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STUDY OF CRUSTAL STRUCTURE OF THE FLORES ISLAND USING RECEIVER FUNCTION METHOD

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ABSTRACT

Flores is an island located in the north of the East Nusa Tenggara region. Formed as a consequence of very complex tectonic setting that might cause relatively high level of seismic in the region. This study aims to characterize the crust structure based on the S wave velocity model, the Vp/Vs ratio, and crustal thickness beneath the station on Flores Island. This study was using receiver function analysis method of teleseismic earthquake data with magnitude criteria ≥ 6 and epicenter distance 30º-90º. Seismic signal recorded on broadband stations three components. This study was using LBFI station. Velocity model of S wave and Vp/Vs ratio determined by using the non-linear Neighbourhood Algorithm (NA) inversion. Furthermore, the velocity and Vp/Vs ratio models will be used to obtain the depth of the migration process of the amplitude of the receiver function to depth. From the results of processing the depth of the Moho layer on the island of Flores under the LBFI station was identified as 41 km. The existence of the slab can be identified quite well that is at depth about 110 to 140 km.

Keywords: Moho, receiver function, non-linear algorithm neighbourhood inversion

INTRODUCTION

The East Nusa Tenggara is part of the Sunda-Banda transition zone with complex tectonic setting which formed by subduction between Indo-Australian plate and Banda arcs [1]. The subduction made the East of Nusa Tenggara region has a relatively high level of seismicity, especially on Flores Island, can be seen in FIGURE 1. The subduction system create changes in subsurface structures such as trench, Benioff zones, outer arc units, and mountains [2]. Structure changes can be like Timor rifting, Savu basin and Sumba evolution [3].

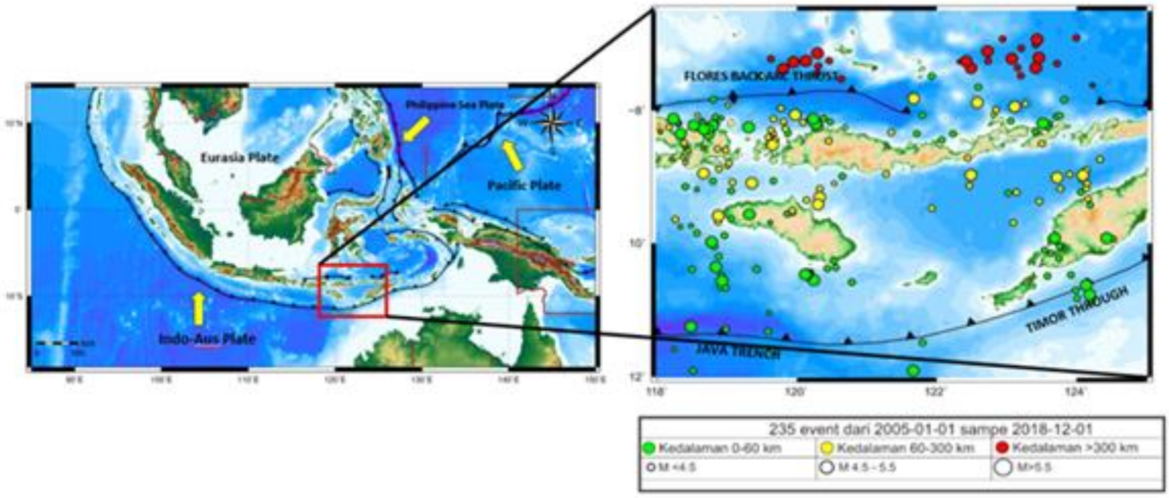


FIGURE 1. Seismicity map of transition zone of the East Nusa Tenggara

The subsurface structures can be identified by various methods, one of them is by using the analysis method of receiver function. This method requires 3 digital seismic components with a dense number of stations so that results of the method will more accurate [4]. This method is a time series to determine the physical condition of teleseismic waves before get into the observer station [5]. That time series will through a process of inversion to obtain a velocity model beneath the station [6].

