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Stress Drop Analysis on Banda Sea

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Abstract

Stress drop is a fundamental parameter of earthquake source that describes stress before and after an earthquake. The purpose of this study was to determine the tectonic characteristics of the Banda sea region. The research method used is a mathematical analysis and Nelder Mead Simplex nonlinear inversion methods. The results show that the Banda Sea is the area with complex tectonic conditions and large earthquake impacts. The Banda sea earthquake generated a stress drop of between 2 MPa -10 MPa from small to medium, it can be concluded that the rocks in the Banda Sea are relatively harder because the Banda Sea has a complex and varied oceanographic profile. The Banda Sea contains many continental fragments and has very deep ocean basins in the North Banda and Weber Deep, as well as plate rollbacks that form geometry in the shape of a spoon. The strength of rocks in the Banda Sea is also strengthened by the results of gravitational anomalies, there are significant differences in the gravity anomalies around the Banda ocean which indicate high density. This information is very important to know the amount of pressure released shortly after the earthquake which has a very large impact as a disaster mitigation measure.

Key words: stress drop, nelder mead simplex method, rock density, mitigation

INTRODUCTION

The value of stress released by an earthquake can be calculated with a stress drop, which is the stress ratio before and after an earthquake where the accumulation of stress on rocks is released right after the earthquake occurs (United States Geological Survey, 2019).

Seismogram signal recording from earthquake events is a combination of some earthquake property information such as earthquake source which is related to earthquake parameters such as seismic moment, source radius, and stress drop, path or path connecting the earthquake source to the earthquake vibration recording device. carry information about subsurface conditions and the effects of earthquake recorders.

According to Scholz (2019), earthquake stress drop Δσ is the most basic scaling parameter to describe the source of an earthquake. Basically, the voltage drop connects the average slip error to the characteristic dimension, which is often simplified by the radius r for circular cracks.

Stress drop values tell us something about earthquake physics: the greater the slip the greater the stress drop will be the opposite the smaller the slip the smaller the stress drop will be in the same dimension. Since the average slip and r dimensions are easily related to the seismic moment Mo, and the angular frequency fc, we can also consider stress drop as a parameter that connects low frequencies, the moment of energy emitted to the high frequency portion to fc. This, then, provides clues about how the voltage drop drives high frequency ground motion, such as peak ground acceleration (PGA) (Baltay, 2019).

The stress drop can also be concluded by assuming the source model (Brune, 1970, Bora, 2016) and estimating the angular frequency of the source spectrum (Abercrombie, 2014). Some authors have also investigated source parameters in the time domain by estimating source duration from source time functions (Bilek & Lay, 1999).

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Estimating the dynamic stress drop requires knowledge of the source time function. One of the methods of its calculation from seismic records is the Empirical Green Function (EGF) technique (Wojciech, 2018)

Almann & Shearer (2009) concluded that very low-stress drop values were found in the subduction zone of Maluku, which is a region with very complicated tectonics. In this paper, the stress drop will be calculated in the Banda Sea and see its relationship with geological conditions.

Geological characteristics on the surface usually use conventional geophysical methods, such as passive and active seismic methods, but with the stress drop approach from earthquake sources, to see rock characteristics is unique. We can see the characteristics of rocks below the surface in general, which can be seen from the response of these rocks to pressure and pressure.

The purpose of this study was to determine the tectonic characteristics of the Banda sea region. Stress drop information is very important to know the amount of pressure released from an earthquake that has a large impact as a disaster mitigation measure.

Banda Sea Geology

The Banda Arc in eastern Indonesia is at the core of the interaction of the three-plate collisions between Australia, Sundaland, and the Pacific. Arc-continent collisions around the Banda Arc have developed largely since the Late Miocene, but previous key tectonic events include the backarc spread in the North Banda Basin that began during the Middle Miocene, and the initial phase of arc-arc collisions and widespread slip translation return to the Oligocene or Early Miocene (Charlton, 2016).

