Local stress and seismic activity at West Sumatra

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Abstract. The Earthquakes that occurred in West Sumatra was dominated by a thrust mechanism. This is due to the western part of Sumatra stretching the subduction zone parallel to the Sumatran coastline and fault movement. The size of the earthquake energy release can depend on local stress conditions and the level of seismic activity. Local tectonic stress conditions were determined using seismotectonic parameters, whereas the distribution of seismic activity levels used earthquake magnitude frequency relationships. Based on this analysis, local stress conditions for each segment in West Sumatra are categorized in a high level. The segment with the highest stress conditions is in the Suliti and Sumani Segment, the medium stress conditions in the Sianok dan Suliti segment, and the lowest is the Mentawai segment. The level of seismicity in the segment of West Sumatra based on seismotectonic parameters is categorized as low seismic level. The segment with the lowest seismic level are Sumani and Suliti, followed by Sianok and Sumpur, the highest level is the Mentawai segment.

1. Introduction
Earthquake activity that often occurs in West Sumatra was dominated by a thrust mechanism. This due to the western part of Sumatra stretches the subduction zone parallel to the Sumatran coastline [1]. The subduction zone results in faults and rows of volcanoes which will further develop into an earthquake source.

Faults located in West Sumatra are SFS (Sumpur, Sianok, difficult, and Sumani segment) which stretches from Pasaman to Solok Selatan [2]. In addition, in the sea there are also MFS which are located between the islands of Sumatra and the Mentawai Islands, which are also a source of earthquakes.

The earthquake in West Sumatra based on the Meteorology, Climatology and Geophysics Agency (BMKG) data records the earthquake that once happened in West Sumatra in 1977 (Sumpur segment), 1926 and 2007 (Sianok segment), 1943 (Sumani segment), 1943 and 2004 (Difficult segment and Sumani) [3]. In 2007 and 2010 the Mentawai Fault Zone also experienced a large earthquake.

The size of the earthquake energy released can depend on local tectonic stress conditions and the level of seismic activity. Rock characteristics and the amount of stress contained by a rock can affect the size of the earthquake energy released in an earthquake repeating cycle. Rocks that have a high level of fragility cause the energy collected is not too large because the energy is directly released in the form of seismic waves, and vice versa [4].

The process of the occurrence of a significant and destructive earthquake in West Sumatra required a strong understanding of the precursors shown by seismotectonic activity and the level of earthquakes specifically in each of the segments located in West Sumatra. Based on seismic history that has been explained is very necessary for this parameter in studying the symptoms of seismicity in the future.
Seismotectonic parameters are obtained by calculating the b-value and a-value that describe local tectonic stress conditions and earthquake activity in West Sumatra [5]. Local stress conditions can be determined by looking at the a-value and b-value seismotectonic parameters based on the relationship of the frequency-magnitude distribution proposed by Gutenberg and Richter in 1944. According to seismologists the b-value is one of the statistical values that reflects the local rock stress conditions in an area, while the a-value is one of the statistical values that reflects the level of seismic activity in an area. Low-a values represent low seismic activity and indicate an accumulation of energy (asperity) [6], and vice versa for high-a values. High-b values are associated with low rock stress conditions [7] [8]. High b-values have high heterogeneity conditions, but low b values correlate with high stress rock conditions and have low heterogeneity medium [9]. Areas with high stress rock conditions have a b-value of 0.4-0.9, while under conditions of low pressure the b-value is around 1.2 [10].

This study focuses on understanding seismotectonic parameters in each segment in West Sumatra. It aims in seismic information and its relationship to earthquake disaster mitigation.

2. Data and Methods

The seismotectonic parameters of a-value and b-value were obtained based on the frequency - magnitude distribution proposed by Ishimoto-Lida in 1939 and Gutenberg-Richter in 1944 [11].

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

Where N (M) is the cumulative number of earthquakes with magnitude larger than M, a and b are constants, and M is the magnitude of the earthquake. The seismotectonic parameters a value and b value determined using the maximum likelihood method like equations 2 and 3[12].

\[
b = \log e \frac{\bar{m}}{m_0 - m_0}
\]

\[
a = \log N(m \geq m_0) + \log(b \log 10) + m_0b
\]

where \(\bar{m}\) is the average magnitude of the earthquake data and \(m_0\) is the minimum magnitude. Calculation of a-value and b-value is helped by using the ZMAP application ver. 6.0.

The data used in this research was taken from NEIC/USGS and ISC earthquake catalog. The research area of the West Sumatra at 3°50’ LS - 1°20’ LU and 98°10’ BT - 102°10’ BT (Sumpur (0.1°N ~ 0.3°N), Sianok (0.7°S ~ 0.1°N), Sumani (1.0°S ~ 0.5°S), and Suliti (1.75°S ~ 1.0°S)) . The observation periods from 1943 to 2018 with magnitude bigger 3.5 SR and the depth less than 70 km. Data dioalah dengan langkah 1) download data, 2) klasifikasi data, 3) konversi ke Mw, 4) mengelompokkan data untuk setiap segmen, 5) calculates the-a and b-values by using ZMAP version 6.0 software, and 6) plotting kurva FMD.

