Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SVC50-01 Room:106 Time:May 20 11:00-11:15

An analytical formula for the longitudinal resonance frequencies of a fluid-filled crack

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The fluid-filled crack model (Chouet, 1986) has been most commonly used to interpret oscillation frequencies of volcanic earthquakes. Kumagai and Chouet (2000) systematically studied the complex frequencies of resonances of a crack filled with various kinds of fluids. Following their study, the complex frequencies of LP and VLP events at volcanoes have been linked to fluids and geometries of the cracks. So far, the crack model simulations have been performed using the finite-difference (Chouet, 1986) and boundary integral (Yamamoto and Kawakatsu, 2008) methods. These methods require computationally extensive procedures to estimate the complex frequencies of crack resonance modes. Establishing an easier way to calculate the frequencies of crack resonances would help to interpret the observed frequencies. In this study, we demonstrate that the longitudinal resonance frequencies of a fluid-filled crack can be described by an analytical formula.

We consider a 1D longitudinal oscillation of a fluid-filled crack. The fluid pressure averaged through the crack aperture, denoted as P, satisfies the following relation (Kumagai, 2009)

$(d^2/dt^2)[P(x,t)+(2b/d)u_d(x,t)]=a^2(d^2/dx^2)P(x,t)$, (1)

where a and b are the sound speed and bulk modulus of the fluid, d is the crack aperture, and u_d is the displacement on the crack surface. To derive the crack wave velocity from Eq. (1), a relation between P and u_d is required. Kumagai (2009) assumed a proportional relation between P and u_d to derive the velocity. We computed P and u_d using the FDM code of Chouet (1986), which indicated that P is proportional to u_d in time but not in space; rather the ratio u_d/P showed an ellipsoidal spatial distribution. Inserting this relation into Eq. (1) yielded a 1D variable-coefficient partial differential equation, which we semi-analytically solved to obtain a formula

$f_m=(m-1)a/[2L\{1+2e_m(b/G)(L/d)\}^{1/2}]$, (2)

where f_m is the frequency of an oscillation mode of a wavelength $2L/m$, m is an integer, G is the rigidity of the solid, L is the crack length, and e_m is a constant which depends on the oscillation mode. To check Eq. (2), we computed the oscillation frequencies for various L/d using the FDM code of Chouet (1986). The results were in good agreement with Eq. (2), suggesting that the equation adequately describes the frequency.

Eq. (2) relates the frequency f_m to the fluid properties a and b as well as the crack geometry parameters L and d. We used the equation to interpret a swarm of more than 40,000 LP events with an almost constant frequency of 0.7-0.9 Hz observed at Taal volcano, Philippines. Our waveform analyses of the events suggested a vapor-filled crack for which the fluid properties were kept constant. However, an inflow vapor volume variation causes a crack geometry change. Thus a frequency variation due to the geometry change may occur, whereas the observed frequencies were almost constant. Eq. (2) indicates that f_m is proportional to $(d/L^3)^{1/2}$ for large L/d, which suggests a constant oscillation frequency if d is proportional to L^3. We consider the crack geometry controlled by a balance between buoyancy and elastic forces. In this case, d is proportional to L^2. Assuming this relation and a vapor temperature of 600 K under a pressure of 5 MPa for the LP events at Taal, we estimated that the observed frequency of 0.7-0.9 Hz can be explained by a crack volume variation by a factor of 4. This suggests that a certain range of the inflow vapor volume variation is possible for the almost constant frequency.

The analytical formula obtained by this study may have a wide applicability to interpret oscillation frequencies of LP and VLP events at other volcanoes.

