Possibility of Earthquake Prediction Using Historical Earthquakes in the Pyeongnam Basin

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1. Introduction

Earthquake is one of major natural hazards which causes fatal damage to humanity. Numbers of destructive earthquakes have occurred over the world and killed people and destroyed structures since the beginning of civilization. The most effective countermeasure to earthquake disaster is predicting earthquakes beforehand. The effort to predict future earthquake has been continued to date though it has not been successful in most cases. The general practice in earthquake prediction study is to study precursory phenomena such as foreshocks, changes in seismic velocity, electric conductivity, and emission of radon, etc. These precursory phenomena are related to dilatancy progressing before major ruptures start on active faults. It has been generally acknowledged the variation of seismicity associated with major earthquakes, especially foeshocks, is the most promising and reliable precursor.

Korean historical literatures documented almost two thousand seismic records over the last two thousand years; among them, a number of records indicate earthquakes of Modified Mercalli Intensity (MMI) greater than or equal to VIII. This fact suggests that destructive earthquakes of that size may occur in Korean peninsula at any time in the future. This study aims at looking into the possibility of earthquake prediction based on the seismicity variation associated with large historical earthquakes of MMI $\geq$ VIII in the peninsula. Since large earthquakes generally accompany small foreshocks, we examined these foreshocks in the hope to find some indicator useful earthquake prediction. In this preliminary study, we used Lee's (2004) historical data for earthquakes occurred in the Pyeongnam Basin.

2. Historical Earthquakes in the Pyeongnam Basin

Pyeongnam Basin occupies the southern portion of North Korea and is composed of Paleozoic deposits overlying precambrian basement. The Songrim Disturbance during the Mesozoic severely disrupted the crustal layers of this region and many historical earthquakes were reported to have occurred in the basin. In this basin, 486 earthquakes over MMI IV are registered in Korean historical literatures. Three largest earthquakes of MMI IX occurred in this basin is listed in Table 1. The b-value in the frequency - intensity relation for the historical earthquakes in the Pyeongnam basin turns out to be 0.41.

Table 1. Great earthquakes of MMI IX occurred in the Pyeongnam basin.

No.	year	month	day	latitude	longitude	intensity
1	1518	7	2	38.2	126.1	IX
2	1546	6	30	38.9	126.4	IX
3	1713	3	7	38.3	126.0	IX

3. Precursory Seismicity

It is generally known that b-value in the frequency-magnitude relation is lowered before the occurrence of great earthquakes (Bogdan and Kiyoshi, 2001). Previous studies indicate the average precursory period for earthquakes of MMI IX, is about 23 years (Rikitake, 1975). The intensity of Korean historical earthquakes was converted to magnitude by the formula of Lee and Lee (2003). The b-values during the precursory periods of the three MMI IX earthquakes in the Pyeongnam Basin are 0.29, 0.26 and 0.25, respectively. The b-value for the whole data of these three MMI IX earthquakes turns out to be 0.27 (Figure 1), in comparison to 0.41 for the whole historical earthquakes of MMI $\geq$ IV in the Pyeongnam Basin. This result clearly indicates that the b-value is lowered before large earthquake in Korea in line with other seismic regions over the world. Accordingly, the variation of b-value may be used in the earthquake prediction study in Korea.

Intensive occurrence of earthquakes before great earthquakes are reported worldwide (Wyss and Fu, 1989). These earthquakes can be classified as foreshocks. For the historical earthquakes of MMI $\geq$ IV in the Pyeongnam basin, the occurrence of earthquakes showed a S-shaped recurrence pattern for events of MMI $\geq$ VII (Figure 2). The S-shaped recurrence pattern in Figure 2 represents decrease-increase-decrease sequence of the frequency of earthquakes. For example, before the event in 1227 the recurrence rate

increased for more than 5 years. The increased rate of released energy by earthquakes before the 1386 event can also be seen in Figure 2. These phenomena can be interpreted as following sequences: 1) the seismic quiescence period in which the frequency decreases below the background level; 2) the period of increasing frequency before the main great earthquake; 3) the period following aftershocks in which frequency returns to the background level. Appropriate treatment applied, this phenomena can be used for earthquake prediction study in Korea.

