SVC50-P01 Room:Poster Time:May 2 16:15-17:30

Tephra-Fall Predictions with the JMA Regional Atmospheric Transport Model for the 1914 Eruption at Sakurajima Volcano

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A hundred years ago, the largest eruption in 20th century Japan, *i.e*. the Sakurajima Taisho Eruption occurred on 12 January 1914. With this eruption, tephra-falls were observed large-area in Japan from Kyushu to Tohoku region (Hasegawa, 1914; Omori, 1916). For such large-scale eruptions, the Meteorological Research Institute (MRI) is going to do new research project of the tephra-fall predictions with the JMA Regional Atmospheric Transport Model (JMA-RATM) from this year. The research will lead to the improvement of the Volcanic Ash Fall Forecasts (VAFFs) of the Japan Meteorological Agency (JMA). For the purpose of investigating the predictability of the current JMA-RATM against large-scale eruptions, predictions of volcanic-ash dispersion and tephra-fall for the Sakurajima Taisho Eruption were carried out. The initial values which are the total volume (ash and pumice) of 6×10^8 m^3, the plume height of 3000-18000 m and the eruption duration of 38 hours are assumed based on Yamashina (1999), Yasui *et al*. (2006), Iguchi (2014) and so on. The input GPVs are the JMA Mesoscale Analysis after 28 March 2013. The forecast time by the JMA-RATM is 72 hours from starting time. Results of the calculations indicate that, under the assumption of the ash-density of 1 g/cm^3, the predictions of tephra-fall depths are over 1 m in Sakurajima Island for weak-wind weather condition, several 10 cm at Kagoshima City for easterly wind in summertime, and of the order of 0.1-1 mm at Osaka, Nagoya and Tokyo Metropolitan area for southwesterly wind field. In the atmosphere, dispersions of volcanic-ash up to Tohoku and Hokkaido region are also predicted at the same forecast time.

In the presentation, from the results of volcanic-ash dispersion and tephra-fall prediction, the predictability and problems of the current JMA-RATM for large-scale eruptions will be reported.

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Keywords: Atmospheric Transport Model, volcanic-ash dispersal, tephra fall, Volcanic Ash Fall Forecast, Sakurajima volcano, 1914

SVC50-P02 Room:Poster Time:May 2 16:15-17:30

Evaluation of wind data for tephra dispersion simulations

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Understanding how pyroclasts disperse from volcanic plumes is a fundamental problem of volcanology to reconstruct eruption conditions from tephra fallout deposits. Tephra dispersion is not only a scientifically interesting but also socially and economically important problem. For this reason, advection-diffusion models for tephra transportation have been developed with simplified assumptions (e.g. TEPHA2, PUFF, FALL3D). Simulation results of these advection-diffusion models are affected by the input wind data. For example, in a case study of the Kirishima 2011 eruption with PUFF, simulation results with finer temporal-spatial resolution wind data (Japan Meteorological Agency Mesoscale Model and ERA Interim) reproduced a more wavy shape of observed eastward extending plume (about 900 km from the vent) than that with coarser temporal-spatial resolution wind data (NCEP/NCAR Reanalysis).

Some wind data are available from Japan Meteorological Agency Mesoscale Model, ERA Interim of the European Center for Medium-Range Weather Forecasts and NCEP/NCAR Reanalysis of the National Oceanic and Atmospheric Administration of the United States. Between these wind data, there are differences in data assimilation methods, forecast models and temporal-spatial resolution. In addition, a finer temporal-spatial resolution wind data can be generated with using weather forecast models, such as the Weather Research and Forecasting (WRF) model. The WRF model is a fully compressible, Euler non-hydrostatic mesoscale forecast model developed by a multiagency collaboration. The WRF model is suitable for use in a broad spectrum of applications across scales ranging from meters to thousands of kilometers.

We are developing a system to generate wind data suitable for simulations of the advection-diffusion models. Such wind data should have a spatial resolution of several hundred meters near the vent, that of several kilometers far from the vent and vertically several tens of layers. In addition, it must be required to reproduce the interaction between ambient atmosphere and volcanic plumes. For this purpose, we are carrying out numerical calculations with the WRF model and the available wind data sets; we attempt to generate wind data with higher temporal-spatial resolution using data assimilation based on the observations from the regions of interest (e.g. volcano locations and downwind area) and other observations (e.g. the radar observations).

