Fault model of the 2012 off-Miyagi intraslab earthquake doublet and its implication for rheological signature of incoming Pacific plate

*Tatsuya Kubota[1], Ryota Hino[2], Syuichi Suzuki[2]

1. National Research Institute for Earth Science and Disaster Resilience, 2. Graduate School of Science, Tohoku University

An Mjma 7.3 earthquake composed of a deep reverse-faulting subevent (~60km, Mw 7.2; subevent 1) and a shallow normal-faulting subevent (~20km, Mw 7.1; subevent 2) occurred on 7 December 2012, within the Pacific Plate near the Japan Trench. Since the fault mechanisms of two subevents are consistent with the stress field within the incoming plate near the trench, characterized by the deep compressional and shallow tensile stresses due to the bending of the subducting plate (bending stress, e.g., Chapple and Forsyth, 1979 JGR), we have estimated the finite fault model of this earthquake to discuss the intraplate stress field in this region (Kubota, 2017 PhD thesis, Tohoku Univ). In this study, we conducted more comprehensive discussions for the intraplate stress state, the physical properties, and the relationship between the 2012 earthquake and the Tohoku-Oki earthquake.

We first estimated the initial sea-surface height distribution by inverting the tsunami records and compared it with the vertical deformation expected from the Global CMT solution, to find that the subsided area was generated only by subevent 2 and the uplift area was by both subevents. Then we estimated the optimum fault model for subevent 2, which explains the subsided area of the initial height distribution and the aftershock distribution determined by Obana et al. (2015 AGU FM). Finally, based on the the teleseismic records and the residual displacement between the initial height and the vertical displacement expected from the subevent 2 fault model, we estimated the subevent 1 fault model. We also evaluated the estimation error of our fault model based on the models which had relatively good reproductivity of the sea-surface deformation. As a result, the depth range of the faults of subevents 1 and 2 fell into ~ 45 –70 km and ~ 5 (seafloor) –35 km, respectively.

The down-dip edge of the shallow normal-faulting seismicity in 2012 (~35 km) significantly deepened compared to that in 2007 (~25 km, Hino et al., 2009 G3). However, consideringthe vertical stress gradient of the bending stress (~15 MPa/km), the coseismic stress change by the 2011 Tohoku-Oki earthquake around the normal-faulting seismicity (~20 MPa) is too small to cause normal-faulting earthquakes in that depth range, suggesting that the plate down to ~ 35 km is required to have been already yielded before the Tohoku-Oki earthquake and the frictional strength in the normal-faulting depth range is required to be significantly weaker than the empirical relationship (e.g., Byerlee, 1978). Accounting for the result of the active seismic survey of Fujie et al. (2018 Nature Comm), who suggested the existence of the pore fluid at the shallow part of the subducting plate (< ~ 5 km), the strength reduction is caused by the pore fluid infiltration down to ~ 35 km, along the bending faults (e.g., Faccenda et al., 2009 Nature Geo).

We also obtained the down-dip depth of the deep reverse-faulting subevent at ~70 km, which obviously below the brittle-ductile transition depth expected for the age of the plate. The deep penetration of the fault is explained by the viscoelastic relaxation following the Tohoku-Oki earthquake (e.g., Tomita et al., 2017 Science Adv), which increases the strain rate in the deeper part of the plate. Since the increase of the strain rate makes the brittle-ductile transition depth (e.g., Scholtz, 1988), the depth range of the brittle rupture are extended deeper than that before the Tohoku-Oki earthquake. This result suggests that deep reverse-faulting earthquake in the incoming plate can grow larger after the massive interplate

earthquake than in the interseismic period.

Keywords: The 2011 Tohoku-Oki earthquake, Intraplate earthquake, Rheology, Stress, Tsunami

