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ScienceDirect

Tectonophysics 466 (2009) 170–183

TECTONOPHYSICS

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Tomographic imaging of the convergent zone in Eastern Taiwan — A subducting forearc sliver revealed?

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Received 28 February 2006; received in revised form 27 June 2006
Available online 21 November 2007

Abstract

This paper investigates crustal features of the plate boundary in eastern Taiwan by joint analysis of gravity anomaly and seismic arrival time data. We found two crustal anomalies: (1) two prominent high-velocity/high Poisson's ratio anomalies in the mid- to lower crust beneath the offshore area; (2) several volumes of relatively high-velocity/high Poisson's ratio rocks in the upper- to mid-crust beneath the Central Range. The former is interpreted as the Luzon arc and forearc blocks from east to west. The latter is interpreted as uplift material from the oceanic crust scraped from the Luzon forearc, which forms the core of the Central Range. The features of northward-narrowing in dimension and deepening in depth of the forearc block are revealed in the velocity solution, implying a subducting Luzon forearc fragment in eastern Taiwan. The values of Poisson's ratios and earthquake activity in the northern domain are generally larger than that in the southern domain, suggesting that the crustal accretion process has not been completed in the northern domain of the study area. Our resulting velocity and Poisson's ratio models provide some insight into the tectonic processes presently operating in eastern Taiwan. It's also suggested that the subducting Luzon forarc acts as a backstop against which accreted rocks are thrust, and this contact may have seismogenic potential.

Keywords: Seismic Tomography; Gravity; Plate boundary; Forearc

1. Introduction

The island of Taiwan located along a segment of the oblique converging boundary between the Eurasian and Philippine Sea plates is a spectacularly deformed, mountainous region dominated by the Central and Coastal Ranges (Fig. 1). Convergence of the Philippine Sea plate and the Eurasian plate in the Taiwan area is accommodated along the eastern Taiwan plate boundary zone and directly along the Taiwan orogen (Biq, 1972; Seno et al. 1993). The Taiwan arc-continent collision therefore arguably represents an ideal locality to investigate the orogenic process and is one of the best-studied active orogenic sites in the world. This convergent boundary shows many along-strike tectonic variations such as accretionary wedge-width, crustal deformation and extreme seismic hazard (Fig. 1). From physical and numerical modeling (e.g. Chemenda et al., 1997; Tang et al., 2002; Malavieille et al. 2002), it has been suggested that the tectonic processes occurring in Taiwan could be associated with a subducting Luzon forearc sliver. Although Cheng et al. (2002) reported high-velocity anomalies in the mid- to lower-crust beneath eastern Taiwan and interpreted these as the oceanic crust of the Luzon forearc, until now there has been no geophysical evidence to support a subducting forearc sliver.

This paper presents a sequential inversion of seismic travel-times and gravity data to obtain a three-dimensional velocity structure of the convergent boundary in eastern Taiwan and to clarify this problem. To this end, a sequential inversion scheme based on the method proposed by Parsons et al. (2001) is utilized with gravity data for eastern Taiwan (Hsu et al. 1998) combined with travel times of seismic waves from local earthquakes recorded by Taiwan's Central Weather Bureau. Both data sets were simultaneously interpreted in terms density and velocity perturbations in the crust. It thus offers insight into the Moho configuration beneath eastern Taiwan, which has lateral velocity–density relations, and its surroundings. It can also significantly improve resolution of the collision structure, especially with respect to continuity from onshore to offshore areas in eastern

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0040-1951/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.tecto.2007.11.010

