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Detailed characteristics of the March 12, 2011 Nagano-Niigata earthquake sequence and its seismo-tectonic backgaround

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The Tohoku-oki earthquake (Mw9.0) occurred on March 11, 2011, involving a large number of aftershocks and widespread induced seismicity all over Japan. About 13 hours later, the March 12, 2011 Nagano-Niigata earthquake (M6.7) occurred within the high-strain-rate zone of Japan. Both the Hi-net and F-net focal mechanism solutions of this earthquake revealed a reverse fault mechanism, with a P-axis trending NNW-SSE. The largest Nagano-Niigata aftershock (M5.9) occurred 30 minutes after the mainshock and was characterized by a NNW-SSE compressional reverse fault mechanism, similar to the one of the mainshock. The Tohoku-oki earthquake caused crustal deformation in a widespread area of Tohoku district (e.g. Ozawa et al., 2011). In such changed stress field, the Nagano-Niigata earthquake occurred. It is important to study in detail this earthquake sequence and the underlying tectonic background to understand the physical mechanism of its occurrence. In this work we analyze the Nagano-Niigata aftershocks and obtain a detailed aftershock distribution. Finally, based on these results, we are able to describe the detailed features of the Nagano-Niigata sequence and suggest a physical model for its occurrence.

We describe the features of this earthquake from the obtained aftershock distribution and the detailed 3-D velocity structure (Enescu et al., 2012). The aftershock region consists of two basement-rock blocks, which divide the area into NE and SW parts. The NE block hosts the source fault of the mainshock, with a SE dipping plane. The source fault of its largest aftershock, with a NW dipping fault plane (different from the one of the mainshock) lies within the SW block. The velocity structure of the two blocks is different; the SW block has a higher velocity than the NE block. Such difference indicates a different rock composition, likely related to the tectonic processes that lead to the formation of the two blocks.

These blocks were formed by normal and transform faulting accompanying the opening of the Sea of Japan in the Miocene. The faulting processes are at the origin of the many tectonic blocks that exist below the high-strain-rate zone. Similar with the sequence analyzed in this study, the mainshock and/or aftershock source faults of the 2004 Niigata Chuetsu earthquake and the 2007 Niigata Chuetsu-oki earthquake are divided into multiple areas (e.g. Kato et al., 2005, Yukutake et al., 2008). Therefore, earthquakes occurring within the high-strain-rate zone may break multiple blocks either at the same time or during a short time period. In most cases distinct ”block-dependent” behavior could be noticed.

Finally, we discuss why the Nagano-Niigata earthquake was induced by the M9.0 Tohoku-oki earthquake. After the occurrence of the Tohoku-oki earthquake, the seismicity in many volcanic regions all over Japan became active. The activated areas include a volcanic region in Kyushu, very far from the Tohoku-oki source region. This indicates that the triggering is likely caused by dynamic rather than static stress changes (that is, stress change induced by the passage of the surface waves from the megathrust event). The tomography result showed the existence of a high Vp/Vs ratio below the mainshock hypocenter, which suggests fluid existence, same as in volcanic areas. The Nagano-Niigata earthquake may have been induced by a stress transfer due to the very large amplitude surface waves from the Tohoku-oki earthquake, similar with the seismicity activation process in volcanic regions.

Keywords: the high-strain-rate zone of Japan, Nagano-Niigata earthquake, Tohoku-oki earthquake