog can at least provide a long-term scientific basis for an estimation of seismic hazard in Korea. For the entire Korean Peninsula, seismic hazard is evaluated in terms of the spatial distribution of seismicity and relative seismic energy release over the 2000 years of the historical record. Results from our preliminary analysis clearly demonstrate that seismic activity in the Korean Peninsula can be categorized into four prominent seismic zones, inside which seismic hazard is much higher than that in the surrounding regions. These four seismic zones include: (1) the western Korean seismic zone extending from Seoul to Pyongyang, which is characterized by a few concentrated regions of high seismicity and a high relative seismic energy release; (2) the eastern Korean seismic zone, which is characterized by a low seismic rate but a high relative seismic energy release from a few large historical events; (3) the northeastern Korean seismic zone, which is probably related to the deep Japan subduction-zone earthquakes underneath northeast China and has a very low seismicity but a very high relative energy release; and (4) the southern Korean seismic zone, which is characterized by many scattered patches of high seismicity and a few zones of high seismicity and high relative seismic energy release from a few large historical events. Among the three most seismically active regions near Pyongyang, Seoul, and Pusan, the probability of occurrence for an earthquake of magnitude greater than 5.0 is estimated to be about 1%, 2%, and 3% per year, respectively. Since significant damaging earthquakes ($M \geq 7.0$) have occurred in these three regions in historical times, an effective assessment of seismic hazard potential in the Pyongyang, Seoul, and Pusan regions cannot be overlooked.

Introduction

Seismic hazard assessment is important for the safety of lives and buildings including hospitals, nuclear power plants, schools, computer centers, factories, military facilities, and government offices. The purpose of seismic hazard assessment in this study is to provide a statistical estimate of the seismic rate, to estimate the probability of the recurrence of moderate to large earthquakes, and, most importantly, to identify the regions of high seismic hazard. Other essential elements of seismic hazard assessments, including the excitation of strong ground motion, the attenuation of seismic waves, and the vulnerability of buildings, should also be considered in addition to the information from earthquake catalogs alone. Modern seismic data (weak and strong motion) and historical earthquake data are among the two most commonly used databases for seismic hazard assessment. There is, however, a trade-off between using modern instrumental seismic data and historical earthquake information for seismic hazard assessment. Modern seismic monitoring in the Korean Peninsula is only available for a very short period of time, and seismicity has been very low during this century (Han, 1996). It is, therefore, far from adequate to be used for a representative seismic hazard assessment.

A global seismic hazard map was recently constructed by compiling and interpreting local and regional earthquake data around the world (Giardini *et al.*, 1999). The Korean Peninsula is classified as a low-hazard region, probably because historical earthquakes were not considered and there is extremely low modern seismicity. Therefore, it is important to explore modern and historical earthquake catalogs to address seismic hazard problems unique to the Korean Peninsula.

Historical earthquake data in Korea span a period of about 2000 years before the present (Li, 1986; Kim and Gao, 1995; Lee, 1999), documented mainly from the felt and damage reports in historical literature. Unlike its neighboring regions in China and Japan, where many large damaging earthquakes have occurred in historical and recent times, the Korean Peninsula is characterized by very low modern seismicity along with widely distributed moderate to large earthquakes ($M \geq 7.0$ or modified Mercalli intensity $\geq$VIII) in historical times (Fig. 1). It is very common that historical earthquake data be subjected to questions concerning the completeness of the database, the accuracy of earthquake location, and the uncertainties on magnitude. However, they can provide an invaluable database for an evaluation of the long-term rate of seismicity for regional hazard assessment. Since the determination of location and magnitude of historical earthquakes were mainly based on the documented felt reports, it is unavoidable that population distribution at the time of earthquakes will have a significant impact on the reported felt information. In a less populated region, for example, a historical earthquake can easily be mislocated up to 20 km, and its magnitude can be easily under- or overestimated by more than 0.5 units. Smaller earthquakes may not be felt and reported. Therefore, the historical earthquake catalog for the Korean Peninsula (Kim and Gao, 1995; Lee, 1999) is considered complete for earthquakes with magnitude greater than 5.0 (Lee, 1999). In spite of the uncertainties and problems with the Korean historical earthquake catalog discussed earlier, an analysis of this database can provide us with at least an estimate of seismic hazard in the region on a relative scale. The ultimate goal of this article is to identify the regions of high seismic hazard from the historical earthquake database and to evaluate the potential of regional earthquake hazard, especially adjacent to the densely populated and quickly developing economic and political centers. The results of this study will provide an important scientific database for the site evaluation of critical facilities in those relatively high earthquake hazard regions and, hopefully, reduce future earthquake damage in the Korean Peninsula.

Available Database

Intensity information for larger historical earthquakes in the Korean Peninsula has been documented in the existing catalogs (Li, 1986; Kim and Gao, 1995; Lee, 1999). Li (1986) reported historical earthquakes in the Korean Peninsula between A.D. 2 and 1983 with magnitude information directly converted from a few typical empirical formulas used in China. Kim and Gao (1995) adapted a few empirical formulas for the Korean Peninsula to convert intensity information to magnitudes for larger historical earthquakes and updated the database to 1995 by including modern earthquakes reported by the Korean Meteorological Administration. In another independent effort, Lee (1999) compiled historical earthquake data in the Korean Peninsula from historical documents and Japanese reports and reported historical earthquake locations and intensity information. A comparison with magnitudes reported by the Japan Meteorological Administration between 1905 and 1945 reveals that the magnitudes reported in Kim and Gao (1995) are probably overestimated. For example, there were 28 historical earthquakes with magnitudes larger than 7.0 reported in Kim and Gao (1995), which would place Korea among the most active intraplate regions in the world. Modern earthquake monitoring in the Korean Peninsula (e.g., Han, 1996) reveals differently: modern seismicity in the region is relatively low compared to that of the neighboring regions in China, Japan, and Taiwan. Therefore, reliable earthquake information, particularly from the historical earthquake catalog, is essential for an earthquake hazard assessment in the Korean Peninsula. Since no magnitude information is available in Lee (1999), historical earthquake location and magnitude information documented in Kim and Gao (1995) is used in this study. Figure 1 shows the historical earthquake epicenters in the Korean Peninsula from Kim and Gao

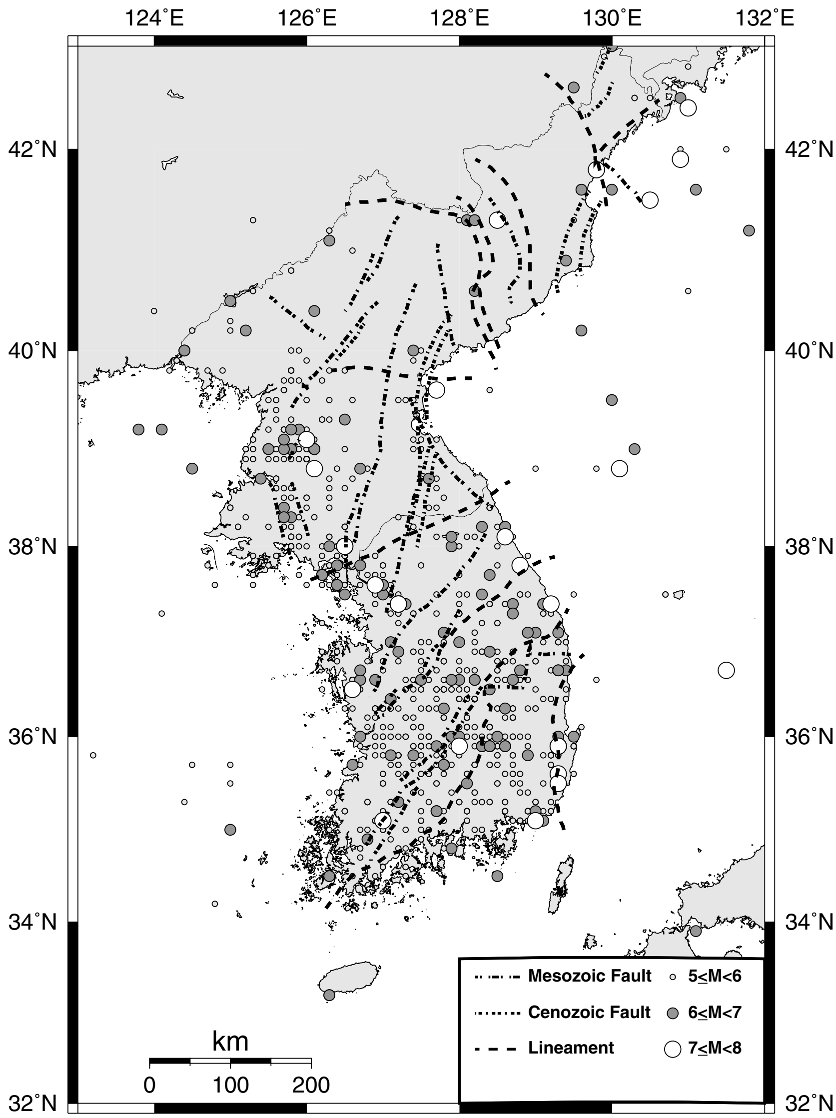

Figure 1. Map showing historical earthquake activity on the Korean Peninsula between A.D. 2 and 1995 from Kim and Gao (1995). Known Cenozoic and Mesozoic faults and structural lineaments are also shown (Masaitisa, 1964).

