Seismicity model of volcanic earthquakes for a quantitative assessment of volcanic activity

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The activity of volcanic earthquakes is one of the well-established indicators of volcanic activities and precursors to volcanic eruptions. An increasing seismicity is often followed by a volcanic eruption (e.g. Mt. Usu 2000, Mt. Ontake 2014 eruptions). The earthquakes are generated not only by the temporal change of stress field that is caused by magma intrusio6n and/or emplacement (e.g. Izu Oshima 1986, Miyake 2000 eruptions), but also by increasing pore pressure on pre-existing faults caused by upwelling volatiles emitted from magma (e.g. phreatic eruption at Hakone 2015). To utilize the seismicity for quantitative evaluations of volcanic activities, we need to discriminate the effect of pore pressure changes from stress changes. To realize a quantitative evaluation, we need a physical model of seismicity and apply it in real case, and asses the model by comparing the estimated and observed seismicity.

One of the models that can relate stress changes to seismicity is rate and state dependence friction (RSF) law proposed by Dieterich (1994). We have already presented that the seismicity at Izu-Oshima volcano well obey the RSF law under the temporally changing inflations and deflations of the volcanic edifice. To check its validity at other volcanoes, we analyze seismicity around the other volcanoes induced by the 2011 Tohoku great earthquake.

Just after the 2011 Tohoku great earthquake, induced seismicity were appeared around more than 20 volcanoes in Japan. The seismicity increased rapidly and then decreases gradually like the sequence of after-shocks that is well-known as Ohmori’s law. We analyzed the seismicity around 3 volcanoes: Nikkoshirane, Hakone and Yake-dake, because many hypocenters were determined by JMA around these volcanoes. At the same time, we estimate stress field around them using GEONET daily position data provided by GIA, Japan. We calculate Coulomb stress from the data and applied it to the RSF law to get an expected seismicity. Then, we compare the expected seismicity to observed one. In this analysis, we suppose that the focal mechanisms of the earthquake swarms are coincide with the expecting ones inferred from the estimated stress field. The great earthquake made a large strain over Japan Islands, and the large after-slip is lasting still now. The earthquake swarm zones are affected by stress rate change as well as stress step generated by the great earthquake. The RSF law can realize the feature and the estimated seismicity well match with the observed one. From this analysis, we can conclude that the RSF law is acceptable model for volcanic earthquake. The parameters of RSF concerning the relation between the stress rate and seismicity are also estimated for each volcano from the decay time of seismicity.

In this presentation, we demonstrate that RSF law is applicable to the seismicity of volcanic earthquakes generated by temporal variations of stress field. The pore pressure change at hypocenter region results in the difference between observed seismicity and estimated one based on RSF law. Therefore, in the case that seismicity is much larger than the estimated one, the effect of the pore pressure is dominant. It represents that of rising volatile affects the fault surface and it is precursor to the eruption. Here, the results for three volcanoes are presented now and further study will be carried out at present.

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