



## **Migrating foreshock prior to a shallow crustal earthquake in Japan**

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The earthquake nucleation process is inherently complex, due to an involvement of several deformation mechanisms with multiple spatial and time scales. We here focus on a foreshock sequence which took place prior to a Mw 5.8 shallow crustal earthquake in 2013, at NE Japan. After relocating the foreshocks using travel time differential data constrained by waveform cross-correlation, we searched for events with similar waveforms to those of each relocated template event, applying a matched filter technique. Furthermore, we extracted one pair of repeating earthquakes from the reconstructed catalog ( $M > 1.8$ ), based on waveform similarity and nearly overlapping locations. The cumulative number of events showed an episodic increase toward the mainshock failure time. The initial crisis characterized as a tiny seismic cluster started from three weeks before the mainshock rupture. During about three days prior to the mainshock, a planer seismic cluster with  $\sim 0.5$  km length had developed. Less than one hour just before the mainshock break, the foreshock activity abruptly became intensive and being concentrated along a eastward-steeply dipping fault plane ( $\sim 0.5$  km length) very close to the mainshock hypocenter. We recognize a distinct sequence of earthquake migration at an average speed of  $\sim 10$  km/day over the fault plane along fault-dip and fault-strike, just after the largest foreshock ( $M 3.6$ ). Its migration front, slowing down with time, is well approximated by a parabolic curve and moved toward the rupture initiation point, which is analogous to the foreshock migration observed before the 2011 M9.0 Tohoku earthquake despite quite different spatial scales. Combining the foreshock migration with repeating earthquake, we suggest that slow slip transient propagated towards the nucleation point of the mainshock rupture. The partial unlocking of fault might take place episodically through interplay between fast and slow slip modes, prompting the subsequent unstable dynamic rupture.