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Hypocenter migration and its cause in the precursory activity and aftershocks of the 2017 M 5.3 Kagoshima Bay earthquake, Kyusyu, SW Japan

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An earthquake occurs when the shear stress acting on the fault plane reaches the frictional strength. It has been suggested that an increase in pore pressure plays an important role in earthquake occurrence (e.g. Hasegawa, 2017; Hubbert & Rubey, 1959; Nur & Booker, 1972; Sibson, 1992). Migration behaviour of earthquake hypocenters is considered to be caused by aseismic processes such as fluid movement or aseismic slip propagations. It is expected that information on aseismic processes ongoing in the crust can be obtained by examining the hypocenter migration in detail. On 11 July 2017, an M 5.3 earthquake occurred at approximately 10 km depth in Kagoshima Bay, Kyusyu, SW Japan. Near the main shock hypocenter, seismicity had been activated since December 2016. In order to investigate the generation mechanism of this seismic sequence, we improved relative locations of hypocenters of the precursory activity and aftershocks by using waveform cross correlations.

First, precise differential arrival times were obtained by calculating cross correlations of the pair of waveforms out of the earthquakes that occurred after January 2010 in the Southern Kagoshima Bay region in the same way as Yoshida & Hasegawa (2018). We used waveform data observed at 20 stations located around the main shock hypocenter. Then, we applied the double-difference location method (Waldhauser and Ellsworth, 2000) to the differential arrival data thus obtained by cross correlations and those listed in the JMA (Japan Meteorological Agency) catalogue. For the initial hypocenters, we used hypocenters listed in the JMA unified hypocenter catalogue.

As a result, hypocenters are concentrated on several thin planes, although the original JMA hypocenters were scattered and showed a cloud-like distribution. Hypocenters of the precursory activity are neatly concentrated on the main plane among these and show obvious migration behaviour. Hypocenter distribution of the precursory activity on this plane also shows a clear seismic gap located adjacent to the main shock hypocenter. Most of aftershock hypocenters are distributed on the same plane but did not fill this seismic gap. This seismic gap might reflect the main shock rupture zone (e.g. Wetzler et al., 2018). Aftershocks including those distributed on other several thin planes tend to move upward with time. This spatial and temporal feature of earthquake hypocenters is similar to those observed in the earthquake swarms in central Tohoku that were triggered by the 2011 M9 Tohoku-Oki earthquake probably due to the upward movement of fluids (Yoshida & Hasegawa, 2018)

These characteristics of the precursory activity, the main shock and aftershocks suggested that this earthquake sequence was caused as follows. (1) Prior to the occurrence of the main shock, crustal fluids penetrated into an existing weak plane from below and reduced the frictional strength, which caused the precursory seismic activity on the plane and the migration of hypocenters (2) Then the seismic gap, which had not been ruptured by the precursory activity, was finally ruptured by the main shock because of the reduction of the frictional strength caused by increased pore pressure as well as the stress concentration caused by the surrounding earthquakes. (3) Due to the stress change associated with the main shock, aftershocks were triggered around the main shock hypocenter. Aftershock hypocenters moved upward due to the upward fluid movements after the main shock.