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Explanation of Clustering Seismic Activity by Pore Fluid Pressure and Tidal Stress in the Western Shizuoka Prefecture

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Introduction

A clustering activity of small earthquakes was observed in the western Shizuoka prefecture from November 2007 through January 2008 and the activity at a lower level continues until now. This seismicity has the characteristic feature that there are periods when the intensive activity appears periodically and seems to correlate with the Earth tide (Miyaoka and Kamigaichi, 2008). Maeda and Miyaoka (2009) have tried to explain the relation between seismicity and the Earth tide by a physical model based on the rate- and state-dependent friction law (Dieterich, 1994: referred as the R-S model after here), and indicated that the normal stress should be small and there need an additional stress change other than the Earth tide. On the other hand, hypocenters at an early stage are spreading away from the initial point of the activity as time passes. These features suggest that fluid diffusion may relate to the clustering activity. Therefore we assume the main stress change other than the Earth tide is caused by fluid injection which causes pore pressure change and results in normal stress change. The purpose of this study is to estimate the absolute value of pore pressure which can explain the observed seismicity change on the basis of the R-S model.

Hypocenter migration

After applying the double-difference hypocenter determination method to the original JMA hypocenter data, we found that the relocated hypocenters exhibit an expanding feature of their locations horizontally as well as vertically along almost a vertical plane. The distance from initial point of activity versus elapsed time plot shows that the hypocenters are spreading according to the theoretical curve expected for hydraulic diffusion (Shapiro, et al., 1997) with diffusivity D=0.1 (m^2/s). This value is not much different from 0.05 and 0.17 that are obtained for induced seismicity caused by fluid injection (Shapiro, et al., 2003). This suggests the observed migration of hypocenters may be related with the hydraulic diffusion process.

Estimation of pore pressure

Under the assumption that the observed clustering activity is caused by the stress change from pore fluid pressure variation and the Earth tide, we estimate the value of pore pressure needed to explain the observed seismicity rate change using the R-S model (Dieterich, 1994). The model parameters we adopt are $1*10^{-5}$(MPa/day) for background shear stressing rate estimated from GPS observation, 0.1 (/day) for background seismicity rate, 0.01 and 0.25 for constitutive friction parameter A and alpha, and 0.55 for initial ratio of shear stress to normal stress. Then the non-linear least-square inversion is performed to estimate the initial value of the normal stress, the value of pore pressuring rate, and the timing of pore pressuring rate change. The obtained values are about 100 kPa for initial normal stress and 0 to several tens kPa/day for pore pressuring rate which is almost equivalent to those by the Earth tide.

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tide using Gotic2 (Matsumoto et al., 2001).

Keywords: seismic swarm, pore fluid pressure, rate- and state- dependent friction law, Earth tide, diffusivity