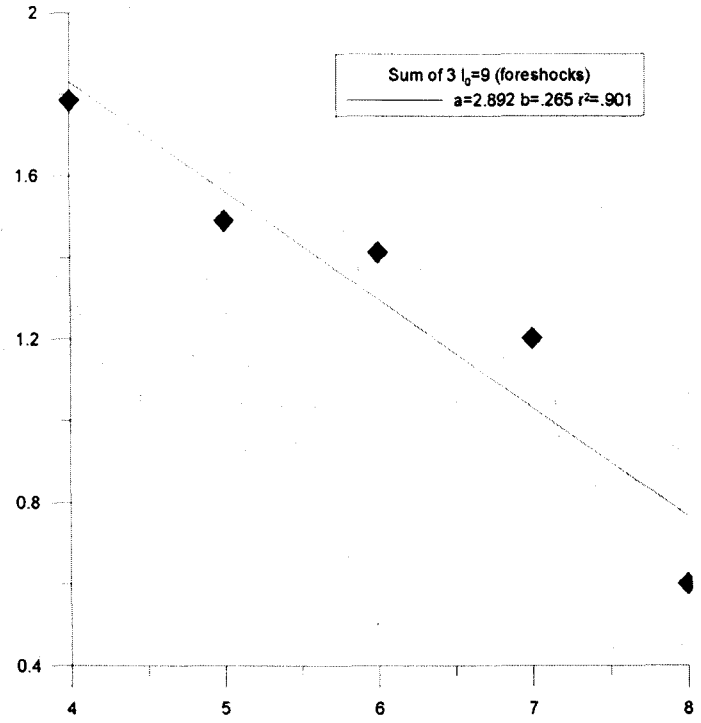

Fig. 1. The distribution of cumulative frequency of earthquakes with the intensity during the precursory period of 23 years for three great earthquakes of MMI IX in the Pyeongnam Basin.

These results suggest that judicious analyses of the variation of seismicity can be applied to earthquake prediction studies in Korea. The drop of b-value and intensive occurrence of earthquakes before large earthquakes as observed in Korean historical earthquakes in line with other seismic regions of the world may be useful precursors in earthquake prediction. Appropriate methods to analyse these precursors may be one of future research topics in earthquake prediction.

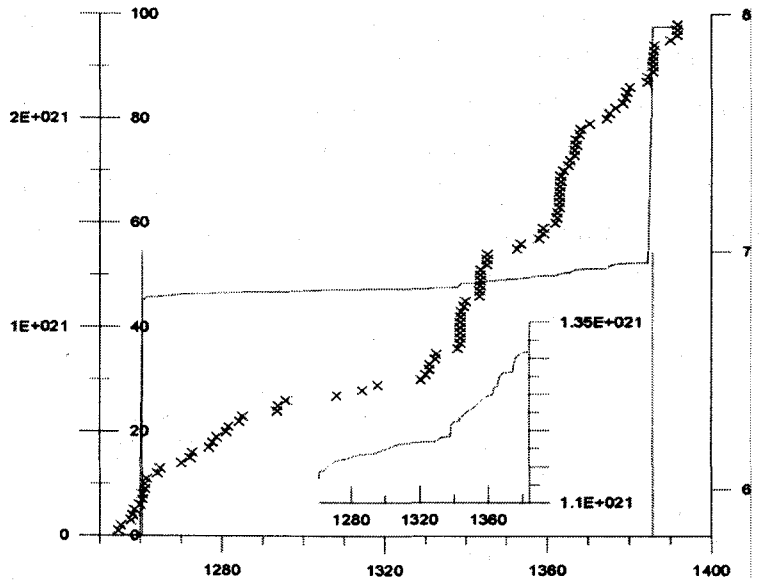

Fig. 2. The recurrence pattern of earthquakes from 1250 to 1400 is illustrated with the occurrence of MMI VII earthquakes. The released energy by earthquakes of MMI ≧ V is also illustrated. The inset shows the activation of releasing energy before the occurrence of great earthquake.

