Earth and Planetary Science Letters 485 (2018) 121–129

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

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Tottori earthquakes and Daisen volcano: Effects of fluids, slab melting and hot mantle upwelling

Dapeng Zhao [a,*], Xin Liu [a,b], Yuanyuan Hua [a,c]

[a] Department of Geophysics, Tohoku University, Sendai 980-8578, Japan
[b] College of Marine Geosciences, Ocean University of China, Qingdao 266100, China
[c] Institute of Geophysics and Geomatics, China University of Geosciences, Wuhan 430074, China

ARTICLE INFO

Article history:
Received 5 September 2017
Received in revised form 8 December 2017
Accepted 21 December 2017
Available online xxxx
Editor: A. Yin

Keywords:
earthquake
volcano
Pacific slab
Philippine Sea slab
adakite
slab melting

ABSTRACT

We investigate the 3-D seismic structure of source areas of the 6 October 2000 Western Tottori earthquake (M 7.3) and the 21 October 2016 Central Tottori earthquake (M 6.6) which occurred near the Daisen volcano in SW Japan. The two large events took place in a high-velocity zone in the upper crust, whereas low-velocity (low-V) and high Poisson's ratio (high-σ) anomalies are revealed in the lower crust and upper mantle. Low-frequency micro-earthquakes (M 0.0–2.1) occur in or around the low-V and high-σ zones, which reflect upward migration of magmatic fluids from the upper mantle to the crust under the Daisen volcano. The nucleation of the Tottori earthquakes may be affected by the ascending fluids. The flat subducting Philippine Sea (PHS) slab has a younger lithosphere age and so a higher temperature beneath the Daisen and Tottori area, facilitating the PHS slab melting. It is also possible that a PHS slab window has formed along the extinct Shikoku Basin spreading ridge beneath SW Japan, and mantle materials below the PHS slab may ascend to the shallow area through the slab window. These results suggest that the Daisen adakite magma was affected by the PHS slab melting and upwelling flow in the upper mantle above the subducting Pacific slab.

1. Introduction

In Southwest Japan, the young Philippine Sea (PHS) plate (15–40 Myr) is subducting beneath the Eurasian plate, whereas the old Pacific plate (110–130 Myr) is descending below the PHS plate, causing intense shallow and intermediate-depth seismicity and volcanic activities (e.g., Hirahara, 1981; Kimura et al., 2005; Sano et al., 2009; Figs. 1 and 2). The Japan Sea coastal area in western Honshu is seismically active, and many strong crustal earthquakes (M 6.0–7.3) have taken place there in the past 1200 yrs (e.g., Usami, 2003; Japan Meteorological Agency (JMA): www.jma.go.jp). It is proposed that the Northern Chugoku shear zone (Gutscher and Lallemand, 1999) or the Southern Japan Sea fault zone (Itoh et al., 2002) exist along the Japan Sea coast, which have right-lateral strike-slip motions. The 6 October 2000 Western Tottori earthquake (M 7.3) occurred about 30 km to the southwest of the Daisen volcano, causing 182 people injured. The 21 October 2016 Central Tottori earthquake (M 6.6) took place approximately 25 km to the east of the Daisen volcano, causing 30 people injured. Both events caused significant damage to local infrastructures. The two Tottori earthquakes had similar left-lateral strike-slip focal mechanisms and aftershock distributions (see Fig. 3 and Zhao et al., 2004). The aftershocks of the 2016 Tottori earthquake are located at depths of 0–15 km along a vertical fault oriented NW-SE (Fig. 3), being consistent with one of the nodal planes of its focal mechanism solution (The Headquarters for Earthquake Research Promotion, 2016).

Daisen is a large composite volcano, more than 120 km^3 in volume, ranging in age from 0.017 to 1.2 Ma, and consisting of several clustered and overlapping lava domes (Kimura et al., 2005; Tokunaga et al., 2010). Seismological studies have shown that the horizontally subducting young PHS slab has reached the Daisen volcano, though there is no intraslab seismicity beneath western Honshu (e.g., Nakanishi, 1980; Hirahara, 1981; Zhao et al., 2002; Liu et al., 2013; Asamori and Zhao, 2015). Many geochemical studies of the Daisen volcanic rocks have been made, suggesting that melting of the young PHS slab occurs beneath the Daisen volcano, producing adakite magmas (e.g., Morris, 1995; Tokunaga et al., 2010; Feineman et al., 2013; Kimura et al., 2014, 2015; Pineda-Velasco et al., 2015), though some researchers proposed that lower crustal water controls on the formation of the Daisen adakitic melts (Zellmer et al., 2012).

* Corresponding author.
E-mail address: zhao@tohoku.ac.jp (D. Zhao).

