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Crustal Shear Wave Velocity Structure Using Dispersion of Rayleigh Wave Beneath Sumatra Stations

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Abstract— The structure of the earth's crust is a fundamental and very important topic in seismology, because the crustal structure can be used as initial information to study the surface conditions of an area. One method to determine the structure of the earth's crustal layers is by analyzing the dispersion of surface waves, because surface waves are very sensitive to S waves. The shear wave velocity as a result of Rayleigh wave velocity inversion can provide the information of the subsurface material properties in the earth that can be study the structure of the earth's crust. The inversion results using the SVAL program can provide the Rayleigh wave dispersion curve with group velocity which shows the station on the island of Sumatra is higher than the velocity on the island of Nias. The structure beneath the island of Sumatera was formed earlier than the island of Nias. The thickness of the crust varies in the Sumatra region, the thickness of the crust on the island of Sumatra (BKNI, LHMI, MNAI and PMBI) is 28 km and 33 km. Specifically on the island of Nias, the thickness of the crust is 19 km. S-wave velocity in the crust is 3.1 km/s to 3.7 km/s.

Keywords— Crustal thickness, Rayleigh wave, dispersion, Shear-wave, Sumatra

I. INTRODUCTION

The shear wave velocity structure is one of the most important parameters in Geophysics because it can describe the condition or geodynamics of a region[1]. The earth's crust has elastic properties that cause pressure, pull and structural deformation. Many methods have been used to determine the shear wave velocity structure in the crustal layer, one of which is using the Rayleigh wave dispersion analysis method. Rayleigh waves have elliptical particle, this is because the vertical movement of the surface is greater than the horizontal movement [2]. Rayleigh waves have unique properties, namely every wave wave propagation that passes through the boundary of the earth's material layer will experience dispersion. Dispersion is the relationship the velocity of the wave with respect to its period, so Rayleigh waves depend on the velocity of the primary and shear. The dispersion properties of Rayleigh waves is very well used to determine the structure of the earth's layers because Rayleigh waves are very sensitive to shear waves. Shear wave is one of type of wave body whose motion perpendicular to the direction of of wave propagation [3]. Shear waves can only propagate in a solid medium, cannot propagate in liquid and gas mediums, because liquid and gas mediums have elasticity is very small or the shear modulus is zero. In contrast to primary waves that can propagate in solid and liquid mediums in the earth's layers.

In the structure of the earth's crust, there are different mediums such as sediments, low velocity zones that are difficult to explain using primary wave analysis but can be explained using shear wave propagation analysis. The characteristics of shear waves and Rayleigh waves are almost the same, this is because Rayleigh waves result from shear wave interference. Shear wave velocity by Rayleigh wave inversion, the properties of matter in the earth as a function of depth can be studied and the velocity of shear waves can be analyzed can be studied and can analyze th shear waves in the structure of the structure of the earth's crust [4].The GE network of broadbrand seismic stations operated by GFZPostdam is more than 80 stations active around the world including Indonesia. There are 23 GE network broadbrand seismic stations in the Indonesian region. Five

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stations broadband seismic stations in the Sumatra region including stations GSI, BKNI, LHMI, MNAI, and PMBI. These stations record every earthquake occurrence over long or short distances, using the data recorded by the five broadband seismic stations in the Sumatra. Based on the explanation above, it can be formulated the problems in this study are how is the relationship between structural shear wave velocity with the the earth's crust at the GSI station, BKNI, LHMI. MNAI, and PMBI using wave dispersion Rayleigh wave dispersion using recorded data from broadband seismic stations in the Sumatra. This research is to explain the subsurface shear wave velocity structure and determine the value of shear wave velocity and crustal thickness at GSI, BKNI, LHMI, MNAI, and PMBI stations

II. METHODS

The location of this research is broadband stations in the Sumatra region, namely GSI, BKNI, LHMI, MNAI, and, PMBI. GSI (Gunung Sitoli) station is located on the island of Nias, BKN (Bangkinang) is located in the Riau area, MNAI (Manna) is in the South Bengkulu South Bengkulu, and PMBI (Palembang) is located in South Sumatra. The type of data used in this study is secondary data obtained from the web page: http://eida.gfz-potsdam.de/webdc3/. This research uses earthquake events in China in January 2022. The magnitude used is 6 SR and The depth of the earthquake source is shallow at a depth of 0 km to 30 km. This is done in order to have a clear surface wave dispersion that is easy to observe. easy to observe.

