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The seismic velocity and attenuation structure beneath the Tatun volcanic area, Taiwan

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ABSTRACT

We have investigated the structure beneath the Tatun volcanic zone north of Taipei metropolitan area of Taiwan, area of five million people. We used the data collected from a seismic network deployed for 5 years over the volcanic zone. This plus another data from Taiwan regional networks allow us to carry out tomographic inversions for V_p, V_p/V_s and Q_p structures beneath the Tatun volcanic zone. Based on our results and other geological, tectonic, and seismic findings, we reconstruct the structural evolution of the crust in the Tatun volcanic zone, and discuss the implication to the surrounding faults, fractured zones, and discuss potential future volcanic activities. From the tomographic results, there appear to exist a tube-shaped, highly fractured ancient magma passage with high seismic velocities that parallel to the Chinshan fault, and magma passage extends to the southeast at the depth about 20 km. This structure suggests plutonic intrusion passage beneath the Tatun volcano group that may have been associated with the earlier subduction of the Philippine Sea plate, melting of the subducted plate at depth has generated the magma intrusion that has brought about the Tatun volcanic activities. The high seismicity today also implies a highly fractured crust due to the hydrothermal activities and induced crustal stress. The hydrothermal fluid-rich upper crust as indicated by the low V_p/V_s ratio may have important bearing on the potential hazards associated with the two active faults cutting through both the Taipei Basin as well as the Tatun volcanic groups.

1. Introduction

Several destructive earthquakes and volcanic eruptions occurred frequently around the world in 2010–2011, especially along the Pacific Ring of Fire. According to a USGS report, the Shinmoedake volcano on Japan's Kyushu Island has become active. The volcano Mount Bulusan in the Philippines also erupted. Taiwan is located between the two active volcanoes and also lies along the Pacific Ring of Fire (see Fig. 1), therefore, whether the potential of volcanic activities in Taiwan is high or not is an important question.

The Tatun volcanic area is located at the northern tip of Taiwan in the immediate outskirt of Taipei metropolitan area with a large population of 5 million people (Fig. 1). Volcanic activities are noted in the geological past, with the last major eruption about 100 thousand years ago (Song et al., 1996). Geologists think that the Tatun volcanic area and the nearby volcanic islands chains in the East-China Sea are part of the SW extending of the Ryukyu Trench (Juang and Chen, 1989; Chen, 1990; Taso, 1994). Teng et al. (1992) and Teng (1996) also suggested that the present low magma activity is caused by the South Okinawa Trough that extends onshore into northern Taiwan. But from continuous core samples deposited in Taipei Basin (an old lake), recent C-14 dating gives a last eruption of 18.6 kyrs (Chen et al., 2007). Although the Tatun volcanic area is considered dormant at the present, the subsurface hydrothermal activity and seismicity are still high (Chen and Yeh, 1991; Kim et al., 2005a). Since this volcanic area is located near large population and two nuclear power plants where two faults are cutting through both the Taipei basin and the Tatun volcano groups, it is of great interest to investigate the evolution of the volcano-crustal structure and the hazard associated with this dormant volcanic field.

Seismic velocities and attenuation are important indicators of the subsurface structure and the state of matters that may lend information to future volcanic and seismic activities. According to Romanowicz (1994), the Q values are sometimes more sensitive to the thermal region than seismic velocities. Particularly, seismic attenuation can be used as diagnostic indicator of earth material properties and to detect the presence of anomalous zones such as partial melting in the crust and upper mantle (Mitchell, 1995; Sato and Sacks, 1989; Tusa et al., 2004). Young and Ward (1980)

