



Structural heterogeneities in the crust and upper mantle beneath Taiwan

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ABSTRACT

High-resolution 3-D P-wave velocity structure at depths of 0–400 km was determined to investigate the structural heterogeneities and their implications for mountain building, plate collision and tectonics beneath Taiwan by simultaneously inverting a large number of arrival-time data from local and teleseismic earthquakes. In the joint seismic tomography, 227,258 absolute arrival times from 8982 local and regional earthquakes and 18,869 relative arrival-time data collected from 3179 teleseismic events were used. Our tomographic images provide direct geophysical evidence for a tectonic model proposed by previous studies and revealed some new features of structural heterogeneity related to the subducted Eurasian lithosphere. The seismic images show that the Philippine Sea slab descends northwestward from the Ryukyu Trench down to a depth of 200 km, showing agreement with the previous seismic, geochemical and geophysical studies. Low-velocity anomalies beneath the Kueishan volcano are revealed at depths of 0–65 km in North Taiwan, indicating its close relationship to the subducting process of the Philippine Sea slab. The Eurasian lithosphere is generally imaged as a high-velocity zone with a thickness of 65–80 km and it has subducted down to a depth of 300 km under South Taiwan, whilst it is not visible beneath North Taiwan. Low-velocity anomalies above the subducted continental lithosphere are observed at depths of 0–200 km, which might reflect, at least part of the subducted continental crust. Our tomographic results indicate that the plate convergence of the Eurasian plate varies from subduction beneath South Taiwan to collision with the Philippine Sea slab under North Taiwan. These features of the structural heterogeneities in the crust and upper mantle suggest that the mountain building process in the central part of Taiwan, arc magmatism in northeast offshore region and seismotectonics are mainly attributed to the subduction–collision configuration at the boundary between the Eurasian continental lithosphere and the subducting oceanic lithosphere of the Philippine Sea slab.

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1. Introduction

The Taiwan region is an important site because it is a transition from subduction of oceanic lithosphere south of the island to underthrusting of continental lithosphere in central and northern Taiwan (Fig. 1). Processes associated with the subduction include mountain building, arc magmatism of the Ryukyu arc and generation of large crustal earthquakes such as the 1999 Chi-Chi earthquake (M7.3). Crustal deformation and active seismicity are still underway due to the convergence of the Philippine Sea (PHS) and Eurasian plates (Tsai, 1986; Yu and Chen, 1996; Kao et al., 1998, 2000; Lin, 2000; Chen et al., 2004). In most parts of Taiwan, the convergent features are more complicated than those in other subduction zones along the Western Pacific island arc due to more than one plate beneath the island.

Different collision models, such as skinned collision and lithosphere collision, have been proposed to characterize the Taiwan Orogen based on different constraints and approaches (e.g., Davis et al., 1983; Dahlen and Barr, 1989; Hwang and Wang, 1997; Wu et al., 1997), but the actual mechanism of the Taiwan Orogen remains a topic of wide debate because of complication of the spatial configuration of the plates under Taiwan. Whether or not and to what depth the Eurasian continental lithosphere has subducted beneath the Taiwan region is still unclear.

In the Taiwan subduction system, local seismicity does not provide direct information on the Eurasian lithosphere with depth greater than 150 km because most of local earthquakes occurred shallower than this depth (Fig. 2). There have been different tectonic views on the structural heterogeneities under Taiwan, for example, the arc-continent collision and crustal exhumation support the existence of a subducted Eurasian plate (Suppe, 1981; Angelier et al., 1986; Teng, 1990; Lallemand et al., 2001; Lin, 2002), whereas the arc–arc collision and lithosphere collision prefer its absence (Hsu and Sibuet, 1995; Wu

