S169-002 **Room: 301B** **Time: May 26 9:13-9:26**

Dynamics of a viscous fluid-filled crack

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To explain the observed properties of volcanic signals, various models including resonator models with various geometries and flow induced oscillations have been proposed. Among these, one of the standard models may be the fluid-filled crack model which is originally proposed by Aki et al. (1977) and extensively studied by the series of works by Chouet and his co-workers. In the model, dynamic interaction of fluid and elastic solid in a thin crack which is the most plausible geometry existing beneath volcanos is considered. Their studies including the studies on elastic wave radiation from the crack and its excitation mechanisms demonstrated that many of the observed characteristics of the volcanic signals can be explained well with the model. Furthermore, recent studies suggest the possibility to estimate the properties of fluid from the observed signals (e.g., Kumagai and Chouet, 2000). However, almost all the applications of the model so far assume the fluid inside the crack is inviscid, and the effect of the fluid viscosity on the oscillatory properties of the fluid-filled crack has not yet been examined enough. Recently, Yamamoto (2007, SSJ) extend his method to simulate the dynamics of the fluid-filled crack using the boundary integral method, and show the relationship between oscillatory properties and the fluid (magma) viscosity. Meanwhile, Ashour (2000) and Korneev (2008) analytically derive expressions of an infinite fluid layer lying between two semi-infinite elastic solids.

In this study, I compare these numerical and analytical solutions for the dynamics of viscous fluid-filled crack, and discuss effects of the fluid viscosity and the finiteness of the crack. For this comparison, I compute the dispersion relation and attenuation of the interface wave traveling fluid-elastic interface using the methods of Yamamoto (2007) and Korneev (2008) with various set of the fluid properties. The obtained dispersion relations for finite and infinite fluid-filled crack show significant difference for long wavelengths, while these two approaches each other for shot wavelengths just like the case of inviscid fluid as pointed out by Ferrazzini and Aki (1987). The attenuation Q values for finite and infinite fluid-filled crack also show differences which are indicative of the effect of shear stress due to the finiteness of the crack.

These results indicate that the fluid viscosity is an indispensable parameter which control the dynamics of the fluid-filled crack, and suggest the importance of careful treatment of the viscosity and the finiteness of the crack in the analysis of volcanic seismic signals.