Rupture on the megasplay fault along the Nankai trough during the off-Mie earthquake (Mw=6.0) on 1 April 2016

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On 1 April 2016, a moderate-sized off-Mie earthquake (Mw=6.0), occurred off the Kii Peninsula, southwest of Japan. The epicenter is located updip of hypocenter of the 1944 Tonankai earthquake (Mw=8.2 after Ichinose et al., 2003). Wallace et al. (2016) determined the hypocenter distribution of the 2016 earthquake and concluded that this earthquake occurred along the plate boundary. Their hypocenter determination was based on a 1D velocity structure, while horizontal heterogeneity along the dip direction is not negligible in subduction zones.
In this study, we determined the hypocenters of the 2016 earthquake by using a velocity structure reflecting the horizontal heterogeneity. We used a 2D velocity structure obtained by a wide-angle seismic survey on a line that passes through the hypocenter region. We manually picked P-wave onset at each DONET station deployed immediately above the source region (Kaneda et al., 2015; Kawaguchi et al., 2015). S-wave arrival was not used because of the uncertainty in the S-wave velocity structure (Wallace et al., 2016). We used the method of Lomax et al. (2000) for the hypocenter determinations.
We obtained hypocenter distributions very similar to that obtained by Wallace et al. (2016), but shallower mainshock depth at 9.7 km compared to that at 11.4 km of their result. The aftershock distribution was very similar to their result including the source depths.
We compared the hypocenter distribution with a reflection profile obtained from multichannel seismic survey (MCS) along a line where the 2D velocity structure was obtained. The source depths were converted to the two-way travel-time (TWT) by integrating the slowness picked from the 2D velocity structure from the sea level to the source depth. The mainshock was located at slightly shallower than, but very close to, the megasplay fault imaged on the MCS profile, rather than the plate boundary. Aftershocks were distributed beneath the deeper extension of this plane, although the reflection phase is not clear there.
Considering the errors in the hypocenter determinations and velocity structure estimations, two possibilities are available for the mainshock fault. One is a fault in the inner wedge such as an ancient splay fault. The other is the megasplay fault. Ancient splay faults in this region are considered to be inactive after ~2 Ma because of a lack of a dislocation plane due to fault activities in the shallow sediments (Tsuji et al., 2014). The megasplay fault is considered to be active at present (Sakaguchi et al., 2011) to which we attribute the mainshock.
In the transition zone of the accretionary wedge between the megasplay fault and the plate boundary is characterized by a zone of low seismic-wave velocity (Park et al., 2010; Kamei et al., 2012; Tsuji et al., 2014). This zone is considered to consist of fluid-rich sediments, which could not support strong shear stress to cause large earthquakes (Bangs et al., 2009; Kitajima and Saffer, 2012; Tsuji et al., 2014). Accordingly, it is difficult to cause large earthquakes along the megasplay fault or the plate boundary in the source region of the 2016 earthquake. Wallace et al. (2016) attributed this earthquake to a slip along

an unstable patch in conditionally stable zone of the plate boundary, but its geological meaning has not been clarified yet.
In MCS profiles we can recognize a portion that the reflection phase is locally very weak along the megasplay fault or the plate boundary around the mainshock source. Weak reflection phase can be interpreted as a difference in lithology or pore-fluid pressure from the surroundings and the material is locally strong (e.g. Moore et al., 2009; Bangs et al., 2004). This portion would be an “unstable patch”, where large earthquakes can occur. We hypothesize that remnant of fragments of seamounts, of which the main body would have been subducted to deeper part, form the strong patch in the sediments.

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