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Keywords: Fluid-filled crack model, LP events, Resonant frequency, Taal volcano

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SVC50-02 Room:106 Time:May 20 11:15-11:30

Characterization of middle-distance infrasound propagation and its utility for grasping volcanic activity

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Infrasound has become an important component of observation for volcanic activity. At present, infrasound observations for volcanoes are concentrated in two distinct scales: close to the volcano in less than 10 km, or in hundreds or thousands of kilometers away. Observations and studies of infrasound in the middle-distances are very few. We have a dense network of well-calibrated infrasound sensors around Kirishima volcano, about 40 km to NNE of Sakurajima volcano. Infrasound from Sakurajima is often observed clearly at the stations, especially at high altitudes. Strengths of the infrasound at these stations relative to a station, 3.5 km from the Showa crater of Sakurajima, show a seasonal variation and large scattering from one explosion to another. The variations are considered to be caused by changes in the atmospheric structures and possibly in the radiation patterns of infrasound. This study is motivated by this observation and aims to understand the middle-distance infrasound propagation. The middle-distance observation is particularly important for monitoring a volcano in an island, including Izu-Oshima and Stromboli. When it has large eruptions, the island may become inaccessible and stations in the island may be broken. Then, the possible nearest observation sites are in the neighboring lands, which are generally in tends of km.

We analyzed signals of Sakurajima explosions in November and December, 2012, when temporal stations were installed in various distances and directions from Sakurajima. Signals recorded at a station 43 km to SSW were quite different and much weaker than those at similar distances in NNE, the stations at Kirishima. Infrasound waveforms observed in the north and east directions were sometimes very similar regardless of distances, but sometimes clear phase splitting was recognized beyond 40 km. These features were qualitatively explained by ray-tracing calculations using atmospheric data (temperature, wind speed, and wind direction) measured at Kagoshima twice a day. Sound propagation is increased by wind toward the down-wind direction and inverse layers of effective sound speed are formed. These inverse layers were frequently formed in the direction of Kirishima but rarely to the south during the analyzed period. The inverse layers prevent upward propagation of infrasound and confine waves to increase the observed amplitudes. When the phase splitting was observed, the altitude of the main reflection was higher than usual and caused the clear splitting. When the inverse layers were not clear or lower than Kirishima peaks, the wave amplitudes were distinctly reduced behind the peaks. In this way, effects of atmospheric structure and topography, and their combination, are significant in the middle-distances. In order to obtain quantitative information of the source, we need atmospheric data with better resolutions in time and space.

Next, we focus on one explosion event. Infrasound from one event consists of an initial strong pulse and gradually decaying coda lasting 5-10 minutes, sometimes accompanying small secondary explosions. The atmospheric structure is assumed to be unchanged in this short time. In fact, the relative amplitudes of the initial pulse and the secondary ones were similar among the stations. Nevertheless, the coda amplitude relative to the initial pulse were different and decayed in various ways from one station to another, and tends to be larger beyond 15 km. Because there were also cases in which coda decayed almost in the same way at all the stations, the variation is not site effects or inevitable results of scattering. We consider it as an evidence indicating that infrasound generated by an explosion and that by a following jet have different radiation pattern and/or different source heights, that is the explosion is from the crater while the jet noise is from the turbulent ash plume (cf. Matoza et al., 2009).

Keywords: infrasound, volcano, eruption, atmospheric structure, explosion, jet

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SVC50-03 Room:106 Time:May 20 11:30-11:45

Glow luminance change at 1 second before an explosion of Sakurajima volcano

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We will present some movies that show the volcanic glow and its luminance change before an explosion of Sakurajima volcano, Japan. Since December 2011, we observed 11 events that show the abrupt glow luminance change at 1 second before an explosion. In this presentation, we will investigate the mechanism of the glow luminance change by comparing movies with infrasound, strain, and seismic data.

SVC50-04 Room:106 Time:May 20 11:45-12:00

Magma reservoir?vent system within Miyake-jima volcano revealed by GPS observations

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Analysis of GPS data during the degassing stage of volcanic activity at Miyake-jima volcano, Japan, in 2000 indicates a source of crustal deformation on the south side of the summit crater wall at a depth of 5.2 km. The rate of volume fluctuation was ?3.8 x 106 m3/month from September 2000 to January 2001 and ?0.8 x 105 m3/month from February to June 2001. As the volume is equivalent to the volume occupied by the volatile components dissolved in the magma, it is proposed that contraction of the magma reservoir reflects degassing of its volatile components. The observations indicate that the magma reservoir is connected to the summit crater by a magma-filled vent. Convection within the vent carries volatile-rich magma upward to the crater, where volcanic gas is released by degassing. The depleted magma is then carried into the magma reservoir, which contracts due to the loss of volume originally occupied by the volcanic gas.