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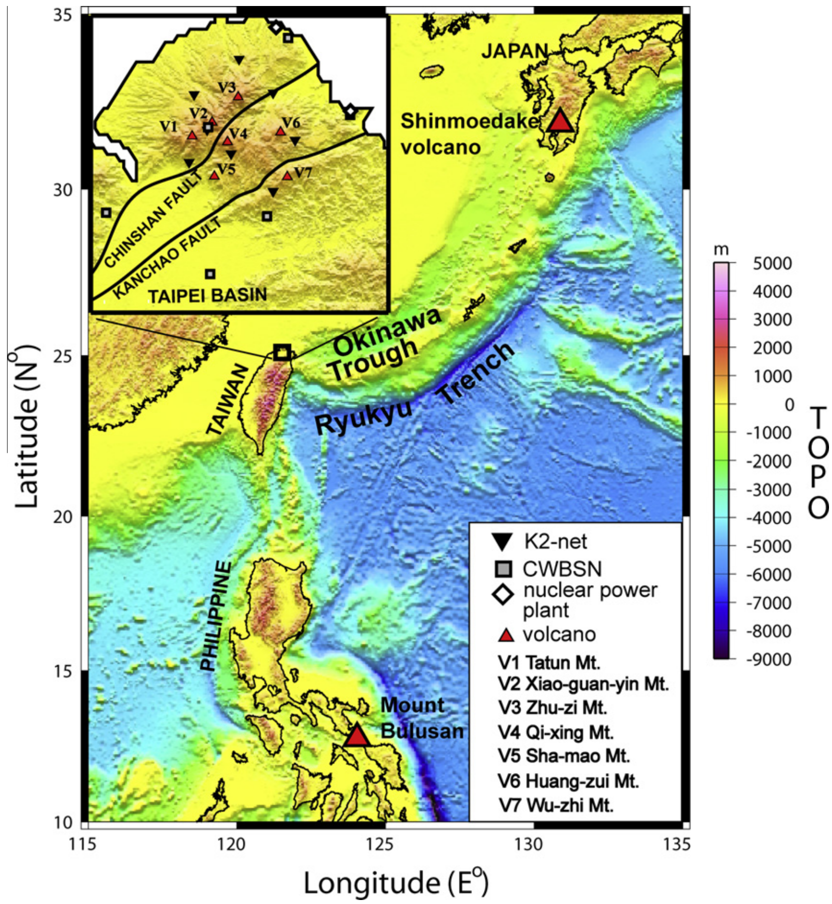

Fig. 1. Topographic map of Taiwan, Japan and Philippines, in which the red triangular is indicated as the volcano. The insertion includes locations of volcanoes (V_1–V_7), the fault traces, the stations of CWBSN and K2-net and two nuclear power plants in our research area. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

investigated the thermal source of springs through the attenuation factor *Q*. Karato and Wu (1993) also used the *Q* structure to study the upper mantle rheology. For velocity tomography, we follow Thurber (1993) to invert both P- and S-wave arrival times from local events for a 3D velocity model. For seismic attenuation tomography, a method similar to Hansen et al. (2004) is applied to P-wave amplitude spectra to obtain the attenuation parameter t^*. We invert the velocity tomography first and then applied it to obtain the attenuation structure. By combining velocity models and the *Q* model, we are able to better understand the physical properties of the crustal rocks and to access the volcanic hazards, especially in the presence of the current frequent seismic swarms outside of the Taipei metropolitan area, together with the potential seismic hazards associated with the two active faults, Kanchao and Chinshan, cutting through both the Taipei basin and the Tatun volcanic area (Fig. 1). Although several 3-D models of V_p or V_p/V_s have been proposed based on seismic travel-time data in Taiwan area (Rau and Wu, 1995; Ma et al., 1996; Kim et al., 2005b; Wu et al., 2007; Wang et al., 2009). These results give large-scale velocity structure mappings and the overall resolution is insufficient to describe velocity variations within the volcanic zone. Our study seeks to obtain more detailed 3-D velocity structures for the region surrounding the Tatun volcanic area, where lateral crustal heterogeneity is known to be strong.

2. Data and method

An 8-station seismic network (equipped with three-component acceleration sensor (FBA-23) and digital recorder (K-2)) was deployed from 1996 to 2001 to investigate the Tatun volcanic area (Fig. 1 and Table 1). A triggered level (3 gal) was applied to identify and record micro-earthquakes. These field records plus data from the Taiwan Central Weather Bureau Seismic Network (CWBSN) during 1991 to 2010 from the basic data for this study: with 1714 events (10847 P-wave arrivals and 4671 S-wave arrival times) distributed across the region 30 km × 30 km and down to

Table 1
Station list.

Station code	Latitude	Lonitude	Elevation (m)
K2-Net			
e01v	25N11.03	121E31.15	840
e02v	25N9.08	121E30.05	550
e03v	25N9.59	121E32.59	870
e04v	25N7.34	121E35.09	440
e05v	25N10.41	121E36.41	440
e06v	25N13.25	121E35.08	210
e07v	25N15.27	121E33.07	220
e08v	25N13.16	121E30.34	300
CWBSN			
TAP	25N2.35	121E31.35	5
ANP	25N11.19	121E31.21	825
TAP1	25N2.35	121E31.35	0
TWA	24N58.81	121E34.81	260
TWS1	25N6.05	121E25.06	60
TWU	24N52.65	121E32.02	330
TWX	25N11.93	121E39.70	40
TWY	25N16.55	121E35.98	20
TWZ	25N5.82	121E34.74	280