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Collisional tectonics between the Eurasian and Philippine Sea plates from tomography evidences in Southeast China

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ABSTRACT

The upper mantle structure of Southeast China is important for us to understand the deformation and mantle dynamics process associated with the interaction between the Eurasian plate and Philippine Sea (PHS) slab. We determined a detailed three-dimensional P-wave velocity (Vp) structure of the crust and upper mantle down to 400 km depth beneath Southeast China by applying teleseismic tomography to 6869 high-quality P-wave arrival times. The data were collected very carefully from the original seismograms of 635 teleseismic events recorded by 65 broadband stations deployed in Southeast China. Our images show that the high-Vp PHS slab subducts toward the north along the Ryukyu trench at the latitude of about 24°N and extends down to 350 km depth and even more. High-Vp anomalies are imaged in the upper mantle under central and southern Taiwan, which represent the subducted Eurasian plate. Break-off Eurasian plate at a big angle subducting eastward is revealed under central Taiwan at depths from the upper mantle to 400 km. While continuous Eurasian plate under South Taiwan is mainly imaged from the Moho down to 400 km depth, a torn mantle window within the Eurasian continent beneath central and northern Taiwan created by the northward motion of the Philippine Sea plate is the upwelling path of the asthenosphere. The tomographic images also show the low-Vp anomalies spread widely under the coastal areas of Mainland China and Taiwan Strait. The structure of the crust and upper mantle suggests that the mountain building process in the central part of Taiwan is mainly attributed to the subduction–collision tectonics at the boundary between the Eurasian continental lithosphere and the subducting oceanic lithosphere of the PHS slab.

1. Introduction

The southeastern margin of China is located at the juncture zone of the Eurasian plate and the Philippine Sea (PHS) slab, with unusual tectonic features (Fig. 1). Particularly, it is famous for the intensive magmatic activities, recording the multiphasic assembly and breakup processes of plates (Cheng, 1994). Taiwan Island is the only zone located in the youngest trench–arc–basin system in China and it is also the most active collision orogen between continental plate and oceanic slab in the world. Therefore, it is the best field laboratory for studying the collision and subduction processes between oceanic slab and continental plate. The upper mantle structure under the southeastern margin of China not only reveals the complex tectonic evolution, but also records and displays the ongoing plentiful geological phenomena during the collision between oceanic plate and continental plate.

About the collision and subduction processes of the Eurasian continental plate and the PHS slab, previous researchers have relatively unanimous viewpoint on the collision and subduction mechanisms in the northern and southern areas of Taiwan Island. In the northern area of Taiwan Island, the PHS slab is subducting under the Eurasia plate along the Ryukyu trench (Ai et al., 2007; Lallemand et al., 2001; Mcintosh et al., 2005; Wu et al., 2009a, 2009b). In the southern area of Taiwan Island, the Eurasia continental plate is subducting under the PHS slab (Kim et al., 2005; Lallemand et al., 2001; Mcintosh et al., 2005; Sibuet and Hsu, 2004; Wang et al., 2006; Wu et al., 2007; Zhang et al., 2008). However, there have been three different points of view on the collision mechanism in central Taiwan. The first point is that there is an eastern-dipping Eurasian continental plate under central Taiwan (Chen et al., 2004; Huang et al., 2010; Sibuet and Hsu, 2004). The Eurasian plate crust is involved in the collision orogen, and its mantle continues to subduct. Wang et al. (2006, 2009) proposed that the Eurasian plate is subducting eastward under the PHS slab in central Taiwan, with depth up to 300 km. The second viewpoint supports the presence of thickened crust and the absence of subducting mantle (Rau and Wu, 1995; Wu et al., 1997; Mcintosh et al., 2005; Zhang et al., 2008). In central Taiwan, the continental crustal layer is thickened to form 'root' under the Central Range when the Eurasia continental plate collides with the PHS slab. The third viewpoint is that the PHS slab is westward subducting under the Eurasia continental plate (Ai et al.,

