Using ArcGIS to Analyze Earthquake Patterns in Java Island, Indonesia

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Abstract--The Indonesian region is one of the most seismically active zones of the earth. Because the tectonics of Indonesia are very complex, as it is a meeting point of several tectonic plates. Advent of earthquakes cannot be denied or avoided but sought for disaster risk can be minimized. One of the manners is to know the earthquake patterns. In this study, we analyze earthquake patterns in Java Island Indonesia. The model used is based on the earthquake catalog of research areas of Java island in latitude 5° S - 12° S and longitude 105° E - 115° E starts from 1950 to the end of 2012 with magnitude value M ≥5 from IRIS (Incorporated Research Institute of Seismology) catalogue.

According to Richter scale of magnitude, 1014 main earthquakes recorded are divided into moderate (90.70%), strong (9.13%) and major (17%). According to focal depth, all main-socks are divided into shallow (67.92%), intermediate (27.24%) and deep (4.44%). Java Island has four earthquake source zones: subduction (with *b-value*= 1.13 and *a-value*=6.81), shallow background (with *b-value*= 2.37 and *a-value*=13.8), deep background (with *b-value*= 1.65 and *a-value*=10.1) and fault zone which are Cimandiri, Lembang, Opak, Pati and Lasem fault.

Keywords: Earthquake, Java Island, a-value, b-value.

I. INTRODUCTION

The Indonesian region is one of the most seismically active zones of the earth. Because the tectonics of Indonesia are very complex, as it is a meeting point of several tectonic plates [1]. Indonesia is located between two continental plates: the Eurasian Plate and Australian Plate; and between two oceanic plates: the Philippine Sea Plate and Pacific Plate.

The high seismic activity in Indonesia was revealed by the record quake in the span of 1897 - 2009 there are more than 14,000 earthquakes with magnitudes M ≥ 5.0 [2]. Advent of earthquakes cannot be denied or avoided but sought for disaster risk can be minimized. One of the manners is to know the earthquake patterns.

The objectives of this study are to know characteristic of earthquake classification, to determine earthquake source zone and to calculate *b-value* of earthquake source zone in Java Island. So it can be used as input for the mitigation of seismic hazard and the manufacture of earthquake resistant buildings in Indonesia. Java Island was selected for this research because most of the population, infrastructure and structure facilities are concentrated in this island.

II. METHODOLOGY

2. 1 Collecting Data

Data is from IRIS (Incorporated Research Institute of Seismology) catalogue for area of 5˚S-12˚S and 105˚E-115˚E. The period is 1950 to 2012 and with magnitude M ≥ 5.

2. 2 Converting Magnitude Scale Into Mw

2. 3 Analyzing Data

- Classification according to magnitude
- Classification according to the focal depth
- Declustering
  The goal of seismicity declustering is to separate earthquakes in the seismicity catalog into independent (main-shock) and dependent (aftershock and foreshock) earthquakes.
- Analyzing earthquake source zones

2. 4 Calculating a-b value

III. PLATE TECTONICS IN JAVA

Indonesia Region, famous as "supermarket of disaster", is located in a tectonically very complex and very active area. According to Bird et al, this region consists of three large tectonic plates and nine small ones. The plates with different types of movement have created subduction and fault zones which are continuously active. The Australia plate subducts beneath the Eurasian plate along the Java trench. The direction of convergence is normal to the trench South of Java, but oblique to the trench Southwest of Sumatra.

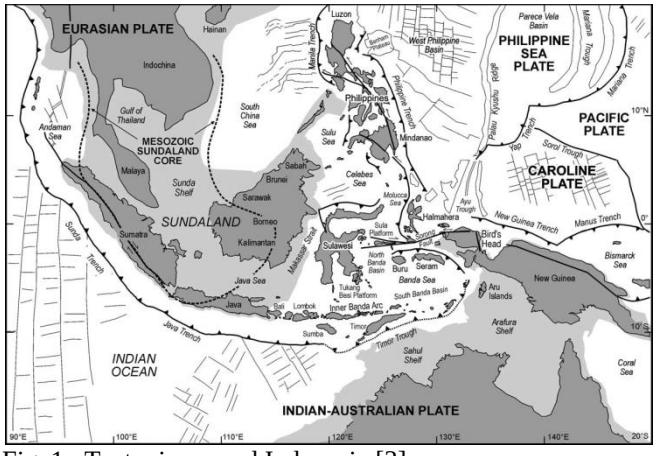

Fig. 1. Tectonic around Indonesia [3].