(1995). Although earthquake locations and magnitudes from the Korean earthquake catalog of Kim and Gao (1995) may not be very accurate, the information revealed from these data will provide a preliminary and a relative assessment of seismicity in the region, which suggests the following:

1. There have been many damaging earthquakes reported during historical times in Korea. The unexpected large earthquakes could have happened in unexpected areas, for example, the Latur earthquake in stable, central India (Gupta, 1993). However, the probability of a damaging earthquake repeating in an area with previous experience of a large earthquake is probably much higher than those in unexpected ones.
2. The southern, southeastern, and western regions of the Korean Peninsula are seismically more active than the rest of the regions (Fig. 1). Seismic activity seems higher in southern than in northern Korea. As is also shown in Figure 1, many Mesozoic and Cenozoic faults along with many geological lineaments trend mainly northeast–southwest (Masaitisa, 1964). The spatial correlations between earthquake activity and the known faults and lineaments are not fully understood, mainly because of the large uncertainties in historical earthquake locations and poorly studied faults. However, the large historical earthquake locations seem to be bounded mostly by the northeast–southwest–trending geological faults and lineaments.
3. Although their locations may not be reliable, the spatial distribution of moderate and larger earthquakes (Fig. 1), $M \geq 5.0$, has shown at least several concentrations of seismic activities, for example in the western region around Seoul, the northwestern region around Pyongyang, and the southeastern region around Pusan. Such historical seismicity patterns are closely associated with the local population centers where more felt reports were documented in historical times. The temporal and spatial nature of this clustered historical earthquake activity should

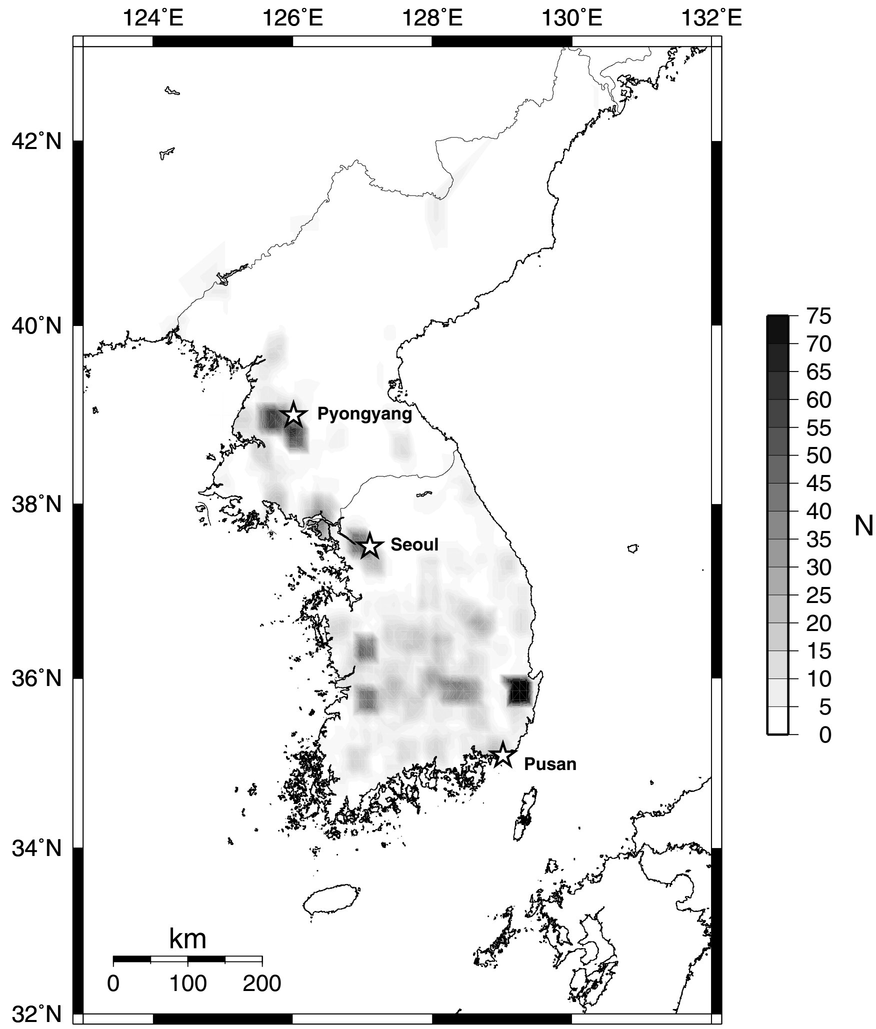

Figure 2. Contour presentation of seismicity on the Korean Peninsula. The study area is divided into 0.1° by 0.1° square blocks, roughly 10 km × 10 km. The total number of historical earthquakes with $M \geq 5.0$ inside each block is counted first and then smoothed by averaging with the numbers of the adjacent eight blocks. Gray scale is scaled to the maximum number of earthquakes among all blocks.

be carefully examined because these three regions are the political and economic centers in the peninsula.

4. While earthquakes with magnitude larger than 7.0 may not occur very often (28 earthquakes over a 2000-year period in Korea), many historical earthquakes were estimated to be in the range between 5.0 and 7.0. Should an earthquake of such moderate size occur in the near future in Korea, significant damage can be expected. Thus it is important to have an understanding of seismic hazard in the region based on historical earthquakes. Such hazard evaluation may be valuable for the safety management of existing facilities and for the secure design and construction of new critical facilities.

Methodology

Historical earthquakes were widely distributed throughout the Korean Peninsula (Fig. 1). It is very difficult to evaluate the seismic hazard of a region simply by using a historical seismicity map alone. Since historical earthquake locations were determined to the nearest 0.1° based on felt reports, we have first designed a two-dimensional surface grid with a block size of 0.1° × 0.1° (or roughly 10 km × 10 km) across the entire study area. The seismic rate and the relative seismic energy release over a period of 2000 years are calculated for each block. The seismic rate provides an estimate of the annual probability that an earthquake beyond a given magnitude will occur again in the same region. The accumulated relative seismic energy release inside a block provides essential information, especially related to larger earthquakes, for an assessment of potential earthquake hazard in a region. In order to accommodate the uncertainties of earthquake locations in the calculations, the resultant value in each calculation for each block is then averaged with the surrounding eight blocks, from which the sharp

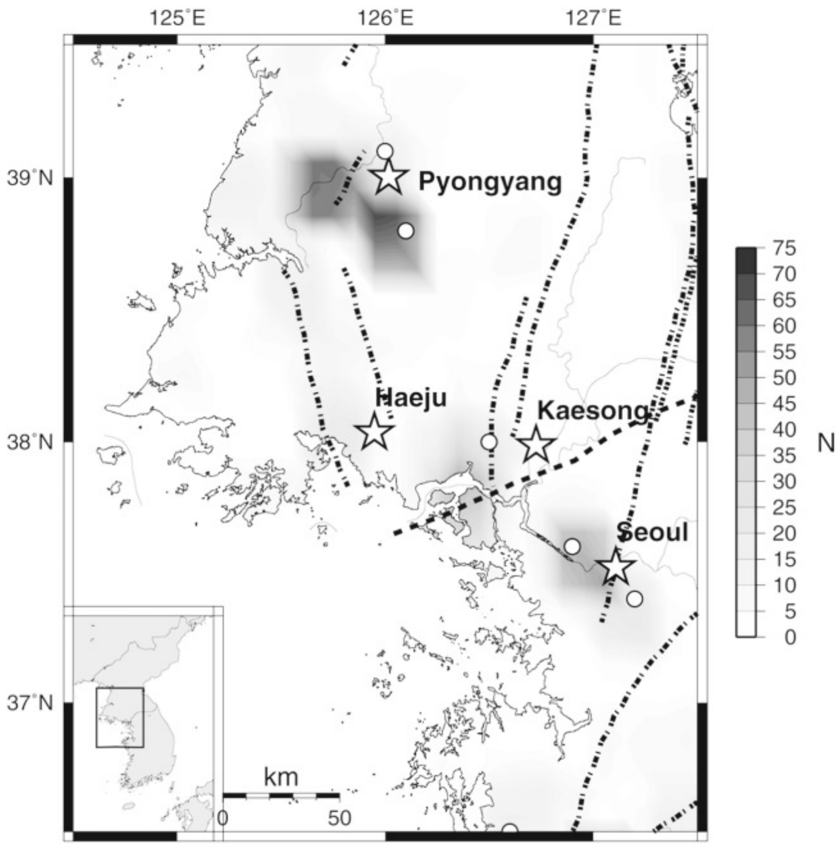

Figure 3. Contour display of seismicity specifically for the western Korean seismic zone between Seoul and Pyongyang, where regions of high seismicity in historical times are apparent near the northwestern Seoul and southern Pyongyang regions. Probabilities of earthquake with magnitude larger than 5.0 to occur in the Seoul and Pyongyang regions are 2% and 1% per year, respectively. Open circles are the reported locations of significant historical earthquakes with magnitude larger than 7.0. Shading scale is the same as in Figure 2.

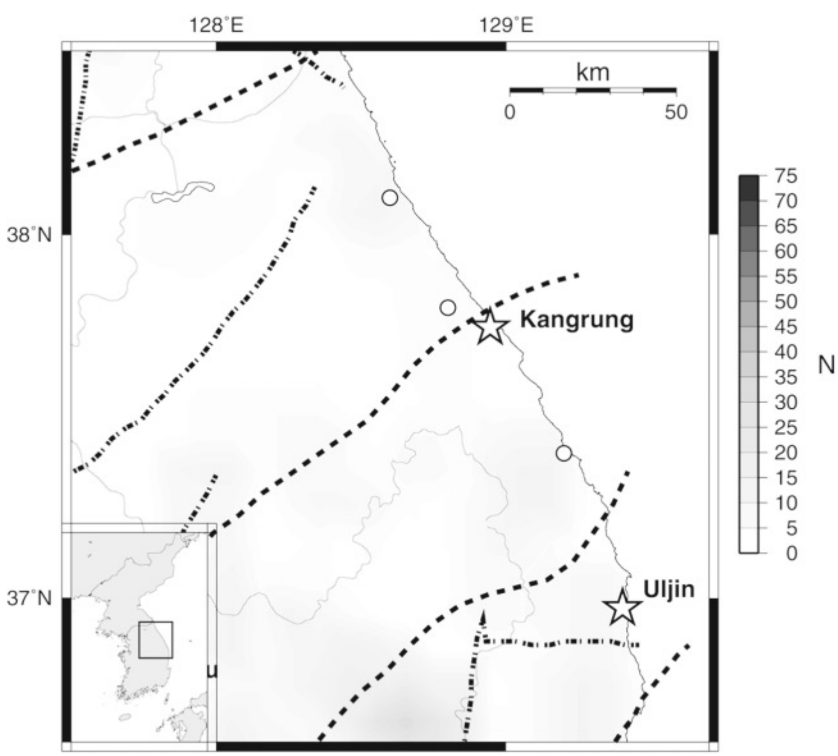

Figure 4. Similar to Figure 3 but for the eastern Korean Peninsula. Although there were several large earthquakes that occurred in historical times, the seismic rate is relatively low in this region.

