Magma mixing/mingling and viscous fingering: Analogue experiments and geometry of interfaces

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Magma mixing/mingling is common in the dynamics of volcanic eruptions and igneous activities, and its processes have been investigated by petrological, experimental and theoretical studies. Especially, the morphology of interfaces between the two magmas having different viscosities shows the various complex patterns due to the differences in physical and chemical conditions under the mixing/mingling process (e.g., Wada, 1995; Perugini et. al., 2005; Sato and Sato, 2009). Since the quantity that we can observe easily is the geometrical patterns of the interfaces, it is important to express this physical phenomenon in terms of the geometrical quantities of the interfaces.

The geometry of interfaces enables us to extract the useful information of the mixing/mingling process from the morphological analysis of the interfaces of rocks in nature (Perugini and Poli, 2005; Sato and Yamasaki, 2012). However, few attempts have been made to consider how the dynamic quantities such as the growth rate of the interfaces affect the geometry of the interfaces in the mixing/mingling process.

In this work, to simulate the replenishment of felsic magma chamber by continuous inputs of mafic magmas, we perform the analogue experiment in which we inject air or water into glycerin using the Hele-Shaw cell. In this case, the mixing/mingling process can be described by the DLA model (e.g., Nittmann et al., 1985), and the interfaces show the viscous fingering pattern due to the instability of the interfaces that also occur in the natural cases (e.g., Perugini and Poli, 2005). The following results were obtained.

1. We estimate the three fractal dimensions: the interfaces *Di*, the area of the high viscosity fluids *Dh* and that of the low viscosity fluids *Dl*. We find that the sum of *Dh* and *Di* is the conserved quantity, and the *Di* is proportional to *Dl*. This implies that the fractal dimension of the interfaces (easily observed quantities) enables us to estimate the fractal dimension of the area of the felsic or mafic magma (hardly observed quantities).

2. We find that the radius of curvature of the viscous fingerling depends on the growth rate of the interfaces. This is agreed with the solutions of the development equation of the curvature in the differential geometry (e.g., Nakamura and Wadati, 1993). This implies that we can estimate the growth rate of the interfaces by the radius of curvature of the mafic magmas.

3. In the case of colorless water and black-colored glycerin experiments, the interface of the two fluids shows light to dark gray color. We measure the fractal dimensions of the gray levels classed into several groups to estimate the degree of mixing. We find that the fractal dimensions correlate with the degree of mixing. This implies that we can estimate the degree of mixing from natural mixed rocks.