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What controls a change of eruption types from a summit eruption to a dike intrusion (a flank eruption)

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It is well-known that dike intrusions sometimes cause caldera formations (for examples, eruptions at Miyakejima in 2000, at Izu-Oshima in 1700BP). The magma is carried outside from the reservoir, which is located beneath a summit, through the dike, and discharge of magma from the reservoir results the downfall of the summit area. It is one of the typical cases of caldera formations. The above mechanism is supported by the temporal change of mineral compositions and petrographical characters of systematically collected rocks from various stratigraphic levels in Izu-Oshima, Miyakejima and the other volcanoes. At Izu-Oshima volcano, the summit eruption is prevailing in the eruption history and the dike intrusion also sometimes happened. Especially, in the eruption of 1986, the type of eruption was changed during a series of one activity. In the first step, magma is discharged from the summit crater, and a dike intrusion with flank eruption started 6 days after the summit eruption began. The branch process from a summit eruption to a dike intrusion is very important for prediction of the activity, but it is still unsolved. In this presentation, I will discuss what controls a change of eruption types from a summit eruption to a dike intrusion (a flank eruption) referring to the 1986 Izu-Oshima eruption.

At the first step, we proposed a hypothesis that the type of eruption is governed by the instantaneous energy used for the processes in each eruption type. If the energy used for a summit eruption is less than that for dike intrusion, magma should be discharged from a summit crater. If it is not the case, magma should be intruded in a dike. This hypothesis seems enough reasonable to understand the branching process from summit eruptions and dike intrusions. We assumed that summit eruption is simplified to the model in which the viscose magma moved inside of a pipe from buoyancy neutral depth to the ground surface. And we also do that the dike intrusion is the model that the magma breaks the ambient rock and spread in vertical plate located around buoyancy neutral depth. Based on the models, we evaluate the energy needed for emplacement of magma for the both cases. Using several the other assumptions, we can deduce the relation between the energy loss rate (energy loss per unit time: E') and intrusion rate (magma volume supplied per unit time: V'). For the summit eruption, energy loss rate is mainly composed by the viscose dissipation and potential energy the carry the magma upward. Applying some reasonable parameters to the model, the E' is proportional to the square of the V'. On the other hand, the E' is proportional to the V' for the case of a dike intrusion. It leads that the summit eruption is dominant when the intrusion rate is smaller, and the dike intrusion is dominant when the intrusion rate is larger. The branch point is determined by geometry of the conduit in the volcanic system, magma viscosity, density gap between magma and ambient rock, and initial length of the dike.

In order check the validity of the model, we evaluate the intrusion rate for 1986 Izu-Oshima eruption. The summit eruption began on Nov. 15, 1986. The discharge rate from the summit crater is not larger than $10^7 m^3$/day. Then, the dike intrusion started on Nov. 21, and total that volume of intruded dike is estimated as $3x10^8 m^3$, and time used for the process is no more than a half day. Therefore, the intrusion rate becomes $6x10^8 m^3$/day. Finally, the intrusion rate for the summit eruption is much smaller than that for dike intrusion. The other summit eruptions at Izu-Oshima had low intrusion rates. Therefore, the model proposed here is supported by historical facts in Izu-Oshima.

In conclusion, we proposed that the type of eruption is largely controlled by intrusion rate. I will introduce the other cases in other volcanoes, and will deduce the validity of our model in this presentation.