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SVC54-01 Room:301B Time:May 20 10:45-11:00

On linkage between researches based on observation and of elementary processes

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Cooperative researches of different methods on various aspects of phenomena became more and more important in any field science. Such cooperation seems to be working and will work well in volcanology. The success might be due to the fact that a variety of phenomena occurs at a clear and concentrated target of research (volcanoes and eruption); therefore various methods and type of studies can be applied to the same phenomenon and it is sometimes also possible, in particular for geophysical monitoring, that the monitoring results are modeled based on a single elementary process. However, accumulation of such observational researches and researches on elementary processes can lead the comprehensive understanding of volcanoes or volcanic processes?

Mathematical modeling of volcanic phenomena has be well developed based on individual modeling of elementary processes and evaluation of their non-linear interaction, that reveals us general behavior of the system which could not be expected only from a linear summation of elementary processes (Koyaguchi, 1995; 2008). Such understanding of general behavior of a system will lead us to the comprehensive understanding of volcanoes. In order to realize such understanding, the general behavior of the system should be described in the way that can be tested by scientific clarification, and the description is the important part of the research. Bifurcation mechanism of silicic magma eruptions between explosive and non-explosive is one of the most significant achievement of the modern volcanology. This modeling became possible because of the intuitive description about the similarity of magmas that caused explosive and non-explosive eruptions based on observation and analyses of eruptive products. Such general images of volcanoes or volcanic phenomena extracted from results of monitoring and observations are necessary to bring the related elementary process and their governing rules to the discussion.

Each datum has its own cause and can be modeled. However, not all the causes and their related elementary processes are equally important to understand the general behavior of volcanoes. Further, it is likely that only part of important phenomena could be detected by observation as most magmatic processes occurred underground. It is also likely that different observational methods are measuring signals from different parts the system or caused by different processes. Therefore, a simple accumulation of interpretations of different observation results does not necessarily results in the general image of the volcano or volcanic processes. We need to interpret each result within the framework of general images to test both the data interpretation and the general images by extracting essential phenomena from the pile of data and models.

Geophysical methods measure phenomena commonly caused by a single physical process and their results are relatively well interpreted based on mathematical models and elementary processes. Results of geochemical monitoring are commonly appeared as integrated phenomena of various processes which are hard to be described by a simple mathematical model, resulting in schematic but ambiguous models. Although it is a great advantage of the geophysical monitoring that the results can be directly interpreted based on mathematical models, it is also possible that completeness of the model does not require an effort to construct a general images which may reduce the completeness of their own model. In contrast, schematic models proposed by geochemical data might be schematic but describing movement of substantial materials; therefore each mathematical or elementary process model can be adjoined into the schematic model to test consistency of the models. In order to realize such cross-evaluation of interpretations and models, it is important to provide general images of volcanoes or volcanic processes from different view points even if they are inaccurate.

Keywords: volcano monitoring, elementary process, modeling

SVC54-02 Room:301B Time:May 20 11:00-11:15

Application of Tensile Crack Model to the Ground Deformation at Sakurajima Volcano

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Sakurajima volcano is an active volcano located at southern edge of Aira caldera. The vertical ground deformation around the volcano associate with its activity after summit eruption activity started at 1955 has been mainly revealed by the results of precious leveling and GPS observation, and the spatial distribution of the ground deformation have been explained by 2 spherical pressure sources at the center of the Aira caldera (about 10km depth) and at beneath the summit crater (about 3km depth) have been assumed (e.g. Eto and Nakamura, 1986).

Hidayati et al. (2007) explained the VT earthquakes occurred during 2003-2004 at SW off the volcano by assuming tensile crack opened by intrusion of magma toward the volcano from the pressure source assumed to be located at the center of the Aira caldera, and also indicated that the depression around Sakurajima volcano during 1978-1980 can be explained with the model with spherical pressure source and additional tensile crack.

In this research, we intended to apply tensile crack to the ground deformation around Sakurajima volcano at expansive period which Hidayati et al. (2007) assumed by the seismic activity at expansive period.