The Banda Sea has a complex and varied oceanographic profile, contains many continental fragments including Banda Ridges, and has very deep ocean basins in the North Banda Basin and Weber Deep (Figure 1). The Banda Sea is located on a curved island chain from the Banda Arc, from Timor to Tanimbar to Seram to Buru. The volcano bow at Mt. Damar to Banda extends east to the more mature Flores volcanic islands, Alor and Wetar. (Pownall, 2018).

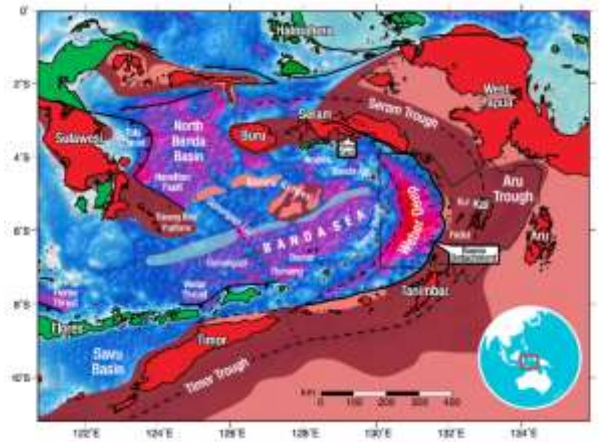

Figure 1. The current configuration of the Banda Sea, underwater bow and blue plateau, volcanic island arc, green collection, and the crust of the Australian Continent agrees in red. (Pownall, 2018).

Weber Deep as deep as 7.2 km is the curve of the arm between the non-volcanic inner and outer volcanic arcs. The Banda Arc is so curved based on the subduction plate geometry, shown by earthquakes that form a very concave spoon or half geometry. As illustrated by tectonic reconstruction, the location of subduction trenches has migrated gradually to the southeast, driven by the sinking of the Proto Banda Sea plate into the mantle through a 'roll slab rollback' process. (Pownall, 2018).

METHOD

This study uses earthquake waveform data from the IRIS-DMC and BMKG networks (Incorporated Research Institutions for Seismology 2020, Repogempa, 2020). The earthquake data used was the Banda Sea earthquake from 2012 to 2019 th, as many as 7 earthquakes were recorded at the ARMA, MEEK, and MORW stations in Australia.

The first step is to collect wave seismograms. The data obtained from the IRIS-

DMC and BMKG networks including downloading data with criteria for distance data between events to the station from 30°-100° recorded at ARMA, MEEK, and MORW stations in Australia.

Table 1. Earthquake Data from 2012-2019 th

Date	Lat	Lon	H	Mag
12/10/2012	-6.4969	129.8684	161.5	7.1
4/20/2013	-6.2786	130.2233	113.9	6
8/12/2013	-7.1167	129.7914	104.8	6.1
12/6/2014	-6.11	130.4829	116	6
11/21/2015	-7.1484	129.9375	82	6.1
3/25/2018	-6.6247	129.8138	169	6.4
6/24/2019	-6.4078	129.1692	212	7.3

We use stations in Australia to avoid interference from other wave phases on the recorded waveform seismogram, including refraction can occur when earthquake waves pass through two different media, diffraction occurs when earthquake waves pass through a narrow gap, interference occurs when two earthquake waves come together to produce maximum and minimum interference patterns.

The next step is convert the full wave data format to SAC format with the RDSEED program. After conversion take the P and S waves done with the SAC program, and 50 seconds windowed with 2 seconds before the P onset. (Figure 2).