This research was initiated by Vinnik in 1977 by using the phase of Ps wave in teleseismic signals. From this study, we know that the phase of P wave teleseismic will be converted at the boundaries of the discontinuity recorded below the observer station and can be indicated as a layer of discontinuity [7]. In 1979, Langston did deconvolution of earthquake signals by removing the instrument response and information of wave propagation to identify subsurface structures of Rainer Mount [8]. In FIGURE 2 the deconvolution of the teleseismic wave signal is shown by using the assumption of two planes of the earth's layers. The vertical component shows a significant amplitude of the P wave in the wave train then compared with the deconvolution results. From the research, it obtained the Moho boundary under Rainer Mount has a relation with the Olympic mountain structure. The Moho boundary below Rainier Mount is at 145 km.

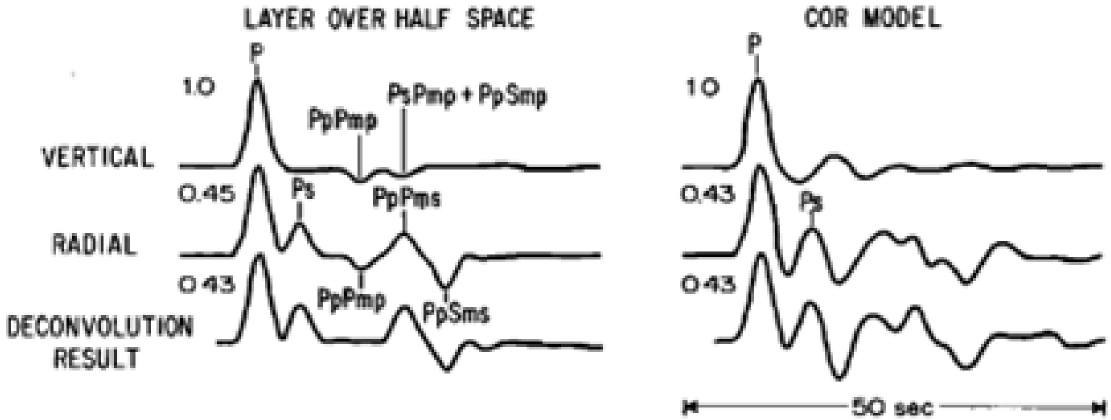


FIGURE 2. Deconvolution tecnic using two planes earth's layer (Langston, 1979)

Ammon in 1990 added a new scheme in the receiver functions method to identify the phase of seismic wave from inversion results by examining the initial model and the solution model [9]. The results of this research performed with matching observational data and synthesis data to show that the inversion of the receiver function gives a illustration of discontinuity velocity and ratio of depth to speed that similar to the reflection seismic study. FIGURE 3 shows a simple diagram of propagating P waves. The angle of incidence formed by teleseismic waves that generate reverberation of near-receivers.

