

# Japan Geoscience Union Meeting 2011

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SVC050-01

Room:302

Time:May 23 08:30-08:45

## Outline and Eruption Scenario of the 2011 Eruption of Kirishima Volcano

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<sup>1</sup>Earth. Res. Inst., University of Tokyo

Subplinina and vulcanian explosions were repeated with a lava dome growth in the eruption of Kirishima Volcano which began since January 2011. Observation researches on this eruption was carried out by Joint Observation Team (led by Yoichi Morita). Phreatic explosions had been repeated at Shinmoedake since August 2008 and inflation had been observed by the GPS network for one year before the eruption. Products of the phreatomagmatic explosion on 19 January 2011 contained ~10 % of juvenile pumice. An explosive phase began on 26 January; subplinian explosions were repeated during the first three days, depositing ~10 million m<sup>3</sup> (DRE) of tephra. On 28 January, a small lava dome appeared on the crater floor nearby the vent of 200 m across for the subplinian explosions. It continued its growth up to ~600 m across (~10 million m<sup>3</sup>) only for 3 days. The growing lava covered the explosion vent completely. The growth was confirmed the next day. Multiple vulcanian explosions occurred on 1 and 2 February, destroying a part of the dome.

The volume of inflation of volcano before the eruption was estimated ~20 million m<sup>3</sup>. It is roughly equal to that of magma erupted during 26-31 January. Deflation was recorded by sub-plinian explosions and growth of lava dome during 26-31 January.

At the night of 31 January, >1,000 people who live along the possible course of pyroclastic flows were ordered evacuation due to a possibility of a plinian explosion. Pumice of this eruption ranges from 57 to 62 % in SiO<sub>2</sub> showing mingling of two magmas with different colors. The progress and the magma chemistry of this eruption is similar to those in the early stage of the 1716-17 eruption at this volcano, which lasted for one year and half including 3-months explosive stage characterized by three pyroclastic flow-generating plinian explosions.

One of the outputs of the national research project for Earthquake and Volcanic Eruption Prediction is preparing the eruption scenario and its testing for on-going eruption. This time eruption is giving us a good chance to test the scenario.

Keywords: Kirishima Volcano, Shinmoedake, magmatic eruption, lava dome, subplinina eruption, volcano eruption

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SVC050-02

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## Eruption of Sinmoedake volcano, Kirishimayama, 2011 (Outline)

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<sup>1</sup>JMA

Sinmoedake volcano, Kirishimayama, at which small phreatic eruptions had occurred since 2008, started eruptive activity on 19 January 2011 and is active still now.

The eruption on 19 January was small magmatophreatic eruption and the continuous eruption since 26 January is magmatic eruption, in which magma reached the summit crater. Lava lake gradually grew up and Vulcanian explosive activity started since 27 January. Window glasses were broken by the strong explosion on 1 February, ballistic bombs reached 3.2 km distant from the crater. SO<sub>2</sub> flux is more than 10,000 ton/day.

From the tilt observation, deflation of a magma chamber has been observed. The deflation rate corresponds with the eruptive activity and lava lake growth.

In this presentation, I will introduce the general view of the eruptive activity with the observational data mainly by the Japan Meteorological Agency.

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SVC050-03

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## Outline of the observation and data analyses of 2011 Kirishima-Shinmoe-dake eruption

Motoo Ukawa<sup>1\*</sup>

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Crustal Deformation; NIED has started the Kiban volcano monitoring network at 8 volcanoes in 2009 and, for the monitoring of Kirishima volcano, KRMV and KRHV stations were installed at about 7 kms to the northwest and northeast of Shinmoe-dake crater, respectively. This network successfully detected the abnormal signal associated with the initiation of eruptive activity at 07:31, January 26th. Then, from the first remarkable eruption on 14:49, tilting change indicated the contraction of volcanic body, which continued till around January 31st at almost constant rate. This deformation source can be modeled by a Mogi source, located at about 7 km to the northwest of the Shinmode-dake, 9.8km depth, whose of shrinkage is  $13.2 \times 10^6 \text{ m}^3$ . In addition, SAR analysis clearly revealed the growth of the lava dome in the summit crater from January 27 to February 1st, with the rate about  $3 \sim 5 \times 10^6 \text{ m}^3/\text{day}$ .

