総　説

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結晶作用から見た噴火時のマグマ上昇
—最近の減圧実験による発展—

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Syneruptive magma ascent revealed by crystallization processes
—Recent progresses with decompression experiments—

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This paper reviews the principles and the methods used to investigate the ascent process of water-saturated magmas based on crystal texture and composition, which are especially relevant to recent progress made in decompression experiments. The primary cause of syneruptive crystallization is an increase in the liquidus temperature and resultant undercooling due to a decrease in dissolved H_2O in the melt. Analyses of ejecta crystal texture provide time-resolvable information.

Firstly, recent decompression experiments have improved knowledge regarding crystallization kinetics and have confirmed correlations made between ascent conditions, texture and crystal composition. The number density of groundmass microlite, crystal size distribution, and crystal form all reflect effective undercooling (ΔT_{eff}). This increases with an increased pressure drop (ΔP), and also with an increased decompression rate ($\Delta P/\Delta t$). If ΔP or $\Delta P/\Delta t$ match in an experiment series, we can compare the texture of the run products with respect to the other parameters. The experiments confirmed that the rates of crystal growth and nucleation show classical bell-shaped curves with ΔT_{eff}. Growth rate reaches a peak at a lesser ΔT_{eff} than for nucleation. Variation of ΔT_{eff} causes a shift in crystallization style.

Secondly, decompression experiments help in estimation of the rate and style of magma ascent during a specific eruption through replication of crystals found in ejecta. To best reproduce natural ascent conditions one needs to know a) the number of syneruptive ascent stages, each of which can be assigned an approximate constant speed, b) temperature and pressure of magma at the start and end of each ascent stage, c) how texture evolved during the syneruptive ascent. Ascent conditions are estimated for each stage based on the experimental reproduction of the texture and composition of the natural ejecta. Accuracy in the estimation of ascent rate is thus influenced by errors in quantitative analysis of natural ejecta and the correlation of the decompression rate with textural parameters. Such experimental approaches improve our interpretation of eruption mechanisms by enabling us to combine observation made upon the eruptive product and time-resolved geophysical data. The application of this approach to the 2000 A.D. eruption of Usu Volcano in Japan is presented. With further improvement in the experimental techniques both laboratory and observational studies on ejecta will play a more important role in linking various volcanology research fields.

Key words: rate and style of magma ascent, effective undercooling, nucleation and growth rates, quantification of groundmass microlite, experimental replication of crystals

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1. はじめに

噴火時のマグマ移動の速度と様式は，噴火機構と密接に関連し，その解明は噴火機構の理解につながる．マグマ移動の速度と様式は，火山噴出物の結晶・発泡組織に反映されており（例えばCashman, 2004; Cashman *et al.*, 2000; Jaupart, 1998; Rutherford and Gardner, 2000, 等のレビュー），物質科学的研究も1990年代以降，マグマの