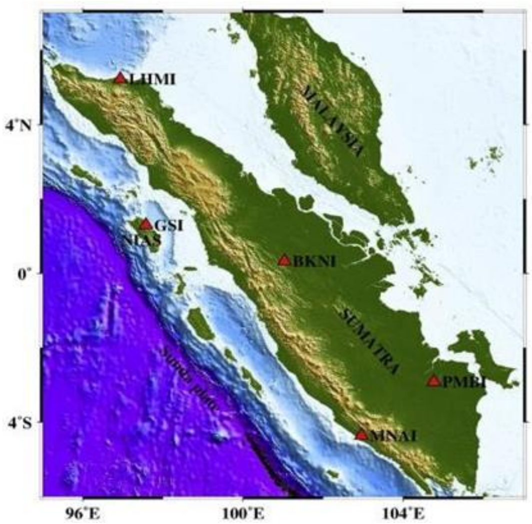

Figure 1. Research Location [5].

III. RESULT AND DISCUSSION

3.1 Surface Waves on Seismograms

Results from time-frequency analysis (FTAN) is a spectrogram that is used as a description of the frequency boundaries for filtering and further signal processing. The spectrogram of the BKNI station was analyzed with blue boundary values so that the boundary values were 0.04 Hz to 0.10 Hz. GSI station is limited by the maximum and minimum limit values and filtered at 0.04 Hz. up to 0.08 Hz. LHMI station is limited with filtered at 0.06 Hz. up to 0.11 Hz., MNAI station is limited with a value of 0.04 Hz. up to 0.10 Hz and 0.03 up to 0.07 Hz. limit on station PMBI STATION. Sampling frequency used in this study varied, namely for stations BKNI, GSI, PMBI which is 40 while for LHMI and MNAI it is 50.

3.2 Rayleigh Wave Inversion

Surface wave inversion in this study using the SVAL program developed by Kollinsky in 2003. SVAL can be used for surface wave analysis and surface wave inversion. Surface wave inversion

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using SVAL requires set parameters such as, epicentral distance to each station, sampling frequency, time interval between the time of origin and the beginning of the recording, smoothing window value to smooth the dispersion curve that will be generated, the value of the smoothing window to smooth the dispersion curve [6]. dispersion curve that will be generated, the value of minimum and maximum period for filtration process, minimum and maximum values of group speed to give a range of time interval used in the analysis in the SVAL program. The result of these parameters provide an analysis of the surface waves in the data recordings and outputs raw signal, quasimonochromatic quasimonochromatic signal and spectrogram of the of the seismic recording.