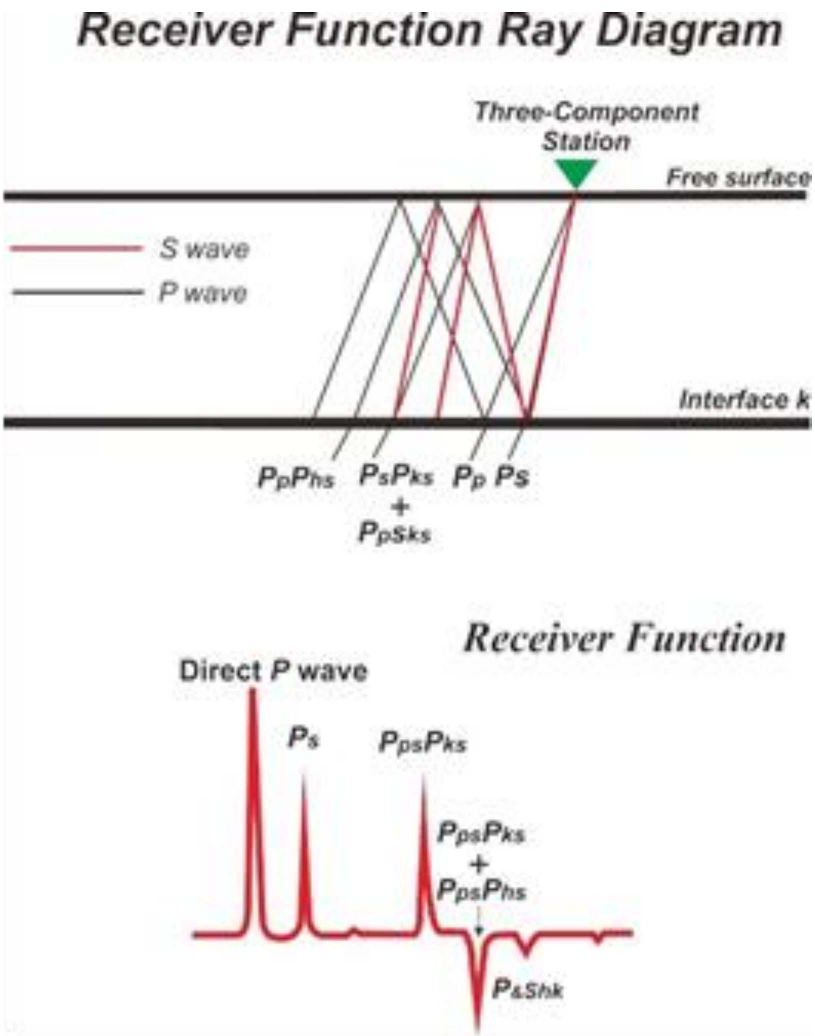


FIGURE 3. The simple wave propagation diagram to identificating conversion phase of P wave [9].

The study was continued in 1997 by Bostock and Sacchi by examinating a teleseismic phase deconvolution sudy to determine the structure of the upper mantle by deconvolution of multi-channel and multi-receiver [10]. Syuhada *et al*., also did a study of analysis the structure of the crust along the Sunda-Banda arc transition zone in 2016. That study using teleseismic earthquake data obatained from a broadband seismometer and then deconvolved. Furthermore, the results of deconvolution processed should be inversion by using a non-linear inversion of the Neighborhood Algorithm (NA) to get the velocity model in the area [11].

Referring to the previous research, in this research the author will focusing on the Flores island to estimate the thickness of the crust by using the receiver function method and also do the inversion to estimate S wave velocity model and Vp/Vs ratio. Then, the results of the inverdion get into migration process to estimate the Moho depth in that area. The results of the migration process is known to be superior in illustrate subsurface structures when compared to other methods that are only interpreted in time domain.

METHOD

This research used waveform data of some event teleseismic taken from the BMKG network station. The data must be fulfill the criteria of epicenter distance 30º-90º with magnitude ≥ 6. Waveform data were downloaded through the archives of BMKG web in full SEED format. Data must be selection based on the criteria of distance and magnitude of the earthquake catalog International Seismological Center (ISC). The author utilized LBFI station broadband with 3 component. Location of the station and distribution map of earthquake epicenters can be seen in FIGURE 4.