- Seismic activity; Kiban volcano monitoring network and Hi-net recorded seismic activities during this eruption. In particular, we observed volcanic tremor (accompanied by the eruption, Harmonic, etc.) and low-frequency earthquakes, but few volcanic earthquakes (VT) were recorded by February 3rd. F-net also recorded seismic activity at explosive eruptions.

Keywords: Kirishima, Shinmoedake, Eruption

SVC050-04

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## Magma of the January 2011 eruption of Shinmoedake, Kirishima Volcano

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<sup>1</sup>Geological Survey of Japan, AIST

A sub-plinian eruption occurred on 26-27 January, 2011, from Shinmoedake, Kirishima Volcano and produced ca  $7 \times 10^7$  ton of andesitic pumice tephra. Prior to the onset of pumice eruption on 26 - 27 January, the volcano repeated small phreatic - phreatomagmatic eruption since 2008. Continuous ash emission and intermittent violent explosions follow the pumice eruption and lava is filling the previous summit crater of Shimoedake since 30 January. Total volume of the products is approaching to 108 tons on 4, February. The tephra ejected on 19 January contain pumiceous particles about 10% of total volume. The tephra ejected 26-27 January consists mainly of poorly-vesiculated pumices. The intense explosion on 1 February ejected bombs with cooling joints and chilled margin. These grains are the magmatic materials which is driving this eruption.

Our primary petrological examinations are revealing the nature of the magma. The juvenile materials erupted during 26-27 January eruption consists mainly of light-gray pumice associating with small amount of white pumice. Banded pumice consists of gray part and white part are often observed.

Whole-rock compositional analysis by XRF indicates that the composition of gray pumice concentrates around  $\text{SiO}_2=57$  wt% and the white pumice  $\text{SiO}_2=62-63$  wt%. These whole rock compositions of the juvenile materials are almost same as the previous magmatic eruption in 1716-17. The gray pumices have andesitic composition and contain olivine, orthopyroxene, clinopyroxene plagioclase and magnetite. Core compositions of plagioclase have wide compositional range from 46 to 90 in An contents. Mg# values of orthopyroxene concentrate around  $\text{Mg\#} = 72$  and clinopyroxene around  $\text{Mg\#}=66$ . These mineral compositions are also similar to that of the 1716-17 tephra.

Keywords: Volcano, Eruption, Magma, Kirishima, Shinmoedake

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## Urgent survey of eruptive deposit in January, 2011, from Shinmoedake volcano, Mt. Kirishima, South Kyushu, Japan

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<sup>1</sup>Geological Survey of Japan, AIST, <sup>2</sup>CRIEPI, <sup>3</sup>Nippon Koei Co., Ltd., <sup>4</sup>DIA CONSULTANTS CO., Ltd.

A sub-plinian eruption occurred on 26-27 January, 2011, from Shinmoedake, Kirishima Volcano and produced about  $7 \times 10^7$  tons of pumice fall deposit. Prior to the onset of pumice eruption on 26 - 27 January, the volcano repeated small phreatic - phreatomagmatic eruption since 2008 and the pumiceous particles have been found in these tephra. Continuous ash emission and intermittent violent explosions follow the pumice eruption and a lava is filling the previous summit crater of Shimoedake since 30 January.

The field survey was done within 4 days after the first subplinian eruption and revealed the facts that the tephra covered an area more than 1000 km<sup>2</sup> and the distribution axis toward N120°E direction. The volume of the tephra is more than 100 kg/m<sup>2</sup> at the point 3 km away from the vent and 1 kg/m<sup>2</sup> at the point about 60 km from the volcano. Pumiceous lapilli and blocks are found in the area within about 10 km from the volcano. In the area more than 10 km away from the volcano, the tephra consists mainly sand - silt size grains. The distribution of tephra indicates that the total mass of the products is  $7 \times 10^7$  ton, including the estimation of proximal and distal phases.