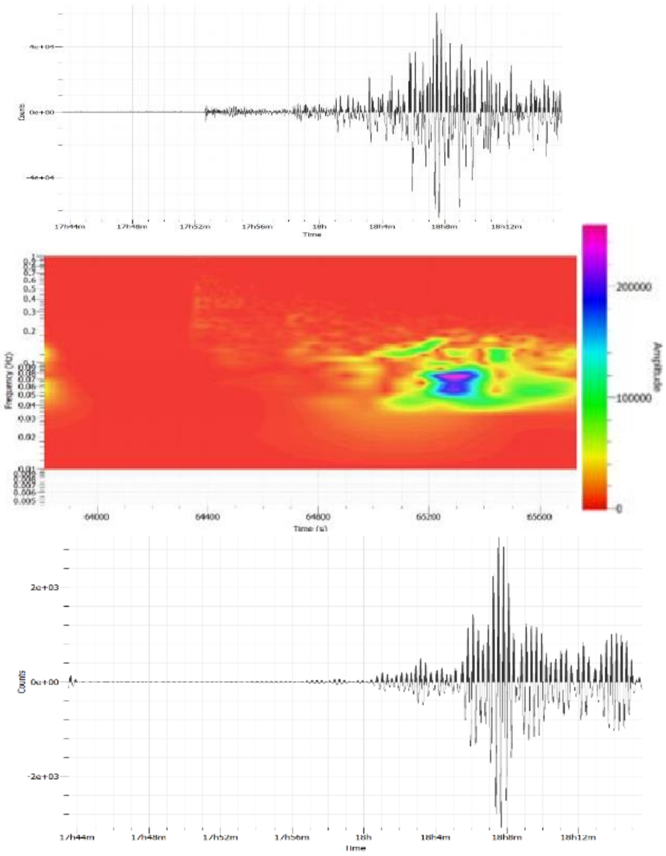

Figure 2. Signal processing and filtering according to the frequency range resulting from the FTAN on the recorded data of the GSI station.

3.3 Dispersion Curve

Figure 3 shows that curves at stations LHMI, MNAI, and PMBI have higher values when compared to stations BKNI and GSI. The dispersion curves of dispersion curves from granitic rock areas have higher group velocity, due to the difference in shear wave velocity which greatly affect the velocity of the Rayleigh wave velocity [7]. Rayleigh wave dispersion curve with minimum period limit of 20 seconds is influenced by the contrast effect between continental crustal rocks with low velocity and mantle rocks with high velocity [8].

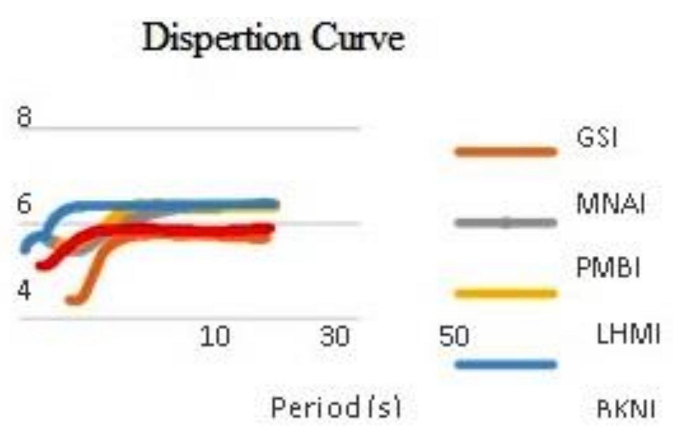

Figure 3. Dispersion Curve of Sumatra station

3.3 Structure v_s

The inversion results at the GSI station on Nias island with an initial v_s value of 1.9 km/s, 19 km depth shows drastic increase in v_s with a value of v_s 3.25 km/s and a 3 km thick sediment layer. . The initial v_s value at BKNI station is 1.4 km/s at a depth of 28 km, while below this station the below this station, the v_s value increases dramatically with a velocity of drastically with a velocity of 3.43 km/s and 1 km thick sediment. LHMI station shows the initial v_s value of 1.3 km/s and at a depth of 31 km the value increases v_s drastically with a value of v_s amounted to 3.1 km/s and a sediment thickness of 5 km. The inversion results of the MNAI station with an initial v_s value of 1.4 km/s are the same as the initial v_s value at the BKNI station, but below the MNAI station, the sediment depth is 31 km with a v_s value of 1.4 km/s. below the MNAI station plunges at a depth of 31 km with a value of v_s of 3.7 km/s and 4 km thick sediment. The initial v_s value at PMBI station is 1.2 km/s with the inversion results under PMBI station at a depth of 33 km v_s is high with a v_s value of 3.37 km/s and a sediment thickness of 7 km. Velocity value v_s at a depth of 41 km to 50 km has the same value at each station.