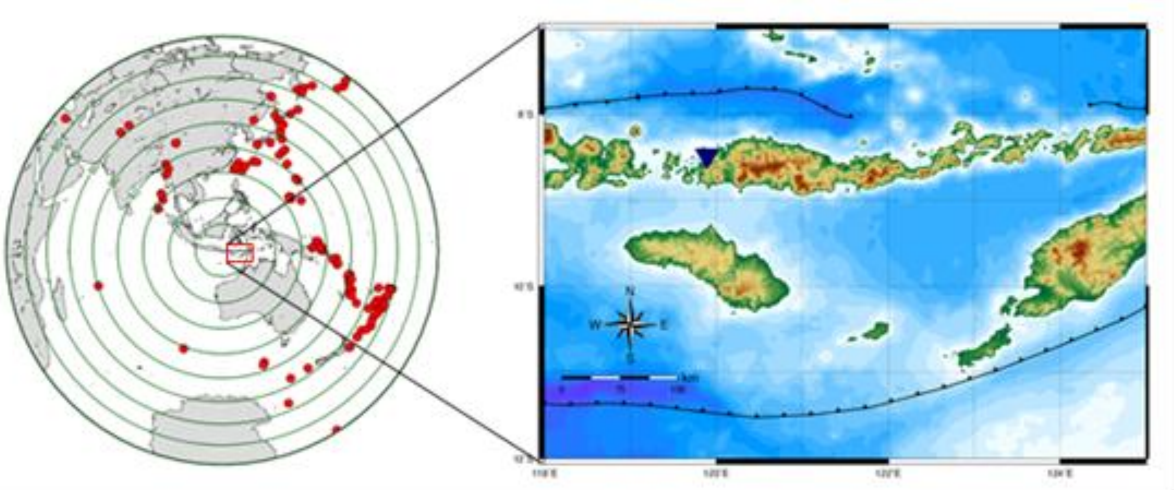
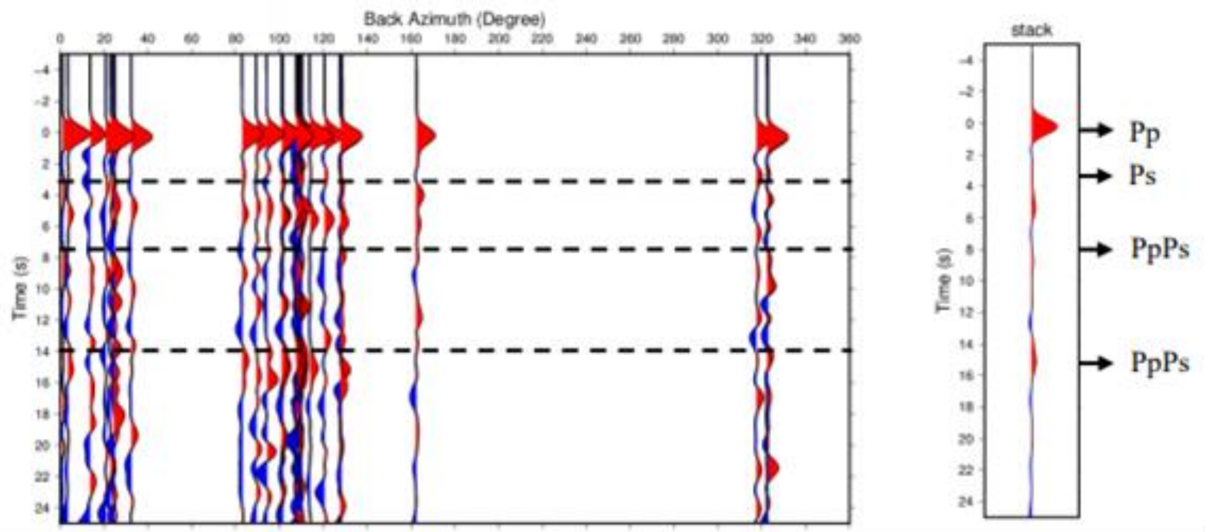


FIGURE 4. (a) Distributin map of earthquke epicenter; (b) Location of station

There are several steps in analyzing using the receiver function method. First, the data in the full SEED format that has been downloaded needs to be changed to SAC format to facilitate the process of determining the P wave. The correction of instrument response correction was used to correct the baseline seismogram. Second, rotation by utilizing the back azimuth from the observer station with teleseismic earthquake event. Rotation is aim to isolate the conversion phase of Ps wave that formed from seismic discontinuity in the three component seismogram. In this process, the data will be rotate from ZNE seismogram component to ZRT component. Then, the signal should be selected by windowing start from 10 s before and 50 s after the arrival of the P wave Third, deconvolution process by iterating 500 times. The result of this deconvolution are radial and transvese componnet of receiver function. The calculation results are selected with a misfit of 90%. In this step, a Gaussian filter with a frequency width α = 1.5 is applied. Frequency width is to eliminate the noise of high frequency of the waveform. Fourth, the deconvolution results are then plotted and stacked to strengthen the main signal by removing the effect of background noise. Fifth, determining the velocity model is using a non-linear inversion Neighbourhoud algorithm (NA) by inputting the initial model parameters and will be iterated 5000 times to find misfit criteria less than 1.5. Sixth, the migration process of the amplitude of the receiver function to depth. Migration in the depth domain is applied to change the seismic data in time series into a depth domain, which is obtained from calculations from the seismic data time series.

RESULT AND DISCUSSION

Labuhan Bajo Station (LBFI) is located at coordinates -8.48 latitude and 119.892 east longitude. FIGURE 5 shows 25 teleseismic receiver functions from several back azimuths of LBFI station. The phase of the direct P wave (Pp) is clearly observed at the 0 s arrival time followed by the phase of the Ps wave at the ~3 s which indicates the presence of the Moho layer. The other phase of Ps conversion in the ~8 seconds is indicated that it was formed due to the influence of the Flores Back Arc Thrust to the north of the LBFI station. That is because the wave phase obtained from the signal stacking process of the teleseismic receiver function comes from quadrant I and IV showing positive phases, while for quadrants II and III showing negative phases. The time of srrival wave at ~14 s, seen conversion phase of Ps wave characterized by positive large amplitude that indicated the scheme of slab subduction of Indo-Australian.



