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Overview of Widespread Seismicity Changes inland Japan Following the 2011 Tohoku-Oki Earthquake and Its Interpretation

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This paper overviews the widespread changes in seismicity rate and distribution of focal mechanism after the Tohoku-Oki earthquake (Mw9.0) and summarize possible contributing factors.

In the Tohoku region, significant increases in seismicity rate were observed in N. and S. Akita, SW off Oga peninsula, and Yamagata/Fukushima boundary area as well as other surrounding areas. The most activated area was the Ibaraki/Fukushima boundary area where shallow normal-faulting earthquakes abruptly began to occur. On the other hand, swarm-like activity in the south of Lake Inawashiro suddenly terminated following the Tohoku-Oki earthquake. In addition, aftershock activities in the source regions of recent large earthquakes such as the 2008 Iwate-Miyagi earthquake (M_{JMA}7.0) have been suppressed. Focal mechanism distributions also showed significant changes in the shallow crust of the Tohoku region; strike-slip and normal-faulting earthquakes were activated following the Tohoku-Oki earthquake, while thrust-faulting earthquakes, which had been predominant due to the compression in the E-W direction, were deactivated.

In the Kanto region, abrupt increases in seismicity rate of the shallow crustal areas were typically observed in the Tochigi/Gunma and Ibaraki/Chiba boundary areas, SE Chiba near Choshi City, N. Tokyo Bay area, SE part of Boso peninsula, Tanzawa, Hakone, and Izu areas. Furthermore, two moderate earthquakes (the earthquake near the prefectural boundary between Nagano and Niigata (M_{JMA}6.7) on March 12th and the earthquake in the E. Shizuoka prefecture (M_{JMA}6.2) on March 15th) occurred. At intermediate depths, interplate earthquakes associated with the subduction of the Philippine Sea Plate (PHS) and the Pacific Plate (PAC) were activated, especially in SW Ibaraki, NE, NW, and SE Chiba areas. Belt-like seismicity that extended from the S. Miura Peninsula to the SW off Chiba area through the S. Boso peninsula, at a depth of 60-70 km, was also activated.

The most plausible factor which caused the changes in seismicity is the static changes in the Coulomb stress transferred by the Tohoku-Oki earthquake which make it possible to retrospectively forecast the changes in seismicity on some level. However, some activated seismicity showed clear counter-evidence. A typical example is a thrust-faulting earthquake sequence which started one week after the mainshock in Yamagata/Fukushima boundary area. The calculated stress changes were negative for most of focal mechanisms of post-Tohoku earthquakes.

Many remotely triggered local events, whose origin times are well coincided with the arrival of seismic waves from the Tohoku-Oki earthquake, suggest that dynamic stress changes due to the passage of seismic waves also contribute seismicity changes. Some swarm-like activities induced by the Tohoku-Oki earthquake such as those in the Yamagata/Fukushima boundary clearly show temporal expansion of the focal area, which is attributed to fluid diffusion. It suggests that pore fluid pressure changes are another possible factor because decreases in failure strength due to increases in pore fluid pressure can also enhance the faulting. The contribution of indirectly triggered earthquakes might be very important in some areas because stress changes imparted by neighboring indirect aftershocks could be comparable with or larger than those from a distant mainshock. Postseisimc slip now observed by GEONET and viscoelastic effect would play an important role for long-term seismicity rate change.

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Keywords: 2011 Tohoku-Oki earthquake, Seismicity change, Static and dynamic stress changes, Pore fluid pressure change, Postseismic slip, Viscoelastic effects