The second step is data processing, starting with instrument and taper correction with multitaper method, to eliminate path noise and factors from the tool, after which the waves are integrated from speed to displacement then using Fast Fourier Transform (FFT). The Maluku Sea earthquake displacement spectrum and Halmahera earthquake obtained at the time of the earthquake (Cramer, 2017, Havskov, 2010, Grandis, 2009) (Figure 3). Before this spectrum is analyzed, the deconvolution process is carried out, i.e. releasing the response instrument, and path effects damping and geometric distribution (Gunawan, 2012). The purpose of this deconvolution is to obtain the true spectrum of earthquake sources. Seismogram signal recording from earthquake events is a combination of some earthquake property information, shown by the following equation:

Seismogram (f) = Source (f) * Path (f) * Site (f) * Instrument (f) (1)

Where source (f): the spectrum of source effects associated with parameters such as seismic moments, source radius, stress drop which describes the mechanism at the earthquake source, path (f): the spectrum due to the effect of spreading from the source to the recording station which is related to the seismic attenuation parameter (Q), site (f): the amplification spectrum which contains information about local (geological) influence, and instrument (f): the spectrum caused by the effect of the instrument response (Hartzell, Mendoza, and Zeng, 2013, Sativa, 2013), For instrument influence (f) the station is corrected so that instrument effects can be temporarily eliminated for source (f), path (f) and site are performed by the inversion method of the Nelder Mead Simplex algorithm (Moraglio, 2010, McGarr, 2014).

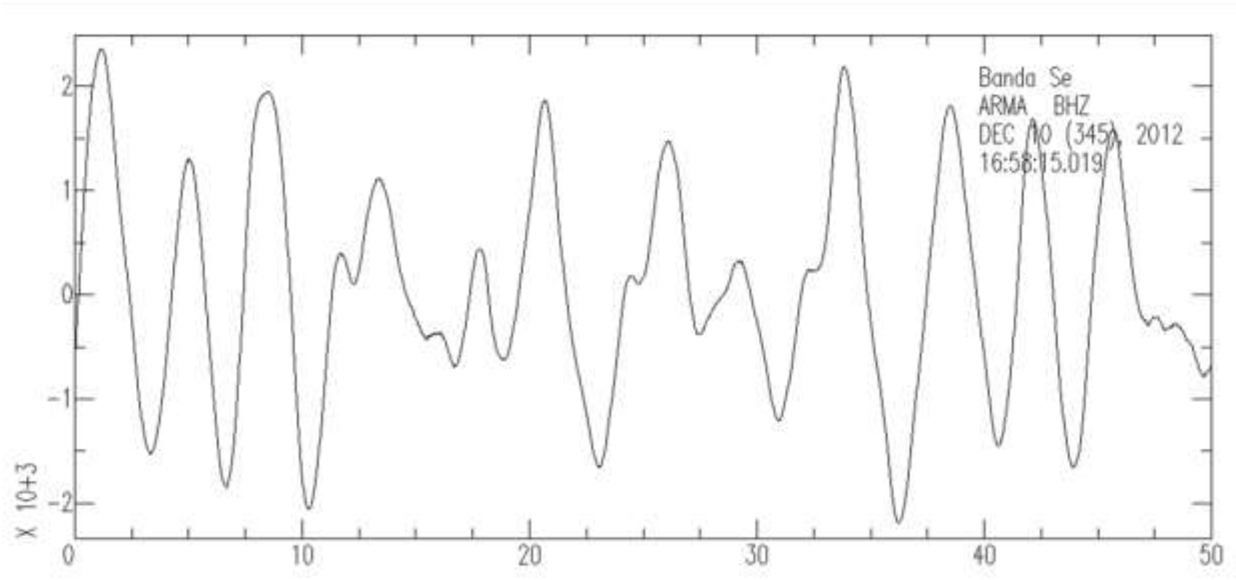

Figure 2. Windowing Seismogram Data 50 seconds.

