P- and S-wave Velocity Structure beneath Central and East Java, Indonesia: Preliminary Study

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Introduction

Plate subduction along the Java Trench plays a major role in producing destructive earthquakes and volcanic complexes for the region. To understand the physical processes related to tectonic activity, seismicity, and volcanism, reliable subsurface information is needed. Seismic tomography is one geophysical tool which can provide information about the three-dimensional distribution of seismic velocities of the subduction zone. For example, the presence of a cold subducted slab and hot magma in the crust and upper mantle is reflected in the strong contrast of seismic velocity, which can be obtained by seismic tomography (Zhao 2015).

The study area covers the Central and East Java region, which is part of the Sunda Arc, a long subduction zone in southwestern Indonesia, where there is orthogonal subduction of the Indo-Australian plate beneath the Eurasian Plate. This study aims to determine the 3-D seismic velocity structure (Vp, Vs, and Vp/Vs ratio) and its relation to geological features, i.e., subducted slab geometry, volcanism, and active faults in the study area.

Data

We collected a series of waveforms from 1,483 events (M>3) in the period January 2009 to September 2017 with more than re-picked ~20,000 P- and S-wave phases from 34 stations of the Meteorological, Climatological, Geophysical Agency of Indonesia (BMKG).

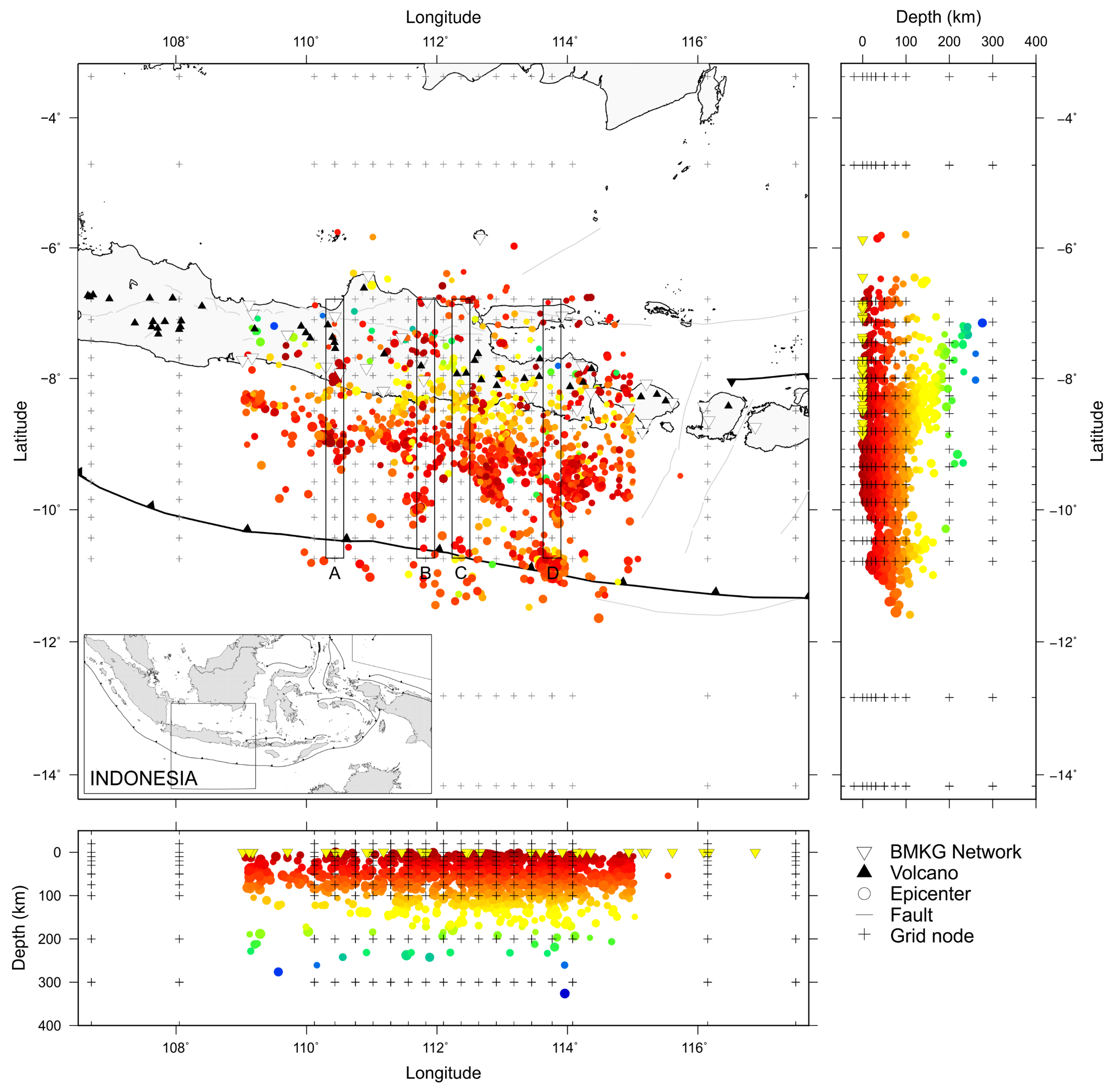

Fig 1. Map showing the distribution of relocated seismicity and grid nodes around Central and East Java, Indonesia. The rectangles A-F are the area used to plot the vertical cross-section in Fig 2

- an intial 1-D seismic velocity model of Muttaqy et al. (2020) with a Vp/Vs ratio of 1.78
- a 30x30 km grid spacing horizontally and various grid spacings of 10-100 km in the vertical sections.

Workflow

Data Preparation → Model Parameterization → Ray Tracing: pseudo-bending (Um and Thurber, 1987) → Tomographic Inverion: SIMULPS12 (Evans et al. 1994) → Resolution Tests: CRT, DWS, DRE, RHC → Interpretation

as shown in Fig 1

Inverted for both hypocenter relocation and velocity structure simultaneously using least-square algorithm and damping regularaization.

The checkerboard resolution test (CRT) is the most common way to examine the resolution of seismic tomography. We perturbed the velocity by ± 10% relative to the initial 1-D velocity model and then calculated the travel times to the stations for each earthquake location.