For this purpose, GPS data observed by SVO (Sakurajima Volcano Observatory) (9 stations) and GEONET data (16 stations) during 2000-2004 were analyzed. In analysis, we used GIPSY OASIS II software. Grid search method was applied to decide the location etc. of pressure sources, and we decided the parameters by least-square method using the observed horizontal displacements and calculated ones reffered to GEONET station 0491.

At first, we presumed one spherical pressure source. Expanding pressure source was located at about 11 km depth at NE off the volcano. Its change rate of volume was $9.2*10^6 m^3$/year. The previous study estimated the change of volume during 1995-2007 $8.0*10^7 m^3$ (Iguchi et al., 2008), so average change rate of volume we obtained is a little large from the previous work.

The ground deformation during 2000-2004 at western stations around Sakurajima volcano seems to have a large horizontal displacement toward west direction. So we added vertical tensile crack from the pressure source toward summit crater. The location and change of volume of the spherical pressure source obtained at the first calculation was fixed. We also fixed the depth and dip of tensile crack 6-9km and 90 degrees respectively, referred to Hidayati et al. (2007), and length and opening of tensile crack were changed. Then, vertical tensile crack with 2.1km length opening about 146cm was located between the spherical pressure source and summit crater.

Although the fitting of large horizontal displacement toward west direction at the western stations were a little improved by adding the tensile crack, there were some stations which have a large difference between observed displacements and calculated ones. The difference may caused by the fragile modeling (we may need to change the parameters of the pressure source in applying tensile crack. And also the direction of tensile crack need to be investigated), or the proper ground deformation at some stations. Also, the stations locate at northern Osumi peninsula should be added to analysis.

Finally, we would like to thank the Geospatial Information Authority of Japan for providing the GEONET data.

Keywords: GPS, ground deformation, Sakurajima volcano, Aira caldera, tensile crack

SVC54-03 Room:301B Time:May 20 11:15-11:30

Hydrokinetic modeling of magma plumbing system beneath Showa crater of Sakurajima volcano, southwestern Japan

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We numerically simulated hydrokinetic magma supplies in the magma plumbing system beneath an active Showa crater of Sakurajima volcano to find dominant geophysical parameters in the magma accumulating process before an explosive eruption on April 9, 2009. Geodetic observations revealed that a periodic inflation and deflation event had lasted 30 hours before the eruption. Our model consists of shallower gas and deeper magma reservoirs connected by a cylindrical volcanic conduit that had been suggested by the past geophysical observations. A pressure difference between the two reservoirs forces the magma to move from the deeper up to the shallower reservoir. We assumed a constant rate of magma supply to the deeper reservoir as an input to the magma plumbing system and a viscous multiphase magma flow, i.e., crystalized materials, melt, and gas, in the volcanic conduit. The effects of the lateral escape of gas from the conduit, the vesiculation of volatiles in the magma, and the relative motion between gas and solid-liquid are taken into account in the simulation. Our simulations prove that the time-dependent inflation and deflation sequences of the two subsurface reservoirs could be reproduced and that the key parameters such as the radius of the conduit, the magma supply rate and the compressibility of the deep reservoir could be constrained through a least-square error criterion.

Keywords: hydrokinetic simulation, magma plumbing system, transient ground deformation, Sakurajima volcano

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SVC54-04 Room:301B Time:May 20 11:30-11:45

Model of eruption mass and style and of their temporal change controlled by fluctuation of degree of supersaturation

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The current big issue of volcanology is to clarify factors controlling the magnitude, style and the temporal behavior of eruption. I propose a model for predicting an eruption mass and style, and their temporal change on the basis of the fluctuation of degree of supersaturation in magma chamber.