4. Predicting Earthquakes

Precursors of great earthquakes in the Pyeongnam basin are recognized to be valid. To predict a great earthquake, some precursory seismicity which tells its coming must be monitored with time. Monitoring the b-value within certain fixed periods, for example, two or three years, may be one of such methods. The calculated b-values from 1200 to 1750 for two and three years are illustrated with the occurrence of MMI ≥ IV earthquakes in Figure 3. It can be noticed that no MMI ≥ VII earthquakes occurred during the period when b-value is equal to or greater than 0.4. And the three great earthquakes of MMI IX occurred during the period when the b-value is dropped down to about 0.1.

Another way of predicting earthquakes is to monitor the frequency of earthquakes. Increasing frequency of earthquakes can be a precursor of great earthquakes (Maeda, 1996). This phenomenon is confirmed to be valid for the earthquakes in the Pyeongnam basin. The intensification of earthquake occurrence before a great earthquake can be shown by the frequency of earthquakes during certain period. The number of earthquakes during certain period is analysed using the historical earthquakes in the Pyeongnam basin. For the historical earthquakes of MMI ≥VII in the Pyeongnam Basin, the frequency scored relatively high value, that is, greater than 3 during past three years

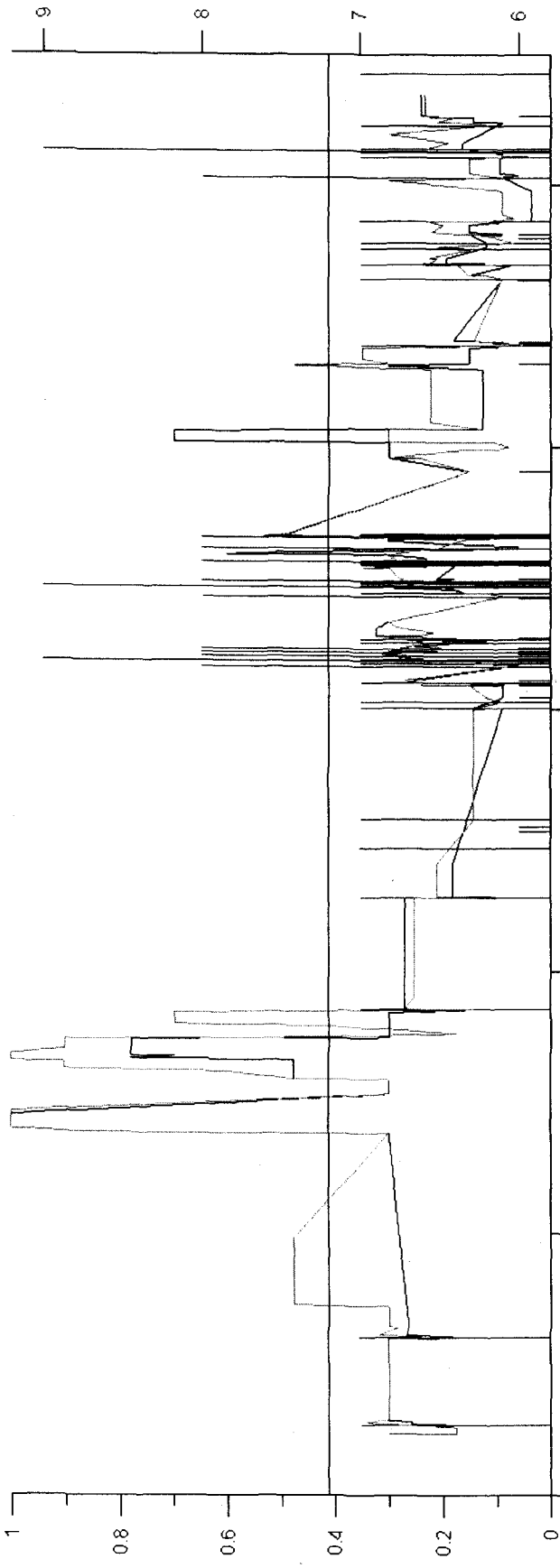

Fig. 3. The b-values during past 2 and 3 years from 1250 to 1750 are plotted as blue and green lines, respectively, with the occurrence of great earthquakes.

