3D Seismic Tomography Imaging of Taiwan Substructure

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Abstract-Taiwan has a high rate of crustal deformation and a strong seismic activity. Taiwan is located on the convergent boundary between the Eurasian and the Philippine Sea plates. Seismic tomography is an imaging technique that uses seismic waves to create three-dimensional images of Earth's interior. We use the earthquake of M > 4.7 and occurred in the period of 1 January 2009 to 31 December 2010. The data processing steps of seismic tomography are picking of P and S wave using SeisGram2K60, hypocenter relocation using Hypo71, and tomography inversion using LOTOS-12. The result shows that there is high Vp and Vs in the eastern Taiwan that represent the western boundary of Philippine Sea Plate with Longitudinal Valley.

Index Terms - Earthquake, Taiwan, relocation, tomography.

INTRODUCTION

Taiwan has a high rate of crustal deformation and a strong seismic activity, and many disastrous earthquakes have occurred in the past [1]. In the 20th century, disastrous earthquakes in this region have caused great damage to properties, as well as to human lives [2]. With large number of earthquakes in and around Taiwan, it is thus important to analyze the seismic velocity structures under Taiwan Island to recognize background seismicity in the Taiwan region for the purposes of future earthquake hazard evaluation. A technique to develop images of individual slices through the deep Earth called seismic tomography. Seismic tomography is one of the main techniques to constrain the three-dimensional (3-D) distribution of physical properties that affect seismic-wave propagation: elastic, anelastic, and anisotropic parameters, and density. Tomography images show the detail of velocity structure under Taiwan.

METHODS

In this study, the data is downloaded from IRIS catalog. The selection of earthquakes was based on the following criteria: (1) earthquakes occurred in the period from 1 January 2009 to 31 December 2010; (2) the events have magnitude *M*> 4.7; (3) the events recorded by 7 stations of Broadband Array in Taiwan for Seismology (TW).

Pick all the arrival time of P and S wave manually using SeisGram2K60 software and re-determine locations of earthquake using HYPO71. The P and S wave arrivals time, latitude, longitude, depth, and a one-dimensional (1-D) horizontally layered P wave velocity model were used as input of Hypo71 for hypocenter relocation.

LOTOS-12 was used for our 3-D Vp, Vs, and Vp/Vs inversion. The LOTOS code is a ray tracing algorithm based on the Fermat principle of travel time minimization. After 1-D velocity model and the preliminary location of the source is known to the optimization of 1-D models, then do relocation with 3-D ray tracing, then the next step is use a gradient method to obtain the location of the source in the 3-D model. Parameterization method using nodes. Overall matrix inversion to be obtained by using the iterative LSQR. Iteration can be repeated in order to get the best results. In order to reduce the effect of node distributions on the results, we perform the inversion using several grids on a horizontal plane. In depth, a total of 9 grid points are distributed at depths of 9, 13, 17, 21, 25, 30, 35, 50, and 70 km.

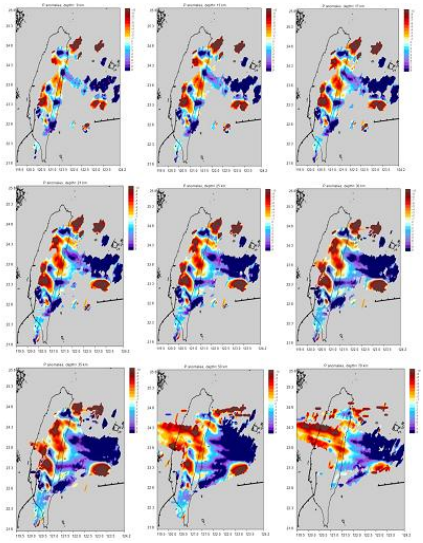

Figure 1. Anomalies distribution of Vp at 9 different depths. Red and blue shows low and high anomalies, respectively.