Keywords: Tephra dispersion simulation, Weather forecast model

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SVC50-P03 Room:Poster Time:May 2 16:15-17:30

Classification of infrasound waveforms and analysis of video images at volcano eruption

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Volcano infrasound is an increasingly useful technique for measuring and analyzing eruptive activity. In order to reveal causes of characteristics of infrasound waveform, we analyzed infrasound records and video images at eruptions that occurred at Yasur Volcano, Vanuatu during an hour at 15:00, 21th September, 2011. Yasur Volcano has three active vents in the summit crater. Infrasound waves are generated every 1-3 minutes at various eruptions with reddish magma, vapor rich gas and ash. Infrasonic waveforms are mostly symmetric with a sharp compressive onset, followed by a small rarefaction phase. In this study, we analyzed infrasound events whose maximum amplitude is more than 50 Pa at one station on the summit crater rim. We conducted cross correlation analysis to 29 wave records and classified them into 3 types; A (13 events), B (12 events) and C (4 events). Time window of the analysis was 5s from a second before the maximum peak time. In contrast to type C, cross correlation coefficient among wave forms of types A and B was very high ($>\sim$ 0.75). The compressive ratio and the ratio of positive and negative peak are different between type A and B. On the other hand, we analyzed selected video sequences of these eruptions. We read the RGB and brightness values on horizontal line above each vent until the end of the eruptions from 2s before the ejecta reaches the line. The maximum R and brightness value of type B events was twice as other type eruptions. This result may suggest that type B eruptions release relative much reddish magma and whitish gas compared to those of type A and C.

Keywords: infrasound, volcano eruption

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Numerical treatment of dry bed problem in the model of pyroclastic flows based on the 1-D shallow-water equations

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During explosive volcanic eruptions, a mixture of pyroclasts and volcanic gases is released from the vent. When the mixture loses its upward momentum before the density of the mixture becomes lower than the atmospheric density, the mixture forms a pyroclastic flow. Dynamics of pyroclastic flows can be approximated by that of an inviscid gravity current. The dynamics of inviscid gravity currents are controlled by an inertial-buoyancy balance on the front (e.g., Benjamin, 1968); we refer to this condition as "the front condition". The front condition, and hence, the dynamics of the inviscid gravity currents strongly depends on the density ratio of the current (ρ_c) to the ambient (ρ_a) (e.g., Ungarish, 2009). When $\rho_c/\rho_a \sim 1$, the current is characterized by a high front, whereas a front height does not develop when $\rho_c/\rho_a \gg 1$. In pyroclastic flows, because density ratio ρ_c/ρ_a varies spatially and temporally, the dynamics of pyroclastic flows becomes complicated; the basic features of pyroclastic flows, such as the run-out distance, have not been fully understood. The aim of our study is to develop a unified model of the inviscid gravity currents for various density ratio ρ_c/ρ_a.

In general, the dynamics of shallow inviscid gravity currents can be described by the shallow-water equations. There are two numerical models to solve the shallow-water equations: "shock front condition model" (SFC model) and "artificial bed-wetting model" (ABW model). SFC model is a model, in which the front condition is applied to the boundary condition (e.g., Ungarish, 2009). The boundary condition is given as a function of ρ_c/ρ_a. On the other hand, in ABW model, an artificial wet bed with the height of ϵh_0 is set on the dry bed in order to express the front condition, where h_0 is a characteristic height scale (e.g., Toro, 2001; Larrieu et al., 2006; Doyle et al., 2007). This model has the only parameter ϵ for the front condition. Although the front condition, and hence the appropriate value of ϵ must be a function of ρ_c/ρ_a, the relationship between ϵ and ρ_c/ρ_a has not been studied. In order to resolve these problems, we carried out parameter studies using the two models for solving a simple "one-dimensional (1-D) dam-break problem".

On the basis of systematic comparisons between the results of SFC model and ABW model, we found the relationship between the parameter ϵ and ρ_c/ρ_a : $\epsilon \sim 8.62 \cdot 10^{-2} \cdot (\rho_c/\rho_a)^{-1.87}$. We also found that the application of ABW model should be limited to $15 < \rho_c/\rho_a$. In the case of $1 < \rho_c/\rho_a < 15$, an unphysical shock wave propagates into the artificial bed so that the velocity and height of the current substantially deviate from the solution satisfying the correct front condition.

