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Seismicity characteristics of a potentially active Quaternary volcano: The Tatun Volcano Group, northern Taiwan

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Abstract

The Tatun Volcano Group (TVG) is located at the northern tip of Taiwan, near the capital Taipei and close to two nuclear power plants. Because of lack of any activity in historical times it has been classified as an extinct volcano, even though more recent studies suggest that TVG might have been active during the last 20 ka. In May 2003 a seismic monitoring project at the TVG area was initiated by deploying eight three-component seismic stations some of them equipped with both short-period and broadband sensors. During the 18 months observation period local seismicity mainly consisted of high frequency earthquakes either occurring as isolated events, or as a continuous sequence in the form of spasmodic bursts. Mixed and low frequency events were also present during the same period, even though they occurred only rarely. Arrival times from events with clear P-/S-wave phases were inverted in order to obtain a minimum 1D velocity model with station corrections. Probabilistic nonlinear earthquake locations were calculated for all these events using the newly derived velocity model. Most high frequency seismicity appeared to be concentrated near the areas of hydrothermal activity, forming tight clusters at depths shallower than 4 km. Relative locations, calculated using the double-difference method and utilising catalogue and cross-correlation differential traveltimes, showed insignificant differences when compared to the nonlinear probabilistic locations. In general, seismicity in the TVG area seems to be primarily driven by circulation of hydrothermal fluids as indicated by the occurrence of spasmodic bursts, mixed/low frequency events and a *b*-value (1.17 ± 0.1) higher than in any other part of Taiwan. These observations, that are similar to those reported in other dormant Quaternary volcanoes, indicate that a magma chamber may still exist beneath TVG and that a future eruption or period of unrest should not be considered unlikely.

Keywords: Taiwan; Seismicity; Dormant volcano; Earthquake location; Tatun

1. Introduction

Volcanic activity can pose a severe threat to nearby densely populated areas and to sensitive facilities such as nuclear power plants (Tilling, 1989; McBirney and Godoy, 2003). Mitigation of volcanic hazards can usually be achieved by a coordinated volcano monitoring program that encompasses a number of multidisciplinary (geophysical, geodetic, geochemical) techniques in order to detect any early signs of unrest. Many such programs have been already implemented in developed countries like Japan or the United States but most of them are restricted to volcanoes that have erupted in historical times. However, one major problem in volcanological research is the distinction between a volcano that is capable of erupting after a long repose time and one that is not. This problem, beyond its

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academic interest, is a highly practical one since many volcanoes belonging to this category are situated next to large cities and/or critical sites around the world.

The Tatun Volcano Group (hereafter called TVG) consists of a number of Quaternary volcanoes that are located at the northern tip of Taiwan, just 15 km north of the capital Taipei and close to two nuclear power plants. In addition to that, the unique natural beauty of the area and the fact that it has been declared a national park, attracts tens of thousands of visitors every year. Its lack of eruptions during historical times was used as the main argument to suggest that it is by now an extinct volcano. In this paper we present a detailed description of the seismicity characteristics of TVG as they stem from its monitoring by a local seismic network for a period of 18 months. These observations are then used in order to draw useful conclusions about the volcano–hydrothermal system at TVG and to perform a comparison between these characteristics and those observed in other Quaternary volcanoes. Finally, a first attempt is made to address the status of this volcano (dormant versus extinct) and to consider the resulting implications.

1.1. Tectonic and volcanological setting

The island of Taiwan was formed as the result of the collision between the Luzon arc carried by the Philippine Sea Plate (PSP) and the continental shelf of the Eurasian Plate (EUP) as proposed by numerous authors (see for example Wu et al., 1997 and references therein) (Fig. 1a). The oblique subduction of the PSP beneath EUP at a present rate of 8.2 cm yr^{-1} (Yu et al., 1997) is responsible for the formation of the Ryukyu subduction zone extending to the east of Taiwan. To the north, the Okinawa Trough (OT), the backarc basin of the Ryukyu trench, is in the process of opening as demonstrated by both GPS measurements at the Ryukyu islands and normal faulting earthquakes occurring offshore NE Taiwan (Kao and Jian, 2001). The combination of all these processes generates a complicated geotectonic environment that has attracted the attention of many geoscientists.

Volcanism in northern Taiwan is believed to be related solely to the Ryukyu subduction zone, thus being a part of the Ryukyu volcanic arc (Teng, 1996). However, more recent studies suggest that it may actually be the result of

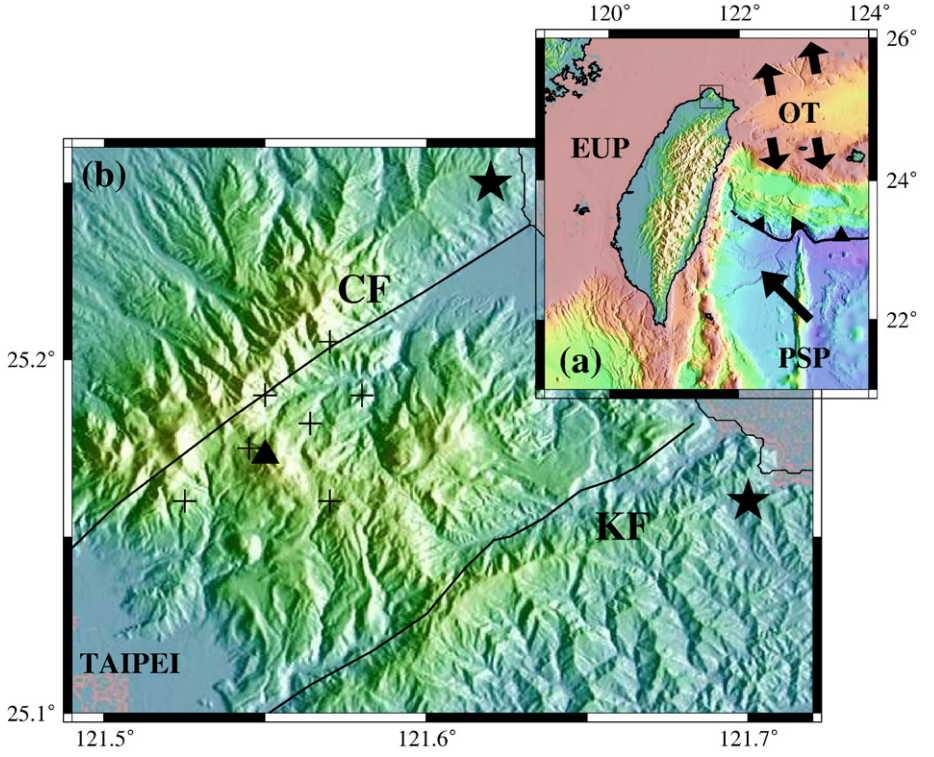

Fig. 1. (a) Map showing the regional tectonic setting and relative motion between the Philippine Sea plate (PSP) and the Eurasian plate (EUP) indicated by an arrow, as well as the opening of the Okinawa Trough (OT) backarc basin. The square in northern Taiwan shows the area of interest. (b) Map showing the area of the Tatun Volcano Group (TVG). The thick line to the south indicates the Kanchiao fault (KF), while that in the north the Chinshan fault (CF). The triangle represents the peak of the Chihsinshan volcanic cone (1120 m), the crosses indicate the place of hot spring/fumarole activity after Yang et al. (1999) and the stars show the positions of the two nuclear power plants. Part of the Taipei sedimentary basin can be seen at the lower left corner of the map.