Experimental approach to magma ascent during the Usu 2000 eruption, Japan

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The rate and manner of magma ascent are important in determining eruption mechanisms. One way to investigate magma ascent is to reproduce volcanic textures (e.g. crystal and vesicle) by hydrothermal experiments. Based on this point of view, we studied phreatomagmatic eruption in Usu volcano on 31 March 2000.

This experimental study followed results in Suzuki and Nakada (2002). Geophysical observations of this eruption revealed that the magma reached below West Nishiyama (2 km deep), the western foot of Usu volcano, after rising from depth beneath the summit. Based on the bubble size distribution (BSD) of ejecta, Suzuki and Nakada (2002) suggested that the magma accelerated after passing beneath West Nishiyama, and thus the whole ascent can be divided into two periods. So, this experimental study carried out two series of decompression experiments to match each period of magma ascent, in addition to isobaric experiments to determine pre-eruptive conditions of magma (determined to be PH2O=1250bar at 900C).

First series of decompression experiment was carried out to match ascent up to below West Nishiyama (500bar). Suzuki and Nakada (2001) showed that crystallization (due to decompression) is limited to period up to West Nishiyama through whole ascent, so overgrowth of phenocrysts and nucleated microlites were replicated to reveal actual ascent condition. Also, this series of decompression experiments aimed to reveal manner of ascent which was not clarified even by geophysical observation (as shown below). So, decompression was caused in two different manners. One was single step decompression (SSD), where samples were decompressed instantly to final pressure (500bar) and held for various times. The other was multiple step decompressions (MSD) where samples were decompressed to 500 bar in 100 bar increments, with the samples held at each lower pressure step for set amounts of time.

As a result, skeletal plagioclase microlites found in natural ejecta were observed only in SSD products.Additionally, plagioclase grown in SSD experiments compositionally matches those in natural ejecta, indicating that manner of magma ascent was single step like. Finally, volume and crystal size distribution of microlites in SSD products constrained that magma stayed at 500bar for 1 to 2days. This experimental result is consistent with the magma ascent inferred by migration of hypocenter over 4days before the eruption (e.g. review by Oshima and Ui,2003). Upward migration of hypocenter did not occur for 42 hours just before the eruption.

Second series of decompression experiments was carried out to reveal condition of magma ascent after its passing beneath West Nishiyama. The initial pressure was 500bar (equivalent to the pressure at below West Nishiayama). The final pressure was set to be 50bar (equivalent to the pressure at aquifer), because magma to have formed micropumice solidified in contact with aquifer.Suzuki and Nakada (2002) used micropumice to infer magma ascent using texture of ejecta. Also, vesicle texture was replicated to know ascent condition in this period,because Suzuki and Nakada (2001) showed that vesiculation and bubble nucleation were in progress even after passing below West Nishiyama. In addition, number of bubbles nucleated in response to decompression can be changed not only by decompression but also by number of crystals in melt.So, we needed to use SSD product (in first series of experiments) as starting material, so that starting material can have same amount of crystal as actual magma had at below West Nishiyama. Decompression rate ranged from 0.25 bar/s to 100 bar/s, and decompression was caused continuously (not step-like). Comparison of natural ejecta and experimental product showed that magma was decompressed at 50-100bar/s (which is equivalent to that in explosive eruption) in this period of magma ascent.