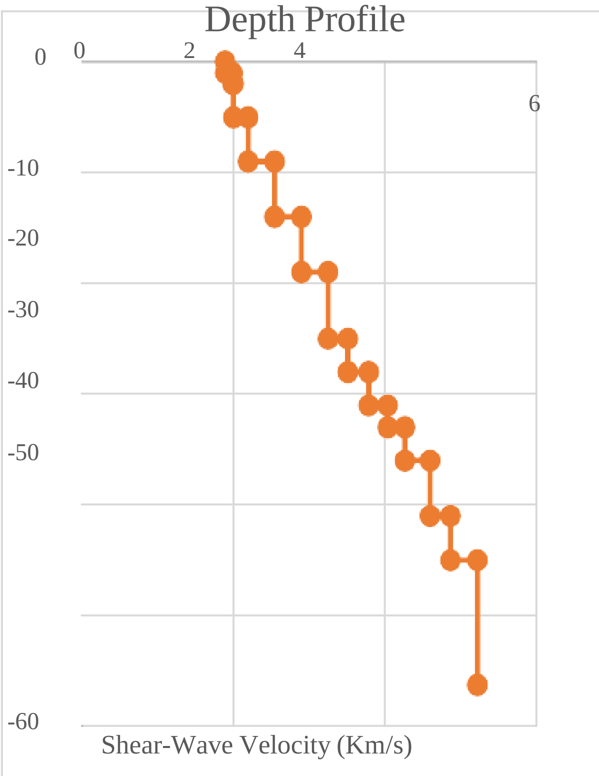

Figure 4. Inversion results at GSI station

The characteristics of the structure of the Sumatra region are thick sediments and lower lower Vs value. GSI station with thick sediments can be caused by the location of this station in the front arc of the island of Sumatra. GSI station is part of accretion formed by marine sediments eroded from the oceanic plate. At a depth of about 10 km the increase in velocity there is no visible velocity around the surface at GSI station. BKNI station sediments with 1 km with a complex structural form this is because the station is on the edge of the this is because the station is on the edge of the basin South Sumatra there is an increase low velocity in the shallow layer. PMBI station is similar to BKNI station located in the southern Sumatra basin by showing an increase in velocity in the shallow layer. layer sedimentary layer of low velocity arises at station LHMI this is probably caused by tertiary sediments in the northern Sumatra basin while at MNAI station there is a low velocity due to the presence of soft tertiary sediments in the Engano basin.

3.4 Regional Crustal Thickness Sumatra

The value of v_s is 3.75-3.85 km/s for the lower crust, so the crust under the Sumatra region station has a thickness between 19 km and 31 km. Mohorovicic discontinuity is the boundary between the earth's crust and upper mantle, It is characterized by the value of vs which increases drastically. The thickness of the crust under GSI is 19 km with a v_s value of 3.25 km/s, the thickness of the crust under BKNI is 28 km and the v_s value is 3.43 km/s. LHMI and MNAI have the same crustal thickness of 31 km and its v_s value is different, namely 3.11 km/s (LHMI) and 3.74 km/s (MNAI).

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The crustal thickness at PMBI station is 33 km and the v_s value is 3.4 km/s. The thickness of the crust under GSI and MNAI in this study is 19 km and 31 km. The thickness of the crust under three stations on the island of Sumatra (BKNI, LHMI, and MNAI) is different, but the difference in the thickness is not too far from the results of research by Bora et al. (2016).

IV. CONCLUSION

The inversion results that at depth of 10 km there is an increase velocity at the GSI station and not visible and low velocity and the presence of a thick sediment layer layer due to the influence of sediment sediments eroded from the plate. BKNI station shape complex structure and the presence of low velocity increase in the shallow layer. PMBI station shows a shallow layer while low velocity layer at depth of 20 km, while stations LHMI and MNAI the sediment layer experiences low velocity. This is due to reflection of tertiary sediments of the Sumatra at the LHMI station and tertiary sediments of the engano basin at station MNAI. Based on the modeling results the value of crustal thickness under the under the Sumatra region stationstation varies, namely 19 km under GSI station and under the BKNI, LHMI, MNAI, and PMBI, from 28 km to 33 km. Average v_s in the earth's crust under the Sumatra region is 3.1 to to 3.7 km/s.

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