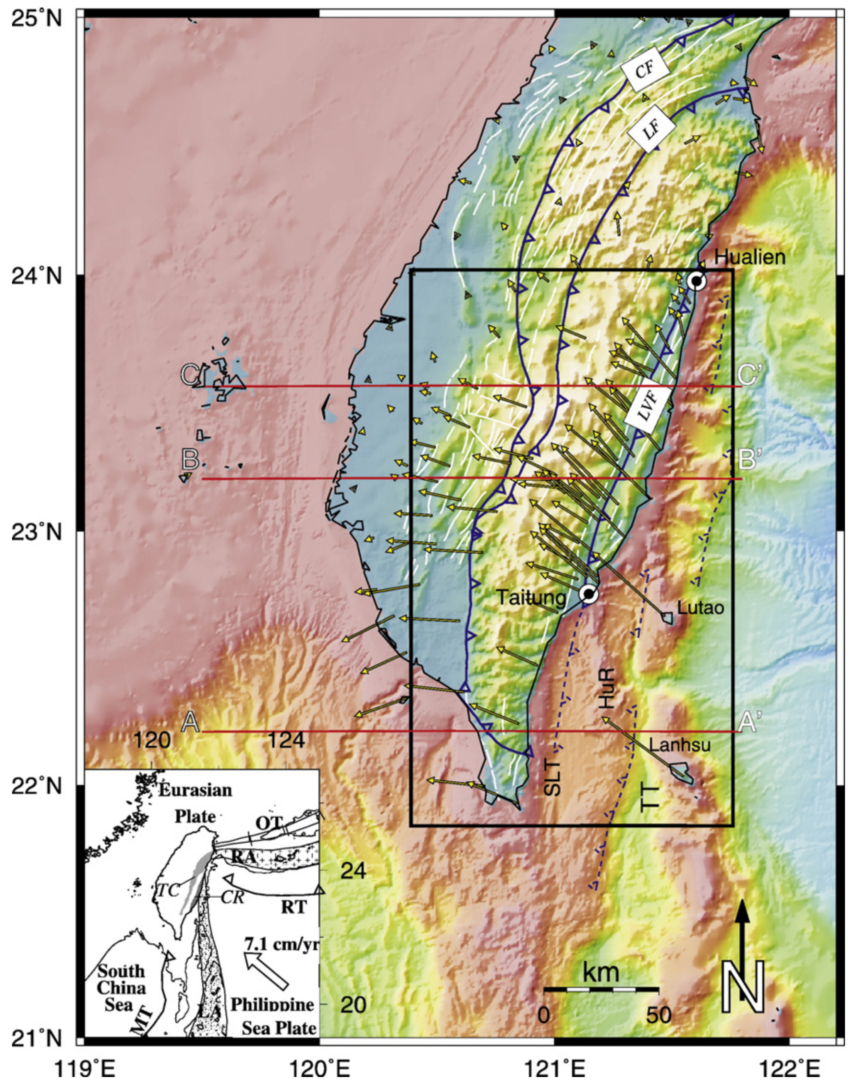

Fig. 1. Tectonic sketch map and bathymetry of the Taiwan region and location of the sections (geodynamic setting in the upper-left). Major thrust faults with open triangles on the upper side. Arrows indicate velocities of GPS stations relative to Penghu (Yu et al. 1997). Several thrust faults located in the eastern and southern Taiwan offshore area are proposed by Malavieille et al. (2002). CF—Chuchih fault; CNR—Central Range; CR—Coastal Range; HuR—Hengchun Ridge; MT—Manila Trench; LA—Luzon Arc; LF—Lisan fault; LVF—Longitudinal Valley fault; OT—Okinawa Trough; PLVF—southern prolongation of Longitudinal Valley fault; RA—Ryukyu Arc; SLT—Southern Longitudinal Trough; TC—Tananao Complex; TT—Taitung Trough.

Taiwan. In this study, S-wave seismic travel-times are also used to obtain a Vp/Vs velocity model and to calculate the corresponding Poisson's ratios. It is expected that modeling the Poisson's ratio may provide further constrains on the lithologic and petrologic interpretation.

2. Tectonic setting

The Philippine Sea plate moves northwestward, with respect to the Eurasian plate at a rate of 80–83 mm/yr on a N306° azimuth (Yu et al., 1997). Such oblique convergence often creates arc-parallel migration of the forearc (e.g., McCaffrey, 1994) and produces extreme seismic hazard as a consequence of the relative motions of the forearc blocks (e.g., Kanamori, 1995). Several great collision zone earthquakes have been recorded in the last century, and much of the region is relatively active seismically (e.g. Wang et al., 2000). Due to the oblique convergence of the Philippine Sea plate with respect to the Eurasian continental margin, the collision in Taiwan propagates southwards (Suppe, 1981, 1984; Page and Suppe, 1981). The intensity of orogenesis thus decreases from north to south, and consequently, is in its initial stage to the south of the island. Previously, studies of Taiwan's tectonics using numerical simulation and physical modeling have always assumed a rigid Philippine Sea plate as one of their boundary conditions (e.g., Lu and Malavieille, 1994; Hu and Angelier, 1996). However, based on moment-tensor inversion for offshore earthquakes, Kao et al. (1998) proposed that simulation of the regional tectonic and orogenic processes in Taiwan should take intraplate deformation into account and allow the Philippine Sea plate to deform internally. Sibuet and Hsu (2004) proposed that the formation of Taiwan was driven by two simple lithospheric motions, the subduction of the Philippine Sea plate beneath Eurasia with a relative westward component of 4.5 cm/year, and the subduction of Eurasia beneath the Philippine