We assume a square consisting of n x n (e.x., 512 x 512) parcels as a magma chamber with the vacant conduit connected to the surface, in which each parcel has a degree of supersaturation of volatile with a Gaussian probability density function (PDF) in space. We think that an eruption is triggered when the volume of parcels with the degree of supersaturation for vesiculation under the lithostatic pressure in magma chamber exceeds the volume equal to that of the vacant volcanic conduit. This triggering condition (triggering supersaturation) links the average supersaturaion and variance of PDF each other. So one of them is automatically determined when the other is given. Once an eruption is triggered, the decompression vesiculation is induced by unloading of magma. Parcels contributing to decompression vesiculation have a certain degree of supersaturation, which is less than the triggering supersaturation according to the saturation curve. Parcels satisfying the decompression vesiculation condition are identified as decompression vesiculation parcels. The connected regions of decompression vesiculation parcels are defined as 8 neighbor connection of decompression parcels. We calculate the size distribution of connected regions, and suvery the largest connected region which is regarded as unit size when magma ascents to the surface. We divide a square (magma chamber) of n x n into sub-squares with unit size of largest connected region. As each sub-square has a different fraction (¥phi) of decompression vesiculation parcels, we have a distribution function of decompression vesiculation fraction for the whole magma chamber. A decompression vesiculation fraction ¥phi corresponds to a potential enthalpy to drive a sub-square of magma to the surface. A sub-square with higher ¥phi generates larger volume of gas phase by decompression at the triggering of eruption, and has a potential to ascend with higher velocity. Thus each sub-square has different potential, according to fraction of decompression vesiculation parcels. We define two thresholds of ¥phi. One is explosive threshold ¥phi_1. A sub-square with ¥phi (> ¥phi_1) can ascend to the surface explosively with high velocity reaching 10 m/s or higher at the surface. The other is effusive threshold ¥phi_2. A sub-square with ¥phi (¥phi_1 > ¥phi > ¥phi_2) ascends up to the surface with mild or very slow ascent velocity less than 10 m/s at the surface. A parcel with ¥phi (< ¥phi_1) cannot ascend up to the surface and remained in magma chamber. In this model, we can define explosive mass and effusive mass and the temporal change of eruption intensity depending on ¥phi of each sub-square. We carried out a Monte Carlo simulation on the basis of the above-mentioned idea. As a result, if PDF of the degree of supersaturation has higher average or the magma chamber is relatively homogeneous, then the eruption is almost explosive and most extent of magma is evacuated, like a caldera-forming eruption. Decreasing the average supersaturation and increasing the variance of PDF, the eruption shift to an explosive eruption followed by an effusive eruption and to an eruption which only produce an effusive flow of magma such as lava flow. This transition of eruption styles from explosive to effusive and the relation to the erupted mass can account for commonly recognized transition between eruption styles in nature.

Keywords: decompression vesiculation, erupted mass, eruption style, temporal change of eruption, degree of supersaturation

SVC54-05 Room:301B Time:May 20 11:45-12:00

An empirical scaling of shear-induced outgassing: Intermittent magma ascent causes effective outgassing

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Outgassing, which changes the distribution of volcanic gases in magmas, is one of the most important processes to determine the eruption styles. Shear deformation of ascending bubbly magmas at the vicinity of the volcanic conduit wall has been considered as an efficient mechanism of outgassing. On the other hand, seismological observations of volcanic eruptions reveal the long-period (LP) earthquakes suggesting that there exists a large void space in the conduit. However both, the quantitative features of shear-induced outgassing and a mechanism to make a large void space, has still remain unknown.

Here I perform a series of model experiments simulating the shear deformation of bubbly magma ascending in a volcanic conduit. Syrup foam including CO_2 gas as an analogue of bubbly magma is deformed by using a timing belt. When the imposed shear strain is large enough, the height of the foam decreases indicating that outgassing occurs. Experiments also show that shear localization of syrup foam causes outgassing by making large bubbles or a crack-like void space, likely a LP earthquake source. Measured CO_2 concentration above the foam increases as an evidence that the gas is came from the inside bubbles. When there is an impermeable layer at the top of the foam, the gas accumulates beneath that layer.

There is a critical strain, gamma, above which outgassing occurs depending on the Capillary number, Ca, gamma $>$ 1 for Ca $<$ 1 and gamma $>$ Ca^{-1} for Ca $<$ 1. The thickening rate of the region in which outgassing occurs is described as a function of $gamma^{-0.54}$ $Ca^{1.2}$. Outgassing occurs efficiently at the very beginning of the deformation, suggesting that intermittent magma ascent causes effective outgassing such that the eruption style becomes effusive. This hypothesis is consistent with the fact that cyclic activity has been observed during effusive dome eruptions.

