Mechanism of the Ascent of Magma to an Eruption

Institute of Geology and Geoinformation
Akira TAKADA

Understanding the mechanism from the ascent of magma to an eruption is indispensable when developing theories based on various observational and surveyed data for predicting a volcano eruption (Figure 1). It is also important when making a program of numerical calculations. The keys to the mechanism are magma movements due to cracking and the vesiculation during the ascent of magma, both of which are dynamic physics and are difficult to analyze theoretically. Although typhoons can be monitored by using satellites, magma cannot be observed directly. There are technologies for observing magma such as geophysical surveys and drillings, equivalent to X-rays and endoscopes; however there are still limits on observational accuracy, depth, temperature conditions, and budget. Thus, we utilize the magic of innovation; we analyze the mechanism by reproducing the magma plumbing system in a laboratory.

Vesiculation During the Ascent of Magma

This is an approach that reproduces a magma plumbing system and artificial magma in a laboratory by generating high-temperature and high-pressure conditions equivalent to the earth’s interior. The size and amount of bubbles in pumice are indicators representing vesiculation process that controls explosivity of volcanic eruptions. In order to observe the process in our laboratory, we have developed a pressure vessel for gas pressure with decompression speed controller that can reproduce the ascending process of magma for observation1 (Figure 2 on the left). Magma, produced by re-melting of actually-erupted rocks at 100 MPa (1000 bar) and 900ºC, was enclosed in the vessel and underwent bubble formation. We measured the vesiculating texture of the artificial pumice formed in the experiment. The results showed that the vesiculating process was greatly affected by the ascending speed of magma2 (Figure 2 on the right).

Magma Movements due to Cracking

This is an approach that reproduces an artificial magma plumbing system in a laboratory by using an analog material and reducing the scale. Oil, designed to function as magma, is injected into transparent gelatin as a brittle elastic body that represents the earth, to form a crack. Then its movement is observed. In this system, the physical properties and stresses of gelatin as well as the physical properties and injection rate of oil can be controlled, depending on purpose. Though the theoretical analysis is limited to two dimensions, this experiment enables us to observe the basic shape of a three-dimensional fluid-filled crack and its movements under various stresses. As a result, new ideas such as mechanical

Figure 1 The purpose and positioning of analog experiments.

Reference
interaction between cracks have emerged\(^5\) (Figure 3). Recently we have reproduced the analog of a fissure eruption under stress.\(^4\) A model of a magma plumbing system due to cracking was created, and it was a common concept to consider that magma moves due to the formation of cracks even at the time of Unzen, Usu, and Miyake-jima eruptions. This concept is applied to explain the difference between a polygenetic volcano and a monogenetic volcano. This experiment is widely used in promotional activities for public and science education.\(^5\)

Figure 3 Examples of the analog experiment of cracks. 3 and 5 are the sides of the cracks. The rest are the front of the cracks. The arrow is the flow of the liquid. The black scale is 3 cm.

Scientific Drilling Reached the Magma Path of 1990-95 Eruption of Unzen Volcano

Institute of Geology and Geoinformation

Kozo UTO

Unzen Scientific Drilling Project (USDP) is a six-year term international project started in April 1999, co-sponsored by the Japanese Government (MEXT) and International Continental Scientific Drilling Program (ICDP). More than 20 institutes nationwide and abroad are participating the project, and AIST is serving as one of the principle research centers. The highlight of this project, to penetrate the magma path (conduit) of the Heisei eruption in the middle of the mountain, was successfully completed after reaching the conduit of the Heisei magma in July 2004.

At Unzen volcano, pyroclastic flows caused by the collapse of lava domes occurred frequently during the Heisei eruption between 1991 and 1995, causing serious damage and 44 casualties. The surveys on these eruptions produced much observational data on such as earthquakes, uplifts, and deformations of mountains, which provided us with a detailed model of the ascent and eruption process of magma.

USDP is aiming to understand the growth history, subsurface structure and magma ascending mechanism of Unzen Volcano not only by scientific drillings but also by related geological, geophysical and geochemical studies. In the project, we planned to drill a hole to reach the conduit of the Heisei eruption in order to clarify the ascending and degassing process of magma and understand the mechanism of an eruption. The drilling work began in February 2003 from the site on the northside slope of Unzen volcano at the altitude of 850 meters. Work was suspended several times, but we were able to reach the Heisei conduit by making some revisions after drilling approximately 1.3 kilometers horizontally and approximately 900 meters perpendicularly, the total drilling distance was 2000 meters.

There was a conduit zone near the area right under Mt. Fugen at around the sea level, where old and new conduits including the Heisei conduit were concentrated within approximately 500 meters. The temperature in the conduit zone is approximately 200°C, lower than expected before the drilling, which is assumed to have resulted from quick cooling due to hydrothermal activities.

Future extensive research is expected to provide the details of the ascending process of magma.

Photo Unzen Scientific Drilling site on the north-side slope of Unzen
Fifty meter-high rig were set up in an area of approximately 2000 m2, and a road was constructed in the national forest. (Pictures provided by Professor Setsuya Nakada, Univ. Tokyo)