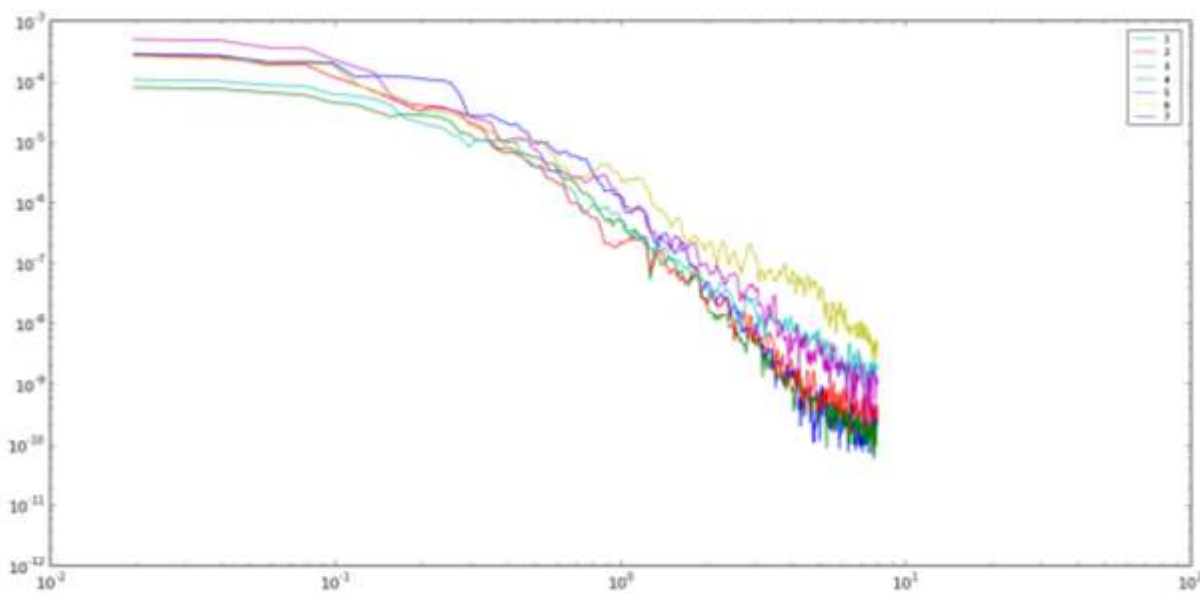

Figure 3. Observational displacement spectrum

The entire inversion process is carried out simultaneously using the Python program (Trugman, 2017). After getting the source spectrum, the calculation of the best angular frequency (fc) of the fitting will be done as input in the calculation of stress drop as in the equation:

$$\Delta\sigma = M_0 \left(\frac{f_c}{0.42\beta}\right)^3 \quad (2)$$

here ∆δ is the stress drop (Mpa), Mo is the moment magnitude (Nm), fc is the angular frequency β is the source constant shear source of 3.3 km/s (Abercrombie, 2014, Andrews, 1986, Beyreuther, 2010).

RESULT AND DISCUSSION

Determination of stress drop from digital seismograms at ARMA, MEEK, and MORW stations is carried out with several stages of data processing as explained in the method, why the Australian seismic station used in this study was provided, instead of using a local station operated by BMKG, because the distance to the earthquake recording station was 30º-100º, to avoid changes from other wave phases such as refraction, diffraction, etc, near short distances. We can be sure that waveform interference will be recorded on a seismogram and will affect the results of data processing.

The following are the best fitting from ARMA, MEEK, and MORW stations from Figure 4 and 5 it can be seen that the receiver spectrum approaches the brune model so that the best source spectrum can be seen in Figure 6 and Figure 7 right. The Brune model is manifested by a green curve while the receiving signal is manifested by a blue signal.

The final result of this study is to determine the stress drop with the following formula (2) the banda sea stress drop from 7 earthquake events classified as small to medium with a stress drop value of 2 MPa to 10 MPa (Table 2).