Keywords: Valocanic eruption, Volcanic gas, magma convection in conduint

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SVC50-05 Room:106 Time:May 20 12:00-12:15

3-D numerical simulations of eruption clouds: Efficiency of turbulent mixing caused by environmental wind

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During an explosive volcanic eruption, volcanic gas and ash are ejected from the volcanic vent. Depending on terminal velocity, the particles (i.e., volcanic ash) are carried up within a convective plume, are advected by the surrounding wind field, and sediment on the ground. The fine particles are expected to have atmospheric residence, whereas the coarser particles form ash-fall deposit. Recently, particle-tracking models such as PUFF and advection-diffusion models such as TEPHRA2 and FALL3D tried to forecast both particle concentration in the atmosphere and particle loading at ground level. In these models, the source conditions (the plume height, and mass release level) should be given on the basis of a simplified model of bent-over plume (e.g., Bursik, GRL 2001) which contains an empirical constant (entrainment coefficient related to the wind-caused entrainment, b). In order to determine the value of the parameter (i.e., b) and the other source conditions for tephra dispersion, we are developing a 3-D numerical model which reproduces the dynamics of convective plume, the ash transport, and fallout deposits.

The model is designed to simulate the injection of a mixture of solid pyroclasts and volcanic gas from a circular vent above a flat surface in a stratified atmosphere, using a combination of a pseudo-gas model for fluid motion and a Lagrangian model for particle motion. During fluid dynamics calculations, we ignore the separation of solid pyroclasts from the eruption cloud, treating an eruption cloud as a single gas with a density calculated using a mixing ratio between ejected material and entrained air (Suzuki et al., JGR 2005). In order to calculate the location and movement of ash particles, we employ Lagrangian marker particles of various sizes and densities. The marker particles are ejected from the vent with the same velocity of the eruption cloud every 10 sec. The particles are accelerated or decelerated by the drag force on the spheres and fall to the ground with their terminal velocities.

We carried out a series of simulations of a small-scale eruption in various crosswind fields with the magma discharge rate of 2.5 x 10^6 kg/s, the initial temperature of 1000 K, and volatile content of 2.84 wt. %. The simulation results show that as the wind speed increases the mass of the entrained air increases and the plume height decreases. Through comparisons between the present results and the 1-D model predictions, we found that the preferable value of b (0.2-0.3) is substantially smaller than those suggested in previous works (0.3-1.0). The simulation results also indicate that (1) the main mass release level of particles is lower than the total height of plume, and that (2) it depends on the particle size. We confirmed that the present model correctly reproduces the plume height and ash fall area during the 2011 Shinmoe-dake eruptions (Suzuki and Koyaguchi, AGU 2012 Fall Meeting).

Keywords: eruption cloud, tephra dispersal, turbulent mixing, volcanic disaster prevention

SVC50-06 Room:106 Time:May 20 12:15-12:30

Relationship between Stratigraphic Variations of Grain Size Distribution in Fall Deposits and Initial Size Distribution

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In general, a stratigraphic variation in characteristics of grain size distributions of pyroclastic deposits may reflect the temporal behavior of the eruption intensity. However, quantitative methodology to link the stratigraphic variation and the temporal behavior of eruption intensity has not been established because of the complex coupling of several processes: eruption column dynamics, fallout process, sedimentation, erosion etc. In this study, we investigate only the effect of sorting process during settling on the stratigraphic variation of pyroclastic deposits.

In order to relate the variation of grain size distribution as a function of stratigraphic height to the sorting process during settling, we developed a theoretical argument from the view point of Lagrangian manner. If we assume that the terminal velocity of a particle is only a function of grain size and coagulation effect is negligible, an increasing rate of deposit layer equals the volume flux which is calculated from sedimentation rate, leading to an integrodifferential equation including the initial size distribution and the height in the deposit layer. If the initial distribution is given, the solution of the integrodifferential equation gives grain size distribution of deposits as function of height.

