

Room A | Regular session : S08. Earthquake physics

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[S08] Earthquake physics

chairperson:Kenichi TSUDA(Institute of Technology Shimizu Corporation), Keisuke Yoshida YOSHIDA(Research Center for Prediction of Earthquakes and Volcanic Eruptions, Tohoku University)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[S08-15] The 2021 Mw 7.0 Miyagi-Oki Earthquake: Rupture Expansion from an Mw 3.7 Repeating Earthquake

*Keisuke Yoshida YOSHIDA¹, Yihe Huang², Satoshi Ide³ (1. Research Center for Prediction of Earthquakes and Volcanic Eruptions, Tohoku University, 2. University of Michigan, 3. Graduate School of Science, The University of Tokyo)

Understanding the nucleation and termination mechanisms of earthquake rupture is essential for elucidating the generation process of large earthquakes. In this presentation, we report on the rupture nucleation process of the 2021 Mw 7.0 Miyagi-Oki earthquake (Yoshida et al., 2022, JGR), which occurred within a cluster that repeatedly generated Mw 2–6.1 earthquakes following the 2011 Tohoku-Oki earthquake, and on the rupture characteristics of nearby Mw 5–6 earthquakes that initiated in close proximity, with the aim of gaining insights into the nucleation and growth processes of earthquakes across a wide range of magnitudes.

First, we relocated the hypocenters and centroids of earthquakes near the Mw 7.0 source area using the waveform correlation-based methods of Ide (2019) and Chang & Ide (2021). The relocated centroids revealed a hierarchical structure in which smaller repeating earthquakes occur within larger ones (Mw 2–6), consistent with the double-difference relocation results obtained by Yoshida et al. (2022) using the method of Waldhauser & Ellsworth (2000). The hypocenter distribution further showed that the Mw 7.0 event nucleated within the rupture area of an Mw 3.7 repeating earthquake. The hypocenters of the Mw 7.0 and Mw 3.7 events were extremely close, and their initial waveforms matched remarkably well at many stations (average correlation coefficient of 0.94 at 26 stations), indicating that they initiated at essentially the same location with highly similar nucleation processes.

Five Mw 5.0–6.1 earthquakes (June 2011, April 2013, November 2016, September 2018, and September 2023) nucleated slightly offset from, but within ~800 m of, the Mw 7.0 hypocenter. Rupture process estimates indicate that these events repeatedly ruptured the vicinity of the Mw 7.0 hypocenter, located at the western edge of its rupture region. In particular, the April 2013 Mw 5.9 and November 2016 Mw 6.1 earthquakes ruptured updip from their hypocenters into the western ~5 km of the Mw 7.0 main rupture area, with the 2016 event also producing significant slip near the eastern edge of the main rupture. The repeated rupture of the rupture-edge area by Mw 5–6.1 events suggests that, before the mainshock, the asperity (locked region) margin—especially on the downdip western side—was progressively weakened, potentially making small earthquake patches within the asperity more prone to slip. Indeed, since the 2011 Tohoku-Oki earthquake, the western edge of the Mw 7.0 rupture region and its surroundings had experienced pronounced afterslip and frequent repeating earthquakes. Under such loading conditions,

an asperity that was approaching a critical state may have been driven to failure by a rupture cascade initiated by the Mw 3.7 repeating earthquake.

These results provide strong evidence that the Mw 7.0 earthquake was triggered through a rupture cascade from a much smaller repeating earthquake (Mw 3.7), consistent with Chang & Ide's (2021) finding that rupture nucleation points are often predetermined by local fault conditions like fault geometry and fault zone structures. The fact that ruptures initiated at the same or nearby locations terminated at widely different magnitudes (Mw 2–7) suggests that rupture growth and termination is strongly influenced by the evolutions of stress, frictional and material conditions on the fault.