(Figure 4). However, this method is not as accurate as the method of b-value variation. In many cases, the frequency increased to relatively high value without occurrence of a great earthquake, may be due to swarms in the region. Also it may be due to the too large region considered to monitor the variation of frequency of earthquakes. If the appropriate foreshock areas for large earthquakes are defined in the Korean peninsula, this method may be used in earthquake prediction study.

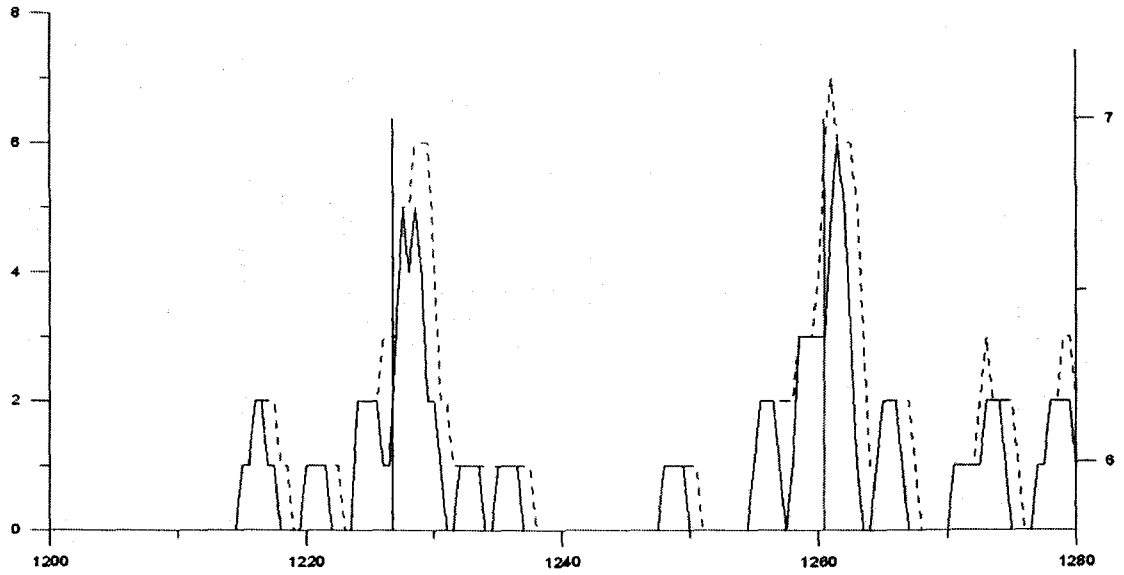

Fig. 4. The frequency of earthquakes during 2 and 3 years from 1200 to 1280 are illustrated as solid and dotted lines, respectively, with the occurrence of the great earthquakes.

5. Conclusion:

For historical earthquakes in Pyeongnam Basin, some precursors of great earthquakes such as the decrease of b-value and increase of earthquake frequency are verified. Judicious analyses of these precursors may shed some light into the difficult but important problem of earthquake prediction in Korea. By carefully refining important parameters such as precursory period and foreshock region, the precursors in seismicity may turn out to be more reliable. This study is rather limited and of preliminary nature, but encouraging in some respect, in using earthquake data in earthquake prediction in Korea. Conscientious works in this direction are needed in the future to define more reliable precursory indicators in earthquake prediction.

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