We carried out some simulations with our numerical model. In the simplest case that grains start to fall from a constant fallout height on an instantaneous time with no duration, grain size uniquely increases depending on stratigraphic height in deposits with no variance. Extending this simplest case to more realistic case with finite duration of falling, results show that the variation of grain size distribution takes non-zero value of variance. In these cases that fallout height and initial grain size distribution are constant with time, it is shown with the mathematical formalism that the values of Md vary from coarse to fine from the bottom to the top, although this grading behavior has been qualitatively predicted.

From comparison with the stratigraphic variation data of pyroclastic deposits of the 2011 Shinmoedake subplinian eruptions, which have the single coarsest peak of the Md value in a single eruption, we concluded that it is impossible to reconstruct this observed variations in the case of constant fallout height and initial size distribution with time. In order to successfully explain the observed grain size data, we need to give the temporal variation of fallout height or initial size distribution in future.

Keywords: grain size distribution, stratigraphic variation, pyroclastic deposit, eruption intensity

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Friction properties controlling deposit shape of pyroclastic flows: insights from eruptions of Soufriere Hills volcano

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Dense pyroclastic flows generated by the collapsing of lava domes are often encountered in effusive volcanic eruptions. Capturing the major characteristics of such flows is important to assess volcanic activities and hazards, but is a significant challenge because the mechanics of the grains and their interactions are incompletely understood. One approach has been to exploit the thinness of the flows relative to their length by employing a depth-averaged description in which the flow is assumed to have a constant bulk density. A key issue is the granular friction law that is introduced into depth-averaged models. Recent laboratory studies on dense granular flows suggest that rheology can be described by a friction coefficient. Variation of this coefficient with shear rate and pressure is captured through a dimensionless inertial number. Under the shallow water assumption how well this friction model works remains unclear when applied to pyroclastic flows.

Recent dome collapse events in Soufriere Hills volcano, Montserrat, provide good examples to study the dynamics of dense pyroclastic flows and to examine granular flow models, because of abundant geological and geophysical data. In this study, the July 2003 and May 2006 dome collapse events and resultant pyroclastic flow deposits are investigated. The most intense phase of the 2003 event produced the deposit 170 M m^3 in 2.6 hours, and the shape of proximal submarine deposit offshore Montserrat is characterized by semicylindrical, steep-sided lobes. The 2006 event produced 97.8 M m^3 in 35 min and the deposit is characterized by a more elongated shape in flow direction than the 2003 deposit and by channel and levee-like facies (Trofimovs et al., 2012, BV). Geophysical observation such as seismic and strain records also constrain the variation of discharge rates of pyroclastic flows during the events.

To investigate the factors controlling the shape of pyroclastic flow deposit, we used a 2D shallow water model with two types of Coulomb-type friction models. One had a constant friction coefficient, and another had a friction coefficient that depends upon the dimensionless inertial number of the motion. The models are applied to a simple system or the terrain of Soufriere Hills volcano. When the latter friction model was examined, the variation of deposit shape such as channel and levee-like facies was reproduced, depending on initial mass, discharge rate or slope angle. Also our numerical results suggest that the inertial number dependent friction model works better after the flow passing a slope break point where slope angle is equal to the friction angle at zero shear rate. Coupling effects of discharge rates, slope and granular friction properties may explain the different shapes of the pyroclastic flow deposits produced by dome collapse events in Soufriere Hills volcano.

Keywords: pyroclastic flows, deposit shape, friction, lava dome collapse, Soufriere Hills Volcano

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SVC50-08 Room:106 Time:May 20 14:15-14:30

Analysis of eruption sequences based on a model of magma plumbing system: Effects of variable magma temperatures

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How the magnitudes and time intervals of volcanic eruptions are determined is one of the basic problems for better understanding of eruption mechanism as well as eruption prediction. We intend to analyze this problem based on a simple model of magma plumbing system. Our main interest is to find physical factors that control eruption sequences. The analysis is based on a model of magma effusion that formulates the opening and closure of an exit conduit through viscous deformation of the ambient country rock responding to magma pressure (Ida, GRL, 23, 1457-1460, 1996). Using this mechanical model, we showed last year how much varieties of eruption sequences are generated under periodic supplies of magma flux, but calculated eruption sequences were not variable enough to compare with natural eruptions. So we here study the problem taking the effect of changing magma temperature into account.

