Tectonophysics 472 (2009) 6–17

Contents lists available at ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

High-V_P/V_S zone accompanying non-volcanic tremors and slow-slip events beneath southwestern Japan

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ARTICLE INFO

Article history:
Received 24 February 2007
Received in revised form 3 May 2008
Accepted 5 June 2008
Available online 19 June 2008

Keywords:
Deep low-frequency non-volcanic tremor
Slow-slip event
High-V_P/V_S zone
Dehydration
High pore pore-fluid pressure
Serpentinized peridotite

ABSTRACT

In southwestern Japan, the Philippine Sea plate subducts beneath the Eurasian plate. Non-volcanic tremors and slow slow-slip events are observed beneath southwestern Japan. Seismic tomography based on the data obtained from the dense seismic network revealed the velocity structure in and around the subducting Philippine Sea plate. The oceanic crust of the Philippine Sea plate subducting from the Suruga and Nankai troughs can be imaged clearly beneath the Tokai region and the Kii peninsula. Non-volcanic tremors and short-term slow-slip events may occur in the high-V_P/V_S zones owing to the fluid dehydrated from the subducting plate where the oceanic crust of the Philippine Sea plate encounters the serpentinized wedge mantle of the Eurasian plate. These tremors and short-term slow-slip events occur in the high-V_P/V_S zone at depths of 30–40 km beneath the Tokai region, the landward edge of the high-V_P/V_S zone beneath the Kii peninsula and eastern Shikoku region, and the seaward edge of the high-V_P/V_S zone beneath the western Shikoku region. Long-term slow-slip events were observed beneath the Tokai region and the Bungo channel and both these events are located on the seaward side of a high-V_P/V_S zone. These long-term slow-slip events are considered to be caused at the plate boundary between the oceanic crust of the Philippine Sea plate and the lower crust of the Eurasian plate by the high pore-fluid pressure caused by the fluid dehydrated from the subducting plate. The existence of the high-V_P/V_S lower crust of the Eurasian plate may control the occurrence of the long-term slow-slip events.

1. Introduction

In southwestern (SW) Japan, the Philippine Sea (PHS) plate subducts beneath the Eurasian (EUR) plate from the Nankai and Suruga troughs (Fig. 1). In the case of the PHS plate beneath SW Japan, deep low-frequency (2–5 Hz) non-volcanic tremors are observed at depths of approximately 30 km along the strike of the PHS plate from the Tokai to the western Shikoku regions (Obara, 2002; Katsumata and Kamaya, 2003). Accompanying the tremors, short-term slow-slip events (S-SSEs) are also observed beneath the Tokai region, northern Kii peninsula, and the western Shikoku region (Obara et al., 2004; Hirose and Obara, 2005; Obara and Hirose, 2006; Hirose and Obara, 2006). The source region of the tremors is consistent with that of the S-SSEs. An S-SSE usually occurs for a duration of 2–7 days. Tremors are characterized by low-frequency wave trains. The Japan Meteorological Agency (JMA) routinely identifies these tremors as low-frequency earthquakes. The hypocenters of low-frequency tremors are relocated primarily with many S-wave arrivals with an error of 3 km. Similar tremors and S-SSEs are also observed beneath the Cascadia margin along the western edge of the North American continent (Dragert et al., 2001; Rogers and Dragert, 2003), where Ramachandran et al. (2005) estimated that the wedge mantle comprises 20% serpentinized peridotite.

A recently installed dense seismograph network enables us to estimate the fine three-dimensional (3D) structures of P- and S-wave velocities (V_P and V_S). The tremors observed beneath SW Japan are located in a high-V_P/V_S zone, as revealed by seismic tomography (Honda and Nakanishi, 2003; Wang et al., 2006; Matsubara et al., 2008). Kamiya and Kobayashi (2000) suggested the existence of serpentine in the wedge mantle above the PHS plate beneath the Kanto region, and Matsubara et al. (2005) estimated that the wedge mantle comprises 20%–30% serpentinized peridotite.

Ozawa et al. (2002) detected a long-term slow-slip event (L-SSE) beneath the Tokai region that started during late 2000 and ended in 2005 at the plate boundary of EUR and PHS plates (Ohta et al., 2004; Yamamoto et al., 2006). Furthermore, in 1997 and 2003, L-SSEs were observed beneath the Bungo channel to the west of the Shikoku region at the plate boundary of EUR and PHS plates (Hirose et al., 1999; Hirose and Obara, 2005).

In addition to the tremors, S-SSEs, and L-SSEs, deep very-low-frequency (0.02–0.05 Hz) earthquakes were observed beneath SW Japan by Ito et al. (2007). We term these low-frequency events "slow events."