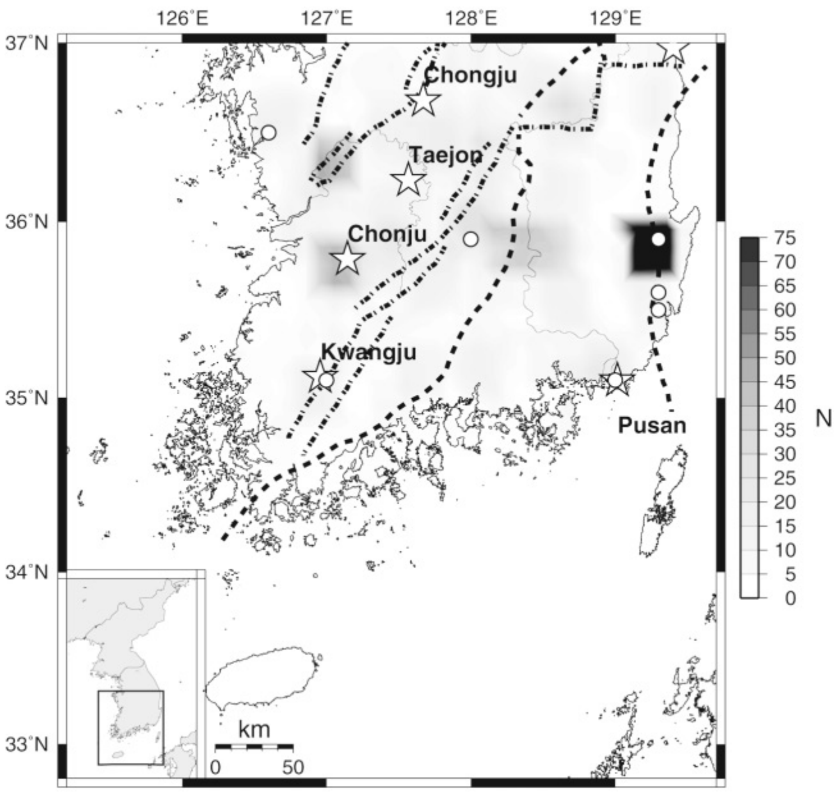

Figure 5. Similar to Figure 3 but for the southern Korean Peninsula. Patches of high-seismicity regions are scattered, for example, around the Kwangju, Chonju, and Pusan areas. The region about 100 km north of Pusan is among the most seismically active areas in Korea.

boundary of an anomalous region will be smoothed. Such a moving window average will most probably emphasize the regions of anomalous high earthquake hazard. The technique applied in this study is similar to that used in Frankel (1995), where historical seismicity in the central and eastern United States has been spatially smoothed to different length scales to study seismic hazard.

Seismic Rate

The total number of earthquakes larger than a given threshold magnitude (e.g., 5.0) inside each block is counted and assigned to the associated block. Dividing the total number of earthquakes inside each block by the number of years of the reporting period provides a preliminary estimate of the seismic rate of the block, that is, number of earthquakes per year. This, in turn, allows calculation of the annual probability of occurrence of earthquakes beyond a threshold magnitude inside each block. The longer the period since the last major earthquake in the block, the higher the probability that a major earthquake will occur (e.g., Johnston and Nava, 1984).

Relative Seismic Energy Release

Seismic moment is commonly used in modern seismic hazard analysis. However, analysis of seismic moment is not practical at this moment for the Korean Peninsula since no such data are available from historical and modern earthquake catalogs. In an alternative approach, assuming that the magnitude of Korean historical earthquakes estimated from felt reports is closely associated with surface-wave magnitude (M_s), then the empirical relationship between energy (E) and magnitude (M_s) of Gutenburg and Richter (1956) ($\log E = 11.8 + 1.5 * M_s$) can be used to estimate the energy released from each earthquake. The first constant term is common to all earthquakes. The second term in the Gutenburg–Richter equation accounts for the log of seismic energy release specifically for each earthquake, which is called "relative seismic energy release" in this study. Undoubtedly, the value of relative seismic energy release in a block will be dominated by the few largest earthquakes inside the block. Since a few large historical earthquakes in Korea occurred as isolated events, that is, not clustered with other historical earthquakes, seismic rate alone is not adequate to represent seismic hazard for these regions. Therefore, although the relative seismic energy release mentioned earlier does not reflect the real amount of seismic energy release in an area, it will provide a simple and easy measurement to assess earthquake hazard in the Korean Peninsula. The accumulated relative seismic energy release for all earthquakes with magnitude larger than 5.0 inside each block is a sensitive indicator to contrast areas of high or low seismic energy release in historical times.

Results

An earthquake of magnitude 4.0 may be widely felt near the epicentral region; however, it takes an earthquake with magnitude larger than 5.0 to cause visible or significant dam-

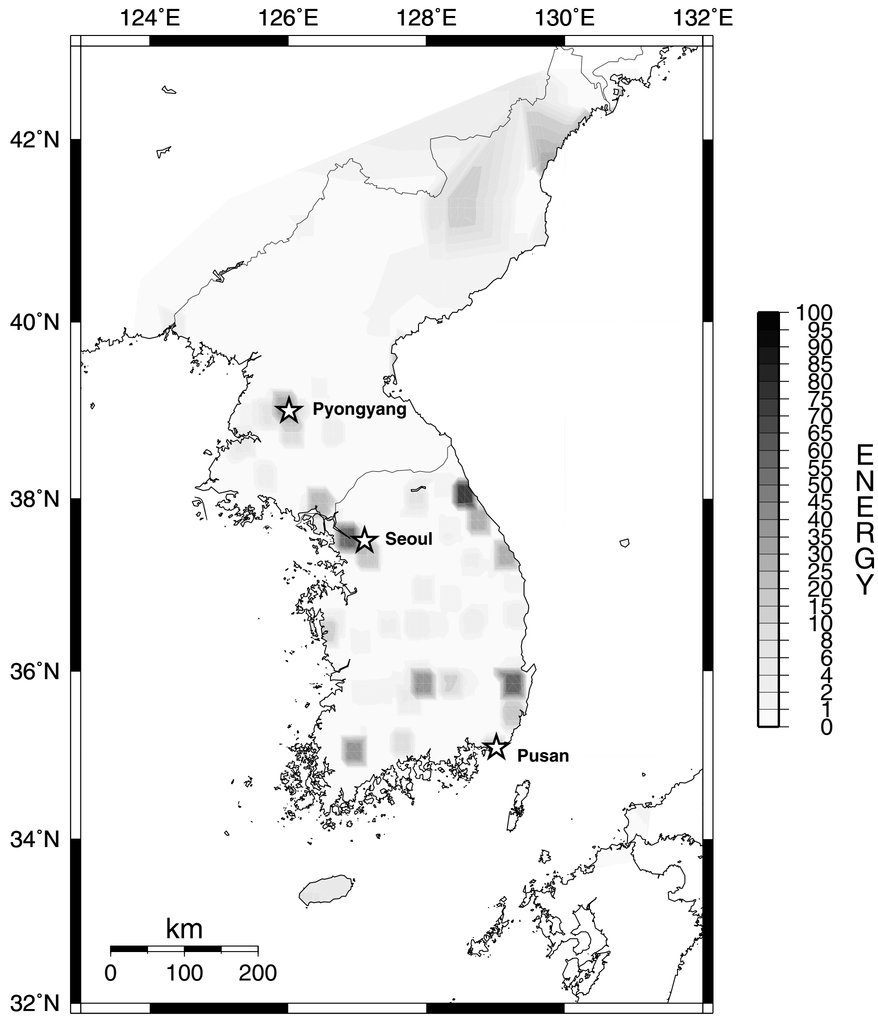

Figure 6. Contour display of relative seismic energy release by historical earthquakes on the Korean Peninsula. Gray scale is scaled and presented in percentile to the maximum amount of relative seismic energy release of all blocks. The eastern Korean seismic zone emerges as a prominent feature.

age. Therefore, we will focus on the analysis of historical earthquakes with magnitude larger than 5.0. Figure 2 shows a map of the seismic rate in the Korean Peninsula for earthquakes with magnitude larger than 5.0. The number of earthquakes inside each block (N) of approximately 100 km^2 was counted and displayed in gray scale. Enlarged displays of the three most active regions are shown in Figures 3, 4, and 5. Since there is no depth information available in the Korean historical earthquake catalog (Kim and Gao, 1995; Lee, 1999), the northeastern seismic zone, which is probably closely related to the deep seismic zone associated with the Japan subduction zone, is not discussed in this article.

The region of highest seismicity (number of earthquakes per block) for $M \geq 5.0$ is located about 100 km north of Pusan (Figs. 2 and 5). The region of second highest seismicity is located south of Pyongyang (Figs. 2 and 3). The region of third highest seismicity is located immediately to the northwest of the suburbs of Seoul (Figs. 2 and 3).

The regions of high seismicity in western Korea are, in general, located along a northwest–southeast–trending zone (Fig. 3). There may be some spatial correlations between the known geological faults and lineaments and the regions of high seismicity, but this is very difficult to quantify simply because of the limitations on the accuracy of the historical data. Seismicity in the eastern Korean Peninsula is relatively low compared to that to the west and the south (Figs. 1, 2, and 4). However, a few large earthquakes have been reported in historical times in the eastern Korean Peninsula (Fig. 1).

Seismicity in southern Korea is relatively very high and is more scattered than in other regions (Figs. 1, 2, and 5). A few areas of high seismicity are located adjacent to the major cities in the region, including Kwangju, Chonju, and Pusan. The most seismically active area immediately north of Pusan (Fig. 5) may be closely related to a known north–south–trending Yangsan fault in the southeast corner of the Korean Peninsula (Lee, 1998).

