Initial Result of P Wave Tomography Model in Sunda-Banda Arc Transition using FMTOMO

P T Brilianti¹, Haolia¹, M I Sulaiman¹, S S Angkasa¹, S Widyanti¹, I Herawati¹, S K Suhardja¹, A D Nugraha², Z Zulfakriza², S Widiantoro²,³, M Ramdhan⁴

¹ Faculty of Exploration and Production Technology, University of Pertamina, Jl. Teuku Nyak Arief, Simprug, Kebayoran Lama, Jakarta 12220, Indonesia
² Global Geophysics Research Group, Faculty of Mining and Petroleum Engineering, Institute of Technology Bandung, Jalan Ganesa No. 10, Bandung 40132, Indonesia
³ Faculty of Engineering, Maranatha Christian University Bandung, Jalan Surya Sumantri No 65, Bandung 40164, Indonesia
⁴ Agency for Meteorology, Climatology and Geophysics, Jalan Angkasa I, No. 2, Kemayoran, Jakarta, Indonesia

*Corresponding author: s4ndy104@gmail.com

Abstract. Our study area is located near island Sumbawa, Sumba, Flores, West Timor, Indonesia and East Timor, popularly known as Sunda-Banda arc transition zone. The tectonic setting is mainly controlled by the movement of the oceanic lithosphere Indo-Australian plate subducting the Eurasian plate and Northward migration of Australian continental lithosphere into western Banda-arc in the region of Flores, Sumba and Timor island. We tried to image velocity structure beneath these regions using regional events and tomography inversion model. We collected 5 years of regional events from the Indonesian Agency of Meteorology, Climatology and Geophysics. In total, we reserved 3186 events recorded on 29 stations. For data processing, we used fast marching method as ray tracing between sources and receiver. We then employed subspace inversion as the tomography procedure to estimate the best velocity model representing the tectonic model in the region. Hypocenter data distribution is concentrated on shallow parts of the region and along the Benioff zone down to a maximum depth of 400 km. One of challenge of this study is that although events are abundance, the stations used are mostly located onshore and does not extend in the south-north direction that leads us to under determined problem in the inversion process. However, checker-board models show most our target area can be retrieved to its initial model with sign of smearing effects shown start from a depth of 50 km. After six iteration and optimized selection of damping and smoothing parameters, we observed low velocity anomaly under Bali, Lombok, Sumba, East Nusa Tenggara at shallow depth that may be related with volcanic activity. Deeper low anomaly can also be seen that may be related with partial melting process. A band of fast velocity is clearly seen that goes deepen to the north depicting subducting slabs own to a depth of 300 km. We also observed a possible of fast velocity in the northern part of our stations at shallow depth that we believe may represent the back arc thrust.

Keywords: Sunda-Banda Arc, Subduction, Back Arc Thrust, FMTOMO.
1. Introduction
The tectonic setting of Indonesia is dominated by the interaction of three major plates. Indo-Australian Plate moves northerly, Pacific Plate which moves westerly, and the Eurasian plate [1]. One example of complex interaction is in eastern part of Indonesia especially in the Sunda-Banda Arc zone and also the subject of this study (Figure 1). The transition zone is affected by the movement of Indo - Australian Plate northerly with a convergence rate of around 7.7 mm/year [2]. The Indo-Australian plate has a variety of subduction ages: in south Java, subduction began from 40 Ma, and in the eastern Indonesia, began from 110 Ma [3]. The differences in subduction age affect the subduction dip. The angle of the slab dipping reaches 55° - 60° in Sunda Arc and 75° - 80° in Banda Arc [4]. One interesting geological feature is the occurrence of Flores back-arc thrust system located in Northeast Bali to Flores [5]. [6] proposed that the mechanism of back-arc thrust is more influenced by the subduction rather than the pressure of volcanic arcs. Based on previous historical earthquakes from BMKG, Flores back-arc thrust generated the 2018 Lombok’s earthquake with a 7.0 magnitude that awakens a 50 km tsunami. This area has the potential for tectonic earthquakes with various scales. This study tried to image the geological structure to better understand the geodynamic system of the region such as the relation between subduction and volcanic arc and seismicity pattern.

