Moderate-velocity slips in plate subduction zone: implications for Tsunami Earthquake

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Recent discovery of slow earthquakes brought insight into diversity of deformation rate along plate subduction zones: plate convergence (~10^{-9} m/s), slow earthquake (10^{-9}–10^{-5} m/s), and fast regular earthquake (10^{-1}–10^{-0} m/s). The gap in the slip velocity can be fundamental to understanding the variation of faulting style, the differences in rupture dynamics, and physical processes of the earthquakes. Yet, we neither experience the "moderate velocity" earthquake filling in the gap, nor know what features the moderate velocity slip has. On the other hand, previous geological study that has evaluated slip parameters (i.e. risetime, slip velocity) using the vitrinite maturation method, found potential moderate velocity slips in the shallow part of the subduction zone, the Nankai Trough. In this study, we investigated on land fossil megathrusts in order to verify the generality of moderate velocity slips. We characterized the moderate velocity slips by compiling earthquake source parameters obtained using seismological, geodetical, and geological methods to shed light on the gap between slow and regular earthquakes.

We focused on three fossilized representative faults; Surusumori, Shirako, and Emi faults in the Boso peninsula, central Japan. This area contains two accretionary complexes: the late Miocene to early Pliocene Miura–Boso accretionary prism and the early to middle Miocene Hota accretionary complex. These accretionary complexes preserved shallow deformation structures related to the accretion event, and the Boso accretionary prism is considered to be an analogue of the megathrusts in the Nankai Trough, where potential moderate velocity slips were geologically identified in the shallow portion of the faults. Geological evaluations of the slip parameters were conducted based on the vitrinite reflectance (R_o %) method, which is the same approach as the slip estimation method used for the Nankai Trough megathrusts. Broad anomaly along the faults show gradual temperature increase caused by frictional slips on the faults. The evaluated rise time (t_r) and slip velocity (v) for the Surusumori and Shirako faults were t_r = 2500 s, v = 1.7 mm/s and t_r = 2570 s, v = 1.5 mm/s, being comparable with the moderate velocity slips in the Nankai Trough. On the other hand, no significant thermal signal was identified in the surrounding host rock of the Emi fault despite that the fault experienced fluid rock interaction at over 350 degrees during faulting.

The moderate velocity slips locate in the "gap" zone in diagrams of slip displacement (D_a) *vs* risetime, and slip velocity (v_a) vs D_a. The D_a –t_r relation of the grope of moderate velocity slips appears to be linearly aligned, and it seems to be proportional ($Da \propto tr$) as with regulars. The mesoscopic structure of the "moderate velocity faults" is similar to that of "regular fast-slip faults", dominated by brittle deformation and strain localization. The slip velocity of 10^{-4}–10^{-3} m/s and the risetime of ~10^3 s are however quite distinct from that of regulars.

D_a and v_a of the low-speed slip components of the 2004 Sumatra–Andaman earthquake are plotted with the moderate slips. These slips northern Nicobar and Andaman segments have been considered as

tsunami earthquakes because they caused tsunami without large seismic wave. The slow components occurred in the shallow part of megathrust, thus the setting of the slower slip is also similar to the location of moderate-velocity slip found in shallow part of the Nankai and the Boso megathrusts. It is suggested that the shallow moderate slip can be the major faulting of tsunami earthquake likewise the slip in the northern part of the Sumatra earthquake, and that there are slip zones that causes tsunami earthquakes in the Nankai Trough. The character of tsunami earthquake, not accompanied by strong ground shaking, obstructs evacuation and leads to enormous human damage.

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