IV. EARTHQUAKE SOURCE ZONES

A seismic source model is defined as a seismically homogenous area, in which every point within the source zone is assumed to have the same probability of being the epicenter of a future earthquake. The Models were developed using earthquake catalogs, tectonic boundaries, and fault information, where composed of background

seismicity, fault and subduction sources as recently developed by USGS for U.S. hazard map [4].

There are three major source types also in Java, Indonesia; (a) fault source, (b) subduction source, and (c) background source. And in the Java Island, there are five faults; Cimandiri, Lembang, Opak, Lasem and Pati Fault [2]. The location of faults can be seen in the figure 2, 3 and 4.

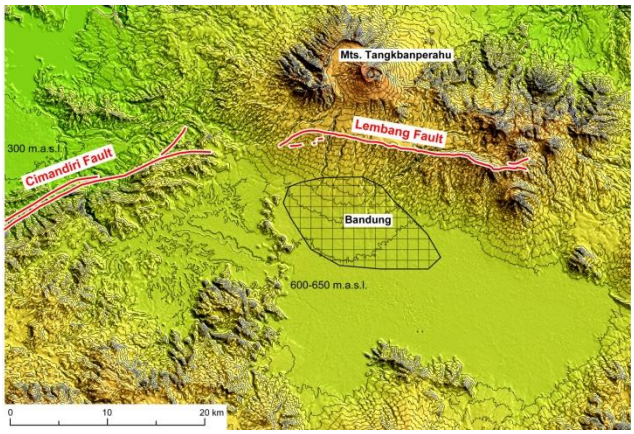

Fig. 2 Cimandiri and Lembang Fault [5].

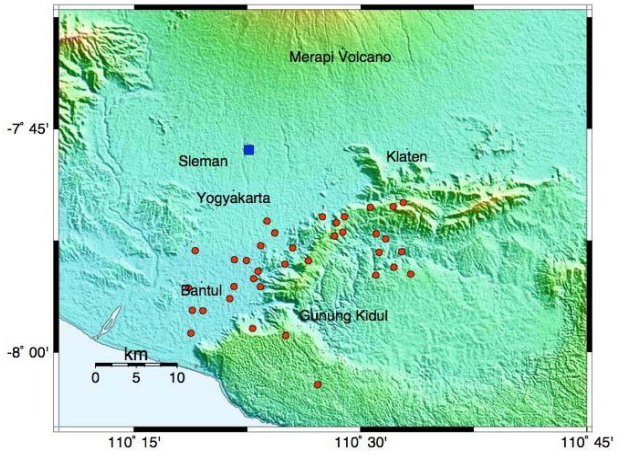

Fig. 3 Opak/Jogja Fault [6].

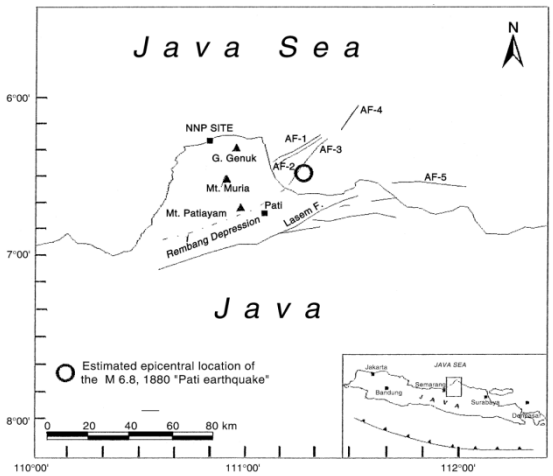

Fig. 4 Pati and Lasem Fault [7].

V. THE GUTENBERG-RICHTER MAGNITUDE FREQUENCY RELATIONSHIP

A fundamental statistical description of seismicity is the Gutenberg-Richter (G-R) law:

$$Log_{10} N(M) = a - bM \quad (1)$$

Where $N(M)$ is the number of earthquakes that occur in a specific time window with magnitude $\geq M$, M the magnitude and a and b are constants . The *b-value* equals the slope of the frequency-magnitude distribution (FMD), and describes the relative size distribution of earthquakes. A higher *b-value* indicates a relatively larger proportion of small events. The *a-value* indicates the seismic activity [8].