The model used in this analysis consists of a magma chamber with variable pressure and an attached exit conduit with variable radius. Magma pressure in the chamber elastically responds to the supply and emission of magma compared with its capacity, and the exit conduit opens and closes through viscous deformation of the ambient country rock following pressure change. The magma flux that flows out in the exit conduit is determined as a continuous function of time by solving a set of simple ordinary differential equations but the flux is actually concentrated into some points of short time intervals so as to give effectively discrete episodic eruptions. We further consider the thermal effect in which heat is lost from the magma chamber by thermal conduction. The magma temperature is determined by the balance between conductive heat loss and mixing of supplied hot magma and influences the magma outflow process through the temperature dependent magma viscosity.

For a constant magma supply rate the calculated magma temperature converges on a certain value that balances cooling effect with magma supply so that the thermal process little affects manners of magma effusion. When the supply changes periodically the magma temperature follows the supply with a delay associated with thermal conduction and influences the effusion process. Time intervals between eruptions as well as erupted masses of individual eruptions change in various ways, fluctuating sometimes periodically and sometimes with their gross long-term variations. Magma temperature changes more moderately over the eruption sequences. Features of eruption sequences sensitively reflect the period of magma supply and the efficiency of thermal conduction.

The calculation result in smaller time scales shows detailed natures of magma supply during individual eruptions. The supply history in an eruption gives an almost symmetric curve before and after the peak. Namely, supplied magma flux increases to the peak in a certain time and decreases to the end in an almost same time. Within the same eruption sequences the duration of an eruption tends to be shorter as the erupted mass is greater. Magma temperature increases a little during an eruption but its change is small.

Because real eruptions occur in a quite variable way it is not easy to find common natures of eruptions empirically. In most volcanoes available data of eruption histories are too poor to draw some definite conclusions on statistical natures of eruptions. Our analysis may help to reduce such difficulties.

Keywords: volcanic eruption, eruption sequences, magma temperature, magma chamber, magma plumbing system, computer simulation

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Modeling of gas bubbles rise in low viscous magma and volcanic deformation

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Eruptions characterized by low viscous magma, such as Strombolian type eruptions, are considered to be generated by a sudden release of a large gas slug. Because ascending slug acts a deflation source, volcanic deformation due to gas slug rise shows deflation at the stations far from the vent (Kawaguchi et al., 2011, JPGU). However, tilt data observed at Stromboli volcano show inflations prior to each eruption at a station away about 1 km from the vent (Genco and Ripepe, 2010). This observation suggests that the slug flow model may not explain these observed data. In this study, we model the gas bubbles rise process in melt and examine the spatio-temporal changes of volcanic deformation due to gas bubbles rise.

We assume that gas bubbles which have a same radius concentrate at a certain depth in cylindrical conduit. According to Stokes' law, individual gas bubbles rise without interaction with surrounding gas bubbles. As gas bubbles rise, the pressure of surrounding melt decreases and gas bubbles expand. Magma head depth ascends by gas bubbles expansion. Using the mass conservation law of liquid melt, temporal changes of the depth and radius of gas bubbles and magma head depth are calculated. Magma pressure at shallow part of the conduit increases with the rise of magma head depth. The void ratio of magma where the gas bubbles exist increases with gas bubbles expansion. As a result, magma pressure at deeper part of the conduit slightly deceases. We examine the spatio-temporal changes of volcanic deformation due to the gas bubbles rise. We assume that many gas bubbles concentrate at the bottom of the conduit at the beginning, and an eruption occurs when the gas bubbles reach the magma. Because the gas bubble velocity is proportional to the square of gas bubble radius, the gas bubbles rise in melt at an accelerated rate. As a result, the magma head depth ascends at an accelerated rate in the conduit. We calculate volcanic deformation due to the gas bubbles rise, assuming an open conduit and elastic half-space. At a station at a same distance of the initial gas bubbles depth from the vent, displacement and tilt increase at an accelerated rate with magma head ascent. The amplitudes of deformation increase with increasing the initial gas bubbles radius or the number of gas bubbles. Because pressure decrease at deeper part of the conduit become smaller than that of slug flow model, volcanic deflation is not likely to appear at a station far from the vent. The tilt changes calculated by gas bubbles rise model fairly well explain with the observed tilt change prior to the eruption at Stromboli volcano which are reported in Genco and Ripepe, (2010). As a result, gas bubble rise model can explain the volcanic inflation at a station far from the vent.