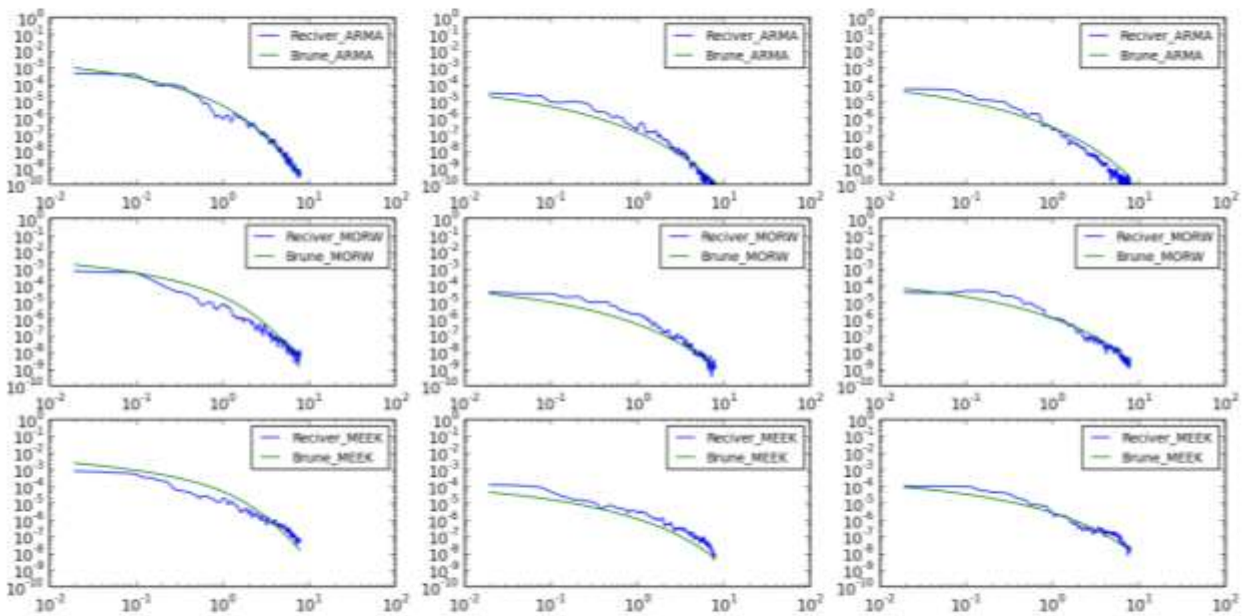

Figure 4. The best fittings with receiver and brune models from ARMA, MEEK, and MORW stations Banda Sea subduction earthquake 10 December 2012, 20 April 2013, and 12 August 2013

It is common in all subduction zones such as the results of Allmann and Shearer (2009) that very low pressure drop values occur along the Cocos subduction zone in Central America with an average value below 1 MPa.

The type of fault most of the thrust that occurs in the subduction zone has a relatively small drop stress value. The value of stress drop is small because it mostly occurs in areas with low districts, generally in shallow subduction slab areas (Garcia, 2016)

The value of stress drop is small because most of it occurs in areas with low districts, generally in shallow subduction slab areas. Variation in stress drop is influenced by variations in stiffness, variations in different material plates, as well as variations in the absolute value of the main stress or orientation of the plate boundary in the direction of the main stress. Allmann and

Shearer (2009) revealed that variations in stress drop are influenced by variations in stiffness, variations in different material plates, as well as variations in the absolute value of the main stress or orientation of the plate boundary in the direction of the main stress.

