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Evidence of a highly attenuative aseismic zone in the active collision orogen of Taiwan

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ABSTRACT

Seismic attenuation across an aseismic zone in the southeastern Central Range of Taiwan is investigated in terms of t^* data with inverted Q models. The t^* data are obtained by fitting the observed spectra of P and S waves with an ω^2 source model using broadband records of a 25-station linear array deployed across southern Taiwan. Both t_p^* and t_s^* data at the eastern stations show remarkable decreasing trends with depth down to 40 km in contrast to the western stations. The inverted Q_p and Q_s profiles across southern Taiwan reveal a high attenuation zone ($Q_p = 288$, $Q_s = 219$) at depth about 20 km beneath the eastern stations traversing the southeastern Central Range. High temperature and possible presence of fluids in the high attenuation zone are derived from the Q models. This high attenuation zone happens to coincide with the aseismic zone, suggesting that the aseismic zone may be due to high geothermal and partial melting effects of a very active collision orogeny. The area is also marked by other geological and geophysical indicators in support of this interpretation.

1. Introduction

Taiwan is located in the boundary between the Philippine Sea and Eurasian plates in western Pacific. Subduction and collision tectonics both exist in and around Taiwan region. The Eurasian plate subducts under the Philippine Sea plate in southern Taiwan, whereas the Philippine Sea plate subducts under Eurasian plate in northeastern Taiwan (Fig. 1). Between the two subduction zones the Philippine Sea plate moves northwestward to collide against the Eurasian plate at about 80 mm/year (Yu et al., 1997). As a result, major geological provinces in Taiwan are oriented generally in the northeast–southwest direction. The geological provinces from west to east are the Western Plain, the Western Foothills, the Hsuehshan Range, the Central Range, and the Coastal Range. The Coastal Range belongs to the Philippine Sea plate and the others belong to the Eurasian plate. The Longitudinal Valley between the Central Range and Coastal Range is the suture zone of the two plates.

Frequent earthquakes occur in and around Taiwan due to active collision between the Philippine Sea and Eurasian plates (Tsai, 1986). Intriguingly, an area around the southeastern Central Range (Fig. 1) is marked by persistent absence of seismicity (Fig. 2). The area has the highest mountains about 4 km in Taiwan. In addition, previous geophysical observations, such as precise leveling (Liu and Yu, 1990), GPS measurements (Yu et al., 1997), heat flows (Lee and Cheng, 1986), seismic velocity structures (Rau and Wu, 1995; Ma et al., 1996; Kim et al., 2005; Wu et al., 2007) and seismic anisotropy (Huang et al., 2006), all pointed to an area of very active collision orogeny. Nevertheless, the cause of this aseismic zone still remains a puzzle. The present study on seismic attenuation is undertaken to provide additional evidence for unraveling this puzzle.

Crustal seismic attenuation structures have been studied in terms of t^* for Taiwan and other regions of the world (Hough and Anderson, 1988; Scherbaum, 1990; Lees and Lindley, 1994; Chen et al., 1996; Chen, 1998; Sarker and Abers, 1998; Rietbrock, 2001; Eberhart-Phillips and Chadwick, 2002; Eberhart-Phillips et al., 2008; Chen and Clayton, 2009). In this study seismic attenuation across the aseismic zone is determined by using a large set of seismic waveform data recorded by a linear broadband array across southern Taiwan from events in northern and central Taiwan. The aseismic zone is well covered by the ray paths resulting from these source–station pairs.

Lee et al. (2009) have shown that a low-Q area exists in the southeastern Central Range using observed t^* data from northeastern events to the linear array. However, the low-Q area was only mapped approximately. More precise delineation of the low-Q area may make its tectonic implications clear. Therefore, additional earthquakes northwest of the linear seismic array are included to increase the traversing ray paths and make the tomographic method in this study possible.

We first obtain the t^* data of P and S waves by fitting the observed spectra with theoretical spectra using an ω^2 source model. These t^*

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