# Preliminary Estimation of Gutenberg-Richter Parameters for South Korea

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## 1. Introduction

With the occurrence of the 2016 Gyeongju and 2017 Pohang earthquakes, South Korea has been on high alert for potential large earthquakes and their associated strong ground motions [1-2]. Prior to these events, the earthquake record was relatively sparse with few large magnitude events. Table I lists the largest earthquakes, in terms of local magnitude, $M_L$, in the past 45 years. The table shows 8 earthquakes with $M_L \geq 5.0$ occurred since 1978, when South Korea started making instrumented recordings of earthquake ground motions. This suggests relatively large earthquakes occurring every 5.6 years on average, although the events seem to be clustered around 1978, 2003, and 2016.

Table I: Gutenberg-Richter parameters for each zone.

| Name | Date | $M_L$ |
|---|---|---|
| Sangju | 1978-09-16 | 5.2 |
| Hongseong | 1978-10-07 | 5.0 |
| Ongjin | 2003-03-30 | 5.0 |
| Uljin | 2004-05-29 | 5.2 |
| Taean | 2014-04-01 | 5.1 |
| Ulsan | 2016-07-05 | 5.0 |
| Gyeongju | 2016-09-12 | 5.8 |
| Pohang | 2017-11-15 | 5.4 |

The sparsity of earthquake data makes it difficult to conduct an appropriate seismic safety assessment for the many nuclear power plants across South Korea. Even so, this study attempts to estimate the seismicity of certain regions in South Korea, in hopes of providing parameter recommendations for nuclear power plant seismic safety studies.

The purpose of this study is to obtain the relationship between the seismicity parameters typically used in a seismic hazard analysis [3]. The most commonly utilized parameters to estimate regional seismicity is described by the Gutenberg and Richter law [4]. Data from the International Seismological Centre and Korea Meteorological Administration was used to derive the seismicity parameters [5-6].

## 2. Methods and Results

As stated previously, the Gutenberg and Richter law describes the total number of earthquakes above a certain magnitude follows a logarithmic pattern [4]. This pattern is described in Eq. (1):

$$\log(N) = a - bm \qquad (1)$$

where N represents the total number of earthquakes greater than or equal to the magnitude m, with regression constants labeled as a and b. The a-value is related to the seismic activity per year and can be thought of as the total number of earthquakes in the study period, while the b-value is the slope of the recurrence relationship, which is a relative measure between strong and weak earthquakes. Typically, b-values are close to 1.0.

Earthquake data were compiled from the International Seismological Centre and the Korea Meteorological Administration [5-6]. The period of study was from 1900 to 2020, which is the maximum time window for the International Seismological Centre. Offshore events within 200 km were considered in this study. A map displaying the epicenters of all the events is shown in Figure 1.

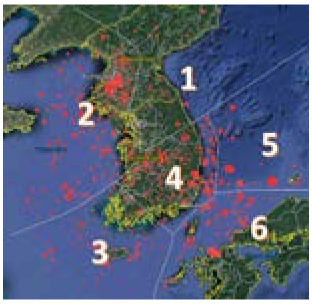


Fig. 1. Seismic source zones for South Korea used in this study.

The map also separates the Korean peninsula into 6 sections for categorization purposes. These areas were developed by eye, where relative clusters of earthquakes appeared most obvious.

To distinguish between the main, fore, and aftershocks, a declustering algorithm by Gardner Knopoff was applied to the compiled earthquake data [7]. This removed only a few small earthquakes from consideration. A log-linear regression was applied to the remaining main shock data to derive Gutenberg and Richter a and b-values.

Sample results for Zone 3 are shown in Figure 2. The data appear to follow the Gutenberg and Richter law very well, with a and b-values regressed as 5.55 and 1.20, respectively. Zone 3 ended up being the region with the highest b-value, which is peculiar because it is significantly > 1.0.

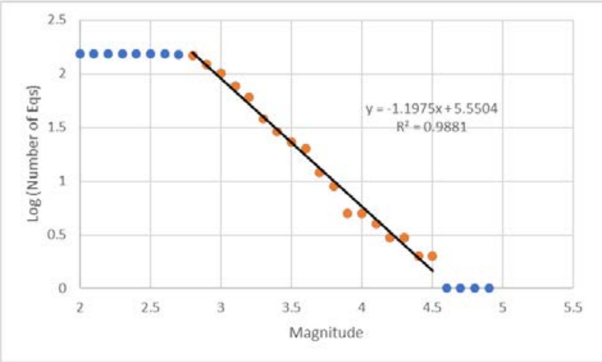


Fig. 2. Sample results for Zone 3 and deriving Gutenberg-Richter parameters.

On the other hand, the results for Zone 6 are shown in Figure 3. The figure shows regressed Gutenberg and Richter a and b-values to be 4.63 and 0.86, respectively. Zone 6 had the lowest b-value of the 6 zones. Note that Zone 6 includes areas north of Kyushu islands.

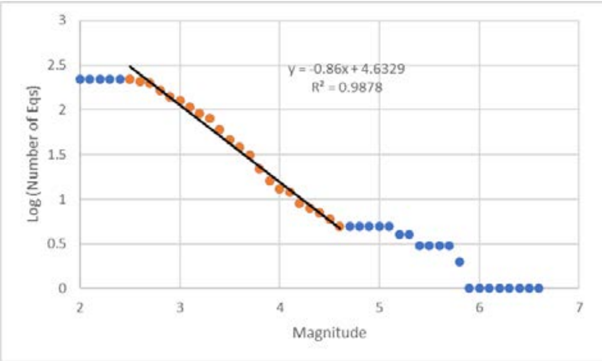


Fig. 3. Sample results for Zone 6 and deriving Gutenberg-Richter parameters.

Table II lists the regressed Gutenberg and Richter a and b-values for all 6 zones. The table also lists the number of earthquakes used in the regressions. Most notable is Zone 5, which has low a and b-values. Interestingly, this is the zone closest to many South Korean nuclear power plants.

Table II: Gutenberg-Richter parameters for each zone.

| Zone | Number of Earthquakes | a | b |
|---|---|---|---|
| 1 | 60 | 4.90 | 1.09 |
| 2 | 456 | 5.10 | 0.86 |
| 3 | 155 | 5.55 | 1.20 |
| 4 | 123 | 5.00 | 0.90 |
| 5 | 48 | 2.73 | 0.42 |
| 6 | 222 | 4.63 | 0.86 |

It should be noted that if more data was available, then these regressions on seismicity parameters may prove to be better constrained. Additionally, if a different or more improved declustering technique was applied, then the resultant earthquake data count might have reflected a more accurate count of earthquakes.

## 3. Conclusions

In this study, an attempt at regressing seismicity parameters as described by the Gutenberg and Richter law resulted in seismicity parameters for 6 zones across the Korean peninsula. Several areas could be improved such as data collection and declustering. Most interesting is that the zone where most nuclear power plants are sited happen to be in a zone with relatively low seismicity.

## Acknowledgement

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