Petrological analysis indicates that the magma has pyroxene andesitic composition with 57-58 wt% of SiO<sub>2</sub>. Detailed observation reveals that the andesite is the products of mixing between dacitic and basaltic magmas. The petrological character and the sequence of the eruption are quite similar to that of the previous magmatic eruption of 1716-17 AD, during which some layers of pumice-fall deposits and pyroclastic flows were produced.

Keywords: volcano, eruption, Kirishima, Shinmoedake, eruptive mass, pumice

SVC050-06

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## Petrological characteristics and time evolution of the 2011 eruptive products from Shinmoe-dake of Kirishima volcano

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<sup>1</sup>Earthq. Res. Inst., Univ. Tokyo, <sup>2</sup>none

Continuous sampling and analyses of eruptive products from an ongoing eruption can give detailed insights into the magmatic processes operating beneath the volcanoes. Furthermore, whole rock compositions and phenocryst contents obtained in the petrological analyses are necessary to model variable eruptive styles in Andesitic volcanoes (such as Plinian, Strombolian), because the compositions and contents partly control viscosity of magma at and near surface. From above points of view, we are analyzing eruptive products from the 2011 eruption of Shinmoe-dake, Kirishima volcano.

In our preliminary study, we used pumice blocks of up to 10 cm size and pumice particles in the ash, both of which were erupted on 26 January 2011. Pumice blocks were used for bulk rock analyses. On the other hand, pumice particles (ca.1-5mm) were used for chemical analyses of groundmass glass and phenocryst, as small particles are convenient for mounting many particles in a limited area in short time.

Both of pumice blocks and particles show a variable color; white, brown and gray. White and gray or brown parts coexist in some blocks and particles (banded pumice). White pumice blocks have higher bulk rock SiO<sub>2</sub> contents (61-62wt. %) than gray and brown ones (57-59 wt. %). On the other hand, MgO contents of white pumice blocks (ca. 3wt. %) are lower than in gray and brown blocks (ca. 4wt. %).

Groundmass compositions of pumice particles are correlated to their bulk rock compositions. Groundmass glass in gray and brown parts of pumice particles has lower SiO<sub>2</sub> and higher MgO contents than in white parts; SiO<sub>2</sub>=66-68wt. % and MgO=1.1-1.4wt. % for the former and SiO<sub>2</sub>=ca. 76wt. % and MgO=ca.0.3wt. % for the latter. Microlites (plagioclase, pyroxene and Fe-Ti oxides) are exceptionally found in gray and brown parts of the pumice particles. Therefore, whole groundmass of gray and brown parts should have lower SiO<sub>2</sub> and higher MgO contents than its glass part.

Above described chemical variety in pumice samples resulted from mixing of high and low temperature magmas. Although our observations are limited to small total area of pumice particles, phenocrysts of clinopyroxene, orthopyroxene, plagioclase and Fe-Ti oxides are commonly found in all colors of pumice particles. Core compositions of these phenocrysts are the same regardless of the colors of pumice particles. On the other hand, olivine phenocrysts are limited to gray and brown parts of the pumice particles. In addition, cores of olivine phenocrysts are not in equilibrium with those of two pyroxene phenocrysts. Furthermore, extensive reverse zonings of orthopyroxene phenocrysts are exceptionally found in gray and brown parts, as in Suzuki and Nakada (2007). These lines of evidence indicate low-temperature magma in the mixing corresponds to the white pumice sample. The high-temperature magma includes at least olivine as phenocryst. The high temperature magma was not erupted independently (i.e. without mixing with low-temperature magma) on 26 January.

The determination of the storage depths of the above two magmas may help to understand origin of the pressure sources detected by geophysical observations. By the way, our continuous examination of ash samples from small-scale eruptions of Shinmoe-dake since 2008 has revealed that fresh pumice particles (juvenile material) first appeared in ash at eruption on 19 January 2011. Hence, this presentation also seeks petrological relationship between the pumice particles issued on 19 January and the pumice samples issued on 26 January. Adding future samples from the ongoing activity and acquiring another data, such as volume ratios among pumice types of different colors and detailed analyses of phenocryst chemical zonings, we aim at revealing evolutions in the interactions between the high and low temperature magmas.