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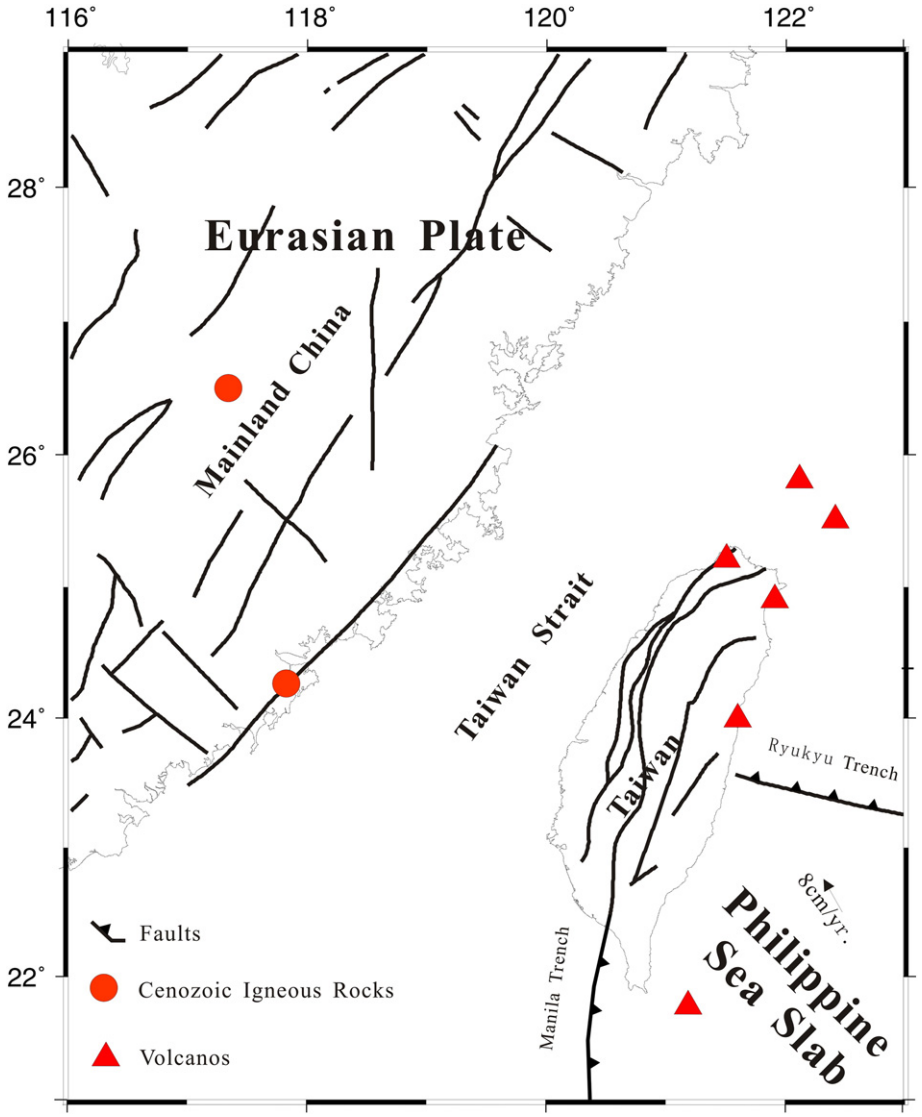

Fig. 1. Tectonic background in SE China.

2007). Ai et al. (2007) thought that this subduction model can be used to explain the phenomena that Taiwan Island moves to the NW direction with velocity of 8 cm/year (Yu et al., 1997). As a whole, knowing whether there is a subducted lithosphere beneath Taiwan is important for our understanding of the regional tectonic evolution.

In this study, we used a large amount of teleseismic events recorded by stations in Taiwan and the Fujian provinces to determine the high-resolution tomography of the crustal and uppermost mantle structures under the southeastern margin of China. Combining the data from Taiwan and Fujian provinces gives a better coverage of the deep structure because their ray-paths cross each other. Furthermore, the detailed crustal and uppermost mantle structures in the two regions can provide more robust evidence for interaction between the Eurasian plate and PHS slab.

2. Tectonic setting

Southeast China is located at the southeastern margin of the Eurasian plate which is strongly interacting with the PHS slab near Taiwan. Most of Taiwan is under a northwest–southeast compression with a convergence rate of about 8 cm/year (Yu et al., 1997). Taiwan Island is formed over the past 4 Ma with a high rate of crustal deformation and a strong seismic activity (Suppe, 1984). There have been different tectonic views on the formation of Taiwan. For instance, the model of arc–continent collision (Angelier et al., 1986; Chai, 1972; Ho, 1986; Lallemand et al., 2001; Lee et al., 2006; Lin, 2002; Suppe, 1981; Teng, 1990) supports the presence of a slab, whereas that of arc–arc collision (Hsu and Sibuet, 1995) favors its absence. Whatever models, all authors agree that the uplift of Taiwan results from the collision of the Luzon arc with the Eurasian plate. The oblique collision between the Luzon Arc and the Eurasian plate is still propagating southwest, which causes the migration of the deformation front and foreland basin westward and southward, resulting in a mature overfilled basin in the north and an immature one in the south (Suppe, 1984; Zhou et al., 2003). To the east of Taiwan, the PHS slab subducts northwestward beneath the Eurasian lithosphere from the Ryukyu Trench and is overriding the South China Sea floor of the Eurasian plate beneath South Taiwan (Wang et al., 2009).

3. Data and method

In this study, we utilized seismic waveforms recorded by portable broadband seismic stations in Fujian Province (FJB) and three local