(a) (b)

FIGURE 5. (a) Receiver function on LBFI station; (b) Receiver function stacking result

FIGURE 6 and FIGURE 7 shows the S wave velocity model, the Vp/Vs ratio from the NA inversion results and wave fitting between inversion wave and the observation waves. The velocity profile of LBFI station showed a sediment layer with thickness less than 1 km with low velocity 1.75 km/s and quite relatively high of ratio Vp/Vs, reach ~2.48. Then the S velocity wave increase up to ~3.1 km/s to ~29 depth km accompanied by decrease the ratio Vp/Vs to 1.78. The presence of the Moho layer is estimated at ~40 depth km.

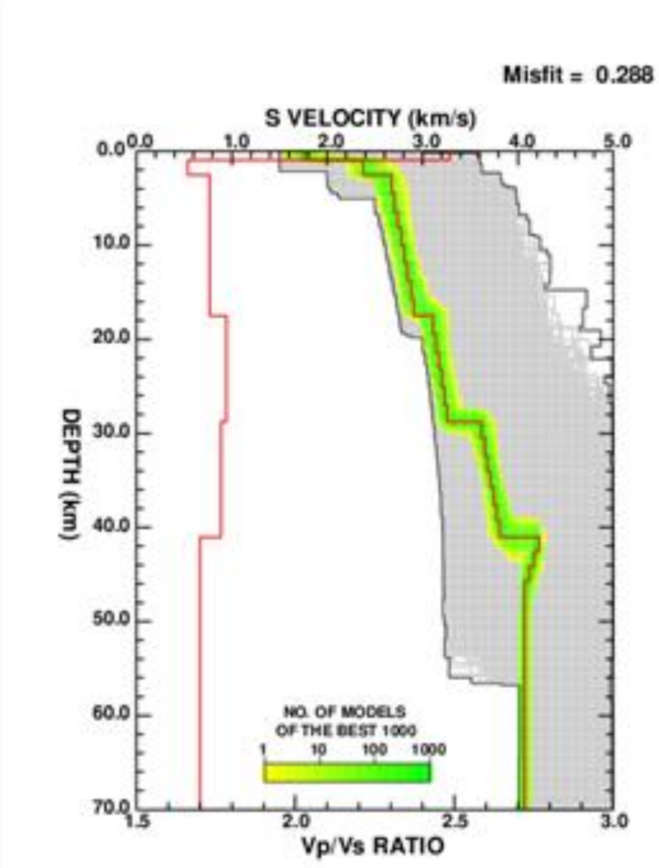


FIGURE 6. The S wave velocity profile and Vp/Vs ratio under LBFI station.