Checkerboard Resolution Test

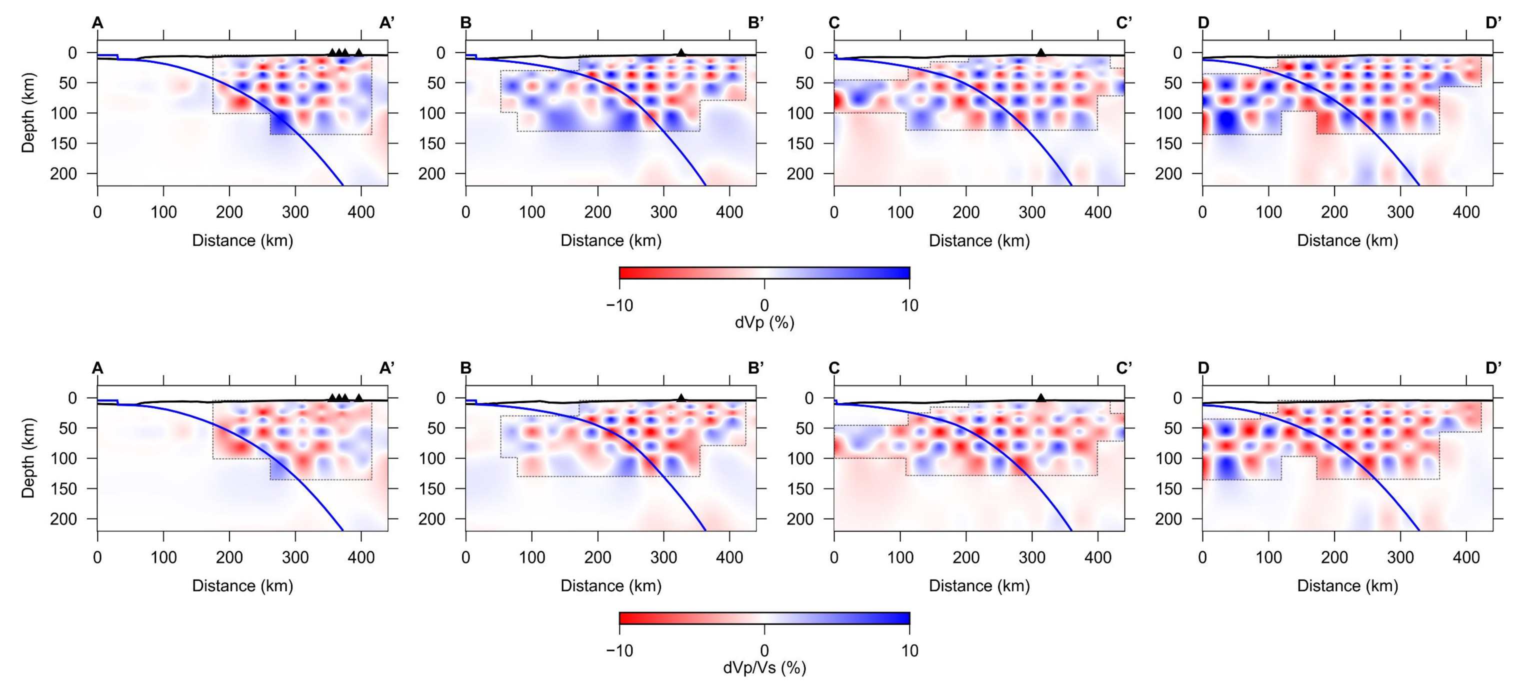

Fig.3. Results of checkerboard resolution test for Vp and Vp/Vs ratio.

