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The March 12, 2011, Northern Nagano Prefecture earthquake - a normal fault event?

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The March 12, 2011, Northern Nagano Prefecture, Japan, earthquake (M6.7), which occurred one day after the Tohoku earthquake, caused significant damage to Sakae village. The aftershock distribution for the initial 24 hours suggests a NE-dipping fault plane, while the CMT solutions from NIED and JMA suggest a reverse-fault event on a NW-dipping or a SE-dipping fault plane. Possible solution for this conflict was investigated. As a result, the possibility of the earthquake being a normal fault event was suggested.

Aftershock distributions for large earthquakes have often been used for the determination of the fault plane. For example, it was based on the aftershock distribution that the 1994 Northridge earthquake was assigned to a south-dipping fault plane, although the nearby 1971 San Fernando earthquake had a north-dipping fault plane. Although some earthquakes have ambiguous aftershock distribution, the aftershock distribution for the initial 24 hours for this particular earthquake (Figure) is much clearer than for the 2004 Mid Niigata Prefecture earthquake (Kato et al., 2005, GRL) or the 2007 Chuetsu-oki, Niigata, earthquake (Kato et al., 2008, EPS). Therefore, it is easy to conclude from the aftershock distribution that the earthquake had a NE-dipping fault plane.

However, the CMT solutions from NIED and JMA suggest a NW-dipping or a SE-dipping fault plane. There have to be some explanation for this conflict.

The author tried to solve this conflict as follows. The strike and dip angles were fixed based on the aftershock distribution and the rake angle was varied to investigate its effect on the SH and SV radiation coefficients. The result indicates that, if the rake angle is assumed to be minus 120 degrees, then the resultant radiation pattern for the far field becomes similar to those associated with a reverse-fault event on a NW-dipping or a SE-dipping fault plane. Thus, even if we assume a NE-dipping fault plane, the far field radiation pattern, from which the CMT solution is obtained, can be explained. In this way, we can solve the conflict between the aftershock distribution and the CMT solution.

By the way, the above solution requires a negative rake angle, which corresponds to a normal fault event. If we can assume that the earthquake is a normal fault event, it is advantageous for explaining other data associated with the same earthquake. For example, for the two strong motion stations just above the fault (Sakae town office and K-NET Tsunan), the initial P waves were negative (tension). It is easier to explain this polarity with a normal fault event. Finally, this earthquake might have been triggered by the great Tohoku event (Okada et al., 2011, EPS). If it is true that the earthquake was triggered by the Tohoku event, it is natural to assume that the earthquake was a normal fault event, because the incremental stress induced by the Tohoku event was mainly a tensile one in the NE-SW direction.

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Keywords: the 2011 Northern Nagano Prefecture earthquake, aftershock distribution, CMT solution, normal fault, radiation pattern, triggered earthquake