Source process of moderate size repeating earthquakes in eastern Japan

*Takashi Okuda[1], Satoshi Ide[1], Naoki Uchida[2]

1. Department of Earth and Planetary Science, University of Tokyo, 2. Research Center for Prediction of Earthquakes snd Volcanic Eruptions Graduate School of Science, Tohoku University

In the Tohoku-Hokkaido subduction zone, several small to moderate earthquakes have occurred repeatedly at almost the same location, radiating almost identical waveforms every time. This phenomenon has been understood as repeated rupture of a patchy structure surrounded by aseismic slip area on the plate boundary (e.g., Matsuzawa et al., 2002, Igarashi et al., 2003). A typical example is the Kamaishi-Oki repeating earthquake sequence of about M4.9 recurring at almost 5.6-year interval. Many smaller earthquakes occurred in clusters in and around the slip area of the main events, suggesting some hierarchical structure in the source region. Such hierarchical structure is considered as a source of diversity in earthquake process, and may control foreshock activities. The lack of aftershocks (Uchida et al., 2012) also suggests that the rupture of main events releases almost all accumulated strain energy around this structure.

Despite a seemingly reasonable interpretation for the Kamaishi sequence, the universality of this interpretation has not been proved. It is not obvious whether similar characteristics are observed for other repeating earthquake sequences. Therefore, this study investigates several repeating sequences of moderate (M4~5) earthquakes, to discuss the applicability of the above interpretation in the Tohoku-Hokkaido subduction zone. We focus on sequences occurred almost beneath the coastline, where seismic activity looks isolated near the bottom of the seismogenic layer. Relatively good station coverage gives high resolution for source imaging. The study regions are Katori in Chiba prefecture, Mito-Oki, Naka-Oki in Ibaraki prefecture, Futabagun-Oki and Iwaki-Oki in Fukushima prefecture, and Kushiro-Oki, Urakawa and Hidaka-Oki in Hokkadio.

In each study region, we selected M > 1 earthquakes from the JMA catalog since 2002, and relocate them using the Network Cross Correlation Method (Ohta & Ide, 2008). Data are velocity records of 1 Hz short-period seismometers in vertical component at stations operated by the National Research Institute for Earth Science and Disaster Resilience (NIED), the Japan Meteorological Agency (JMA), Earthquake Research Institute (ERI), University of Tokyo, Hokkaido University, and Tohoku University. The original sampling frequency is 100 Hz, and we used 2-8 Hz bandpass filter.

In the Kushiro-Oki region, earthquakes of M~4.9 occurred fairly regularly at ~6.6 year recurrence interval. Figure 1(b) shows the relocated hypocenters by circles of approximate source size calculated using the formula of Eshelby (1957), assuming the stress drops of the earthquakes are 3 MPa. The cluster of small earthquakes are located inside the source are of the main event, suggesting some hierarchical structure. Magnitude of these small earthquakes increased before the main events, and seismic activity is relatively low after main events. Similar behavior is observed in the other seven regions.

We also estimate the slip distribution of the main events in repeating earthquake sequences using an empirical Green’ s function (EGF) method. Data is the same as the relocation analysis, except that 1-8 Hz bandpass filter is used. Figure 1(e) shows an example of tentative results for the Kushiro-Oki region. EGF event is a small earthquake occurred inside the slip area of the main event. The snapshots indicate that

the location of the initial rupture of the main event is a little shallower than that of the EGF event (cross).

References: Igarashi, T., T. Matsuzawa, and A. Hasegawa, JGR, 2003; Matsuzawa, T., T. Igarashi, and A. Hasegawa, GRL, 2002; Ohta, K., and S. Ide, EPS, 2008, Uchida, N., T. Matsuzawa, W. L. Ellsworth, K. Imanishi, K. Shimamura, and A. Hasegawa, GJI, 2012.

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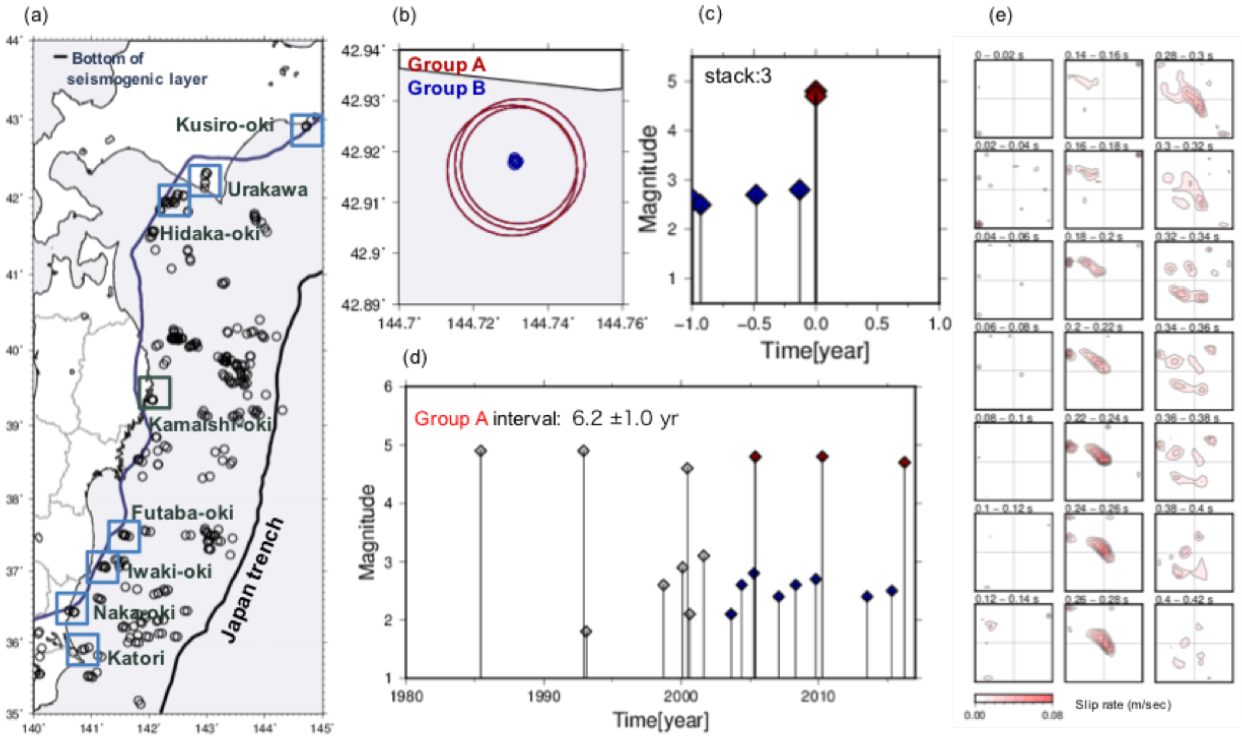

Figure 1. Source process analysis of Kushiro-oki repeating earthquake.
(a) Study region. (b) the location of hypocenter and the size of circle shows the approximate source size calculated using the formula of Eshelby (1957), assuming the stress drops of the earthquakes are 3 MPa. (c) MT diagram for one year before and after the M ~ 4.9 sequence. The data for 2005, 2010 and 2015 earthquakes are collapsed based on the occurrence time of the each earthquake. (d) MT diagram for Kushiro-Oki region. (e) Slip evolution of the 2010 earthquake.