Keywords: open conduit, gas bubble rise, volcanic deformation, Strombolian eruption

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SVC50-10 Room:106 Time:May 20 14:45-15:03

Perspective on textural study of volcanic products

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The textural and compositional characteristics of erupted products record the history of dynamics which magmas experienced in the conduit invisible. During this decade, the methodologies have been increasingly developed to quantitatively decode the records from the textural and compositional data. For instance, estimations of saturation depth, decompression rate during magma ascent and retention time at depth have been made possible on the basis of microlite compositions, bubble and microlite size distributions. As the results, together with data by the geophysical and geochemical observations, we have been able to draw a realistic view of magma migration from the source region to the surface. This development is a convincing consequence from the simultaneous progresses in three different areas; experimental studies reproducing textures and chemical compositions of erupted products, technology of observations and measurements, and theoretical studies to physico-chemically interpret the textural and compositional data. However, in spite of such progresses, we have not yet succeeded to exactly predict the motion of magma and to quantitatively reconstruct the temporal developments of past eruptions combining the geological information. Much less, we have a long and winding road to discover the rules related to eruption phenomena, such as key observational signals to indicate the mass and style of a future eruption. When we look at the circumstances in material sciences of volcanic products from the view point of this difficulty, we inevitably recognize the defects in current understandings on several fundamental problems, such as the physical origin of the variety in bubble and microlite size distributions and the chemical compositions of minerals crystallizing under disequilibrium conditions. In this talk, I present the current circumstances of CSD (Crystal Size Distribution) studies and propose a new methodology to inversely estimate changes of pressure and temperature as functions of time from CSD with applications to erupted products.

Keywords: textural study, volcanic products, CSD

SVC50-11 Room:106 Time:May 20 15:03-15:18

Magma mixing/mingling and viscous fingering: Analog model experiment 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 several experimental and theoretical studies (Eichelberger, 1980; Koyaguchi, 1985; Wada,1995). Especially, the morphology of interfaces between the magma have different viscosity shows the various complex patterns due to the difference in physical and chemical condition under the mixing/mingling process (De Rosa et. al., 2002; Perugini et. al., 2005; Sato and Sato, 2009). Since the quantity that we can observe easily now is the geometrical patterns of the interfaces, it is important to express this physical phenomenon in terms of the geometrical quantities of the interfaces. In this work, we call it as the geometry of 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. The purpose of this work is to clarify this point based on the analog model experiment and the differential geometry.

In this work, to simulate the replenishment of felsic magma chambers/pockets by continuous inputs of mafic magmas, we perform the analog model experiment in which we inject air 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 higher viscosity fluids Dh and that of the lower 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.

Keywords: magma mixing, viscous fingering, fractal dimension, Hele-Shaw cell, curvature, DLA

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Basaltic magmas at high pressures and the origin of the lithosphere-asthenosphere boundary

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Basaltic lavas rise buoyantly from the Earth's mantle to form the oceanic crust, and are an important source of terrestrial volcanism. The density and viscosity of basaltic magmas moderates igneous processes ranging from volcanic activity to fractionation, and is intimately linked to its atomic structure. Here we show that basaltic magmas undergo rapid densification with increasing pressure and exhibit a viscosity minimum near 4 GPa, correlated with an increase in coordination number for Si^{4+} and Al^{3+} cations. Magma mobility- the ratio of the melt-solid density contrast to the magma viscosity- exhibits a peak at 120-150 km depth that is up to an order of magnitude greater than values in the shallower lithosphere and deeper mantle. Thus the driving force for melt separation in Earth's asthenosphere diminishes as melts ascend, which could lead to excessive melt accumulation at depths of 80-100 km, providing a simple explanation for the occurrence of a seismically-observed Gutenberg discontinuity.

Keywords: basalt, magma, high pressure, density, viscosity, structure