Table 2. Final Result of Stress Drop on Banda Sea

Date	Lat	Lon	H	Mag	m0	fc	Δσ (Mpa)
12/10/2012	-6.4969	129.8684	161.5	7.1	4.4E+19	1.097	2.181639
4/20/2013	-6.2786	130.2233	113.9	6	8.2E+17	5.4044	4.861459
8/12/2013	-7.1167	129.7914	104.8	6.1	1.5E+18	3.338	2.095369
12/6/2014	-6.11	130.4829	116	6	1.1E+18	4.255	3.182744
11/21/2015	-7.1484	129.9375	82	6.1	1.1E+18	3.952	2.55008
3/25/2018	-6.6247	129.8138	169	6.4	4E+18	4.158	10.8
6/24/2019	-6.4078	129.1692	212	7.3	6.9E+19	0.979	2.431686

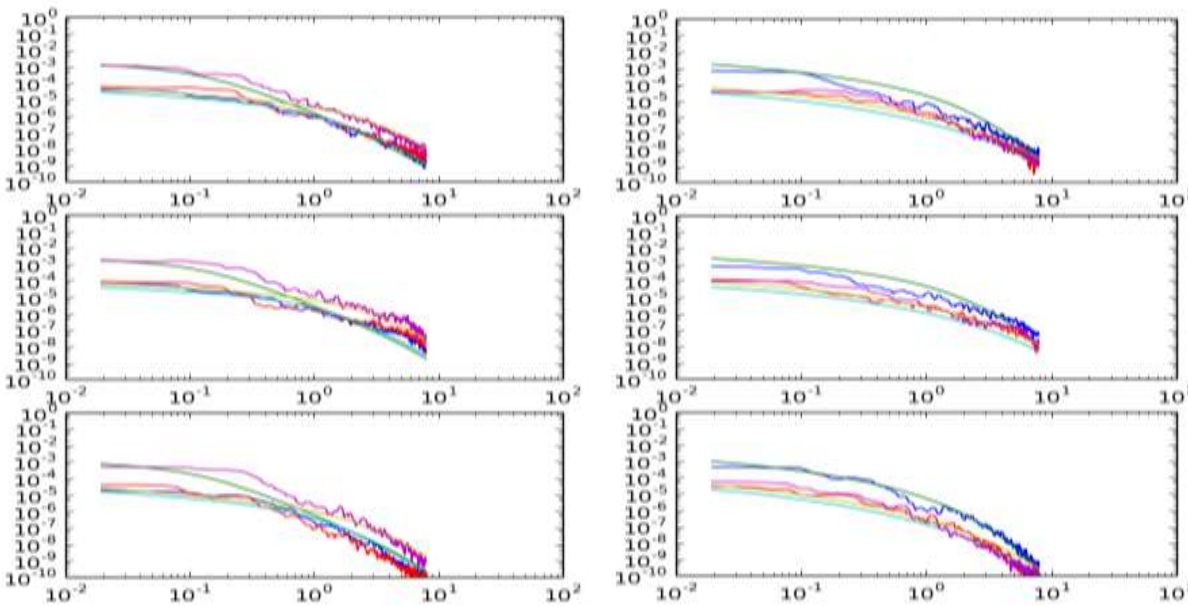

Figure 5. The best fittings with receiver and brune models from ARMA, MEEK, and MORW stations Banda Sea subduction earthquake 6 December 2014, 21 November 2015, and 24 June 2019

