Identifying Intraplate Mechanism by B-Value Calculations in the South of Java Island

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Abstract. Java is the most populous island in Indonesia with 50 million people live there. This island geologically formed at the Eurasia plate margin by the subduction of the Australian oceanic crust. At the south part of Java, beside the occurrence of 2-plate convergence earthquake (interplate), there are also the activities of the intraplate earthquake. Research for distinguish this 2 different earthquake type is necessary for estimating the behavior of the earthquake that may occur. The aim of this research is to map the b-value in the south of Java using earthquake data from 1963 until 2008. The research area are divided into clusters based on the epicenter mapping results with magnitude more than 4 and three different depth (0-30 km, 30-60 km, 60-100 km). This location clustering indicate group of earthquakes occurred by the same structure or mechanism. On some cluster in the south of Java, b-value obtained are between 0.8 and 1.25. This range of b-value indicates the region was intraplate earthquake zone, with 0.72-1.2 b-value range is the indication of intraplate earthquake zone. The final validation is to determine the mechanism of a segment done by correlating the epicenter and b-value plot with the available structural geology data. Based on this research, we discover that the earthquakes occur in Java not only the interplate earthquake, the intraplate earthquake also occurred here. By identifying the mechanism of a segment in the south of Java, earthquake characterization that may occur can be done for developing the accurate earthquake disaster mitigation system.

Keywords: intraplate, interpolate, b-value, Java Island

1. Introduction

Java Island, which has population of 50 million people, is the most populous in Indonesia. This island geologically formed at the Eurasia plate margin by the subduction of the Australian oceanic crust. At the south part of Java, beside the occurrence of 2-plate convergence earthquake (interplate), there are also the activities of the intraplate earthquake. Indo-Australia plate subduction occurs until 100-200 km beneath the surface, which made Java has high seismicity (Rohadi et al., 2007). In southern part of Java there are two types of earthquake, the first is earthquake that happened in boundary of the plates (interplate), the other one is earthquake that happened inside the plate (intraplate).

Based on previous researches, b-value on the frequency-magnitude distribution depends on tectonic characteristic and stress level or structure material of an area (Scholz, 1968). The b-value variation is related to structure heterogeneities and stress distribution of that area. The b-value for intraplate area is approximately 0.72-1.20 (Al-Hetty, 2011). Nugraha et al. (2016), have done b-value mapping for Sunda arc, based on this research b-value of Java has both high b-value (>1.2) and low value (0.6-0.8).
2. Basic Theory

2.1. Tectonic Settings
Seismicity in southern Java Island occurs because of two-plate interaction those are Indo-Australia and Eurasia. The Indo-Australia plate is relatively moved to the north 7 cm/year to the Eurasia plate. These tectonic processes have produce Indonesia Island and its volcanoes; beside that there are many big and small earthquakes that have been happened.

Overall, the slab subducted below Java Island was continuous, except the southern part of east java where there was a slab hole. Based on Widyantoro et al. (2011), using seismic velocity tomography, there is a slab hole below the Eurasian Plate. After the trench stepped back, subduction resumed behind the plateau causing the hole to develop (Hall et al., 2009). Only a few of big earthquakes occurred in southern Java Island. Some of big earthquakes are the 1921, 1937, and 1943 Java earthquakes that classified as intraplate earthquakes based on past research. (Okal, 2012). Meanwhile, earthquakes that generate tsunami such as Banyuwangi Earthquake in 1994 and Pangandaran earthquake in 2006 were classified as interplate earthquakes (Okal, 2012; Gunawan et al., 2016a; Raharja et al., 2016; Gunawan et al, 2017).

2.2. Intraplate & Interplate Earthquakes
Kanamori and Anderson (1975) classified the earthquake into two groups, interplate and intraplate earthquakes. The interplate earthquakes refer to those that occur along, or parallel to, the major plate boundaries with a large slip rate. Major thrust earthquakes along subduction zones (Anugrah et al., 2015; Ardika et al., 2015; Alif et al., 2016) and along transform faults (Ito et al., 2016; Gunawan et al., 2016b; Pratama et al., 2017) are classed into this group. Earthquakes that occur clearly within the plate are intraplate earthquakes. In the present paper, earthquakes whose fault planes are not along the plate boundary are classed as intraplate earthquakes, even though they occur near the plate boundary. By this definition, the San Fernando and Kern County events are intraplate earthquakes (Kanamori and Anderson, 1975).