VI. RESULT AND DISCUSSION

6.1. Collecting Data and Converting to Moment Magnitude (M_w)

Data is from IRIS (Incorporated Research Institutions for Seismology) catalogue for area of 5˚S-12˚S and 105˚E-115˚E. The period is 1950 to 2012 and from magnitude ≥ 5.. The total data of earthquake is 1172 events with different magnitude scale.

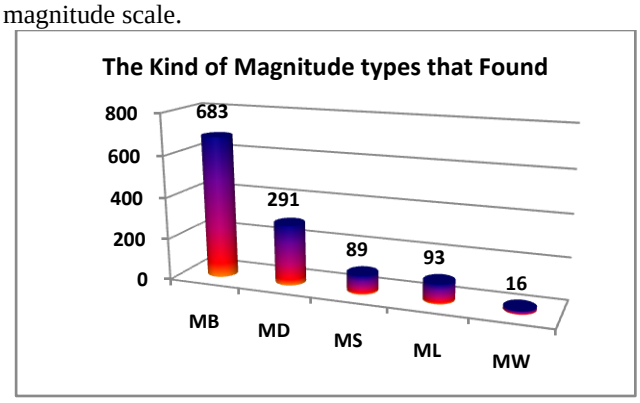

Fig. 5. The kind of magnitude types that found

Where M_w is Moment magnitude, M_B is Body-wave magnitude, M_S is Surface-wave magnitude, M_E is Magnitude used in Purcaru and Becrkhemer, M_L is Local magnitude and M_D is Magnitude used in Duda.

6.2. Converting to Moment Magnitude (M_w)

We use the moment magnitude (M_w) as data analyzed. As conversion relation formula, we use formula from The team of Indonesia`s Earthquake Map Revision (2010) like in the table 1.

TABLE I
CONVERSION CORRELATION FORMULA SEVERAL MAGNITUDES SCALE FOR INDONESIA REGION.

Conversion correlation	Convert
$\mathbf{M_w = 0.143M_S^2 - 1.051M_S + 7.285}$	M_S to M_w
$\mathbf{M_w = 0.114M_B^2 - 0.556\ M_B + 5.560}$	M_B to M_w
$\mathbf{M_w = 0.787M_E + 1.537}$	M_E to M_w
$\mathbf{M_B = 0.125M_L^2 - 0.389\ M_L + 3.513}$	M_L to M_B
$\mathbf{M_L = 0.717M_D + 1.003}$	M_D to M_L

6.3. Declustering

After declustering, the number of data becomes 1014 events. It is the main-shocks.

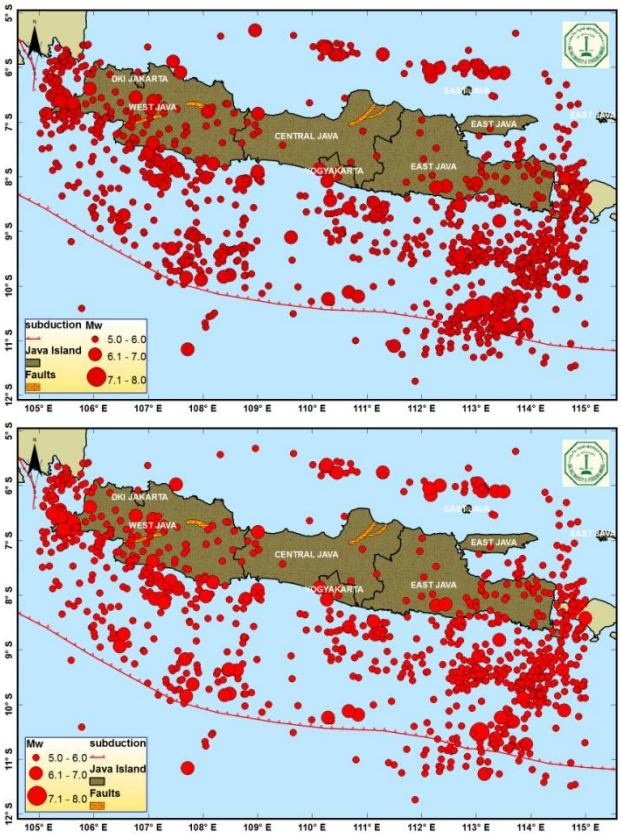

Fig. 6. Picture above is before declustering (1172 events) and picture below is after declustering (1014 events).