Keywords: pyroclastic flows, gravity currents, shallow-water equations, numerical simulation, volcanic disaster prevention

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SVC50-P05 Room:Poster Time:May 2 16:15-17:30

Moment tensor representation of elliptical volume sources

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A moment tensor inversion is a powerful tool to extract source information from seismic and geodetic observations. However, widely-used moment tensor representation for volumetric sources has been limited to a few basic geometries such as a sphere, a flat crack, and a cylinder. These sources give particular diagonal component ratios: (M_1:M_2:M_3)=(1:1:1) for a sphere, (1:1:3) for a crack, and (2:2:1) for a cylinder. When different component ratios are obtained from the inversion analysis, they are interpreted as combination of these simple geometries without considering internal pressure balance.

Although the moment tensor representation for elliptical sources was obtained 30 years ago (Davis, 1986), the solution has been rarely applied in volcanology. We consider two disadvantages of Davis (1986). The one is that the theories to relate the actual volume change to moment tensor have been proposed but not unified , which has caused some confusion. The accompanying paper (Ichihara et al., 2014, this meeting) presents a unified explanation based on the representation theorem and makes a clear link among volume change, geometry, and moment tensor. In this context, we have confirmed the applicability of Davis (1986) to the observed moment tensor.

The other disadvantage is that researchers have to search in the numerical table to find a geometry fitting to the observed moment tensor. Here we develop a facilitative tool that diagnoses the diagonal part of observed moment tensors to given the aspect ratios and the apparent compressibility. In addition, if the density and the compressibility of the internal material are given, the tool estimates mass change inside the source, which is an important parameter in volcanology.

This tool will provide a reference model satisfying pressure balance and help improving the volumetric source modeling beyond the conventional kinematic summation of simple sources.

Keywords: moment tensor, volumetric source, volcano seismology, magma

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SVC50-P06 Room:Poster Time:May 2 16:15-17:30

Volume source representations: a possible unified explanation based on the representation theorem

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The moment tensor inversion is a powerful tool to extract source information from seismic and geodetic observations. A moment tensor for earthquake faulting has been determined and its non-diagonal components give the seismic moment (rigidity x slip x fault area), which is one of essential source parameters of an earthquake. The sum of the diagonal components (the trace) of a moment tensor represents volumetric change at the source. A moment tensor determined for a volcanic source frequently has non-zero trace. However, it has been failed to uniquely relate the diagonal components to the actual volume change, which remains a critical issue in volcanic seismology (Kazahaya et al., 2011). For example, two different volume changes DV and dV have been proposed for the seismic moment of a spherical source geometry; DV comes from the moment tensor definition of a seismic fault having opening displacements whereas dV is obtained from the equivalence of resultant displacement fields due to the former moment tensor and an isotropically expanding sphere in an elastostatic equilibrium.

The difference between DV and dV has been discussed in the last decade. Muller (2001) considered an open crack of a spherical shell shape and showed that DV is the volume of the opening and dV is only the part opening outward. Aki and Richards (2002) and Richards and Kim (2005) adopted Eshelby's approach which considers virtual operations consisting of cutting, stress-free transformation, elastic straining, and welding, and concluded that the difference is due to whether the volumetric change occurs in an unconfined condition (DV) or in a confined condition (dV). Kumagai et al. (2013)reconsidered this problem and concluded that the displacement field due to a spherical source does not coincide with that due to a three-perpendicular-crack source though they both are represented by isotropic moment tensors. They also extended the insights into sources in a bimaterial medium. It is worth mentioning that the approaches of AR2002 and RK2005 give a conceptual explanation on how to adjust DV to the actual volume change dV for a sphere, but not for arbitrarily shapes. Here we address how to make such adjustments for general geometries on the basis of the representation theorem. Our imaginary operation below gives a unified explanation for the two different volumetric changes and newly proposes a method of estimating dV of the inversion results for arbitrary source geometries.