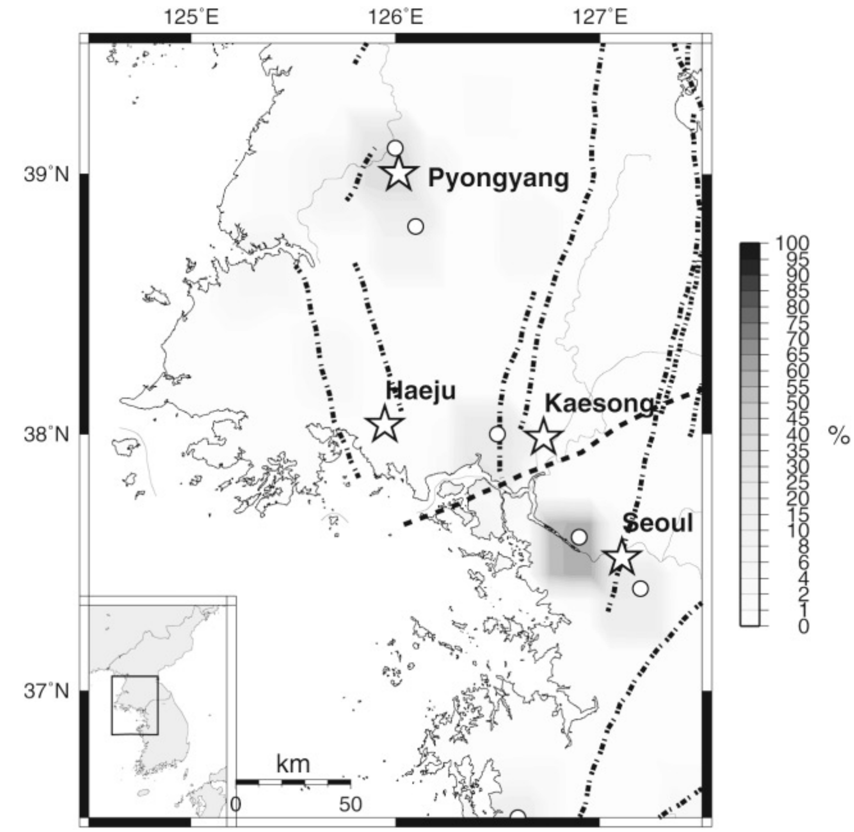

Figure 7. Contour display of relative seismic energy release for the western Korean Peninsula showing high seismic hazard in the Seoul, Kaesong, and Pyongyang regions. Open circles are the locations of large historical earthquakes ($M \geq 7.0$). Shading scale is the same as in Figure 6.

The annual probability of a moderate to large earthquake ($M \geq 5.0$) occurring in the regions of Seoul, Pyongyang, and north of Pusan is about 1%, 2%, and 3%, respectively. It is apparent that the southern Korean Peninsula is the most active region for earthquakes with magnitude larger than 5.0 in historical times.

So far, our analysis has focused only on the number of earthquakes that have occurred inside each block and has not accounted for those larger earthquakes that have been reported in historical times (Fig. 1). Seismic rate alone is not adequate for an evaluation of seismic hazard in Korea. The occurrence of large historical earthquakes must also be considered. Figure 6 shows a contour presentation of the relative seismic energy release from the earthquakes inside each block. Since seismic energy release from magnitude 3 or 4 earthquakes is not significant compared to that from M 5.0 and larger events, only earthquakes with magnitude greater than 5.0 are considered here. When relative seismic energy release is accounted for, the seismic hazard in regions that have experienced large earthquakes but lack other smaller earthquakes in historical times has been enhanced, while the seismic hazard for areas with high seismic rate but without any major large historical events may have been suppressed. The major difference between the results shown in Figures 2 and 6 is the emergence of the eastern Korean seismic zone, where the seismic rate is lower than the neighboring areas but where several earthquakes with magnitude as large as 7.6 have occurred in historical times; thus it is characterized by a high relative seismic energy release.

Enlarged displays of the three regions with high relative seismic energy release in the western, eastern, and southern Korean Peninsula are shown in Figures 7, 8, and 9, respectively. The region from Seoul following the Han river valley northwestward to Pyongyang remains very active for earthquakes larger than 5.0, so it may be called the Seoul–Pyongyang seismic zone (Fig. 7). The eastern Korean seismic zone near Kangrung, where three large earthquakes with magnitudes of 7.6, 7.3, and 7.3 occurred in June 1681, has now emerged (Figs. 6 and 8). It is interesting to note the alignment of the three big earthquakes along the near-coast lineament of eastern Korea (Fig. 8), which suggests that it may be an active fault. The regions of high relative seismic energy release in the southern Korean Peninsula remain very similar to those shown by the seismicity map (Fig. 5), except that regions near Kwangju and east of Chonju are among the three most active regions, next to the area about 100 km north of Pusan (Fig. 9). Not only is the known north–south–trending geological lineament east of Pusan active, but also, the northeast–southwest–trending Mesozoic faults across Kwangju seem to be active in historical times.

Since the regions around Pyongyang, Seoul, and Pusan, the three most important economic and political centers on the Korean Peninsula, coincide with the three most seismically active regions discussed earlier, we have further in-

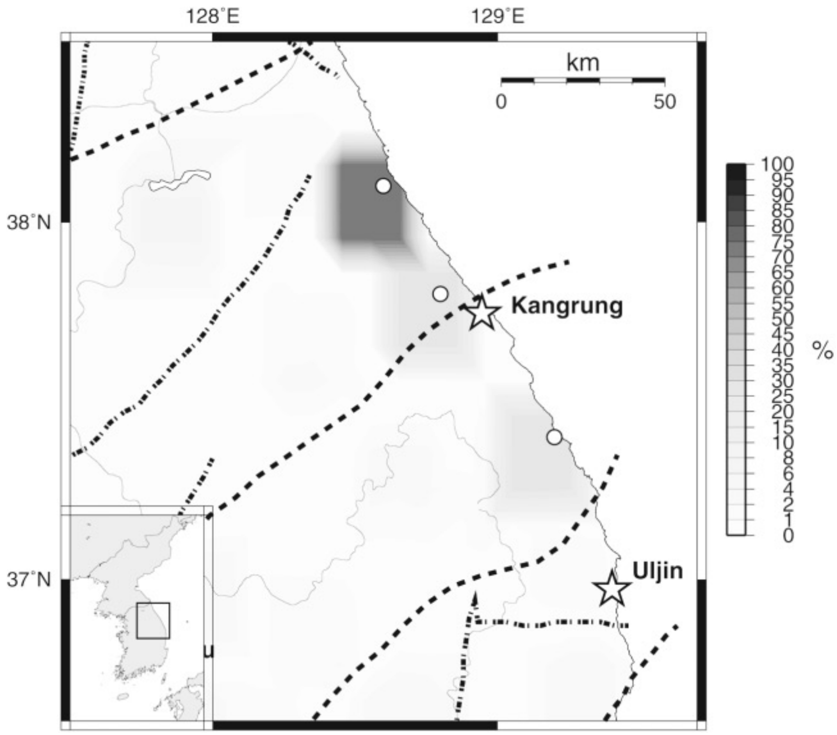

Figure 8. Display of relative seismic energy release for the eastern Korean seismic zone showing a region of high seismic hazard adjacent to Kangrung. Open circles are the locations of large historical earthquakes ($M \geq 7.0$). Shading scale is the same as in Figure 6.

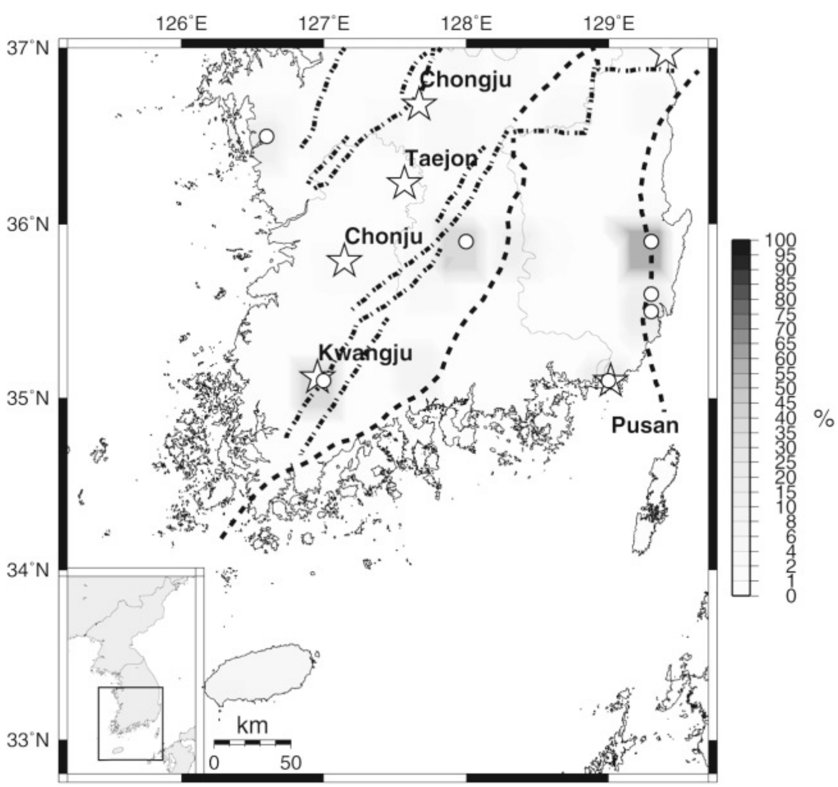

Figure 9. Display of relative seismic energy release for the southern Korean seismic zone showing regions of high seismic hazard adjacent to Kwangju, about 100 km north of Pusan, and about 100 km east of Chonju. Open circles are the locations of large historical earthquakes ($M \geq 7.0$). Shading scale is the same as in Figure 6.

spected the distribution of historical seismicity near these three regions.