6.4. Analyzing Data depend on earthquake classification

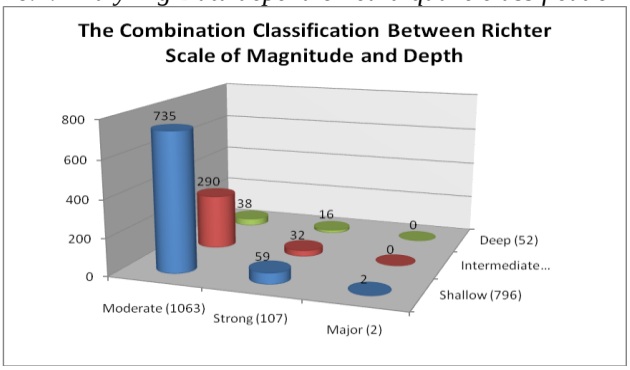

Fig. 7. Earthquake classification depend on scale of magnitude and depth.

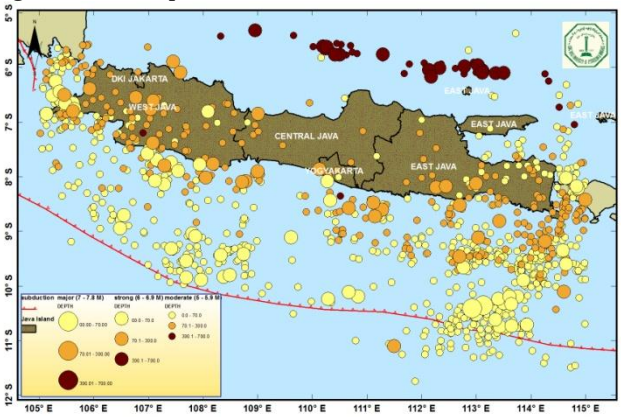

Fig. 8. Map of earthquake classification depend on scale of magnitude and depth.

6.5. Earthquake Source Zones

The first step is to make polygon layer of the source zones by ArcGIS.

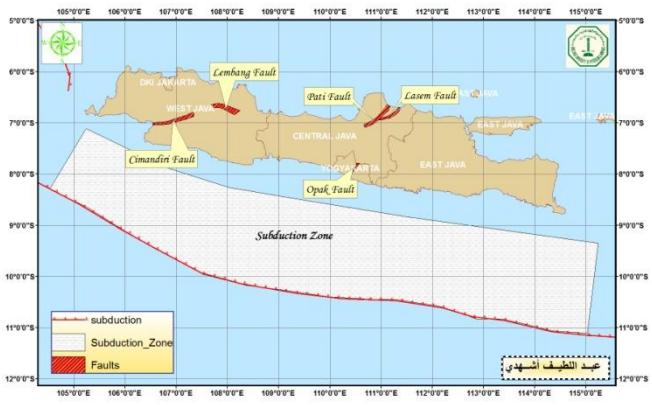

Fig. 9. Polygon layer of the source zones in Java Island.

By selection tool, we can find the earthquake which happens in each source zone. The sample of selection by ArcGIS can be seen in the figure 10. And the result depend on earthquake source zone is like in the table 2. Whereas mapping of the result can be seen in the figure 11.

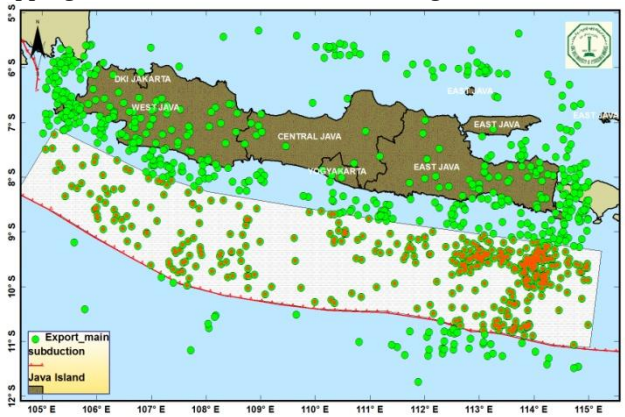

Fig. 10. Selection of subduction earthquake.

