# Constraints on the Mechanism of Intermediate and Deep Earthquakes from Local Array Studies of the Tonga Subduction Zone

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The Tonga slab shows the highest rates of intermediate and deep seismicity of any subduction zone worldwide. It also has the highest convergence rate and the lowest estimated slab temperatures, and the convergence rate varies along strike from about 240 mm/yr in the north to 100 mm/yr in the south, making it ideal for studying the effect of slab temperature on the mechanism of intermediate and deep earthquakes. However, the remote oceanic location has limited resolution of earthquake processes. Here we use 17 land and 50 ocean bottom seismographs deployed from 2009-2010, as well as previous local seismograph deployments, to carry out more detailed studies.
Relocation of intermediate depth seismicity reveals that the double seismic zone (DSZ) in northern and central Tonga, first discovered by Kawakatsu (1985), extends from 70 to 300 km depth (Wei, 2016). This is deeper than has been observed previously in NE Japan and other subduction zones worldwide, where DSZs are limited to about 180 km depth. Examination of numerical thermal models for the different subduction zones suggest that the existence of a DSZ is controlled by a range of slab temperatures, which occur deeper in Tonga due to its rapid convergence rate. Additionally, we observe a band of high seismicity extending from the upper zone into the center of the DSZ at a depth of 300 km in the north, decreasing continuously to 200 km depth in the south. Numerical models reveal that these events occur at various pressures but at nearly constant temperatures because of the changing convergence rate. We suggest that the band of seismicity delineates the depth at which the subducted uppermost mantle reaches temperatures high enough to dehydrate serpentine (500-600 degrees C) and possibly other higher pressure hydrous phases, as the phase diagrams are poorly known at these pressures. The liberation of large amounts of water by dehydration reactions greatly increases the pore pressure within this part of the slab, producing the band of seismicity.
The Tonga subduction zone is also associated with a wide region of “outboard” 500 to 680 km deep earthquakes to the west of the main slab, which are poorly understood. The 9 November 2009 earthquake (Mw 7.3, depth 591 km) in a previously aseismic region beneath the Fiji Islands represents the largest earthquake located in this area. Waveform inversion shows a compact bilateral rupture in a NE-SW direction and an overall fault length of 30 km, yet the aftershocks are widely distributed along a sharp EW line at distances of up to 140 km from the mainshock (Cai and Wiens, manuscript in preparation). This line extends towards the Vitiaz deep earthquake cluster to the west, and is consistent with tectonic reconstructions of the fossil Vitiaz trench which subducted Pacific lithosphere from the north prior to 10 Ma. We suggest that this line of earthquakes represents the remnants of the Vitiaz slab in the transition zone. Many of the aftershocks were dynamically triggered along this line, suggesting that this fossil slab is composed of material with faults near the critical stress, but where earthquake nucleation is difficult without triggering by a nearby large earthquake.

Kawakatsu, H. (1985), Double seismic zone in Tonga, *Nature*, *316*(6023), 53-55.
Wei, S. (2016), Seismic studies of the Tonga Subduction Zone and the Lau Back-arc Basin, PhD Thesis, Washington University, Saint Louis, USA.

 

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