Permeability change due to the earthquake estimated by using atmospheric effect on groundwater migration

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Groundwater migration due to atmospheric loading variation is dependent on hydraulic property in aquifer. Therefore, observed atmospheric effects on groundwater discharge and pore pressure have some information about permeable structure in the surrounding crust. In this study, we estimated permeability and storage coefficient changes due to the 2011 off the Pacific coast of Tohoku Earthquake by using atmospheric effects on groundwater discharge and pore pressure observed in the fault fracture zone, and considered cause of their changes.

Groundwater migration due to atmospheric loading is considered to mainly occur in a fracture zone, because permeability in that area is higher than the surrounding crust. Mukai et al.(2015) made a one-dimensional groundwater migration model, in which groundwater is assumed to migrate laterally in fracture zone, and derived the theoretical equation showing frequency dependence of atmospheric effect on groundwater discharge. When this theoretical equation is applied to the observed atmospheric effect on groundwater discharge, we can estimate change of value 'k*S' multiplying permeability 'k' by storage coefficient 'S'.

We can also obtain the theoretical equation showing frequency dependence of atmospheric effect on pore pressure by using the above groundwater migration model. One of the variables for this theoretical equation is 'S/k' dividing storage coefficient 'S' by permeability 'k'. Thus, it is possible to estimate permeability and storage coefficient independently by analyzing both atmospheric effects on groundwater discharge and pore pressure.

We estimated change of permeability and storage coefficient in the fracture zone of Manpukuji fault, which is penetrated by the Rokko-Takao station, by using groundwater discharge and pore pressure observed at the station as well as atmospheric pressure on the ground at the Kobe local meteorological office in period from August 2010 to December 2011. In this estimation, we first divided the period into some sections with length of 512 data (21.3 days) and calculated frequency dependence of atmospheric effect for each section. Secondly we applied the theoretical equation on the one-dimensional groundwater migration model to the observed atmospheric effects, and estimated permeability and storage coefficient changes as the most adequate model parameters.

Estimated storage coefficient increased by 3 times just after the earthquake. Mukai and Otsuka (2012) estimated change of groundwater source pressure by using the model on groundwater migration from the source to the station. They reported that the groundwater source pressure decreased just after the earthquake and had not recovered for a few months. These results suggest that seismic motion induced outflow of mud accumulated in the cracks and excessive outflow of groundwater in the groundwater source and the surrounding crust.

Estimated permeability decreased by about 40% just after the earthquake. This result appears to disagree with the above conjecture that seismic motion induced the outflow of mud. This disagreement might be caused by inhomogeneous variation in permeability in the crust. It is considered that the permeability estimated in this study shows that near the station, because periodic atmospheric loading causes groundwater flow in a small scale. The mud outflow owing to seismic motion might have been concentrated near the station where groundwater discharge occurs, which in turn might have caused the decrease in permeability in that area.

Keywords: permeability change, groundwater migration, 2011 off the Pacific coast of Tohoku Earthquake