Results

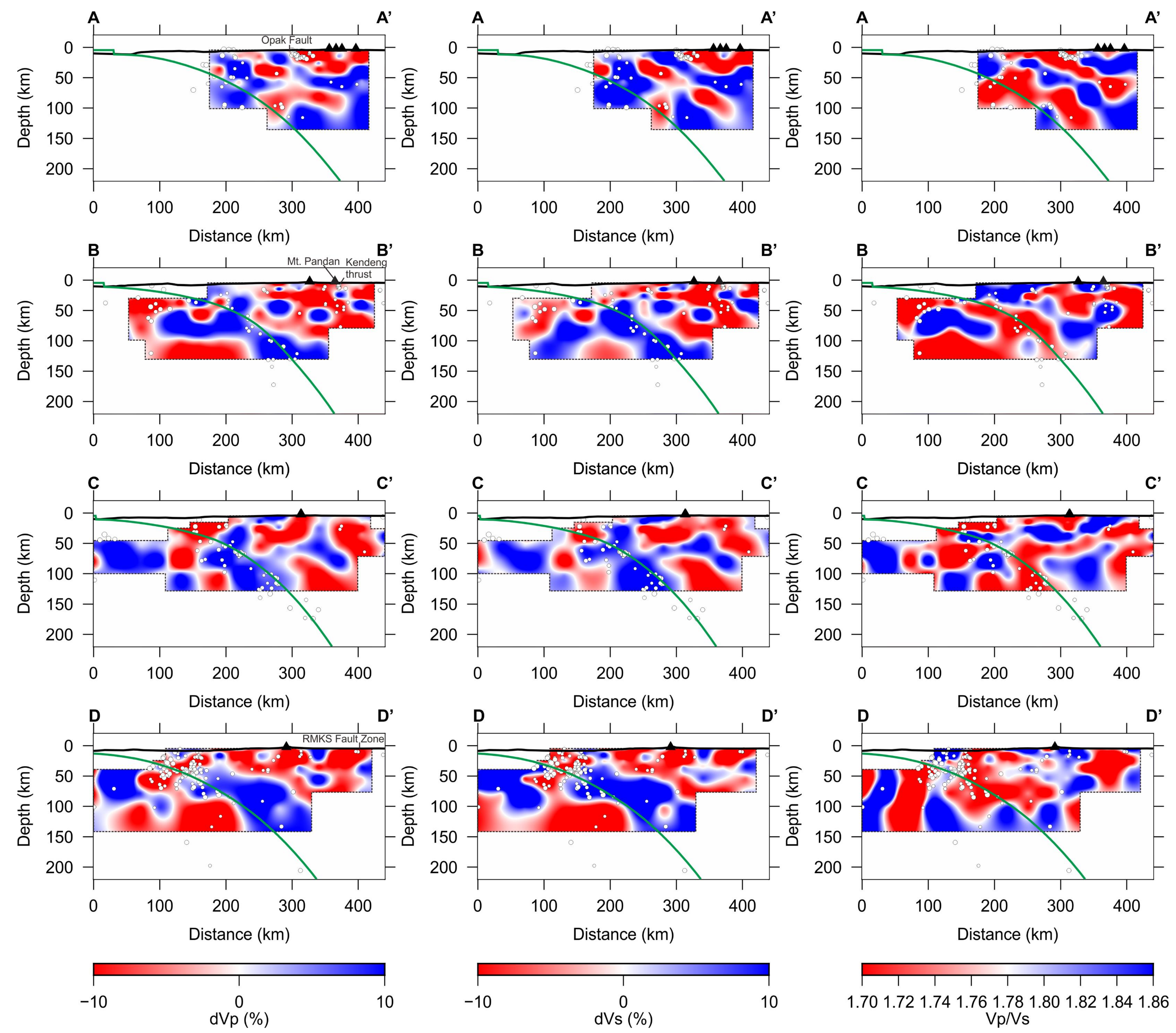

Fig 3. Vertical sections for Vp, Vs and Vp/Vs ratio with relocated seismicity across Mt. Merapi-Merbabu (A-A'), Mt. Wilis (B-B'), Mt. Kelud (C-C'), and Mt. Ijen (D-D'). Blue line indicates the slab 1.0 model (Hayes et al., 2012). Black triangles show locations of volcanoes.