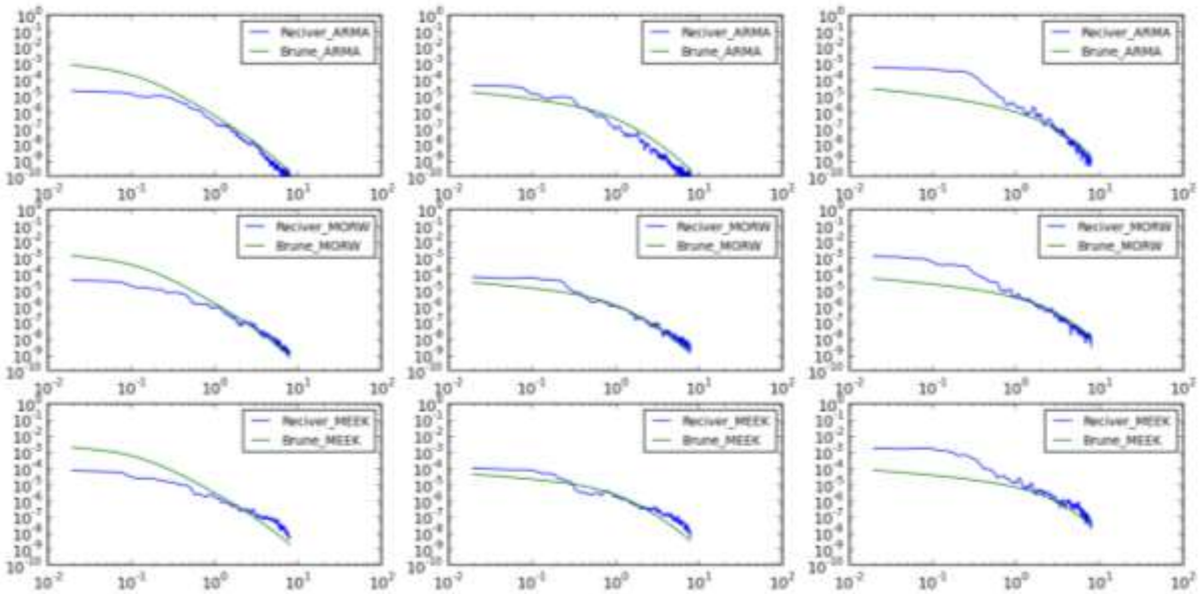

Figure 6. Source Spectrum Banda Sea subduction earthquake

Allmann and Shearer (2007) revealed that stress drop is sensitive to the tectonic type of the regime. The type of fault most of the thrust that occurs in the subduction zone has a relatively small drop stress value. The value of stress drop is small because it mostly occurs in areas with low districts, generally in shallow subduction slab areas as stated by Goebel (2015).

The unique stress drop in the sea banda subduction zone is not small when compared with most stress reduction in the subduction area which results in relatively small or even very small values as stated by Allmann and Shearer (2009). subduction zone. Cocos Central America with an average value below 1 MPa.

The value of stress drop is small because most of it occurs in areas with low districts, generally in shallow subduction slab areas. Variation in stress drop is influenced by variations in stiffness, variations in different material plates, as well as variations in the absolute value of the main stress or orientation of the plate boundary in the direction of the main stress Yuliatmoko, (2017).

