Constraining the thickness of tremor source region on the basis of seismological and geological observations in southwest Japan

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Recent studies have shown that slow earthquakes such as tremors and slow slips along subduction zones are shear slips on the plate interface of subducting oceanic slab (e.g. Ide et al., 2007). Although the seismologically determined depth range of tremors is several km and still has large uncertainties, such tremor zone is usually treated as a flat fault plane with no thickness. On the other hands, the recent geological observation has discovered the records of past tremors and suggested that tremors occur in the deformation zone with the thickness of tens of meters (Ujiie et al., 2016, AGU Fall Meeting). Here we try to reconcile these two observations by estimating the thickness of the tremor zone based on both the seismological and geological approaches.
For the seismological approach, we focus on the thickness of the hypocenter distribution of tremors in Shikoku region, southwest Japan. As representatives of tremor sources, we use the deep low frequency earthquakes (LFEs). By applying the NCC hypocenter determination method (Ohta and Ide, 2011) based on the summed cross-correlation coefficients across the network (NCC) to Hi-net velocity seismograms, we accurately relocate 2450 LFEs in the catalog of Japan Meteorological Agency from 2004 to 2011. Relocated hypocenters of LFEs are highly concentrated in the depth direction and show gradual inclinations consistent to the geometry of the oceanic Moho of the subducting Philippine Sea Slab (Shiomi et al., 2008). We fit a polynomial surface to the distribution for each cluster by minimizing the vertical offsets in the least-squares sense and measure the thickness as their deviation. The thickness of each cluster ranges from ˜50 m to ˜1700 m.
For the geological approach, we examine the vein distribution in the Makimine tectonic mélange in the Shimanto accretionary complex in southwest Japan. The mélange is considered to be shear zone along subducting plate and preserve numerous shear veins accompanied by extension veins. We regard the shear vein concentration zone as the tremor zone and measure its thickness along the transect perpendicular to the foliation. We further examine the number and length distribution of the veins. Within the entire exposure of ˜120 m thickness, shear veins are concentrated in the zone of ˜60 m thickness. We observed numerous shear veins as well as foliation parallel extension veins. The number of veins along the transect is 1147 in total. The lengths of the shear veins are from 1 to 7 m and most are around 1 m.
The geologically determined thickness (60 m) of the tremor zone is within the range of the seismologically determined thickness (50-1700 m), which supports the idea that the observed shear veins are the faults of tremors. The lengths of veins (˜1 m) are much smaller than the fault size of tremor and other slow earthquakes (>100 m). However, a cascading failure of the faults caused by the entire zone deformation can possibly produce larger events. The coexistence of the shear veins and foliation parallel extension veins indicates high pore pressure in the tremor zone that exceeds the least stress. We further expect extension components associated with extension veins in the focal mechanism of slow earthquakes.

Keywords: tremor, low frequency earthquake, Makimine tectonic mélange, subduction zone

