Micromechanical model connecting earthquake statistics and observed spatiotemporal changes in source parameters of fluid induced seismicity

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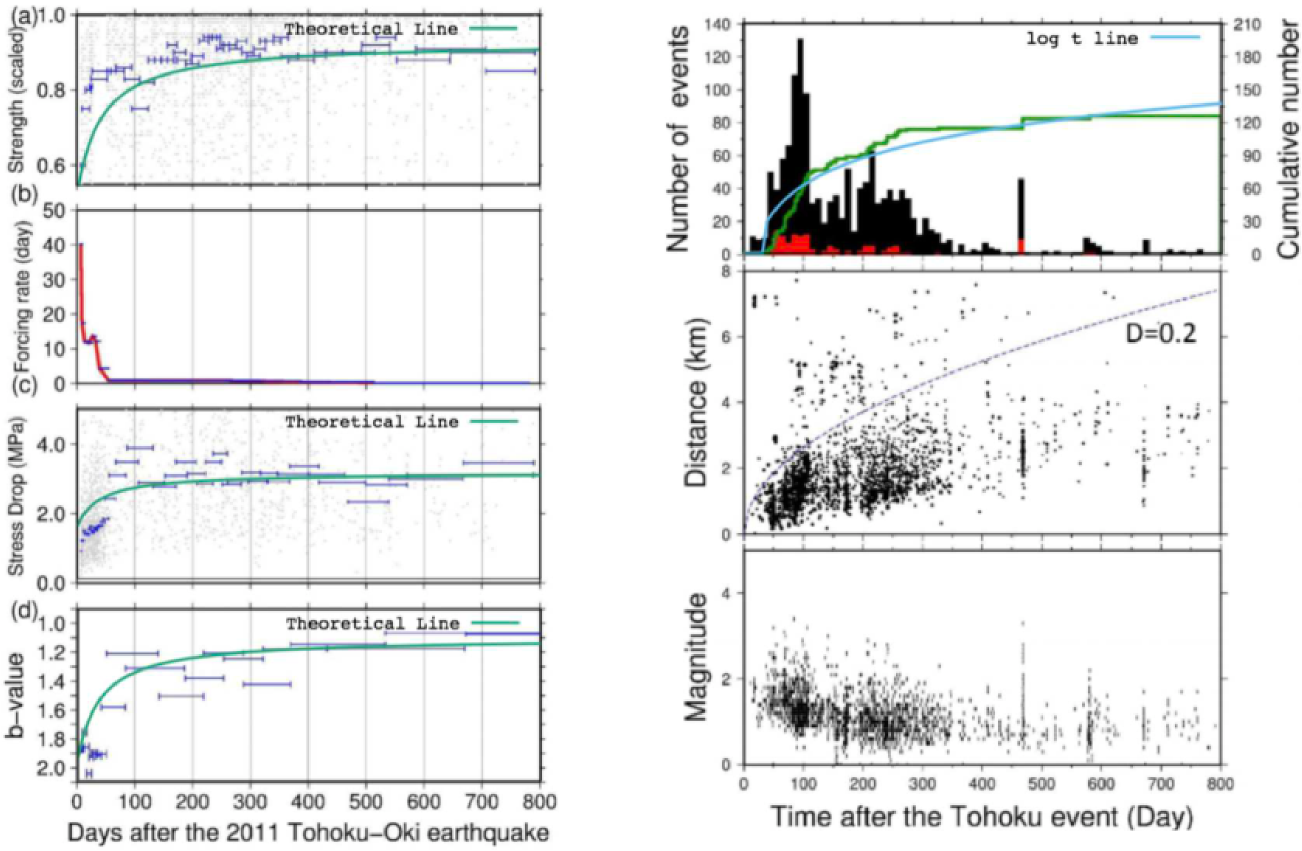
In the context of the hazard assessment of fluid-induced seismicity, the earthquake activities are known to successively continue even after the stop of fluid-injection. The change in earthquake statistics (typified by b-values and seismicity rate) is shown to be the functions of elapsed time from fluid injection similar to the Omori-law of aftershocks, even without any mainshocks (Bachmann et al., 2012). Such statistical features are also seen in the natural earthquake swarms, and simultaneously, it is further shown that the corresponding change of the stress-strength state can be captured by using source parameters (such as stress drops, strength) (Yoshida et al., 2017). The model is now required to describe synchronized observed changes in the source parameters and earthquake activities (Segall and Lu, 2015).

In this research, by considering strength heterogeneity of faults expected from experimentally verified physics, we provide the micromechanical model of such seismicity induced by on-fault fluid diffusion, and explain the results of the above data-driven analysis. Presentation contains following four contents. First, a micromechanical model is proposed. In the model, many patches are distributed randomly on a fault so that the patches are sufficiently small (or distant) to interact with each other; those patches rupture when the effective strength becomes smaller than applied shear stress due to the fluid diffusion, and the rupture cascades in each patches as in Scholz (1965). The assumption of the on-fault diffusion is based on the recent observation that the earthquake activities propagate facially (e.g., Yukutake et al., 2010, Yoshida et al., 2017). Second, the spatiotemporal changes of the source parameters are obtained as the solutions of the model. Consequently, multiple source parameters are parametrized by injected pressure, diffusion radius of fluid, normal stress on the fault, and the fluctuation of the excess strength; after the parametrization, those source parameters are shown to follow the common master curve. Third, the observed data is fitted, and the consistency between the theory and the observation is suggested. Fourth, the theoretical prediction for the temporal transience in the moment release rate is checked by the data of Yoshida et al. (2017), and the result strongly supports the theory.

Keywords: Induced-Seismicity and Earthquake Swarms, Micromechanical Model, Source Paraemters



Yoshida et al. (2017)

Fig. 1. A data example of Yoshida et al. (2017) fitted by our theoretical model (written as theoretical or log t line in the figure), after Yoshida et al (2017). (Left) Temporal evolution of the source paramters. (Right) Number of events and the spatial patterns of the seismicity.