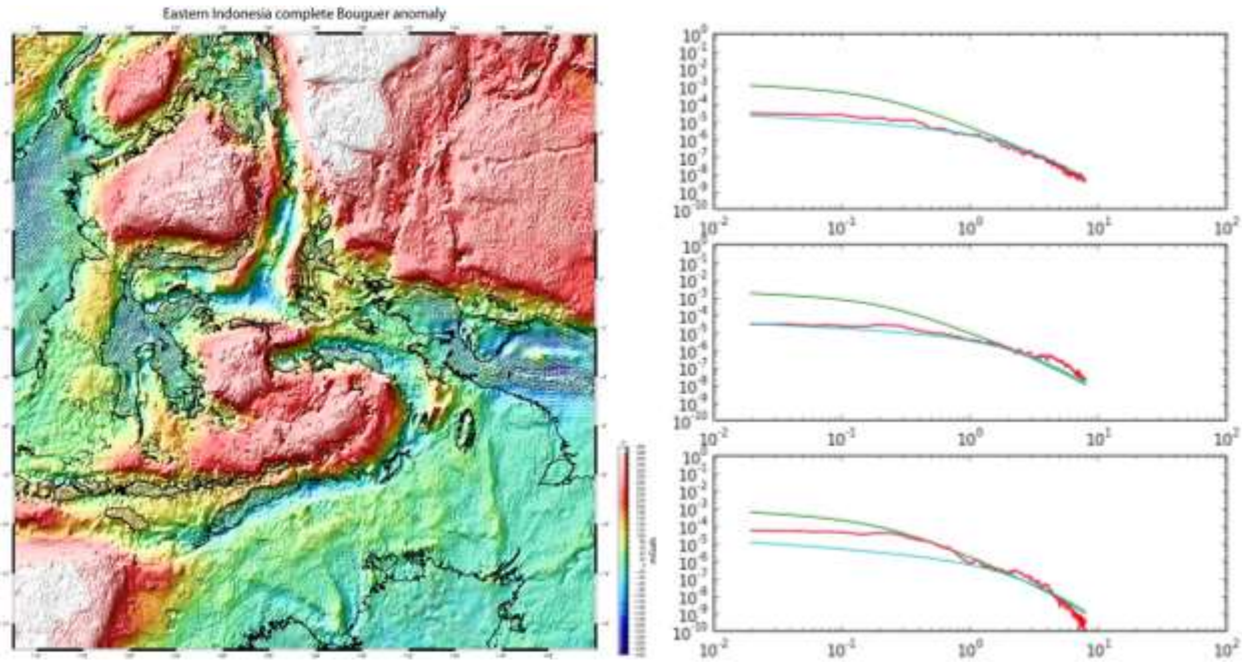

Figure 7. Eastern Indonesia complete Bouguer Anomaly (Kaye, 1987) (Left), Source Spectrum Banda Sea subduction earthquake interplate banda sea (Right)

Allmann and Shearer (2009) revealed that variations in stress drop are influenced by variations in stiffness, variations in different material plates, as well as variations in the absolute value of the main stress or orientation of the plate boundary in the direction of the main stress. Shearer (2006) revealed that stress drop is sensitive to the tectonic type of the regime.

The unique stress drop in the Banda Sea subduction zone is not small when compared with most stress drop in the subduction area which results in relatively small or even very small values as stated by Allmann and Shearer (2009). subduction zone. Cocos Central America with an average value below 1 MPa.

The stress drop value is not too small even in subduction zones in the Banda sea because rocks in the Banda sea are relatively tougher when compared to other subduction zones because the Banda Sea has a complex and varied oceanographic profile, contains many continental fragments including the Banda Arc, and has a sea basin very deep in the North Banda Basin and Weber Depth and there is a 'rollback plate' process that forms geometry in the form of a spoon or half of a very concave basin.

A similar thing also happened High stress drop values in subduction areas will occur in areas with high regimens according to Allmann and Shearer (2009) examined in the Tonga subduction area. The earthquake along the Tonga subduction showed a higher stress drop at the northern end of the subduction zone, the Wadati Beniof zone.

The strength of the rock in the sea banda is also strengthened by the results of the full gravity anomaly Bouguer in figure 7, Kaye (1987) explains that there is a significant difference in the gravity anomaly around the sea of Banda which can be seen from the complete red color of the Bouguer anomaly representing high density (Figure 7, Left)

The impact of research on stress drop in the field of geophysics is that stress drop is a manifestation of the mechanism of earthquake sources, which is closely related to tectonic conditions in the area around the earthquake. Relation Stress drop and tectonic regime this phenomenon is an interesting thing for the advancement of geophysical science because it is usually to determine our tectonic conditions through a surface approach rather than at the source of an earthquake

CONCLUSION

The value of stress drop in the Banda Sea is between 2 MPa to 10 MPa from small to medium, the variation of stress drop values varies due to the influence of geological conditions in the surrounding area, the value of the stress drop in the Banda Sea is greater than in other subduction zones, indicating that rocks in the Banda sea can withstand stress due to greater stress drop is directly proportional to the ability of rocks to withstand stress, the Banda Sea has complex tectonic characteristics and various oceanographic profiles, contains many continental fragments including the Banda Arc, and has very deep ocean basins in the North Banda Basin and Weber Depth and there is a 'rollback plate' process that forms a geometry spoon.

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