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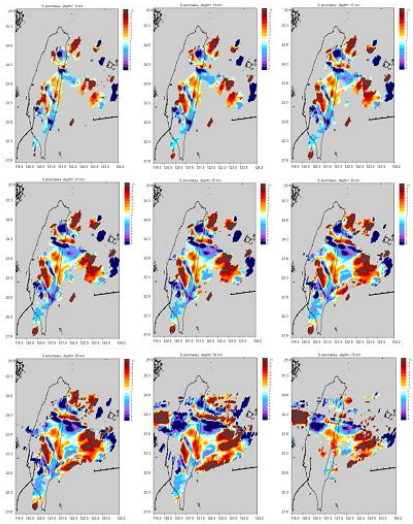

Figure 2. Anomalies distribution of Vs at 9 different depths. Red and blue shows low and high anomalies, respectively.

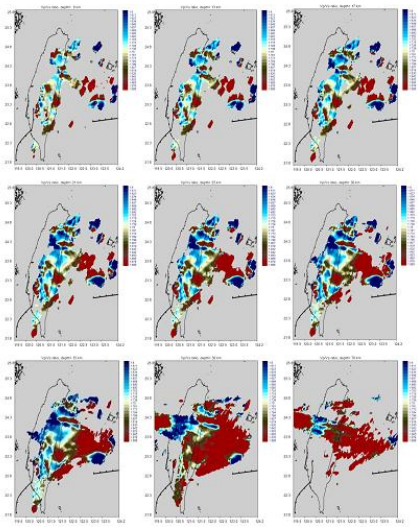

Figure 3. Vp/Vs perturbation maps at nine different depths. Blue and red show high and low velocity, respectively.

RESULT AND DISCUSSION

The 3-D Vp structure from our inversion largely agree with that obtained in previous studies [1] [3]. Figure 1, in shallow depth (<10 km deep) was found the negative anomaly of Vp and Vs, low Vp/Vs that are associated with Neogene sedimentary rocks in the Western Foothills.

Negative anomaly of Vp and Vs also found in the northern part of Taiwan at the depth of 9 km to 35 km. It is agree with [3] that show the negative anomaly is probably related to the Tatun and Chilungshan volcanic groups. Reference [4] showed that the active volcanic regions are generally underlain by low-velocity zones. A low-velocity zone in the northern part of Taiwan is probably related to this geothermal effect, which reduces the P wave velocity.

Figure 3 show high Vp/Vs was found in Coastal Range at the depth of 13 km to 30 km that indicate fluids in the crust at depth, possibly along the major fault zones of the suture, Longitudinal Valley.

Longitudinal Valley is suture zone between Central Range and Coastal Range. Figure1 and Figure 2 show a very sharp boundary between high and low Vp coincides with the Longitudinal Valley in eastern Taiwan. High Vp and Vs to the east of this boundary clearly reflects the oceanic crust of the Philippine Sea plate. The Central Ranges west of this boundary, however, has much lower Vp. This indicates clearly that a fundamental material difference exists between the oceanic Philippine Sea plate and the basement of the Central Ranges.

Along the Ryukyu trench is dominated by positive anomaly of Vp and high structure of Vp/Vs that indicates the high seismicity in this region. The different pattern of P-wave and S-wave images in this zone suggests that the resolution of S-wave is lower than that of P-wave due to less reading of S arrivals.

CONCLUSION

The eastern part of Taiwan was dominated by positive anomaly of Vp and Vs reflect the west boundary of Philippine Sea Plate with Longitudinal valley as a suture zone. The negative anomaly of Vp and high seismicity in Central Range was correspond to active fault zone, Lishan Fault. This anomaly may indicate heat intrusion from the Philippine Sea plate. Negative anomaly of Vp and Vs, low Vp/Vs that show Western Foothills is consist of Neogen sedimentary rock. High Vp/Vs in Central Range correspond to large amount of young sediments, active fault zone, and may indicate fluids there.

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