One of the Typical Cases of the Dyke Intrusion Process - Earthquake Swarm Activities Occurring East off the Izu Peninsula

Yuichi Morita[1], Shigeru Nakao[2], Yoshinari Hayashi[3]

[1] E.R.I. Univ. of Tokyo, [2] ERI, Univ of Tokyo, [3] NIED

After 40 year of quiescence, earthquake swarms in the area of east off the Izu Peninsula have been active since June 1978. The earthquake swarms in this region were accompanied with crustal deformations and were assumed to relate to volcanic processes. Many researchers have tried to consider the mechanisms of the activities, and they successfully proposed dyke opening processes to interpret final amount of crust deformations. However, most of them explained the deformations by single dyke opening at shallower region, and no studies have ever tried to reveal the dynamic process of the dyke intrusion and migration of magma.

We relocated the hypocenters in 1998 swarms in high precision using waveforms based on their similarities and found out that hypocenters were mainly aligned on the vertical plane at the depth of 3 to 7km (We call this area main region hereafter), but small part of events occurred deeper area (deeper region hereafter). We also pointed out that the migration of hypocenters in the main region had characteristic pattern that suggest spreading-outward process of the intruded magma (Hayashi et al, 2001). From the analysis of the dense GPS array, the volumetric changes at two presumed dykes located at the deeper region and the main region were estimated by time dependent inversion method, and the they showed the upward migration of magma (Morita et al, 2001). In this paper, we will propose the dynamic process of magma intrusion process based on our previous studies, and will show that the 1998 activity consists of simple volcanic processes: Magma rising by buoyancy, its stagnant at buoyancy neutral point, and its spreading with elastic fracture by an inside excess pressure.

At the first stage of the 1998 swarm, hypocenters migrated upward from a depth of 9km intermittently with a velocity of 1km/hour. This upward migration repeated a few times during 24 hours. Simultaneously, the volume of the deep region increased about 3-5 mega cubic meters. These facts coincide with the buoyancy driven fluid magma model proposed by Dahm(2000). On the other hand, the magma melting zone were expected in this region at a depth of around 16km from high amplitude of reflected seismic waves. Considering his model and observational facts, we propose a model described below: The dyke was generated at a depth of around 16km, it grew gradually and its top reached at a depth of 9km just before the swarm activity began. When the length of the dyke reached at the critical value that causes the fracture of the host rock at the top of the dyke, the dyke rose abruptly and generated earthquakes at the deeper part of the swarm.

The rising fluid magma reached at the buoyancy neutral point located at a depth of around 6km, and was accumulated there. As internal pressure of the dyke increased, area of the dyke expands outward on the plane whose normal direction coincides with that of the ambient tectonic extension. Earthquakes occurred at the tip of the dyke, and migrated outward as the dyke expanded.

Using the volumetric change of the dyke estimated by GPS array and the dyke area by hypocenter distribution, an excess pressure inside of the dyke is estimated based on the circular crack model in the elastic medium. The temporal variation of the pressure shows that it increased during around one week, and kept constantly until the activity was concluded. It may show that the magma rising was stopped one week after the breakout of the activity, because the pressure inside of the dyke became enough high to balance with buoyancy force of the magma that were supplied from the reservoir at the depth of around 16km.

The swarm activity in the area of east off the Izu Peninsula is composed of the simple processes of magma movement described above. From the features of hypocenter distribution, this mechanism is repeated there, and occurs frequently at the place under the same tectonic setting.