Pyongyang Region

In all, 168 earthquakes with magnitude larger than 5.0 have occurred in the past 2000 years around Pyongyang (Table 1, Fig. 10). Among them were 16 events with magnitude larger than 6.0 and 2 events larger than 7.0. The largest event known in this region was a magnitude 7.3 on 30 June 1546, which was probably proceeded by a forshock of magnitude 6.8 and followed by many aftershocks with mid-5.0 magnitude within 1 month (Table 1). Also of interest is the 1565

Table 1
Historical Earthquake Locations near the Pyongyang Region in the Korean Peninsula between A.D. 2 and 1995, Magnitude ≥5.0

No.	Ref.	Month	Day	Year	Lat. (°N)	Long. (°E)	Mag.
1	26	8	0	254	39.000	125.800	5.30
2	27	12	0	262	39.000	125.800	5.30
3	28	2	0	272	39.000	125.800	5.30
4	29	10	0	288	39.000	125.800	5.30
5	30	10	0	292	39.000	125.800	5.30
6	31	2	0	300	39.000	125.800	5.70
7	32	2	0	300	39.000	125.800	5.00
8	36	1	0	386	39.000	125.800	5.30
9	44	11	0	492	39.000	125.800	5.30
10	45	1	0	501	39.000	125.800	6.70
11	48	1	0	535	39.000	125.800	5.30
12	59	4	0	668	39.000	125.800	6.00
13	104	11	0	991	39.000	125.800	5.00
14	106	0	0	1007	39.000	125.800	5.00
15	158	9	17	1223	39.000	125.800	5.90
16	159	9	18	1223	39.000	125.800	5.90
17	281	12	22	1406	39.000	125.800	5.40
18	347	5	13	1428	39.300	125.600	5.30
19	448	10	6	1453	38.600	125.800	5.40
20	467	3	28	1459	39.000	125.500	5.40
21	513	9	1	1500	39.000	125.700	5.20
22	514	9	4	1500	38.800	126.400	5.10
23	519	12	3	1502	39.000	125.700	5.40
24	527	10	24	1503	39.500	126.300	5.70
25	563	3	15	1516	39.200	125.900	6.10
26	572	12	19	1516	38.700	126.300	5.10
27	619	4	18	1519	39.000	125.700	5.80
28	644	3	9	1520	38.800	126.700	5.40
29	735	5	31	1525	38.900	125.200	5.70
30	748	6	23	1526	38.600	126.500	5.30
31	756	11	30	1526	38.500	126.000	5.30
32	759	1	8	1527	38.600	126.300	5.30
33	761	1	22	1527	39.000	125.900	5.10
34	778	3	23	1528	39.300	126.300	5.30
35	794	6	3	1529	38.600	125.700	5.00
36	852	1	27	1543	39.500	126.000	5.60
37	864	3	3	1544	39.500	126.600	5.50
38	868	3	10	1544	38.500	126.300	5.00
39	878	6	29	1546	38.700	125.400	6.80
40	879	6	30	1546	39.100	126.000	7.30*
41	880	7	1	1546	39.100	126.000	5.60
42	881	7	2	1546	39.100	126.000	5.60
43	882	7	3	1546	39.100	126.000	5.60
44	883	7	4	1546	39.100	126.000	5.60
45	885	7	5	1546	39.000	126.000	5.60
46	889	7	23	1546	39.000	126.100	5.70
47	899	1	22	1547	39.200	125.700	5.80
48	902	1	28	1547	39.000	126.000	5.40
49	908	6	15	1547	38.800	126.100	5.00
50	924	8	11	1548	39.000	125.700	5.20
51	927	11	9	1548	39.200	125.700	5.40
52	932	1	10	1549	39.000	125.700	6.00
53	940	10	21	1549	38.800	126.100	5.10
54	943	11	25	1549	39.000	125.700	5.30
55	990	8	2	1555	38.600	125.600	5.40
56	991	8	23	1555	38.600	125.600	5.00
57	992	11	28	1555	38.600	125.600	5.00
58	1003	6	22	1556	39.300	126.200	5.30
59	1004	8	18	1556	38.700	126.600	5.50
60	1043	6	27	1561	39.300	126.500	6.40

(*continued*)

Table 1
Continued

No.	Ref.	Month	Day	Year	Lat. (°N)	Long. (°E)	Mag.
61	1066	5	28	1565	38.800	126.100	7.00
62	1068	9	8	1565	38.800	126.100	5.00
63	1073	9	13	1565	38.800	126.100	5.40
64	1074	9	14	1565	38.800	126.100	5.10
65	1078	9	18	1565	38.800	126.100	5.40
66	1080	9	20	1565	38.800	126.100	5.30
67	1086	9	26	1565	38.800	126.100	5.40
68	1089	9	29	1565	38.800	126.100	5.40
69	1090	10	1	1565	38.800	126.100	5.40
70	1095	10	8	1565	38.800	126.100	5.00
71	1100	10	15	1565	38.800	126.100	5.00
72	1101	10	17	1565	38.800	126.100	5.10
73	1105	10	21	1565	38.800	126.100	5.40
74	1107	10	25	1565	38.800	126.100	5.00
75	1110	10	29	1565	38.800	126.100	5.40
76	1111	10	30	1565	38.800	126.100	5.10
77	1115	11	3	1565	38.800	126.100	5.40
78	1119	11	10	1565	38.800	126.100	5.00
79	1121	11	14	1565	38.800	126.100	5.00
80	1124	11	19	1565	38.800	126.100	5.00
81	1126	11	23	1565	38.800	126.100	5.00
82	1128	11	25	1565	38.800	126.100	5.00
83	1131	11	29	1565	38.800	126.100	5.00
84	1132	12	1	1565	38.800	126.100	5.00
85	1133	12	2	1565	38.800	126.100	5.40
86	1137	12	7	1565	38.800	126.100	5.40
87	1138	12	10	1565	38.800	126.100	5.00
88	1144	12	18	1565	38.800	126.100	5.00
89	1145	12	21	1565	38.800	126.100	5.00
90	1146	12	24	1565	38.800	126.100	5.00
91	1147	12	25	1565	38.900	125.900	5.50
92	1148	12	26	1565	38.900	126.000	5.10
93	1149	12	28	1565	38.900	126.000	5.00
94	1150	12	30	1565	38.900	126.000	5.00
95	1151	1	1	1566	38.900	126.000	5.00
96	1153	1	5	1566	38.900	126.000	5.40
97	1154	1	7	1566	38.900	126.000	5.00
98	1160	1	14	1566	38.900	126.000	5.00
99	1161	1	16	1566	38.900	126.000	5.00
100	1163	1	21	1566	38.900	126.000	5.00
101	1164	1	23	1566	38.900	126.000	5.00
102	1166	1	26	1566	38.900	126.000	5.00
103	1167	1	26	1566	39.500	125.500	5.50
104	1168	1	27	1566	39.100	125.300	5.20
105	1172	6	29	1566	38.700	125.400	5.40
106	1173	11	1	1566	38.800	126.700	5.40
107	1175	11	29	1566	39.000	125.700	5.70
108	1179	3	4	1567	38.900	125.600	5.20
109	1189	9	8	1585	39.100	125.300	5.40
110	1222	12	10	1598	38.900	125.500	5.60
111	1227	3	23	1600	39.000	125.800	5.20
112	1232	10	7	1601	39.000	125.200	5.00
113	1233	11	21	1601	39.000	125.200	5.00
114	1234	11	23	1601	39.000	125.200	5.80
115	1235	11	24	1601	39.000	125.200	5.40
116	1254	1	29	1606	39.300	126.200	5.30
117	1257	1	1	1607	39.000	125.300	5.40
118	1260	9	23	1609	38.600	125.600	5.00
119	1267	12	28	1612	38.800	126.100	5.00
120	1290	3	19	1631	39.000	125.700	5.20
121	1309	2	1	1636	38.900	125.300	5.70

(*continued*)

Table 1
Continued

No.	Ref.	Month	Day	Year	Lat. (°N)	Long. (°E)	Mag.
122	1314			1638	39.000	125.800	5.60
123	1316	11	2	1639	38.900	125.700	5.50
124	1318	2	9	1640	39.200	126.000	5.10
125	1321	11	23	1640	38.700	125.600	5.00
126	1365	10	4	1655	39.000	125.700	5.20
127	1401	9	26	1663	39.200	125.500	5.50
128	1404	6	7	1664	38.900	125.600	5.90
129	1411	7	3	1665	39.000	125.800	5.70
130	1427	9	8	1669	39.000	125.600	5.60
131	1428	10	8	1669	39.100	125.700	6.00
132	1440	1	14	1671	39.000	125.700	5.30
133	1451	3	1	1672	39.000	125.700	5.20
134	1461	10	25	1675	38.600	125.600	5.70
135	1465	5	22	1676	38.900	125.300	5.20
136	1471	2	11	1678	38.600	125.600	5.90
137	1472	2	0	1678	39.000	125.500	5.20
138	1483	1	31	1680	39.500	125.600	5.20
139	1484	2	15	1680	39.500	125.600	5.20
140	1517	2	14	1682	38.700	125.600	5.50
141	1537	5	2	1686	39.000	125.500	6.10
142	1594	9	8	1696	39.000	125.700	5.80
143	1624	10	20	1701	38.700	125.600	5.50
144	1647	2	20	1703	39.400	125.600	5.00
145	1680	10	18	1707	39.000	125.700	5.70
146	1692	3	21	1710	39.000	125.700	5.20
147	1696	11	26	1710	39.000	126.100	6.30
148	1697	11	27	1710	39.200	125.800	6.00
149	1700	4	20	1711	39.000	126.100	6.90
150	1701	4	21	1711	39.000	126.100	6.40
151	1704	5	7	1711	39.000	125.300	5.30
152	1706	5	2	1711	39.100	126.100	5.60
153	1707	5	31	1711	39.200	125.700	5.80
154	1718	9	24	1712	39.000	125.700	5.60
155	1719	10	2	1712	39.000	125.700	5.30
156	1723	3	27	1713	39.000	125.700	5.70
157	1729	3	7	1714	38.800	126.700	6.70
158	1754	12	3	1721	39.000	125.700	5.20
159	1757	1	5	1723	39.000	125.700	5.90
160	1769	4	16	1726	38.500	125.800	5.70
161	1770	4	27	1726	39.000	125.700	5.80
162	1788	9	15	1734	38.800	126.100	5.00
163	1796	6	24	1742	39.300	125.800	5.70
164	1934	2	5	1926	39.000	126.500	5.00
165	2026	3	16	1937	38.500	125.700	5.30
166	2054	6	20	1940	38.500	126.000	5.30
167	2075	3	19	1952	39.000	125.500	6.30
168	2087	2	26	1960	38.900	125.800	5.10

*The largest historical event that has occurred in this region.

sequence, which had a mainshock of 7.0 and was followed by about 30 aftershocks with magnitude larger than 5.0 within the next 7 months. The most recent large earthquake in the region occurred on 19 March 1952 with a magnitude of 6.3. Thus, the spatial patterns of seismic rate and relative seismic energy release over historical time may suggest that the potential for future damaging earthquakes in the region is high.

