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Shallow crustal velocities and volcanism suggested from ambient noise studies using a dense broadband seismic network in the Tatun Volcano Group of Taiwan

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ABSTRACT

The Tatun Volcano Group (TVG) is situated adjacent to the Taipei metropolis and was active predominantly around 0.8–0.2 Ma (Pleistocene). Various recent lines of evidence suggest that the TVG is a potentially active volcano and that future volcanic eruptions cannot be ruled out. Geothermal activities are largely constrained to faults, but the relationship between volcanism and detailed velocity structures is not well understood. We analyzed ambient seismic noise of daily vertical components from 2014 using a dense seismic network of 40 broadband stations. We selected a 0.02° grid spacing to construct 2D and 3D shallow crustal phase velocity maps in the 0.5–3 s period band. Two S-wave velocity profiles transect Chishingshan (Mt. CS) in the shallow 3 km crust are further derived.

The footwall of the Shanchiao Fault is dominated by low velocity, which may relate to Tertiary bedrock buried under andesitic lava flows dozens to hundreds of meters thick. The hanging wall of the Shanchiao Fault is the location of recent major volcanic activities. Low velocity zones in the southeast of Dayoukeng (DYK) may be interpreted as hydrothermal reservoirs or water-saturated Tertiary bedrock related to Cenozoic structures in the shallow crust. High velocities conspicuously dominate the east of the TVG, where the earliest stages of volcanism in the TVG are located, but where surface hydro-geothermal activities were absent in recent times. Between the Shanchiao Fault and Kanchiao Fault high velocities were detected, which converge below Mt. CS and may be related to early stages of magma conduits that gradually consolidated. These two faults may play a significant role with the TVG. The submarine volcanism adjacent to the Keelung coastline also requires further attention.

1. Introduction

1.1. Tatun Volcano Group

The Tatun Volcano Group (TVG) is located at the northern tip of Taiwan Island, where it covers a roughly circular area with a radius of 10 km and an area of nearly 300 km^2. Most land in this region is protected by the Yangmingshan National Park to preserve the primitive volcanic features. Based on the active fault map published by the Central Geological Survey (CGS) in 2012, the active normal fault named Shanchiao Fault, displaying with high angle dipping to the east, traverses the TVG between Beitou and Jinshan in a northeasterly direction (Fig. 1). Airborne LiDAR topographic mapping with a resolution of 2 m and geological observations indicate a sequence of normal faults and scarps on the hanging wall (i.e. southeast) of the Shanchiao Fault, subparallel to its NE-SW or N-S orientation throughout the extent of the TVG (Liu et al., 2007; Chan et al., 2011). Since evidence for major geothermal activities is exposed on the hanging wall of the Shanchiao Fault in the form of fumaroles, solfataras and hot springs, the fault is thought to be a passage for volcanic and hydrothermal gases and fluids. Besides, the nearby Kanchiao Fault is a suspected active fault, which is an important geological feature in the southeast of the TVG (Fig. 1).

Approximately one-third of Taiwan's population is concentrated in the Taipei metropolis (nearly 8 million inhabitants), which is situated south of the TVG (Figs. 1 and 2). It is therefore crucial to investigate possible magma conduits and hydrothermal reservoirs with the aim of understanding the volcanism, magma plumbing system, movement of volcanic fluids, and the potential geothermal energy distribution underneath the TVG. Recent investigations provide increasing evidence that the TVG is potentially an active volcano (e.g., Yang et al., 1999; Lin et al., 2005a, 2005b; Konstantinou et al., 2007; Belousov et al., 2010;

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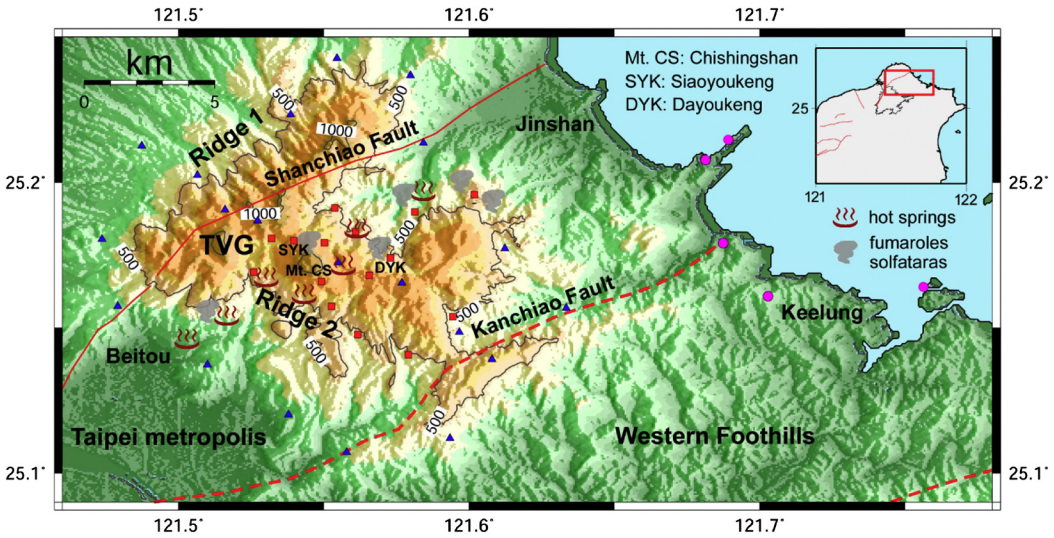