We start with the representation theorem that gives the displacement field by two terms (without a body force): a surface integration on the source region with convolution of the surface displacement and the gradient of the Green's function normal to the surface (1), and that with convolution of the surface traction and the Green's function (2). Only (1) has been considered for the seismic fault because (2) vanishes due to the balance of the traction at the contacting surfaces of a fault. On the other hand, (2) does not vanish in the case of a volumetric source, and therefore a quantitative adjustment is required to include the effect of (2) into (1). We here demonstrate that such an adjustment,is always realized by introducing an additional imaginary volumetric change, which works as 'displacement glut' in our representation of moment tensor. Our representation is found to be mathematically equivalent to the rather conceptual 'stress glut' representation proposed by Backus and Mulcahy (1976). We present a unified explanation for the existing various representations and propose a method to practically evaluate the moment tensor components from the boundary conditions of the volumetric source. The proposed representation will be useful in connecting dynamical models of volcanic processes and moment tensors.

Keywords: Moment tensor, Volumetric source, Representation theorem, Green's function, Volcano seismology, Explosion source

SVC50-P07 Room:Poster Time:May 2 16:15-17:30

X-ray CT observation of delayed fragmentation of vesicular magma analog

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A laboratory experiment was performed to understand the mechanism of fragmentation of vesicular magma, which is a trigger of explosive volcanic eruption. From the observation of Shinmoe-dake 2011 eruption, the viscosity of magma is not so high as its response is in solid manner. Thus, we aim to reveal the mechanism of brittle-like fragmentation of the magma which behaves in fluid manner.

Rapid decompression test was conducted using syrup containing oxygen bubbles as a magma analogue. The decompression facility consists of a high-pressure chamber in which the specimen can be placed, and an electromagnetic valve. The pore structure of interior of the specimen was observed by X-ray microscopic tomography. The X-ray tomographic microscopy was performed at the BL20B2 beamline of the Japan Synchrotron Radiation Research Institute (JASRI, Hyogo, Japan). Initial structure of the specimen was observed by three-dimensional tomographic imaging. A digital charge-coupled device (CCD) camera was used as the detector whose imaging area is about 2048 pixels (horizontal) by 644 pixels (height) with spatial resolution of 8 μm/pixel. We took 1800 projections over 180 degrees of rotation for tomographic imaging. High-speed radiography was performed during the decompression. The framing rate of radiography is 200 frames per second.

The specimen has a semi-spherical shape whose diameter was 20 mm. The initial pressure (p_0) was 1.5 MPa, the characteristic time of decompression (t_{dec}) was 50 ms, the viscosity of syrup was about 1×10^8 Pa s, the initial averaged void fraction ϕ_0 was about 10%. We tested nine samples whose pore structure was different to each other.

The fragmentation occurred with two samples in which a 10-mm-diameter bubble was contained, while the fragmentation did not occur using the seven samples whose pore structure was relatively uniform. The onset of fragmentation is 960 ms after the decompression was started. The onset was substantially delayed not only from the characteristic decompression time but also from the relaxation time of Maxwellian viscoelastic material (viscosity/rigidity = 150 ms). Referring to the radiographic images, we found that the fracture was initiated from a chain of small gas bubbles and a notch in the vicinity of the 10-mm (large) bubble. The internal crack may grow in ductile manner when the hoop stress around the large bubble increased due to decompression. At a certain instance the stress concentration and the brittleness at crack tip may exceed the critical level, which leads to brittle failure of the crack.

The experimental result indicates that brittle-like fragmentation can occur in the non-uniform vesicular magma even if the response of magma is in fluid manner.

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Model experiments on magma migration in a viscoelastic host rock : effect of viscosity

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Magma generated from partial melting ascends upwards by its buoyancy to the magma chamber, some of which erupt at the Earth's surface. Magma is considered to ascend in the form of diapir in the asthenosphere and transforms to dykes in the lithosphere (Rubin, 1995) . These two end member cases have been studied in detail, but the mechanism of magma ascent in the transitional regime is still poorly known. We have been studying the ascent mechanism in the transitional regime by model experiments using a viscoelastic agar (Sumita and Ota, 2011). Here we report the results of experiments which focus on the effect of fluid viscosity on the magma migration in a viscoelastic medium.