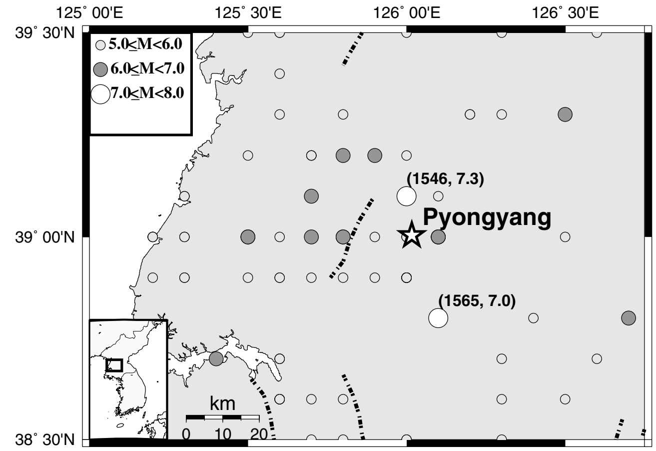

Figure 10. Historical seismicity near the Pyongyang region showing scattered epicenter locations. In total, there are 168 events with magnitude larger than 5.0. The largest historical earthquake in the region occurred on 30 June 1546 with a magnitude of 7.3.

Seoul Region

The area around Seoul, the largest city and an important economic and political center, is among one of the most seismically active regions in historical times. As shown in Figure 11, there have been 130 events with magnitude larger than 5.0, 18 events with magnitude larger than 6.0, and 5 events with magnitude larger than 7.0 (Table 2). The largest event in the region was a magnitude 7.5 event that occurred on 2 July 1518 slightly to the northwest of Seoul. Two magnitude 7.0 earthquakes occurred in 1260 and 1385, apparently adjacent to each other to the west of Kaesong, near the border between North and South Korea (Fig. 11). Another two magnitude 7.0 earthquakes occurred in the years of 27 and 89, at approximately the same location, about 15 km to the southeast of Seoul (Fig. 11). The most recent significant earthquake in this region occurred in 1906 with a magnitude of 6.0 at the estuary of the Han River near the border between North and South Korea. Historical seismicity seems to orient along a northwest–southeast trend.

Pusan Region

Seismicity near Pusan is the highest in the entire Korean Peninsula, especially for large historical earthquakes. As shown in Figure 12, there were 208 events with magnitude larger than 5.0, 28 events with magnitude larger than 6.0, and 6 earthquakes with magnitude larger than 7.0. The largest event, with magnitude 7.3, occurred in April 779 about 60 km to the northeast of Pusan, where another magnitude 7.0 earthquake occurred in 1643. Two magnitude 7.0 earthquakes occurred in 100 and 1036, probably colocated about 130 km north of Pusan. An earthquake of magnitude 7.1 occurred near the city of Pusan in 1643. The most recent significant earthquake in the region occurred in 1943 (magnitude 6.0), immediately to the north of a magnitude 7.0

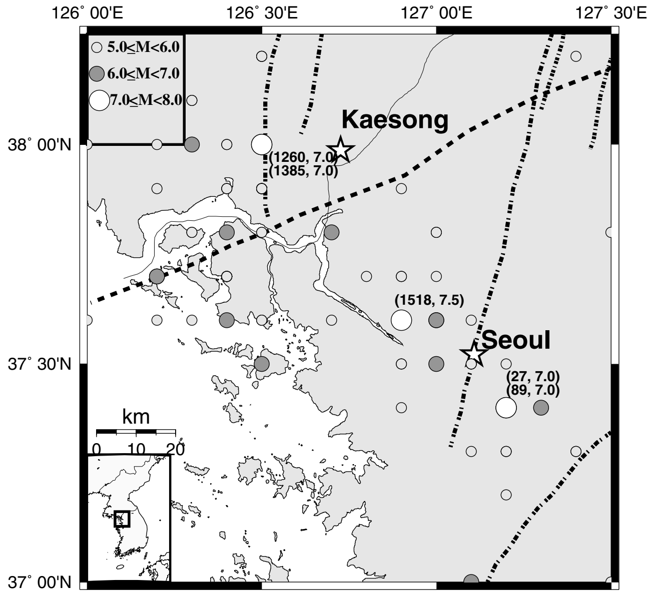

Figure 11. Historical seismicity near Seoul. In total, there are 130 events with magnitude larger than 5.0. The largest historical earthquake in the region occurred on 2 July 1518 with a magnitude of 7.5.

earthquake that occurred in 1036. Although earthquake locations from the historical catalog are not accurate, the coincidence of large earthquakes aligned with the known surface lineaments and faults is a strong suggestion of active faulting during historical times.

Discussions and Conclusions

The historical earthquake catalog of Korea was compiled from felt reports in historical documents (Li, 1986; Kim and Gao, 1995; Lee, 1999). The information in the catalog may be significantly affected by the population distribution at the times of the events. However, historical seismicity over a long period of time can provide adequate information for estimation of the recurrence rate for earthquakes of various magnitude in the active regions. For example, the annual probability of a magnitude 5.0 or larger earthquake occurring in the regions of Seoul, Pyongyang, and north of Pusan can be estimated approximately to be around 1%, 2%, and 3%, respectively.

It is important to understand that seismic hazard cannot be viewed simply from the seismic rate alone. Some regions may be characterized by many small earthquakes and no large ones, while other regions may be characterized by rare large damaging events but few smaller ones. Estimation of relative seismic energy release over historical time has provided a better representative view of what has happened in the past, which may also lead to a prospect of what is to be expected in the future in the region. Furthermore, we understand that earthquakes can happen in places with no record of previous historical earthquake activity. The recent

Table 2
Historical Earthquake Locations near the Seoul Region in the Korean Peninsula between A.D. 2 and 1995, Magnitude ≥5.0

No.	Ref.	Month	Day	Year	Lat. (°N)	Long. (°E)	Mag.
1	2	5	0	13	37.400	127.200	5.70
2	3	5	0	13	37.400	127.200	5.00
3	5	12	0	27	37.400	127.200	7.00
4	7	12	0	37	37.400	127.200	5.30
5	9	7	0	89	37.400	127.200	7.00
6	10	12	0	89	37.400	127.200	5.30
7	13	4	0	111	37.400	127.200	5.30
8	14	12	0	111	37.400	127.200	5.30
9	22	8	0	199	37.400	127.200	5.30
10	35	8	0	372	37.600	127.000	5.30
11	40	12	0	429	37.600	127.000	5.30
12	102	12	6	971	37.800	126.500	5.30
13	103	3	0	972	37.800	126.500	5.30
14	162	11	5	1226	38.000	126.500	6.70
15	164	3	6	1227	38.000	126.500	5.90
16	165	3	19	1227	38.000	126.500	5.90
17	169	2	14	1235	37.700	126.400	5.00
18	170	12	26	1246	37.700	126.400	5.00
19	171	9	24	1254	37.700	126.400	5.00
20	172	4	0	1255	37.700	126.400	5.00
21	174	4	1	1258	37.700	126.400	5.00
22	175	8	0	1258	37.700	126.400	5.00
23	176	1	2	1260	37.700	126.400	5.00
24	177	7	30	1260	38.000	126.500	7.00
25	181	7	27	1261	37.900	126.500	5.90
26	183	11	17	1264	38.000	126.500	5.70
27	184	3	18	1270	37.900	126.500	5.90
28	194	6	8	1293	37.600	126.400	6.80
29	195	9	18	1293	37.800	126.400	5.00
30	196	11	28	1293	37.800	126.400	5.00
31	198	3	4	1308	37.900	126.400	5.90
32	208	6	28	1338	38.000	126.300	6.10
33	209	7	7	1338	38.000	126.300	5.80
34	211	7	18	1338	38.000	126.300	5.50
35	217	4	10	1343	37.800	126.400	5.80
36	218	4	14	1343	37.800	126.400	5.60
37	220	6	24	1343	37.800	126.400	5.60
38	222	2	19	1345	37.800	126.400	5.60
39	224	7	7	1352	37.900	126.400	5.90
40	226	8	13	1355	38.000	126.400	5.80
41	227	11	5	1357	38.000	126.400	5.90
42	235	11	27	1362	37.900	126.400	5.60
43	243	6	29	1366	37.900	126.500	5.90
44	244	7	10	1366	37.900	126.500	5.90
45	245	11	15	1366	37.800	126.400	5.80
46	251	12	19	1374	37.900	126.500	5.90
47	252	6	12	1376	37.900	126.500	5.90
48	254	12	10	1378	37.900	126.500	5.50
49	256	1	28	1380	37.800	126.400	5.10
50	259	9	1	1385	38.000	126.500	7.00
51	260	9	2	1385	38.000	126.000	5.00
52	262	1	13	1387	38.000	126.500	5.10
53	285	5	19	1408	37.600	127.000	5.80
54	439	5	17	1452	37.600	127.000	5.30
55	511	2	9	1500	37.200	126.200	5.30
56	524	7	14	1503	37.000	127.100	6.00
57	558	9	27	1515	38.200	127.400	5.60
58	561	3	3	1516	37.600	127.000	5.20
59	569	8	5	1516	37.300	127.100	5.70
60	588	7	2	1518	37.600	126.900	7.50*