https://doi.org/10.1016/j.epsl.2017.12.040
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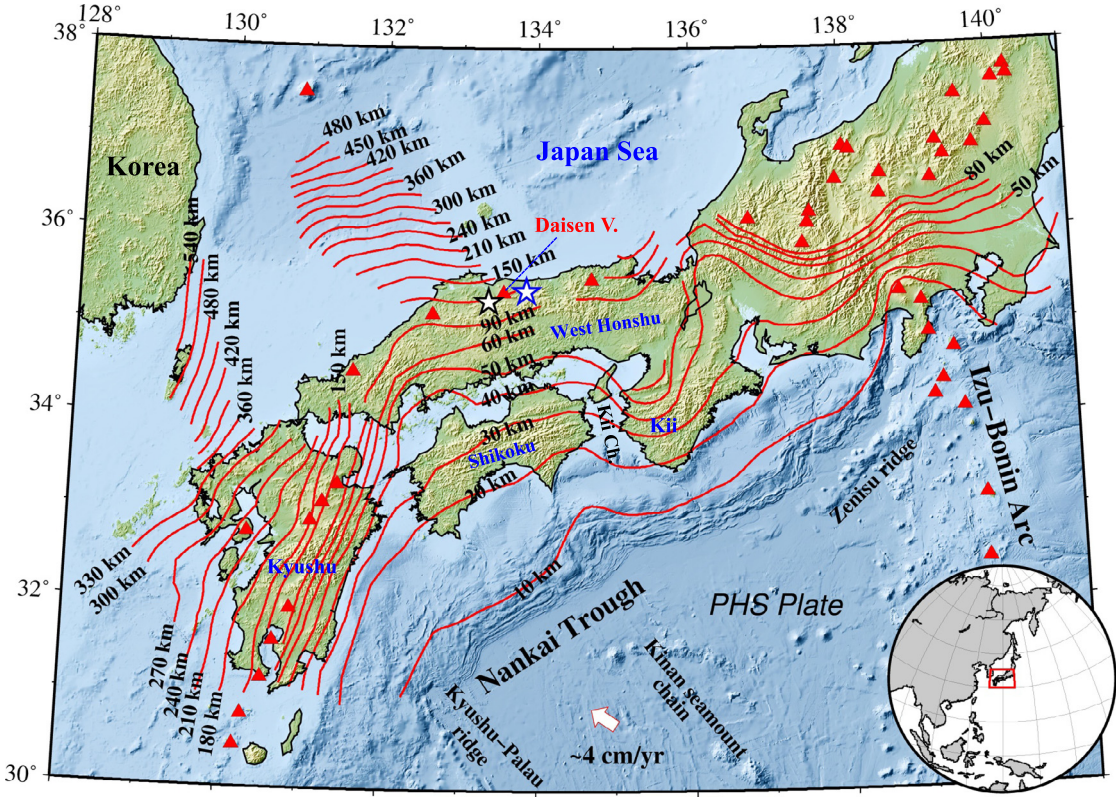

Fig. 1. The surface topography and bathymetry of Western Japan and adjacent regions. The red lines denote depth contours of the upper boundary of the subducting Philippine Sea plate (Asamori and Zhao, 2015; Nakajima et al., 2009; Zhao et al., 2012). The red triangles denote active or Quaternary volcanoes. The black and blue stars denote the 2000 Western Tottori earthquake (M 7.3) and the 2016 Central Tottori earthquake (M 6.6), respectively. Daisen V., the Daisen volcano. Kii Ch., the Kii Channel. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

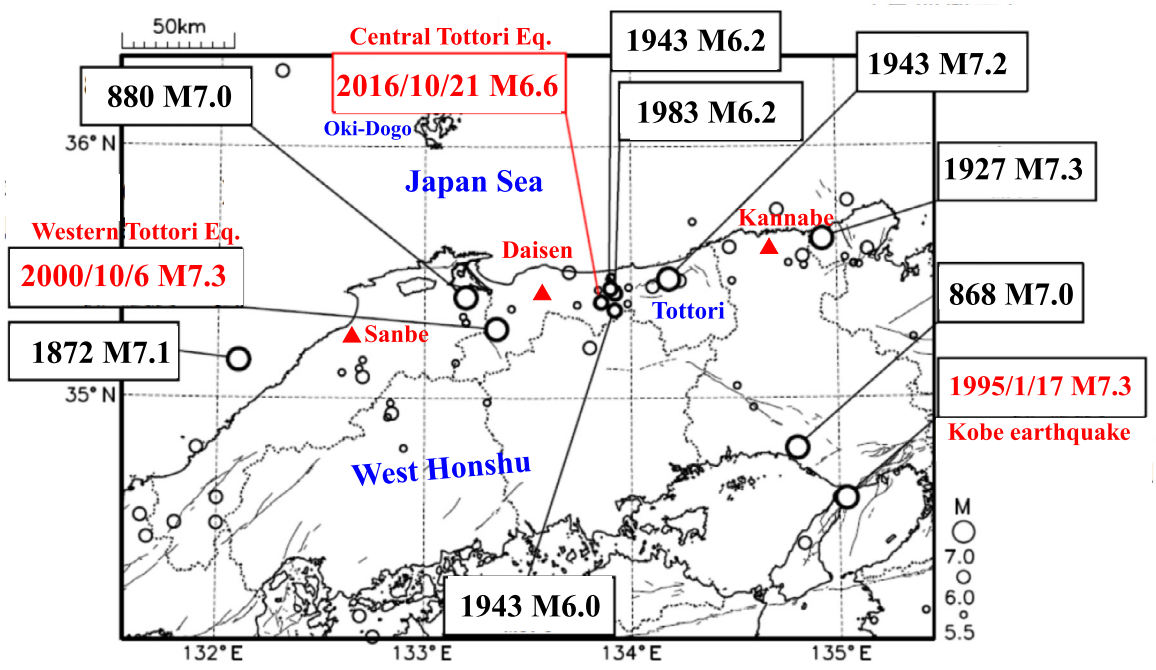

Fig. 2. Epicentral distribution of significant earthquakes (M > 5.5) during 800 to 2017 (open circles) in western Honshu, Japan (modified from the report of The Headquarters for Earthquake Research Promotion on the 2016 Central Tottori earthquake: http://www.jishin.go.jp/). The earthquake magnitude scale is shown on the right. The occurrence years and magnitudes of some major events are shown. The red triangles denote Quaternary volcanoes (Daisen, Sanbe and Kannabe). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)