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doi:10.1016/j.tecto.2008.06.013

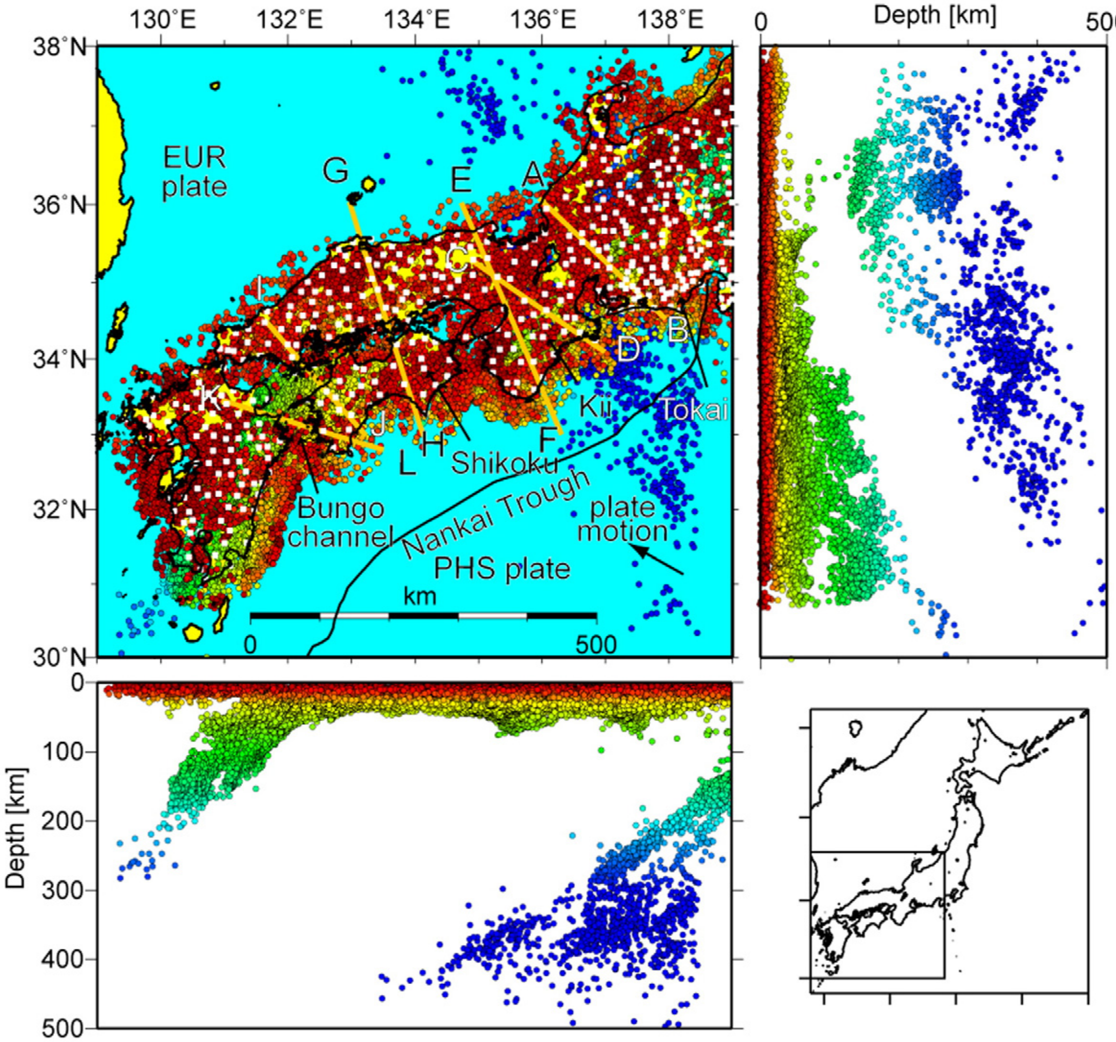

Fig. 1. Distribution of hypocenters and seismic stations used in this study. The circles and white squares denote the hypocenters and seismic stations, respectively. The thick yellow lines indicate the locations of the cross sections shown in Figs. 5–11. The solid lines indicate the locations of the Suruga and Nankai troughs.

The National Research Institute for Earth Science and Disaster Prevention (NIED) had deployed a high-sensitivity seismograph network in Japan (Hi-net) from 1996 and started operating the system from October 2000 onward (Okada et al., 2004; Obara et al., 2005). This network provides a large amount of arrival time data and allows us to estimate the fine-scale 3D V_P and V_S structures beneath SW Japan. In this study, we investigate the relationship between P- and S-wave velocity structures and slow events.

2. Data and method

The target region – 30–38°N and 129–139°E – covers SW Japan from Tokai to Kyushu. Earthquakes occurring at depths of 0–200 km within 50 km of Hi-net and those occurring at depths of 200–500 km

Table 1
Grid interval and resolution size.

Depth	Grid interval		Resolution/checkerboard pattern	
	Horizontal	Vertical (km)	Horizontal	Vertical (km)
0–40		5		10
40–60		10		20
60–180	0.1°	15	0.2°	30
180–300		20		40
300–		25		50

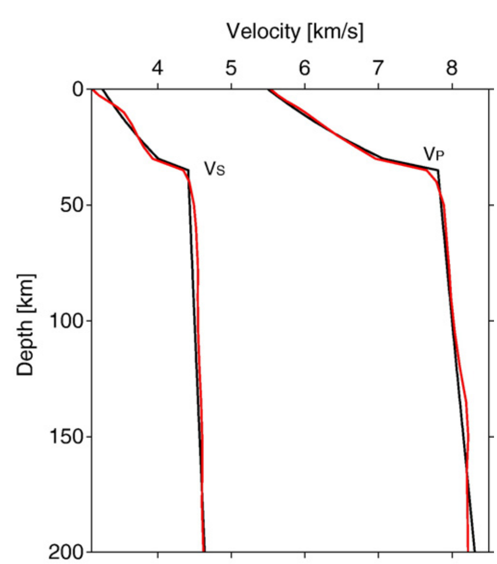

Fig. 2. Velocity models used in this study. The black lines denote the initial P- and S-wave velocities (Ukawa et al., 1984). The red lines denote the horizontally averaged final P- and S-wave velocities, respectively.