Keywords: outgassing, shear deformation, magma, bubble, Capillary number

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SVC54-06 Room:301B Time:May 20 12:00-12:15

An experimental study on the mechanism of fracture healing in a rhyolitic glass using a spring pressure device

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Introduction

I have carried out a series of fracture healing experiments on a rhyolitic glass at 920 degC and 5-100 bars in order to determine the fracture healing time in a shallow silicic magma. Two cylindrical obsidian cores were inserted in a magnesia container, juxtaposed on the base flats and pressurised by a newly developed spring pressure device. The base flats of the obsidian cores are nominally flat, but have fine-scale irregularity of ˜10ˆ-6 m. The pressurised sample was then heated in a furnace for 3 or 6 hours. The fracture healing time was determined by using the water-diffusion profile method (Yoshimura and Nakamura, 2010 JGR).

Results

The contact interface became coherent and disappeared in all experiments. Two types of pressure dependence were observed in the fracture healing time. When the pressure is greater than 30 bars, the healing time decreased monotonically with increasing pressure, from 50 to 4 minutes at 30 to 100 bars. When the pressure is smaller than 30 bars, on the other hand, no clear pressure dependence was observed. The healing time was 42 minutes at 10 bars.

Discussion

The fracture healing requires the viscous flow of the glass driven by the load pressure and capillarity. The difference in the pressure dependence may reflect the switching of the driving force. When the load pressure is greater than the capillary pressure, the load is the dominant driving force and thus significant pressure dependence is expected. When the load pressure is lower than the capillary pressure, on the other hand, the capillary pressure is the dominant driving force. In this case no load-pressure dependence is expected. Because the scale of the irregularity is ˜10ˆ-6 m and the surface tension is ˜10ˆ-1 N/m, the capillary pressure is ˜10 bars. Thus the switching may have occurred at about 30 bars.

Keywords: fracture healing, magma, rhyolitic glass

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SVC54-07 Room:301B Time:May 20 13:45-14:00

Potential Ability of Weather Radar for Volcanic Ash Detection

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Operational weather radar data of 27 big eruptions from Shinmoedake volcano in the Kirishima range in Kyushu, Japan in the period from January to March 2011 are analyzed to examine possibility of radar for quantitative volcanic ash estimation. The radars used in the analysis are C-band radars located at Kunimiyama and Shakadake, which are operated by the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT). The eruption time period, maximum and accumulated reflectivity, and differential reflectivity were collected for each eruption. It is concluded from the radar data analysis that operational weather radar has potential ability to quantitative detection of volcanic ash amount. An empirical relationship between the reflectivity and ash amount is proposed based on comparisons of radar data with ground ash distribution measured after the eruption on 26-27 January. Meanwhile the radar could not detect eruptions in such a case where the ash particle size is too small to be detected by the radar: the ash reflectivity is lower than the minimum detectable signal of the radar receiver. Naturally, it is impossible to detect an eruption when its height is below the radar beam height. It is also hard to detect eruptions under rain conditions when erupted ash particles are contaminated with precipitation particles. Differential reflectivity which is one of polarimetric radar parameters fluctuates over the crater in space and time while it shows significant distributions over downwind regions from the crater which suggests sorting of ash particles.

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SVC54-08 Room:301B Time:May 20 14:00-14:15

Feasibility study of immediate eruption scale estimation by using image analysis

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In order to reduce volcanic disaster, it is necessary to detect eruptions, and it is important to monitor and/or forecast eruption style, eruption scale and volcanic ejecta in real time.

Eruption series of the 2011 Shinmoedake was the volcanic activity with huge quantity of ejecta, including sub-plinian eruption. By using various data observed in this eruption, we made a start on researching feasibility of estimating the eruption scale.

We investigate the eruptive velocity of volcanic plume by applying particle image velocimetry (Takimoto et al., 2011) to video images of the 2011 Shinmoedake eruption taken by monitoring camera of JMA. The eruption on March 13 is analyzed by reason that the analysis condition is good because of the calm wind. By the PIV analysis, the kinetic energy of ejecta of eruption was estimated for 30 minutes when the eruption continued. The time variation of the kinetic energy is highly correlate with the time variation of the squared amplitude of the infrasonic signal of the eruption.

