Possible aseismic phenomena causing the hypocenter migration 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 behavior of earthquake hypocenters is considered to be caused by aseismic processes such as fluid movements or aseismic slip propagations. It is expected that information on aseismic processes 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 a pair of waveforms out of the earthquakes that occurred after January 2010 in the Southern Kagoshima Bay region. We used waveform data observed at 20 stations located around the main shock hypocenter. Calculations of cross correlations of waveforms were performed in the same way as Yoshida & Hasegawa (2018). Then, we applied the double-difference relocation method (Waldhauser and Ellsworth, 2000) to the differential arrival time data thus obtained by cross correlations and those listed in the JMA (Japan Meteorological Agency) unified catalog. We used hypocenters listed in the JMA unified hypocenter catalog as the initial hypocenters in the relocation.

The relocated hypocenters are concentrated forming several thin “planes”. The dominant orientations of the planes agree with the eithers of nodal planes of focal mechanisms of the main shock and aftershocks.

Hypocenters of the precursory activity are neatly concentrated along one of the planes and exhibit distinct migration behavior. Hypocenter distribution of the precursory activity along that plane shows a clear seismic gap located adjacent to the main shock hypocenter. Most of aftershock hypocenters are distributed along the same plane but did not fill this seismic gap. We calculated the corner frequency of the mainshock source spectrum using the spectral ratio method and estimated the mainshock fault size. The estimated fault size is consistent with the size of the seismic gap. It suggests that the seismic gap reflects the main shock rupture area (e.g. Wetzler et al., 2018).

Aftershocks tend to move upward with time along several thin planes. This spatiotemporal 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)

We explain the characteristics of the precursory activity, main shock and aftershocks 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 along the plane and the migration of hypocenters. Aseismic slip might also contribute to the hypocenter migration. (2) Then the seismic gap, which had not been ruptured by the precursory activity, was finally ruptured by the main shock. (3) Due to the stress change associated with the main shock, aftershocks were triggered in the region surrounding the main shock hypocenter. Aftershock hypocenters moved upward due to the upward fluid movements after the main shock.

Keywords: seismic activity in Kagoshima Bay, precursory seismic activity, aftershocks, hypocenter migration, seismic gap

