

The rupture process of M5-6 earthquakes after the 2011 Tohoku earthquake in the focal area of the off-Kamaishi repeaters

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For more than 50 years from 1957, earthquakes of $M \sim 4.8$ have repeatedly occurred on the plate boundary off Kamaishi, NE Japan with the recurrence interval of about 5.5 years (the repeating earthquakes off Kamaishi). Previous studies reported that the repeating earthquakes have been caused by repeated ruptures of the same asperity (Matsuzawa et al, 1999, 2002; Okada et al., 2003; Uchida et al., 2007; Shimamura et al. 2011a). Moreover, no earthquakes of M5 or larger have occurred around the off-Kamaishi repeaters since at least 1957. Nevertheless, after Tohoku earthquake of M9.0 on 11 March, 2011, events of M5-6 occurred with the interval of a few days to a few months in vicinity (1-2km in JMA catalogue) to the repeating events off Kamaishi (Uchida, 2011; http://www.aob.geophys.tohoku.ac.jp/info/topics/20110311_news/index.html). Generally, the extent of rupture areas of the M5-6 earthquakes is from a few km to 10 km, thus, it is possible that these M5-6 event ruptured the asperity of the repeating earthquakes off Kamaishi.

In this study, in order to investigate the relation of the M5-6 earthquakes to the repeating earthquakes off Kamaishi, we conducted hypocenter relocation and seismic waveform inversions. Here, among the M5-6 events, for the event on 20 March 2011 (M5.9) we reported the results of analyses of the event on 20 March 2011 (M5.9) in SSJ FALL MEETING 2011 (Shimamura et al., 2011b, in Japanese) and those of the events on 20 March (M5.9), 1 April (M6.0), 13 April (M5.5), and 29 April 2011 (M4.8) in AGU FALL MEETING 2011 (Shimamura et al., 2011c). In this study, we analyzed the events on 5 May (M5.3), 11 July (M5.0), and 23 September, 2011 (M5.0) in addition to the events mentioned above.

Except the event on 1 April (M6.0), the following results are commonly obtained: 1) Hypocenters of the M5-6 events are located within only 1-2km from those of the repeating earthquakes off Kamaishi before 2011. 2) The M5-6 events ruptured the asperity of the off-Kamaishi repeating events and areas around (mainly east of) it. These results are basically the same as those reported by Shimamura et al. (2011b, 2011c).

In previous studies, for example Uchida et al. (2005), a velocity-weakening region corresponding to the asperity of the off Kamaishi events is considered to be located in a velocity-strengthening region where two plates slip aseismically. However, this model cannot explain our result that the area around the off-Kamaishi asperity also slipped seismically during the M5-6 events. In order to explain the results, we infer that conditionally stable areas (e.g., Scholz, 1990; Boatwright and Cocco, 1996) are located near the off-Kamaishi asperity. A conditionally stable area has velocity-weakening nature but the frictional parameter $a-b$ is nearly equal to zero. Such a conditionally stable area slips aseismically in usual. However, if a large stress perturbation is applied to the conditionally stable area, it might slip seismically (Kato, 1996). In the model proposed here, the conditionally stable areas around the off-Kamaishi asperity slipped seismically during the M5-6 events only. Actually, large afterslip of the Tohoku earthquake was estimated (Ozawa et al., 2011; GSI, 2011) in the area and it is supposed that stress perturbation caused by the large afterslip forced the conditionally stable area to slip seismically.

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