Melt dehydration and bubble resorption in open-system heating experiments of rhyolitic glasses

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In order to investigate degassing mechanisms in open-system environments, we conducted a series of vesiculation experiments of rhyolitic melts in a permeable and isovolume stainless cylinder. Starting material is rhyolitic obsidian with 0.67 wt.% initial water content cored into ca. 4.8 mm in diameter and ca. 6.3 mm in height, which is ca. 10 % (in volume) smaller than the sample chamber. The samples were put in the stainless cylinder and externally heated at 1000 deg. C in a muffle furnace for 1 to 288 hours, then quenched in water. The run products typically show a texture consisting of two regions: bubbly central region (bubbly core, BC) and bubble-free margin (BFM). The BFM continuously surrounds BC at any run durations, showing that the permeable flow degassing through interconnected bubble network did not take place during the run. Thickness of BFM and porosity in BC increased and water content in BC decreased with increasing run duration. All these observations can be explained by the following degassing mechanisms (Yoshimura and Nakamura, 2005 JGL meeting). 1) By initial heating, the obsidian glass turns into supersaturated melt and expands by vesiculation, filling up the sample chamber. 2) The maximum pressure is achieved when the increasing pressure and decreasing water content satisfy solubility law. At this point melt water content and bubble distribution are almost uniform over the run charge. 3) Because the cylinder is open to water vapor, water content on the sample surface is kept on the solubility curve at atmospheric pressure. At this stage, only the thin surface is undersaturated with water. 4) Bubbles dissolve into the undersaturated surface glass and a bubble-free melt region (BFM) begins to be formed. 5) The BC is always saturated with water. Since the chamber volume is kept constant during the run, bubble resorption leads to local decompression at the surface. The decompression propagates across the whole sample immediately, causing bubble growth in BC. Consequently, water content in the melt decreases and porosity increases in BC. 6) The BC-BFM boundary moves inward by diffusion of water in the melt.

Numerical model for melt dehydration and bubble resorption

We have developed a numerical model that describes the observed degassing processes as a moving boundary problem. Governing equations are as follows: (1) diffusion equation of total water in BFM (2) equality between outward diffusive flux and water supply by bubble resorption on the BFM-BC boundary (3) conservation of bubble (and melt) volume (4) solubility law of water in the melt (5) equation of state for bubbles (6) mass balance equation of water in the melt and bubbles in BC region. For simplicity, we assume that viscosity of melt can be ignored and that diffusion distance around bubbles is small compared to the thickness of BFM, namely, bubbles dissolve immediately when surrounding melt gets undersaturated, and pressure is homogeneous in the run charges. Chemical equilibrium in the BC is also assumed. The calculation results in an infinite cylindrical coordinate system showed good agreement with experimental data within the uncertainty due to the infinite approximation.

Implications for eruption dynamics

Our results suggest that if some surfaces are formed in a vesiculated magma, dehydration and bubble resorption might occur on the surface. Gonnermann and Manga (2003) proposed a degassing model in which permeable flow through a fracture network was assumed. In such a degassing mode, water supply by bubble resorption and diffusive transport toward the fracture may occur. Resorption of isolated bubble which is expected to be left by the collapse only of interconnected bubbles may explain the genesis of nearly bubbleless silicic lavas.