We conducted (1) rheology measurement of agar and (2) fluid injection experiments. We inject magma (CsCl solution to which a thickener is added) using a syringe from the top of a cylindrical acrylic tank (height of 250 and 500 mm). The fluid has a volume of 1ml, density difference with the agar of 0.108 g/ml, and is injected at a constant rate of 0.1 ml/s. We vary the agar concentration in the range of 0.04-0.5 wt% and the fluid viscosity in the range of 10ˆ-3 - 650 Pas. As we increase the agar concentration in this range, we find that the yield stress and the rigidity of the agar increases by 3 orders of magnitude. By shearing the sample under a constant stress (creep test) we find that the agar can be approximated by a Voigt model to which a spring is connected in series. The experiments are recorded using video cameras from two sides and from the bottom of the tank.

From the injection experiments, we find that as the agar rigidity (G) decreases, the crack shape transforms from 2D (blade-like) to 3D (having a bulged head). The critical rigidity (Gc) of the 2D-3D transformation is around Gc=10 Pa, and this value becomes smaller when a high viscosity fluid is injected. The value of Gc is consistent with the rigidity estimated from the balance between the elasticity and buoyancy at which the strain becomes 1. The crack consists of a bulged head and a thin sheet-like tail, and the head becomes thinner and smaller as the crack elongates. When a stiff agar is used as the host, or when a high viscosity fluid is injected, the crack propagation stops within a certain distance from the injection point. We find that this propagation distance becomes shorter as we increase the agar yield stress or the viscosity of the injected fluid, and this result can be associated with the transformation of the crack shape to 2D. We fit the time-distance data to a power-law relation, and find that the exponent varies from 1/3 to 1. An exponent of 1/3 corresponds to the scaling obtained for a 2D crack which thins uniformly as it elongates (Taisne et al, 2011). An exponent larger than 1/3 corresponds to the crack shape becoming more 3D. To conclude, we find that the magma viscosity not only slowers its migration velocity, but also controls the crack shape, its deceleration, and the propagation distance until it stops.

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Keywords: viscoelasticity, Magma ascent, rheology, crack

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SVC50-P09 Room:Poster Time:May 2 16:15-17:30

Bubble growth and resorption in magma: insights from dissolved water distributions in volcanic glass

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Volcanic eruptions are driven by the growth of gas bubbles in magma, which grow and shrink as volatile species exsolve from and dissolve back into the melt in response to changes in the local environment, particularly in pressure and temperature. This movement of volatiles, particularly water, is recorded in the glass around vesicles and recent studies have used this record to interpret natural samples. Here we investigate the processes that control bubble growth and resorption in magma, by measuring the distribution of dissolved water in experimentally-vesiculated volcanic glasses. Water concentration profiles obtained using SIMS-calibrated BSEM imaging and water speciation data obtained using FTIR spectroscopy, are interpreted in the context of the known pressure and temperature history of the samples.

Samples are found to have undergone partial bubble resorption during the quench to glass at the end of experiments, as a result of increasing water solubility with decreasing temperature. Analysis of the lengthscale and timing of the resulting water concentration profiles demonstrates that the majority of resorption occurs above the glass transition. This quench resorption is associated with a reduction in bubble volumes that creates characteristic textures, such as buckled melt films between adjacent vesicles and reoriented cracks around resorption halos. Highly disequilibrium water speciation ratios within resorption halos are found to be diagnostic of quench resorption and can preserve evidence of pre-quench bubble growth

Quench resorption can increase sample water concentrations and ratios of molecular to hydroxyl water species, and reduce bubble volumes and sample porosities. Studies based on these parameters must therefore consider the potential impact of quench resorption, which is expected to be greatest for samples with high water concentrations, slow quench and low initial sample porosities. Water speciation data offer a way to investigate these impacts in unconstrained natural samples and could provide a tool for forensic interrogation of their eruptive history.

Keywords: Bubble growth, Bubble resorption, Water speciation, FTIR, SIMS, Backscatter SEM

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SVC50-P10 Room:Poster Time:May 2 16:15-17:30

Formulation of the 1-D magmatic flow including vesiculation kinetics

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In most of existing fluid mechanical modeling and numerical calculations, the equilibrium vesiculation has been assumed according to the solubility relation. However, in order to understand the transient behaviors such as triggering of eruptions and shifts of eruption intensity, we need to examine the effect of vesiculation kinetics on the fluid mechanical behaviors in the conduit. In this study, we formulate the governing equations describing the one dimensional fluid mechanics taken into account the vesiculation kinetics, that is, the nucleation and growth of bubbles, assuming the homogeneous flow.