(continued)

Table 2
Continued

No.	Ref.	Month	Day	Year	Lat. (°N)	Long. (°E)	Mag.
61	589	7	3	1518	37.500	127.000	6.50
62	590	7	4	1518	38.000	126.300	5.40
63	591	7	5	1518	37.500	127.100	5.50
64	593	7	8	1518	38.000	126.500	5.70
65	595	7	17	1518	37.500	127.200	5.70
66	601	10	20	1518	37.600	126.400	5.40
67	622	5	17	1519	37.700	126.900	5.20
68	647	3	27	1520	37.600	126.000	5.00
69	651	4	14	1520	37.700	126.200	6.00
70	659	5	4	1520	37.500	126.500	5.20
71	681	4	26	1521	38.000	126.200	5.70
72	755	11	21	1526	37.300	127.400	5.50
73	789	11	29	1528	37.800	127.000	5.10
74	837	2	8	1542	37.400	127.300	6.40
75	847	6	23	1542	37.600	126.200	5.10
76	858	3	11	1543	37.500	126.500	6.20
77	893	10	19	1546	38.200	126.500	5.20
78	947	7	11	1550	37.600	127.000	5.30
79	951	2	4	1552	37.400	126.900	5.20
80	968	3	4	1554	38.100	126.300	5.20
81	995	1	29	1556	37.800	126.400	6.40
82	997	3	28	1556	38.100	126.300	5.50
83	1008	1	13	1557	38.200	126.500	5.10
84	1017	6	9	1557	37.500	127.100	5.20
85	1026	11	21	1557	37.600	127.000	5.00
86	1028	12	30	1557	37.500	127.100	5.70
87	1052	3	7	1564	37.900	126.900	5.40
88	1193	1	28	1590	37.600	127.000	5.30
89	1194	1	12	1591	37.600	127.000	6.70
90	1196	7	13	1594	37.700	126.900	5.40
91	1197	7	18	1594	37.600	127.000	5.00
92	1209	9	22	1596	37.600	127.000	5.20
93	1242	1	9	1604	37.000	127.500	5.20
94	1252	12	19	1604	37.600	126.700	5.20
95	1269	7	16	1613	37.600	127.000	6.50
96	1271	10	28	1616	37.600	127.000	5.60
97	1272	10	31	1616	37.600	127.000	5.40
98	1275	1	29	1618	37.600	127.000	5.50
99	1278	12	22	1621	37.600	127.000	5.20
100	1282	1	5	1624	37.500	126.900	5.40
101	1297	2	26	1632	37.800	126.700	6.50
102	1306	2	9	1635	37.600	127.000	5.30
103	1343	1	15	1648	37.800	127.000	5.00
104	1420	9	9	1667	37.800	126.300	5.60
105	1434	4	10	1670	37.800	126.300	5.00
106	1478	10	30	1678	37.400	127.300	5.00
107	1494	6	20	1681	37.600	126.900	5.70
108	1508	7	31	1681	37.300	127.200	5.50
109	1509	8	1	1681	37.300	127.200	5.10
110	1531	9	18	1684	38.200	126.500	5.20
111	1552	7	17	1689	37.600	127.000	5.20
112	1564	12	21	1692	37.900	126.200	5.10
113	1579	1	25	1695	37.800	127.500	5.10
114	1582	8	22	1695	37.500	126.500	5.80
115	1591	4	16	1696	37.200	127.200	5.10
116	1673	1	3	1707	37.600	126.500	5.90
117	1682	1	2	1708	37.600	126.500	5.50
118	1683	8	17	1708	37.700	127.000	5.30
119	1724	4	27	1713	37.600	127.000	5.30
120	1735	4	21	1715	37.300	127.400	5.10
121	1749	6	20	1719	37.600	126.300	5.70

(*continued*)

Table 2
Continued

No.	Ref.	Month	Day	Year	Lat. (°N)	Long. (°E)	Mag.
122	1752	4	9	1721	37.500	126.900	5.00
123	1764	7	24	1724	37.600	127.100	5.00
124	1814	10	31	1751	37.600	127.000	5.00
125	1828	2	27	1784	37.600	127.000	5.00
126	1832	4	5	1838	37.600	127.000	5.00
127	1839	1	0	1883	37.600	127.000	5.00
128	1840	11	0	1888	37.600	127.000	5.00
129	1858	4	6	1906	37.700	126.200	6.00
130	2022	1	25	1937	37.700	126.800	5.30

*The largest historical event that has occurred in this region.

damaging Killari earthquake (M_s 6.4, National Earthquake Information Center; M_w 6.1, Seeber *et al.*, 1996) occurred in 1993 in central India, where the earthquake probability is extremely low (e.g., Gupta, 1993; Seeber *et al.*, 1996).

In summary, the historical earthquake catalog for the Korean Peninsula provides an important constraint for the identification of areas of high seismic hazard. The Seoul–Pyongyang seismic zone is characterized by high seismicity and high relative seismic energy release over historical time. The eastern seismic zone is characterized by low seismicity but high relative seismic energy release, while the seismic zone north of Pusan is characterized by high seismicity and high relative seismic energy release. A few significant earthquakes with magnitude larger than 7.0 have occurred in historical times adjacent to the Pyongyang, Seoul, and Pusan regions. It is unavoidable that many critical facilities have been and will be constructed near the largely populated cities of Pyongyang, Seoul, and Pusan. Our study has clearly demonstrated that a few regions of high seismic hazard can be identified from analysis of the historical earthquake catalog. The location of important economic centers and critical facilities in the areas of higher seismic hazard makes stringent seismic requirements in building codes essential. The regions of high seismicity and high relative seismic energy release should be either avoided or reinforced with a higher standard of building codes.

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Table 3
Historical Earthquake Locations near the Pusan Region in the Korean Peninsula between A.D. 2 and 1995, Magnitude ≥5.0

No.	Ref.	Month	Day	Year	Lat. (°N)	Long. (°E)	Mag.
1	6	3	0	34	35.900	129.300	6.70
2	8	1	0	65	35.900	129.300	5.30
3	11	11	0	93	35.900	129.300	5.00
4	12	12	0	100	35.900	129.300	7.00
5	17	11	0	128	35.900	129.500	5.70
6	21	8	0	170	35.900	129.300	5.00
7	24	10	0	229	35.900	129.300	5.30
8	25	12	0	246	35.900	129.300	5.00
9	33	10	0	304	35.900	129.300	6.00
10	34	10	0	304	35.900	129.300	6.70
11	37	6	0	388	35.900	129.300	5.00
12	38	8	0	388	35.900	129.300	5.00
13	39	12	0	406	35.900	129.300	5.00
14	41	3	0	458	35.900	129.300	6.00
15	42	4	0	471	35.900	129.300	6.30
16	43	11	0	479	35.900	129.300	5.00
17	46	6	0	510	35.900	129.300	6.70
18	49	1	0	540	35.900	129.300	5.30
19	51	11	0	615	35.900	129.300	5.30
20	53	4	0	633	35.900	129.300	5.00
21	56	4	0	664	35.700	129.200	5.30
22	57	9	12	664	35.600	129.300	7.00
23	58	3	0	666	35.900	129.300	5.00
24	60	2	0	671	35.900	129.300	5.00
25	61	2	0	673	35.900	129.300	5.30
26	62	6	0	681	35.900	129.300	5.30
27	63	11	0	695	35.900	129.300	5.00
28	64	4	0	698	35.900	129.300	5.70
29	65	3	0	708	35.900	129.300	5.70
30	66	2	0	710	35.900	129.300	5.70
31	67	6	0	717	35.900	129.300	5.30
32	68	4	0	718	35.900	129.300	5.30
33	69	3	0	720	35.900	129.300	5.30
34	70	3	0	722	35.900	129.300	5.00
35	71	5	0	723	35.900	129.300	5.30
36	72	11	0	725	35.900	129.300	5.70
37	73	3	0	737	35.900	129.300	5.30
38	74	6	0	737	35.900	129.300	5.30
39	75	3	0	742	36.000	129.300	5.30
40	76	9	0	743	35.900	129.300	5.30
41	77	5	0	765	35.900	129.300	5.30
42	78	7	0	767	35.900	129.300	5.30
43	79	8	0	768	35.900	129.300	6.00
44	80	12	0	770	35.900	129.300	5.00
45	81	5	0	777	35.900	129.300	5.70
46	82	5	0	777	35.900	129.300	5.00
47	83	4	0	779	35.900	129.300	7.30*
48	84	3	0	787	35.900	129.300	5.70
49	85	12	0	791	35.900	129.300	5.00
50	86	3	0	794	35.900	129.300	5.30
51	87	8	0	802	35.900	129.300	5.30
52	88	5	0	803	35.900	129.300	5.30
53	89	11	0	803	35.900	129.300	5.30
54	90	12	0	805	35.900	129.300	5.30
55	91	3	0	831	35.900	129.300	5.30
56	92	7	0	839	35.900	129.300	5.30
57	93	0	0	844	35.900	129.300	5.30
58	94	5	0	870	35.900	129.300	5.00
59	95	5	0	872	35.900	129.300	5.00
60	96	3	0	875	35.900	129.500	5.70

(*continued*)