Conclusions

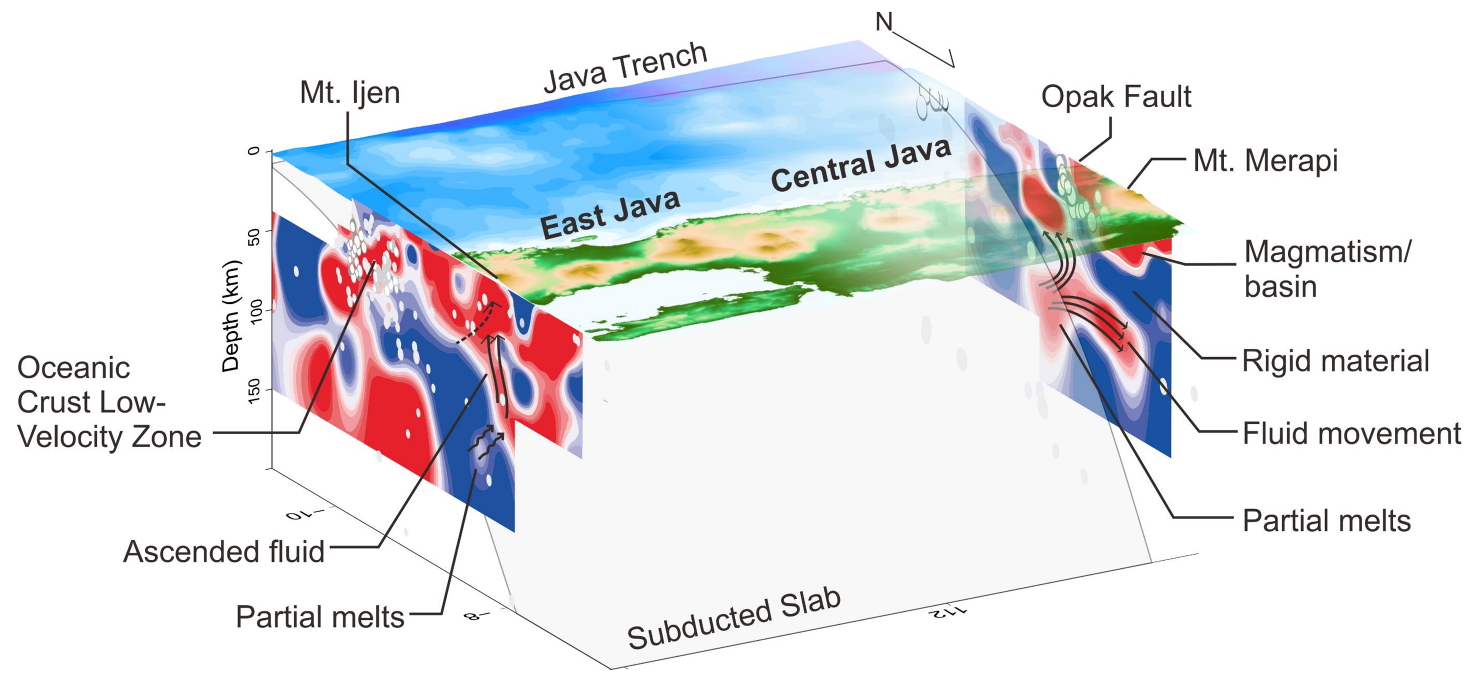

Fig 4. Schematic seismic velocity structure beneath Central and East Java subduction zone. The cross sections show Vp distributions which pass through Mt. Merapi-Merbabu and Mt. Ijen, respectively.

- Generally, the presence of a subducted slab is quite recognizable dipping toward the north at depths of about 50 to 100 km, by the high-velocity areas with a low Vp/Vs ratio and is roughly compatible with the slab model 1.0 (Hayes et al., 2012).
- In Central Java, rigid material with high Vp, high Vs and low Vp/Vs appears to surround the molten material that corresponds to the low-velocity anomaly area at the depth of 25 km beneath Mt. Merapi. We proposed that the low-velocity anomaly area is at a cooling stage, or the thick sediment does not allow the supply of molten material. This is why the fluids and melts derived from the subducted slab cannot directly ascend to the surface, as illustrated in Fig 4.
- The oceanic low-velocity zone is likely to be found at ~50 km depth beneath East Java, as illustrated in Fig 4. The high-fluid conditions may be responsible for this anomaly — the water released from marine sediments and oceanic crust of the subducted slab.
- Several instraslab earthquake clusters are located at the oceanic crust low-velocity zone. It is suggested as the subduction seamount, which are more hydrated than the surrounding slab. However, we have no evidence that the seamount chain extends to the west over a length ~150 km.

References

Evans, J. R., Eberhart-Phillips, D., and Thurber, C. H. (1994): User's manual for SIMULPS 12 for imaging Vp and Vp/Vs: A derivative of the Thurber tomographic in version SIMUL3 for local earthquakes and explosion, Open-File Report 94-431.
Hayes, G. P., Wald, D. J., and Johnson, R. L. (2012): Slab1.0: A three-dimensional model of global subduction zone geometries, Journal of Geophysical Research: Solid Earth, 117(1), 1–15.
Muttaqy, F., Nugraha, A. D., Puspito, N. T., Sahara, D. P., Zulfakriza, Z., Rohadi, S., and Supendi, P. (2020): Hypocenter Determination and Relocation with Updated 1D Seismic Velocity Model and Waveform Cross-Correlation Data around Central and East Java Region, Indonesia, in publication.
Um, J., and Thurber, C. (1987): A fast algorithm for two-point seismic ray tracing, Bulletin of the Seismological Society of America, 77(3), 972–986.
Zhao, D. (2015): Multiscale Seismic Tomography (1st ed.), Springer Japan, Tokyo, 304.

Full-paper

Muttaqy, F., Nugraha, A. D., Mori, J. J., Puspito, N. T., Rohadi S. and Supendi P. (2020): Tomographic Imaging of 3-D Seismic Velocity Structure beneath the Central and East Java Region, Indonesia, (submitted to Earth, Planets, and Space).

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