TABLE. II
ANALYZING EARTHQUAKE SOURCE ZONES

The Source Zones	Color in fig.11	Events
Subduction	Violet	330
Shallow-Background	Yellow	212
Deep-Background	Orange	466
Fault	Blue	6

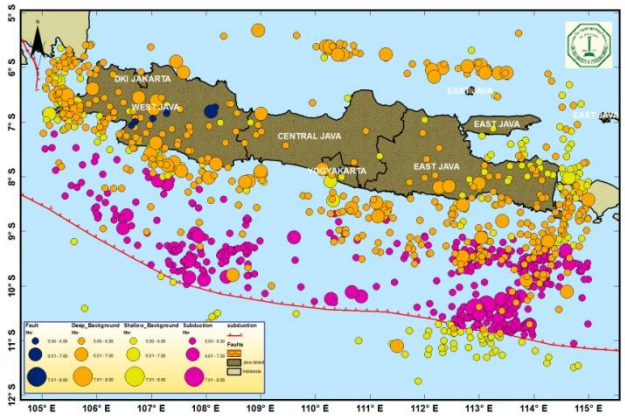

Fig. 11. Map of earthquake source zones.

6.6. Calculating a-b value

To calculate a-b value, we use Zmap software from Stefan Wiemer. The result of calculating a-b value for subduction, shallow-background and deep-background can be seen in the figure 12, 13 and 14.

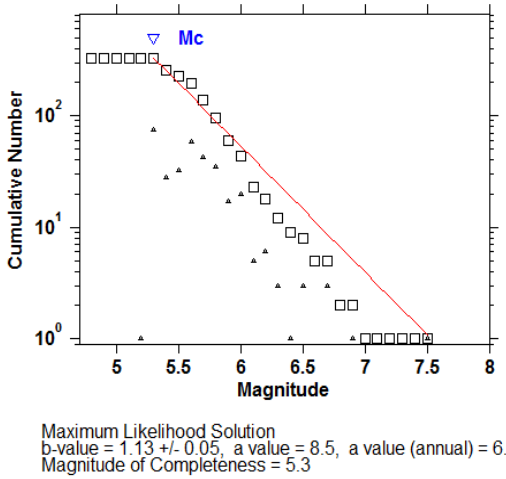

Fig. 12. The result of calculating a-b value for subduction event.

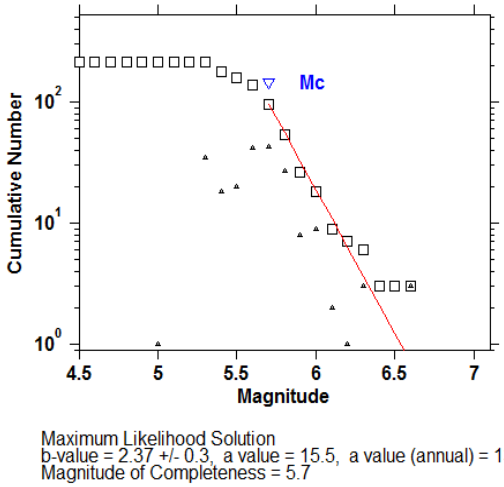

Fig. 13. The result of calculating a-b value for shallow-bacground event.

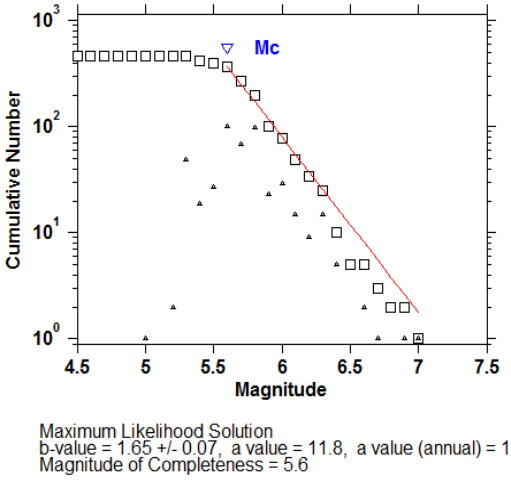

Fig. 14. The result of calculating a-b value for deep-bacground event.

VII. CONCLUSIONS

Java Island is classified to high seismicity area, 1014 main shocks (from 1172 all shocks) recorded within 1950 to 2012. According to richter scale of magnitude, all socks are divided into moderate (90.70%), strong (9.13%) and major (17%). According to focal depth, all socks are divided into shallow (67.92%), intermediate (27.24%) and deep (4.44%). Java Island has 4 earthquake source zones: subduction, shallow background, deep background and fault. And the result of calculating *a-b value* is:

- For subduction, *b-value*= 1.13 and *a-value*=6.81,
- For shallow background, *b-value*= 2.37 and *a-value*=13.8.
- For deep background, *b-value*= 1.65 and *a-value*=10.1.

VIII. REFERENCES

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