The apparent total amount of ejecta evaluated by the PIV analysis is 70 million cubic meters. This apparent total amount includes the amount of volcanic gas and entrained air besides ejecta. By the field survey (ERI, 2011), the total amount of the ashfall was estimated to 1 million tons. This is equivalent to 0.5 - 1 million cubic meters. In other words, the apparent total amount of ejecta calculated by the PIV analysis is equivalent to 700 - 1400 times the total amount of ashfall surveyed at this eruption case.

The time variation of the kinetic energy is highly correlate with the time variation of the squared amplitude of the infrasonic signal of the eruption. Based on the above results, if the relationships between the kinetic energy and infrasonic signal would be able to determined, we can monitor eruptive rate of ejecta by infrasound monitoring.

Keywords: eruption scale, Shinmoedake, PIV analysis, infrasound

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SVC54-09 Room:301B Time:May 20 14:15-14:30

Large-eddy simulation of eruption column based on multi-fluid approximation - Effects of turbulent model on development

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In the transport of volcanic ash in an explosive eruption, the turbulence is one of the important elements which determine the eruption styles (for example, an eruption column and a pyroclastic flow). The conventional steady one-dimensional eruption column models assume that the effect of turbulent mixing is represented as a constant by a theoretical formula, although it is indicated that the assumption is insufficient in the evaluation of an eruption column near the vent and the estimation of column collapse conditions. In recent years, unsteady three-dimensional eruption column models, which represent the turbulent mixing more directly, have been developed (for example, Neri et al. 2007, Suzuki and Koyaguchi 2010). However, the turbulent modeling of the transports of gas and pyroclastic materials are left unclarified. In this research, the unsteady three-dimensional simulation code of an eruption column based on the multi-fluid approximation is newly built. The effects of the turbulent model are discussed through the comparisons between the simulation results using two kinds of SGS models (sub-models) and the result by the steady one-dimensional model (Woods 1988).

In this code, the model concept of Neri et al. (2007) is adopted, which has advantages in the applicability to various eruption styles and to the transport of the pyroclastic materials of various sizes. The open-source-code FrontFlow/red (Ver.3.0) is used, and the large-eddy simulation (LES) technique based on a sub-grid scale (SGS) model is adopted as expression of turbulence. The gas component and pyroclastic materials of various diameters are classified into two or more phases. The basic equations are the mass, momentum, and energy conservation equations to each phase. The SGS model is a part of the sub-model of the stress term and the diffusion term in the basic equations. As the SGS models of the gas phase, the Smagorinsky model which is generally widely used and the Yuu model which considers the effect of the SGS drag (Yuu et al. 2001) are used, and as the SGS model of the particle phases, the proposal equation of Hinze (1975) considering the relation between the relaxation time of particles and the temporal duration of vortex is used. For the spatial discretization, the third-order TVD scheme is used for the advection terms of the equations of particle phases, and the second-order central difference method for the others. For the time integration, the fractional step method which combined the Euler implicit method and the third-order Adams-Moulton method is applied.

Firstly, the validity of this simulation code was partially estimated in the comparison with the existing experimental data in the simple systems (a single-phase buoyant plume, a gas-particle two-phase jet). As a result, it was confirmed that (1) the simulation values satisfy the similarity law of a buoyant plume, and correspond well with experimental values of the single-phase flow, (2) to the varieties of velocity and turbulent intensities resulting from the velocity difference between the gas phase and the particle phases, the simulation also corresponds well with experiments, (3) and the effects of the SGS model are small in the small-scale laboratory experiment system. Secondly, the simulation results compared with the result of the steady one-dimensional model for an eruption column in a Plinian eruption. As a result, the one-dimensional model and this simulation corresponded well with each other in the style variation of an eruption column according to the velocity at the vent. Moreover, it was suggested that the SGS model considerably affects to simulation results in the real-scale eruption column simulation, since the properties such as the column height varied according to the selection of SGS models.

Keywords: large-eddy simulation, multi-fluid approximation, eruption column, turbulent model