2. Data and Method
This study is a joint research between Universitas Pertamina and the Agency for Meteorology, Climatology and Geophysics, Indonesia. We selected events data with a ≥ 3 magnitude and 20-400 km depth range within 4 years (January 2015 - December 2018). The total number of earthquake events is 3186. Figure 1 show the seismicity patterns of our data set. Most event shows a gradual depth increase from South to North direction. Interestingly a gap of shallow-mid range depth seismicity is seen between 121° to 123° longitude near the Timor Island. We also observed a series of deep events with depth more than 300 km at the north section of our study. The same area shows a few numbers of shallow events close to geological featured plotted as back-arc thrust.

![Figure 1](image.png)

**Figure 1.** Map of distribution of seismicity and stations in the study area using BMKG data. Magenta inverted triangles represent the seismic stations. Red to blue circles represent the epicenters of earthquakes between January 2015 and December 2018 as a function of earthquake depth. Black triangles are volcanoes.

To illuminate structures in this study, we applied P wave delay time seismic tomography method. We used the fast-marching method for ray tracing reconstruction between sources and receivers [7]. We preferred to select 1-D velocity model from ak135. For the parameterization, we set an interval depth of 56 km in vertical direction, 105.45 km of x-direction (longitude) and 56.61 km of y-direction (latitude). Due to imbalances data set and grid parameterization, we applied damping and smoothing, and the number is set by using the trade-off between data variance and model.
3. The result, Discussion, and Conclusion

3.1. Checkerboard Resolution Test

The checkerboard resolution test is used to investigate an area that has a good resolution. The input model used positive and negative perturbation of 0.2 km/s relative to the 1-D reference velocity model. The size of grid anomaly is adjusted with the expected model size of our geological model and similar with our real model inversion.

![Checkerboard Resolution Test](image)

**Figure 2.** Top is horizontal slices of checkerboard model at different depth. Bottom is vertical slices of checker boards at different cross section from north (left) to south (right).

The checkerboard horizontal section (Figure 2) shows good structures recovery beneath East Java, Bali, Lombok, Sumbawa, Flores, Sumba, Savu Sea, Timor, and Flores back-arc thrust at the depth of 20 to 70 km. We confidence to image our target model within this area though the resolution start to disappear from a depth of 200 km. Vertical cross section at Figure 2 show a possible smearing effect from the North and less resolution in the East, coincidence with the area of seismicity gap near Timor island.
3.2. Vp Tomography Model

Figures 3 and 4 show the final tomography model in horizontal slices and vertical slides. Horizontal slices at shallow section displays a slower or negative velocity anomaly in Bali, Lombok, western Sumbawa, western Flores, and Sumba that coincidence with volcanoes line. Low velocity anomaly also seen beneath western Flores and southern Sumba that extend at deeper depth. We pre-interpreted the low anomaly might be related with a partial melting zone. [8] mentioned that the deeper low anomaly is the result of continent-arc collision related to the northern boundary of the Indo-Australian plate. From the previous study, [9] mentioned that they presented the low anomaly beneath Flores and NE of Sumba at a depth of ~50km. [10] also mentioned that they presented a low shear wave velocity anomaly at a depth of 15-25 km in this area. Vertical section from the west to east shows a similar features of fast velocity model that the dip from south to north direction. They slightly show that the extend of fast velocity anomaly is deeper in the east. The fast velocity most likely represents the subducting Indo-Australian plate to the Eurasian plate. We observed the dipping of slab changes from slightly steep at shallow depth and very steep from a depth of 80 km. A possible break in slab is seen at line D near Timor Island that coincides with a gap of seismicity in this area. A feature of back-arc thrust is slightly seen though not clear in the northern part of the stations. [9] detected of forearc sliver beneath the Savu Sea, central and eastern Flores, and western Timor, however we have not seen that due to less station number in the East.

![Figure 3]( attachment: figure3.png)  
**Figure 3.** Horizontal slices for Vp models for the depth section at 20-250 km of depth.
Figure 4. Tomogram Vp models for the vertical section along A-A', B-B', C-C', and D'D' lines. Models are plotted with a perturbation scale of ± 4 km/s. The location of vertical sections is shown in Figure 2.

3.3. Conclusion
As the conclusion, this study promises a good tomography model in illuminating subduction slab in the Sunda-Banda arc. A zone of low velocity band is also seen near volcanic line and partial melting area. However, we would like to improve our imaging by adding more regional data set in the near future.

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