

Nucleation Process of the 2011 Mw6.2 Northern Nagano Earthquake

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Introduction. Previous research.

An Mw6.2 inland earthquake occurred in northern Nagano region, central Japan, about 13 hours after the Mw9.0 Tohoku-oki megathrust earthquake. The regional seismic activity recorded by the Japan Meteorological Agency (JMA) catalog in the first hours following the megathrust event was highly incomplete, thus not allowing a detailed analysis of triggering mechanisms. By applying a Matched Filter Technique (MFT) to the continuous Hi-net (NIED) waveform data, Shimojo et al. (2014) revealed an immediate post-Tohoku seismicity activation in an area located about 10 km south of the Mw6.2 Northern Nagano source region. They also detected a few foreshocks close to the hypocenter of the Mw6.2 mainshock, within one hour before the occurrence of the moderate-size event. However, the physical processes that led to the occurrence of the Mw6.2 earthquake remained unclear. In this study we take advantage of the data recorded by a dense temporary seismic network operated by NIED from 2008 to 2012 to reveal with an unprecedented resolution the nucleation process that culminated with the occurrence of the Northern Nagano earthquake.

Data and Method

We use the waveform data of the NIED “Hizumi” temporary network, with station spacing of about 5 km or less in the study area. The data recorded by the permanent Hi-net stations (spacing of about 20 km) complements that of the dense regional network. We have first picked P- and S-wave arrivals of earthquakes on the continuous seismograms and use the pick data to locate the events. The earthquakes were then relocated using the tomoDD software (Zhang and Thurber, 2003) and a 3D velocity structure in the region (Sekiguchi et al., 2013). The newly located earthquakes were further used as MFT templates to search for new events within the 13-hour time interval, in the hypocentral region of the Mw6.2 earthquake.

Results and Discussion

We have detected a total of 285 earthquakes in the source region of the Mw6.2 event. The earthquakes are relatively small, with magnitudes less than 2.5, and distribute within two spatially distinct clusters: one of these clusters was located close to the hypocenter of the Mw6.2 event (“West” area), the other about 5 km to the east (“East” area).

In the “East” the seismicity starts within one hour after the Tohoku-oki earthquake. The events occur off the Mw6.2 fault and expand with time from shallow towards deep locations. In the “West” the seismicity starts immediately after the passage of surface waves excited by a moderate earthquake in the Tohoku-oki aftershock area, which occurred 21 minutes after the Mw9.0 megathrust; most of these events distribute along the fault line of the Mw6.2 mainshock. Within the “West” seismicity area, a tight sub-cluster that occurred in the immediate vicinity (within about 2 km) of the Mw6.2 hypocenter was strongly activated twice: about 3 hours before and 50 minutes before the mainshock, respectively.

In both “West” and “East” areas some events occurred during or immediately after the passage of surface waves from some $M_{JMA} \geq 6.0$ Tohoku-oki aftershocks. In particular, the final activation in the “West” starts during the passage of surface waves from a moderate event occurred off-shore Fukushima and continues until the occurrence of the Mw6.2 Nagano earthquake. Such activations may indicate that

successive dynamic stress changes caused by the remote Tohoku-oki mainshock and its subsequent aftershocks contributed to the weakening of the seismogenic region in northern Nagano, culminating with the Mw6.2 earthquake. Excitation of crustal fluids might have been at least partly involved, as revealed particularly by the migration pattern of activated seismicity in the “East” .

Keywords: the 2011 Northern Nagano earthquake, dense temporary regional network, Matched-Filter Technique, dynamic stress change