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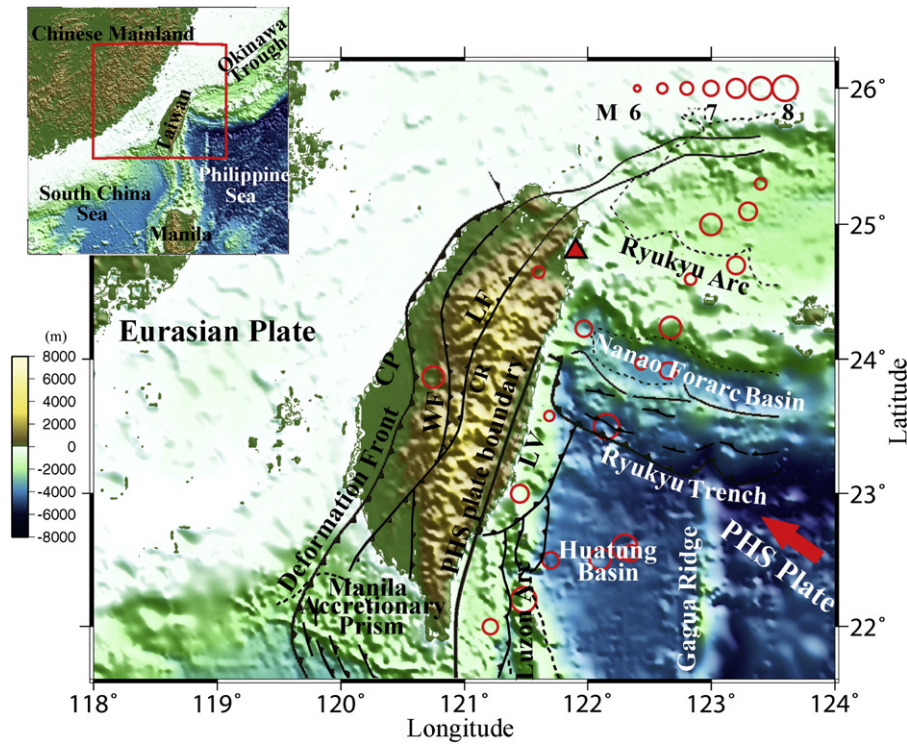


Fig. 1. Topographic and geodynamic context of Taiwan and its surrounding regions. The major plate boundaries are also shown on the map (modified from Sibuet and Hsu, 2004; Wang et al., 2006). LF, Lishan fault and its extension in the Okinawa Trough. LV, Longitudinal Valley. CR, Central Range. WF, Western Foothills. CP, Coastal Plain. A red arrow indicates the subducting direction of the Philippine Sea plate. A red triangle represents the Kueishan volcano. Open circles denote large historical earthquakes ($M_b > 6.0$) occurred during the period from 1771 to 2005. Magnitude scale of the earthquakes is shown on upright corner of the map. A red box on the insert map shows the present study region.

et al., 1997). A global tomographic model showed that the Eurasian lithosphere subducted to a depth of 670 km under the southern portion of Taiwan (Bijwaard et al., 1998; Lallemand et al., 2001). However, the evidence from the global model is less reliable because

its resolution (~ 120 km at 0–200 km depths and ~ 200 km at 200–710 km depths) is not high enough to provide direct evidence for the detailed seismic structures under Taiwan. Alternatively, although a recent local tomographic study provided the high-resolution V_p and

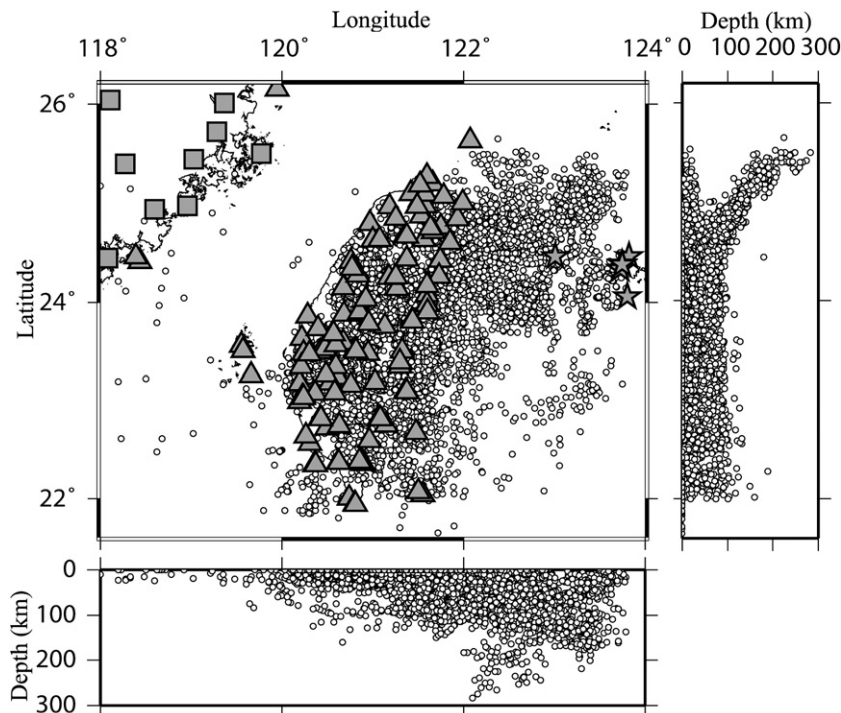


Fig. 2. 3-D hypocentral distribution of the 8982 local earthquakes (white dots) with magnitude larger than 1.5. Squares denote 9 stations deployed by Fujian province of China. Stars indicate 6 stations by JMA of Japan. Triangles show the 96 stations installed by BATS and CWBNS of Taiwan.

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