Fig. 1. Topography of the TVG and location of faults, fumaroles, solfataras, hot springs, and stations of the broadband seismic network analyzed in this study. Map drawn with 500 m interval contours based on 40 m DTM. Shanchiao Fault is shown as solid red line, Kanchiao Fault as dashed red line. The seismic network is composed of three sub-networks indicated by red squares, blue triangles, and purple circles, respectively. Station names shown in Fig. 2. Inset shows the locations of study area (red box) and active faults (red lines) on the Taiwan Island. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Ohba et al., 2010; Komori et al., 2014; Murase et al., 2014; Lin, 2016). To address the lack of comprehensive monitoring of volcanic activities in the TVG, the Taiwan Volcano Observatory at Tatun (TVO) was established in Yangmingshan National Park in October 2011 led by the Ministry of Science and Technology. It is hoped that the potential threat from volcanic activities near the Taipei metropolis can be minimized through early warnings to the government and the public.

1.2. Previous studies in the TVG

The orogeny of Taiwan is the result of plate collision and suturing processes between the Eurasian Plate and the Philippine Sea Plate in a compressional stress field (e.g., Angelier, 1986; Wu et al., 1997; Hsu et al., 2009). The tectonic environments of northern Taiwan are further complicate by the opening of the Okinawa Trough and the collapse of a post-collisional mountain belt in an extensional stress field (e.g., Teng, 1996; Wang et al., 1999; Song et al., 2000a). Due to the complexity of tectonic conditions in northern Taiwan, the origins and mechanisms of TVG volcanism are still under debate.

The question whether the TVG is extinct or still active is under frequent discussion (e.g., Song et al., 2000b). Based on the absence of records of volcanic eruptions in recorded history, with the exception of five possible submarine volcanic eruptions in northern and eastern offshore regions of Taiwan documented in the historical literatures (Chen and Shen, 2005), the TVG is considered extinct. Detection of past volcanism in the TVG is based on various radiometric dating methods, which suggest that major eruptions occurred at 0.8–0.2 Ma and have formed the foundations of andesitic volcanic edifices (e.g., Song et al., 2000a; Teng, 2007). Based on 2 m resolution digital terrain model (DTM) from airborne LiDAR topographic mapping, Chen et al. (2007) identified volcanic landforms including 51 lava domes in the TVG. Seven major eruption stages with mainly andesitic lava of high viscosity are thought to have occurred, and minor amounts of basaltic lava are thought to have formed lastly during the Pleistocene.

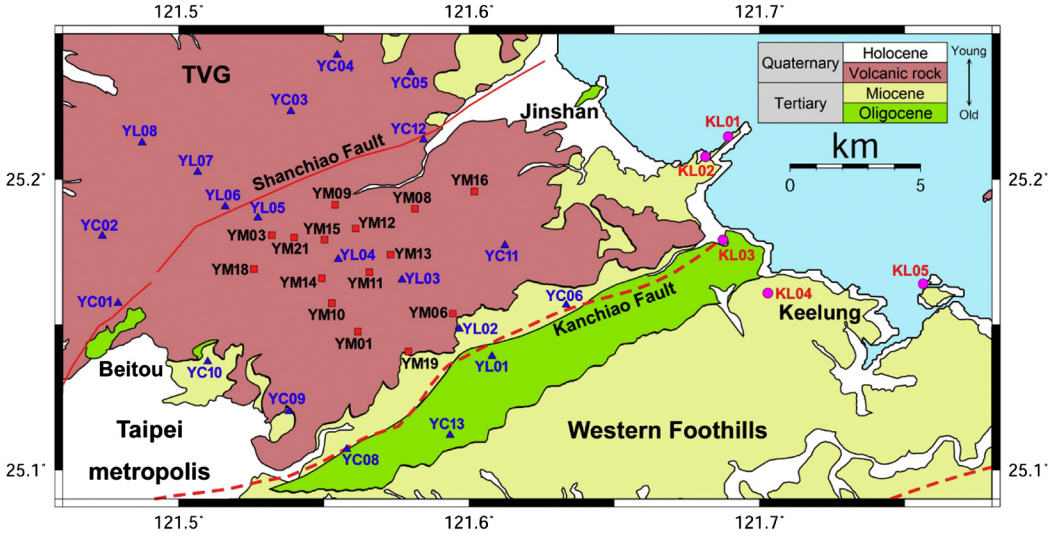

Fig. 2. Surface geology of study area. Shanchiao Fault is shown as solid red line, Kanchiao Fault as dashed red line. Seismic stations are marked with the names used in this study. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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