3. Result and Discussions

Catalog of earthquakes in the West Sumatra segment with the period 1943 - 2018. Catalog data of seismic activity in West Sumatra segment shown in Figure 1.
Figure 1. Seismicity Map in West Sumatra Region and Surrounding Period 1943 - 2018 (data source: USGS and ISC).

Figure 1 shows the seismicity of earthquakes originating from faults in the segment of West Sumatra and Surrounding areas in the period 1943 - 2018. Earthquake activity in the Mentawai segment numbered 106 earthquake events. Earthquake activity on the mainland of West Sumatra occurred in the Sumpur segment as many as 35 earthquake events, Sianok segment as many as 40 earthquake events, Sumani segment as much as 37 earthquake events, and faults Segment as much as 29 earthquake events. Calculation of a-value and b-value based on frequency – magnitude distribution proposed by Gutenberg-Richter in 1944. This method is based on likelihood statistics and obtained values as shown in Figure 2.
Figure 2 shows that the segment zone that has a low value is in the segment on the mainland of Sumatra. These segments are the Suliti, Sumani, Sianok and Sumpur faults. The Mentawai segment in the ocean has the greatest a-value. b-value for the segments in West Sumatra and Surrounding areas has the highest value from the lowest to the Mentawai segment, Sumpur segment, Sumani segment, Sianok segment, and the lowest is the Suliti segment.

The b-value calculation value for each segment in West Sumatra in Figure 2 was categorized as low. This is consistent with the b-value characteristics that have been explained in theory. The comparison of segments that have the lowest b-value is in the Sumani and Difficult segments, followed by the Sumpur and Sianok segments, and the quite high is the Mentawai segment. A low b-value means that the area shows high stress conditions. An area that has a low b-value can also be called an area of asperities, which in this zone is an active seismic area that is still locked. It means destructive earthquakes can occur in this region [5]. Therefore, segments that have a low b-value should be wary of releasing large and destructive earthquake energy.

The Mentawai segment itself is still categorized under high stress conditions. This is due to the fact that every segment with this situation has experienced a large earthquake. Earthquakes based on their repetitive nature and will reappear. During the earthquake it will experience a large accumulation of energy. Faults that experience energy accumulation are characteristic of high stress conditions. Therefore, the Mentawai segment is categorized under conditions of high local stress and can experience major earthquakes.

Fault that is on the mainland of Sumatra Island and the Mentawai Segment has a low seismicity level. This is seen based on the low a-value. A low a-value indicates the rare occurrence of earthquake in the area as explained in theory. There is an association between low a-value and low b-value [5]. As previously explained, segments in West Sumatra have a low b-value.

Areas with low seismicity indicate an accumulation of energy and the potential for large earthquakes. This means that areas with low seismicity mean that the region is experiencing energy accumulation and vice versa [8]. This reinforces that the segments in West Sumatra have a large potential for earthquake energy.

Based on the a and b values of each segment in west sumatra, it is obtained a plotting curve of the relationship of the magnitude frequency distribution of all segments in west Sumatra as shown in Figure 3.
Figure 3. Relationship of Frequency-Magnitude Distribution of All Segments

The graph in Figure 3 shows the relationship of the frequency of occurrence of earth earthquakes with magnitude for all segments. Segments that are on the mainland of West Sumatra have small values and are relatively equal to each other. Values that have a large frequency are in the Mentawai segment.

The graph of the earthquake frequency-magnitude distribution relationship shown in Figure 23. A slope of the b-value begins with the curve falling on the graph. This shows a sloping b-value slope for segments on the mainland of western Sumatra. This indicates that the lower a-value possessed by the Sumatra fault area indicates a low level of seismic activity. Wiemer and Wyss (1997) say that areas with low seismicity and producing fewer large earthquakes will result in sloping b-value slopes on the curve. While the curve for the Mentawai segment is different compared to the fault that is on the land of West Sumatra.

The slope b value for the Mentawai segment is steep, which indicates that the Mentawai segment has a-value and b-value greater than other segments. The high level of seismicity of the Mentawai segment is due to the fact that this segment is near the Subduction Zone. Budiman (2011) states that this area is an active seismicity affected by the geological location of this segment which is close to the subduction zone. Subduction zone movement affects the Mentawai segment movement activity and makes it more active.

4. Conclusion
Local stress conditions based on b-values for each segment in West Sumatra are categorized at a high level. The segments with the highest stress conditions are in the Difficult and Sumani segments, followed by Sianok and Sumpur, and the lowest conditions are the Mentawai segment. The level of seismicity for each in West Sumatra based on a-value is categorized as a low level of seismicity. The segments with the lowest seismic level are Sumani and difficult, followed by Sianok and Sumpur, and the highest level is the Mentawai segment.

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