2.3. Gutenberg-Richter
Frequency-Magnitude Distribution Relation is one from many methods to determine the seismicity in a region. This relation firstly stated by Gutenberg-Richter (1944). Frequency-Magnitude Distribution are power relation which modified in logarithmic equation. The method to determine the seismic and tectonic parameter of a region using Gutenberg-Richter relation written as:

\[ \log n(M) = a - bM \]

where a and b are the regression parameter model, and n(M) is the number of earthquake with magnitude M. A-value is seismic parameter which the value depends on the amount of event for particular region depend on volume determination and time window. B-value shows the gradient from relationship of earthquake frequency and magnitude on linear equation.
3. Method

Data that we used in this research were Engdahl earthquake catalog data (EHB) between 1963-2008 with depth 0-100 km, the number of events recorded are 1033 events. The catalog we used still consists of every type of earthquake, the main shock, foreshock, and aftershock, so we filtered the events to get only the main shock. Furthermore, we transform all the magnitude with different scale to moment magnitude scale before the data inputted in b-value processing. We filter the main shock data using de-clustering method. If we use all the earthquake data without de-clustering, the b-value we obtain probably less accurate because not all of the events are main shock events.

After we get main shock catalog then we applied smoothing distance in calculating the grid rates. Smoothing distance used to calculate the value in each grid especially grid with less earthquake (Petersen et al., 2008). Earthquake above M 4 are counted in each grid cell and used Gaussian operator to smoothing, this study used grid 0.1x0.1 degree of longitude and latitude as in Figure 2. When smoothing distance we tried some distance as 10 km, 30 km, 50 km, and 75 km to get great model. The catalog divided into three-depth range 0-30 km, 30-60 km, and 60-100 km. Generally, the amount of data decreases with increasing depth. From the trial distance we get result that smoothing distance 50 km has more accurate model than the other distance, so the b-value calculated based on this result. Smoothing distance will produce patterns of earthquake distribution, from the pattern we will get earthquake cluster and we can calculate a-value and b-value of each cluster.
4. Result and Discussion
The initial earthquake distribution map is shown in Figure 3. This map has foreshock, main shock, and aftershock. The earthquake distribution map after applied de-clustering is shown in Figure 4. There is different amount of data in both figures, its mean that in the southern Java occurred many foreshock and aftershock. By using main shock data only, the obtained the b-value becomes more accurate.

![Figure 3. Earthquake distribution before de-clustering (foreshock, main shock and aftershock).](image)

4.1. Smoothing Distance
The result of smoothing distance 50 km to the earthquake at depth 0-30km is shown in Figure 5. From the image obtained two clusters of earthquake with b-value in cluster 1 is 1.181 and cluster 2 is 1.164. The both of clusters are located in south of Java subduction zone. In cluster 1 was occurred Pangandaran earthquake on July 17, 2006.

![Figure 4. Earthquake distribution after de-clustering.](image)
Figure 5. Earthquake cluster at depth 0-30 km.

The result of smoothing distance 50 km to the earthquake at depth 30-60 km is shown in Figure 6. From the image obtained three clusters of earthquake with b-value in cluster 1 is 0.884, cluster 2 is 1.253, and cluster 3 is 0.853. Cluster 1 is located in the south of West Java, cluster 2 is located in the south of Central Java, and cluster 3 is located in the south of East Java. The location of all cluster in this group are closer to Java than clusters at depth 0-30 km.

Figure 6. Earthquake cluster at depth 30-60 km.

The result of smoothing distance 50 km to the earthquake at depth 60-100 km is shown in Figure 7. From the image obtained three clusters of earthquake with b-value in cluster 1 is 1.214 clusters 2 is 0.893, and cluster 3 is 0.994. Cluster 1 and 2 are located in the south of West Java and cluster 3 is located in the south of Central Java. The location of earthquake in this group is tending to be more to the north than the both of depth group before.

Table 1. a-value and b-value at depth 0-30 km

| cluster | a-value | b-value |
|---------|---------|---------|
| 1       | 7.406   | 1.181   |
| 2       | 6.936   | 1.164   |

Table 2. a-value and b-value at depth 30-60 km

| cluster | a-value | b-value |
|---------|---------|---------|
| 1       | 5.99    | 0.844   |
| 2       | 7.816   | 1.253   |
| 3       | 5.582   | 0.853   |

Table 3. a-value and b-value at depth 60-100 km

| cluster | a-value | b-value |
|---------|---------|---------|
| 1       | 7.842   | 1.214   |
| 2       | 5.764   | 0.893   |
| 3       | 6.165   | 0.994   |

Figure 7. Earthquake cluster at depth 60-100 km.
5. Conclusion
From our study, we conclude:

- Based on the distribution of earthquake from each group depth, the tendency of the hypocenters is deeper towards the north. These earthquakes follow the direction of subduction in southern Java.
- The b-value of the southern Java regions from Engdahl (1963-2008) ranges from 0.85 to 1.25.
- Referring to Al-Hetty (2011), states that the region with b-value range of 0.7-1.2 is an intraplate zone, hence we can say that the earthquakes derived from Engdahl (1963-2008) in Southern Java were intraplate earthquake. However, many reports define Banyuwangi Earthquake 1994 and Pangandaran Earthquake 2006 as interplate earthquake, hence there should be more consideration that not all of earthquake zone with b-value 0.7-1.2 is an intraplate earthquake.

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