The Effect of Magma Solidification on the Dike Intrusion Process

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1. Introduction

The earthquake swarms related to volcanic activities often occur intermittently. They are composed of several bursts of activities, and also have several quiescence periods during an activity. Why does the seismicity related to volcanic activities have the above features? One of the possible scenarios may be the intermittent magma supply from deep origin zone. On the other hand, another mechanism in the dike intrusion process is proposed here to cause the intermittency of the seismicity. From the quantitative analysis of dike intrusion process for 1998 East off Izu Peninsula, I evaluate the effect of the solidification inside of the dike quantitatively, and demonstrate that intermittent seismicity is probably caused by the solidification effect.

2. How the solidification of magma controls its expansion

For the 1998 East off Izu Peninsula earthquake swarm activity, we estimated temporal variation of the dike area and its volume from the precise hypocentral distribution and dense geodetic data, simultaneously. And I inferred its dynamic process of magma intrusion quantitatively. In this analysis, we estimated the temporal variation of viscosity inside of the dike based on the theories of elasticity and viscose flow. The estimated viscosity increased 10**6 to 10**9 Pas during the two weeks of the activity. The value is much larger comparing with the intrinsic viscosity of the basaltic magma that is most possible in this area. However, it is the value that represents the gross dynamic magma flow of the dike intrusion process, and it is a reliable value inferred from the geophysical observations.

From the estimated pressure, flow rate distribution and viscosity for the dike of the activity, we calculate the energy loss of the viscose dissipation of magma flow inside of the dike, and found out that it can not be neglected comparing with the energy to make fracture at the tip of the dike. It means that the criterion for expanding dike should be evaluated not only from the fracture energy but also from the viscose dissipation.

In the case of the 1998 activity, we compared total energy loss (fracture energy and viscose dissipation) for expanding dike (the dike makes fracture continuously) and settled one (dike does not make fracture, but is thickened in the same area), based on the parameters in our previous study. I found out the following points. 1) Expanding dike is stable if the effect of the solidification inside of the dike is negligible. 2) In the case that the solidification effect cannot be neglected (i.e. the later period of the activity), the stable condition is changed from the settled dike and the expanding dike, alternatively. It shows that the intermittent dike expansion is realized under the solidification of the magma inside of the dike.

3. Intermittent seismicity of the swarm events at the East off Izu Pen.

The most of the earthquake swarms at the East off Izu Peninsula have intermittent seismicities. And they have following common features: 1) the upward migrations of earthquakes at the deep region, probably related to the magma raising process from the origin, occur only one day just after the first break of the activities, and they never occurred during the activity. 2) Each swarm event composed of many burst activities whose term is around a few hours. 3) The earthquakes in a burst are located closely and migrate linearly. 4) The directions of the migrations are often downward, rarely upward. 5) The location of the burst is closed to the hypocentral area that had already occurred before the burst.

The above features strongly supports that dike intrusion process mentioned previously causes an intermittent seismicity. From the observational facts at East off Izu Peninsula, the effect of the solidification is one of the key processes of the intermittency in the dike intrusion, and it probable induce the intermittent seismicity in the earthquake swarms.