A permeability evolution model for the 2014 eruption of Mt. Ontake inferred from tilt waveform analyses

*Yuta Maeda[1], Aitaro Kato[1,2], Toshiko Terakawa[1], Yoshiko Yamanaka[1], Shinichiro Horikawa[1], Kenjiro Matsuhiro[1], Takashi OKUDA[1]

1.Earthquake and Volcano Research Center, Graduate School of Environmental Studies, Nagoya University, 2.Earthquake Research Institute, The University of Tokyo

During 450 s before the onset of Mt. Ontake 2014 eruption, very long period (VLP) seismic events and a summit-uplift tilt change were observed. Our waveform inversion solution of the largest VLP event, that took place 25 s before the eruption onset, was an NNW-SSE striking tensile crack at a 600 m depth beneath the eruptive vent region; this result was interpreted as an opening and a closing of one of the preexisting seismic faults caused by ascent of water vapor (Maeda et al., 2015, EPS). Our waveform inversion of the tilt change pointed to a semi-vertical tensile crack at 1 km depth that inflated by 10^6 m^3. The tilt waveform is well explained by a linear function of time during the first 168 s, then switched to an exponential growth at a time constant of 84 s (Maeda et al., 2015 VSJ fall meeting). Interpretations of these results were kept unsolved at that time.

In this presentation, we show our latest model of the tilt change developed after the 2015 VSJ fall meeting. We assume that the inflation of the crack was caused by boiling of underground water at a constant depth (pressure: 20 MPa; depth: ~1 km).

The linear function of time is explained by boiling of underground water under a constant heat supply from depth. Using the volume change rate estimated from the waveform inversion, the heat supply rate is estimated to be 10^{10} J/s, consistent with the surface heat emission estimated after the 2014 eruption (Terada et al., 2014 VSJ fall meeting).

To realize the exponential function, a positive feedback process is needed such that a larger amount of water vapor in the crack leads to more rapid boiling of underground water. As long as a single large crack (10^6 m^3) filled with water vapor is considered, a slow growth lasting for up to 450 s is difficult to realize according to the force balance of Lister and Kerr (1991, JGR). We then regard the tilt source to be a region of many small subparallel cracks filled with water vapor, and model this system as a vertical permeable flow driven by the buoyancy of water vapor. The Darcy velocity equation suggests that the permeability is the only quantity that could significantly vary with time. We therefore consider the following positive feedback: the larger the water vapor in the source volume, the larger the porosity, permeability, and Darcy velocity, leading to faster water vapor migration upward from the boiling depth, which is compensated by increasingly rapid boiling of underground water. We quantified this idea and obtained an exponential growth of the water vapor volume under a proportional relation between the porosity and permeability. The observed time constant of 84 s is explained by a realistic permeability in this model.

In summary, the source process before the Mt. Ontake eruption is modeled by initial boiling of underground water under a constant heating, followed by exponential acceleration of the boiling rate caused by increased porosity and permeability, VLP events caused by ascent of the water vapor, and finally the eruption.

Keywords: Mt. Ontake, Phreatic eruption, Tilt