As we adapt the single fluid approximation, we build upon the advantage of the formulation in which the mass conservation equation about density is converted to the pressure equation through the equation of state. We make the similar procedure to obtain pressure equation while in our case the density is a function of not only pressure but also gas phase fraction. The gas phase fraction is calculated by the vesiculation kinetics. As a result we have four equations; 1) pressure equation (mass conservation), 2) equation of motion (momentum conservation), 3) constitutive equations describing vesiculation kinetics. These partial differential equations consisting of pressure, velocity and gas phase fraction, can be solved numerically.

In order to confirm the validity and fundamental characters of the formulation, we numerically solve the shock tube problem, using modified CIP method for advective terms. In the case that the kinetic effect is negligible due to relatively large initial gas fraction in the high pressure region, we obtain the similar solution to that of single fluid, consisting of shock wave in downstream and rarefaction fan in upstream. On the other hand, in the case that kinetics of vesiculation works effectively, we have different behaviors in the high pressure region in which rarefaction front, nucleation pressure front and nucleation event propagate with different velocities, while the behavior in the low pressure region is basically same as the case without the kinetic effect. Each propagation velocity depends on nucleation pressure (liquid/gas interfacial energy), bubble growth rate, initial gas faction in the high pressure region. The essential difference between two cases, the pressure of bubble formation becomes lower in the case with the kinetic effect than in the case without kinetic effect. If the kinetic effect is dominated, it is expected that the time to the vent from the bubble nucleation is relatively short. On the other hand, in the case that the vesiculation proceeds at equilibrium without the kinetic effect, it needs longer time to the vent, suggesting that the relative motion between gas and liquid, the bubble coalescence and degassing become dominate. Thus, this suggests that the kinetics of vesiculation may control the transition of eruption styles such as explosive and non-explosive eruptions.

Keywords: conduit flow, vesiculation kinetics, bubble nucleation, shock tube

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Pre-eruptive conditions of rhyolitic magma from Kawagodaira Volcano, Izu Peninsula

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Kawagodaira volcano is a rhyolotic monogenic volcano located in the Higashi-Izu monogenic volcano field at Izu Peninsular. The volcano erupted at ca. 3060˜3190. During the eruption, transition of eruption style was occurred from Plinian explosion to obsidian extrusion. Such transition offen occurred in silicic magma, and depend on pre-eruptive condition and outgassing during magma ascent in the vent. However, detailed mechanism is still under study. In this study, we collect volcanic products of 3 eruption style which are plinian eruption, pyroclastic flow, and lava flow. We conducted petrography and analysis of chemical compositions of glass and phenocryst minerals for these volvanic products, and we estimated the pre-eruptive condition of temperature and pressure and water content to examine mechanism in transition of eruption style.

All samples in this study include ca. 15 vol. % of phenocrysts chiefly composed of hornblende and plagioclase with minor amount of orthopyroxene and magnetite, and include ca. 85 vol. % of grandmas composed of glass. Hornblende phenocrysts show chemical zoning with obvious gap of Al content near rim. Al content is higher in core part (ca. 1.7 atoms per formula unit (apfu)) than rim part (ca. 1.2 apfu).

The estimated pressure using hornblende Al content geobarometer shows bimodal distribution with ca. 100 MPa and 200-300 MPa in each sample. The former and the latter correspond to the crystallization pressure of rim and core part of hornblende, respectively. The estimated temperature using plagioclase-hornblende geothermometer indicate constant in all samples, and average to be 1132K. The water content is estimated to be 5wt. % by using plagioclase-melt geohydrometer, and this value coincident with H2O solubility in rhyolitic melt at 100MPa.

The estimated P-T conditions show that magma decompressed from 200˜300MPa to 100MPa without change of magma temperature. This indicates that transition of eruption style occurred less than 100MPa. The coincidence between water content and the H2O solubility at 100MPa suggest that bubbles were already formed at this pressure. And, we think that magma stopped at 2.5˜3km depth until growth of hornblende and plagioclase phenocrysts finished. During cessation of magma ascent, bubbles rised to upper part of magma chamber, forming bubble zoning in magma chamber. This zoning might relate to transition of eruption style.

Keywords: Higashi-Izu monogenetic volcanic field, rhyolitic magma, eruption style, hornblende