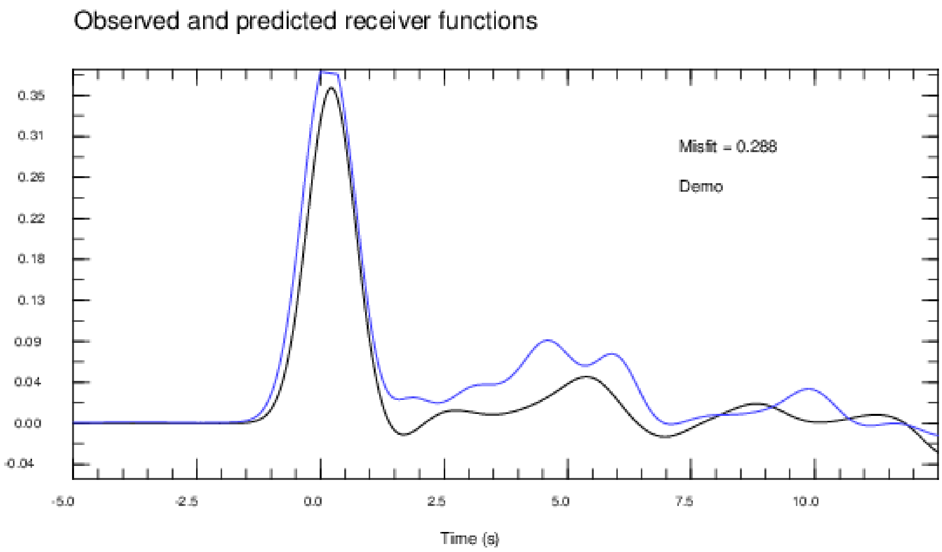
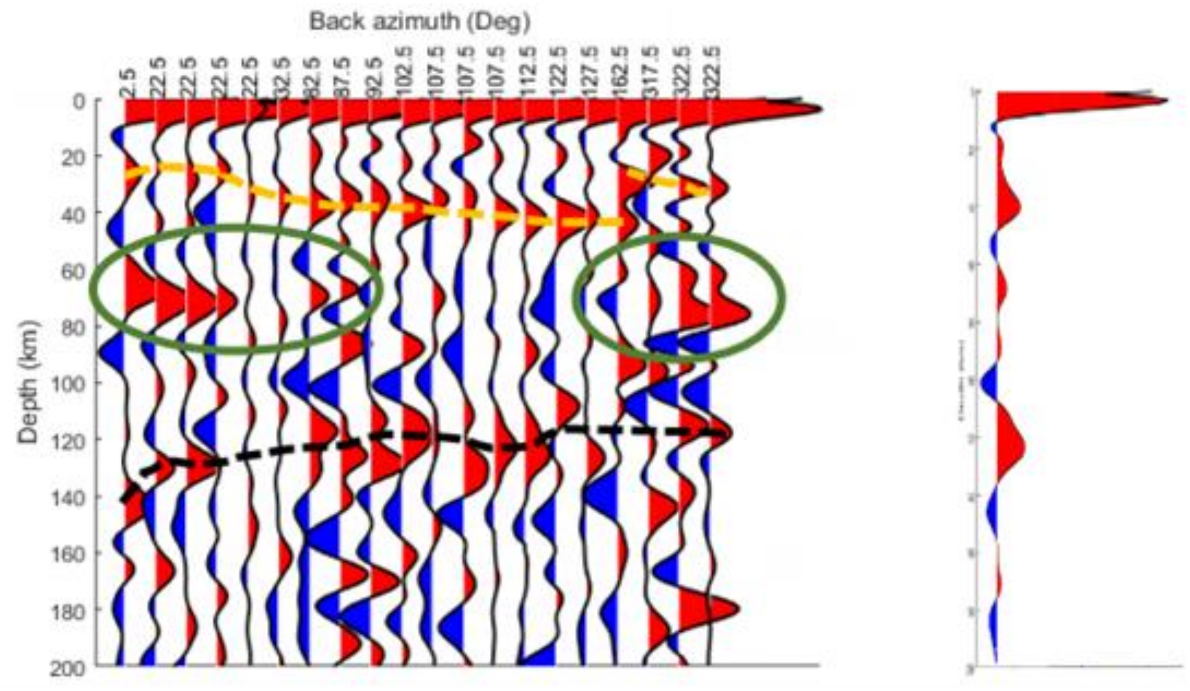


FIGURE 7. The inversion wave and the observation wave.

The crust thickness and slab presence can be analyzed from the results of migration process of the receiver function to depth using data from the velocity model obtained through the NA inversion process. In FIGURE 8, the thickness of the crust is estimated to be around 20 – 41 km, which is shown with the phase of Ps wave which has a positive amplitude, marked by a yellow dotted line. The slab presence indicated at 100 – 140 depth km, marked by a black dotted line. The slab is indicated based on the conversion phase of the Ps wave.



(a) (b)

FIGURE 8. The result of migration process

Flores Island is an oceanic crust which is part of the active Sunda-Banda magmatic arc. This magmatic arc is accommodated by the northern subduction of the Indo-Australian plate. The Moho layer of Flores island, especially under the LBFI station mapped based on the NA inversion calculation results, i.e. at ~41 depth km. Prasetyo in 1992 estimated this area had a crust thickness exceeding 22 km [11]. Indication of slab subduction of Indo-Australian plate is seen from the phase of conversion Ps wave at 100 – 140 depth km. This also corresponds to USGS global slab modelling for the Indo-Australia subduction zone at a depth of ~110.83 km. Also based on research conducted by Hayes et al., in 2012. It found that the slab under the LBFI station ranged from 110 – 150 km which can be seen in FIGURE 9. The presence of the Flores Back Arc Thrust in the area at the LBFI station is indicated by the existence of another phase conversion of Ps wave in the ~8 s. However, to ensure indications of the Flores Back Arc Thrust and subduction slab, further research and dense number of station needs to be improved so it can be properly analyzed.