Table 3
Continued

No.	Ref.	Month	Day	Year	Lat. (°N)	Long. (°E)	Mag.
61	97	5	0	913	35.900	129.300	5.30
62	98	11	0	916	35.900	129.300	5.70
63	99	3	0	928	35.900	129.300	5.30
64	100	6	26	928	35.900	128.300	6.20
65	101	2	0	932	35.900	129.300	5.30
66	107	4	3	1012	35.900	129.300	5.00
67	108	2	3	1013	35.900	129.300	5.00
68	109	4	10	1013	35.900	129.300	5.00
69	110	5	3	1013	35.100	128.800	5.00
70	111	12	31	1013	35.100	128.800	5.00
71	112	2	7	1014	35.300	129.000	5.90
72	113	9	26	1014	35.900	129.300	5.00
73	114	1	17	1016	35.900	129.300	5.00
74	116	0	0	1022	35.300	129.000	5.90
75	117	6	9	1023	35.300	129.000	5.70
76	119	5	25	1025	35.900	128.300	5.80
77	120	5	26	1025	35.900	128.300	5.00
78	121	5	29	1025	35.900	128.300	5.30
79	122	8	9	1025	35.900	128.400	6.40
80	125	7	13	1033	36.000	128.500	5.80
81	128	11	1	1035	35.900	129.300	6.30
82	129	7	23	1036	35.900	129.300	7.00
83	130	9	21	1036	35.900	129.300	6.30
84	279	4	9	1406	35.600	128.700	5.30
85	288	12	20	1410	35.200	129.000	6.10
86	314	12	22	1421	35.900	128.300	5.40
87	338	3	9	1425	35.900	128.300	5.50
88	344	10	14	1427	36.000	129.300	6.60
89	360	3	12	1430	35.700	128.700	5.30
90	362	3	21	1430	35.200	129.000	5.30
91	365	10	9	1430	36.000	128.800	5.90
92	369	3	19	1431	35.700	128.500	5.90
93	371	6	23	1431	35.200	129.200	5.40
94	376	11	19	1432	35.900	128.300	5.00
95	394	3	24	1438	35.900	128.600	6.10
96	397	2	25	1439	35.900	128.600	5.00
97	464	3	17	1457	36.200	128.700	5.30
98	476	1	5	1463	35.300	128.400	5.40
99	480	9	28	1465	35.200	128.900	5.10
100	482	12	23	1467	35.900	128.900	5.20
101	484	9	14	1471	35.100	128.800	5.20
102	490	8	6	1478	35.900	128.600	5.40
103	491	4	7	1480	35.200	128.900	5.20
104	494	7	25	1482	35.100	128.800	5.30
105	506	7	9	1498	35.800	128.500	5.40
106	507	7	11	1498	35.800	128.500	5.10
107	522	1	30	1503	36.100	128.400	5.00
108	540	10	6	1511	36.200	128.600	5.20
109	547	5	16	1512	35.800	128.700	5.20
110	557	3	29	1515	35.100	128.900	5.40
111	568	6	7	1516	36.100	129.600	5.80
112	646	3	24	1520	35.900	128.300	5.10
113	649	4	4	1520	35.200	128.600	5.30
114	687	10	4	1521	35.500	129.300	5.60
115	691	1	22	1522	35.200	128.900	5.20
116	713	12	20	1523	35.500	129.300	5.80
117	722	2	6	1525	35.800	129.300	5.40
118	729	4	22	1525	35.000	128.300	5.50
119	731	5	7	1525	35.200	128.600	5.80
120	743	11	12	1525	35.400	128.900	5.20
121	753	9	24	1526	35.800	129.200	5.90

(*continued*)

Table 3
Continued

No.	Ref.	Month	Day	Year	Lat. (°N)	Long. (°E)	Mag.
122	757	12	25	1526	35.300	129.200	5.50
123	770	11	8	1527	35.500	128.500	5.00
124	808	1	30	1531	35.500	128.500	5.20
125	820	5	17	1532	35.600	128.700	5.10
126	821	5	26	1532	35.200	128.600	5.50
127	823	11	10	1532	35.200	129.200	5.90
128	839	2	20	1542	35.500	128.700	5.30
129	840	2	23	1542	35.900	129.500	5.20
130	854	2	15	1543	35.900	128.600	5.00
131	863	12	3	1543	35.900	128.600	5.00
132	871	11	1	1545	35.300	128.600	5.70
133	872	11	4	1545	35.300	128.600	5.30
134	875	5	29	1546	36.200	128.700	5.30
135	912	7	16	1547	35.900	128.300	5.10
136	926	10	2	1548	35.500	129.100	5.70
137	928	11	27	1548	35.500	128.700	5.90
138	945	4	22	1550	35.800	128.700	5.70
139	966	3	4	1554	35.600	128.600	5.30
140	972	9	28	1554	35.200	128.900	5.50
141	981	1	19	1555	35.900	128.300	5.10
142	984	2	18	1555	35.700	129.200	5.70
143	985	3	12	1555	36.000	128.500	6.00
144	988	5	24	1555	35.800	129.300	5.40
145	998	3	29	1556	35.300	128.400	5.90
146	1018	6	9	1557	35.900	128.600	6.10
147	1041	1	21	1560	36.000	128.300	5.80
148	1055	6	18	1564	35.800	129.100	5.60
149	1127	11	24	1565	35.400	128.800	5.50
150	1195	7	1	1594	35.900	128.600	5.50
151	1246	3	4	1604	36.000	128.700	5.70
152	1248	5	3	1604	36.000	129.300	5.30
153	1258	1	1	1607	36.000	128.700	5.90
154	1293	5	17	1631	35.900	128.300	5.60
155	1317	1	3	1640	35.600	129.300	5.80
156	1326	6	11	1641	36.100	128.400	5.80
157	1332	11	13	1641	35.200	129.100	5.70
158	1334	5	30	1643	35.100	129.000	7.10
159	1336	7	24	1643	35.500	129.300	7.00
160	1340	7	6	1647	35.600	128.800	5.40
161	1350	3	12	1650	35.800	129.200	5.30
162	1351	3	19	1650	35.500	128.800	5.40
163	1356	10	10	1652	35.900	128.600	5.30
164	1360	11	18	1654	35.900	128.600	5.30
165	1361	11	24	1654	35.900	128.500	5.30
166	1371	12	15	1657	35.900	128.600	5.20
167	1395	6	5	1662	35.900	128.300	6.00
168	1403	3	24	1664	35.000	128.300	5.60
169	1413	1	12	1666	35.900	128.300	5.70
170	1417	3	3	1667	36.200	128.700	5.20
171	1418	5	1	1667	35.100	129.100	6.40
172	1437	8	10	1670	35.200	129.000	5.00
173	1519	5	1	1682	36.000	128.600	5.20
174	1543	9	28	1687	35.300	128.300	5.60
175	1545	1	17	1688	35.600	128.700	5.40
176	1551	12	29	1688	35.900	129.500	5.20
177	1574	3	6	1694	35.700	128.400	5.70
178	1576	3	13	1694	35.700	128.400	5.70
179	1577	5	1	1694	35.800	129.200	5.20
180	1588	3	19	1696	35.900	128.600	5.70
181	1590	4	1	1696	35.900	128.600	5.70
182	1603	6	11	1698	36.100	128.400	5.00

(*continued*)

Table 3
Continued

No.	Ref.	Month	Day	Year	Lat. (°N)	Long. (°E)	Mag.
183	1604	12	31	1698	35.600	128.800	5.10
184	1607	7	16	1699	35.900	128.600	5.00
185	1608	7	17	1699	35.900	128.300	5.80
186	1609	7	19	1699	35.900	128.300	5.10
187	1610	7	22	1699	35.900	128.300	5.10
188	1636	8	26	1702	35.900	128.400	6.90
189	1637	9	5	1702	35.900	128.400	6.20
190	1638	9	11	1702	35.900	128.500	5.20
191	1654	1	16	1704	35.900	128.500	5.00
192	1655	1	18	1704	36.000	128.900	5.80
193	1663	11	19	1704	35.100	128.700	5.30
194	1670	11	20	1705	35.900	128.600	5.00
195	1678	4	2	1707	36.000	128.400	5.70
196	1691	3	11	1710	35.800	129.200	5.30
197	1694	5	30	1710	35.600	128.700	5.30
198	1720	10	19	1712	35.900	128.300	5.10
199	1725	7	23	1713	35.900	128.600	5.20
200	1733	11	18	1714	35.900	128.600	5.10
201	1740	10	0	1716	35.200	128.900	5.20
202	1745	2	2	1717	35.800	128.900	6.00
203	1784	5	11	1733	35.100	128.800	5.50
204	1800	3	25	1743	35.500	129.300	5.10
205	1823	8	30	1760	36.100	128.400	5.70
206	1824	1	4	1762	35.900	128.300	5.10
207	2041	8	3	1939	35.600	129.500	5.60
208	2068	7	1	1943	36.000	129.500	6.00

*The largest historical event that has occurred in this region.

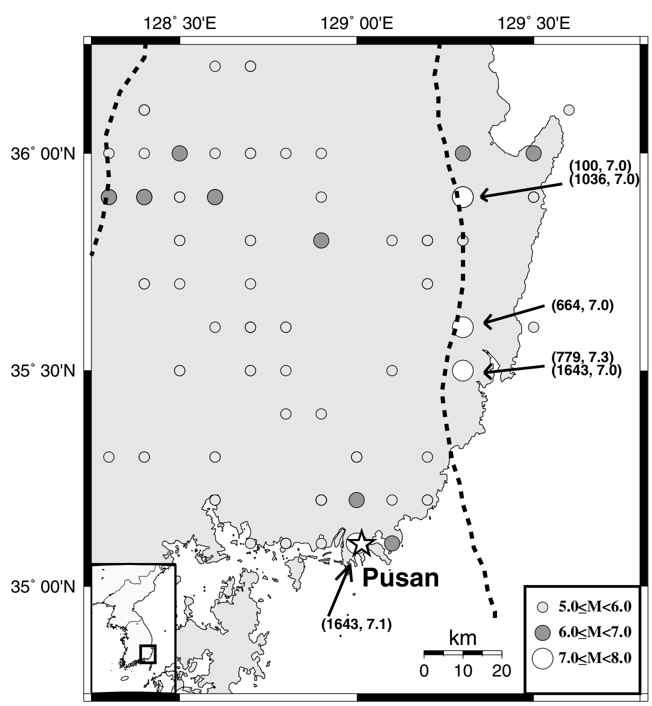

Figure 12. Historical seismicity near Pusan. In total, there are 208 events with magnitude larger than 5.0. The largest historical event in the region occurred in April 779 with a magnitude of 7.3.

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