

# Microstructure of Vesiculated Crystal Mush: Implications for Degassing From Cooling Magma Chambers

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Crystallization of hydrous magmas results in vapor saturation and bubble formation. To evaluate the degassing efficiency and excess pressure accumulation in cooling magma chambers, distribution and movement of the bubbles in crystal mush should be constrained. To address this issue, we have studied microstructure of vesiculated crystal mush experimentally. Granodiorite and pegmatite powders with various grain sizes were partially melted in water-saturated conditions by using piston-cylinder apparatus at 0.7GPa and 680-750deg.C for 6-192hour. Relict minerals with diameter of tens of micrometers were intentionally preserved to produce the vesiculated crystal mush. The run products were cut and observed with SEM. The 13 slabs were cut out of 7 run products and analyzed with X-ray CT at BL20B2 at SPring-8\* using 18-25 KeV monochromatized X-rays (Uesugi et al., 2001). The plucking-free, three-dimensional images were composed of accumulated 2D slices with linear attenuation coefficient distribution. Two types of detector system were used: their effective voxel sizes and imaging areas of the 2D sections are 3.14 and 5.83 micrometer-cube, and 4220 and 5830micrometer-square, respectively. The CT images were thresholded to binary images of pore (aqueous fluid) and matrix (melt + crystals).

The vesicularity of the run products became almost constant for 48hr, showing that the system reached apparent equilibrium, leaving the feldspars zoned compositionally. In the run products, we observed wide variety of wetting properties between minerals and the aqueous fluid. The (001) planes of biotite and muscovite have contact angle smaller than 90 deg., namely, they are wet with aq.-fluid. Magnetite, zircon and garnet are not wet with bubbles (i.e., contact angle is larger than 90 deg.), and quartz and feldspars scarcely show bubble adhesion (contact angle = ca.180 deg.), probably because the adhesion increases the total interfacial energy.

The aqueous fluid distributes preferentially in contact with biotite and muscovite due to their small contact angle. In the mush with crystallinity (crystal / crystal+melt) of ca.40-70 vol.%, aqueous fluid bubbles show flat or elongated shape with many indentations. In the mush with vesicularity of 2-10 vol.%, the maximum vertical continuity reaches up to ca.250 micrometer, which is several - 10 times longer than the typical crystal size. However, the connectivity, the ratio of the volume of the largest fluid cluster to the total volume of fluid clusters, commonly remains less than 20%. This means that the fluid bubbles are not interconnected but isolated, even though they are considerably elongated. Both vertical continuity and the connectivity increase with increasing vesicularity. The formation of three-dimensional fluid network and percolative degassing from mushy magma chamber upon cooling, therefore, require large vesicularity, probably at least ca. 30%. Permeability of crystal mush at the rind of magma chamber and solidifying plutonic body strongly depends on the initial conditions (water content and crystallinity), pressure (fluid density), and phase relations such as liquidus temperature and modal composition of wet minerals such as micas.

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