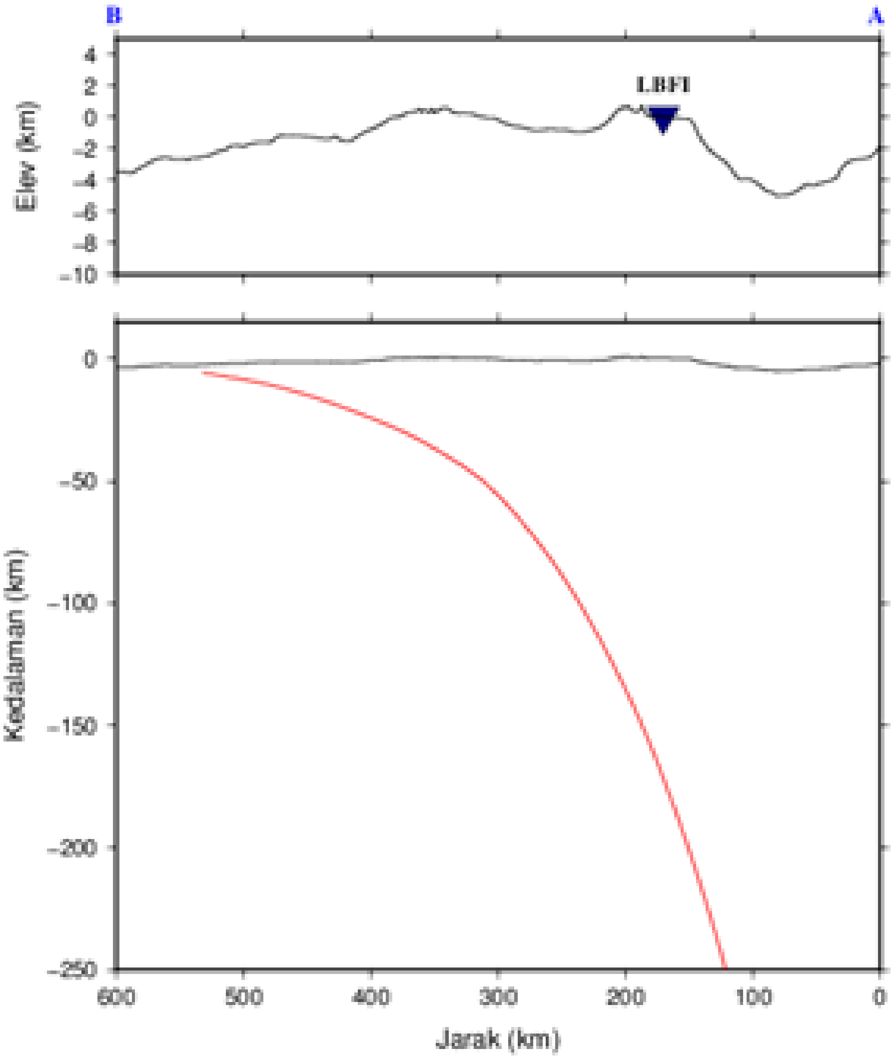


FIGURE 9. Vertical cross section of model slab

CONCLUSION

Analysis of receiver function to determination the structure of the subsurface Flores Island, East Nusa Tenggara have been carried out using the method of inversion algorithms Neighborhood. It can be concluded that the crust thickness of the Flores island, especially under the LBFI station reaches ~ 41 depth km, which is shown by the phase of the Ps wave that has a positive amplitude. This also adjusted by the increase of S wave velocity to ~3.1 km/s to ~29 depth km followed by the Vp/Vs ratio decrease to 1.78. Slab presence indicated at 100 – 140 depth marked by the phase of conversion Ps wave. However, for more properly results, it requires further study using more data from all directions back azimuth to determine subsurface structures.

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