Keywords: magma mixing, banded pumice, bulk composition, groundmass glass composition, volcanic ash, juvenile material

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## Transition of Shinmoe-Crater activity inferred from correlation patterns between infrasound and ground motion

Mie Ichihara<sup>1\*</sup>, Jun Oikawa<sup>1</sup>, Takao Ohminato<sup>1</sup>, Minoru Takeo<sup>1</sup>

<sup>1</sup>ERI, University of Tokyo

Shinmoe-dake of Kirishima volcano complex started major eruptions on January 26, 2011. Three eruptions occurred in two days from 26th to 27th, each of which emitted a large ash cloud for a couple of hours. Isolated explosions generating large N-shaped airwaves started on 28th. The volcanic activity is still changing. In December, 2010, we installed a microphone at 1-km north of Shinmoe-Crater, and the data is being sent to the institute with the pre-installed broad-band seismometer signals. This is the closest station to the crater available during these eruptions. Correlation function between infrasound and seismic signals measured at this station is continuously calculated and change of its pattern is investigated. This method has been found to be useful in detecting the crater activity at Asama Volcano. Clear correlation patterns are observed associated with the activities of Shinmoe-Crater, and the patterns change with time visualizing the change of the crater activities. The strength of the correlation is not related to the amplitudes of the seismic or infrasonic waves. Distinct changes of the correlation pattern are sometimes observed in the middle of a sequence of ash cloud emission. In some periods, a couple of patterns are overlapped and an alternate one of them sometimes dominates the others. Such a feature may indicate existence of plural active craters changing their strength alternately. It is confirmed that this method is useful in detecting the crater activities. The mechanisms generating the correlation between infrasound and seismic signals and controlling its patterns are to be understood.

Keywords: Shinmoe-dake, eruption, infrasound, explosion, Kirishima

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SVC050-08

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## Numerical simulation of the volcanic ash transpotation during the eruption of Mt. Shinmoe-dake of Kirishima Mountains

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The volcanic ash transpotation during the eruption of Shinmoedake for 26 to 27 January, 2011 is simulated with the volcanic eruption cloud/ash fall model (See V159-P026, JPGU2009) which is developed on the basis of Japan Meteorological Agency Non-Hydrostatic Model (JMA-NHM). The simulation is conducted with the domain covering the region of 2500km x 2500km centering south coast of Japan so as to reproduce the atmospheric condition on the eruption date. In the simulation, volcanic ash is emitted from the prescribed eruption column. The top height of the eruption column varies according to the temporal variation of echo top height observed with the meteorological radars at Fukuoka and Tanegashima. The distribution of volcanic ash simulated with the model well reproduced the observation from the meteorological satellite (MTSAT). Another simulation is performed in the 60km x 60km wide domain with the horizontal rezolution of 200 m to irustrate the behavior of ash cloud in detail. At first, the ash cloud distributed with its axis directing vertically over the crater. The top of ash cloud flows to the east while the bottom flows to the southeast, tilting its axis. This feature indicates that the vertically sheared wind, as well as the top height of eruption column, considerably influence the volcanic ash transpotation.

Keywords: Mt. Shinmoe-dake, volcanic ash, advection and diffusion, numerical simulation



SVC050-09

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## Volcanic earthquakes and tremor associated with the 2008-2011 Shinmoe-dake eruption

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<sup>1</sup>ERI, University of Tokyo

Shinmoedake, one of a volcano in Kirishima volcanic chain, southwest, Japan, erupted on 30 March 2010, for the first time since 22 August 2008. Subsequently, it erupted on 17 April, 27 May, 27 June, 28 June, and 5 July. Here we overview seismic observation associated with these eruptions.

Figure shows a displacement seismogram of the volcanic tremor associated with an eruption on 27 May recorded with a broadband seismometer with a natural frequency of 40 seconds. This seismogram was recorded at a site approximately 1 km north of the eruption site. The record shows that an outward-upward impulse preceded the eruption by about 4 minutes, followed by a large inward movement. This can be interpreted to be due to a combination of a translation and tilting by a pressurization at the conduit. Similar observations are made during eruptions on 27 June, 28 June, and 5 July, too.

Seismic activity around the area is relatively high with depths at 2 km below sea level or shallower. The activity consists of temporal clustered earthquakes; for example, significant quiescence was observed right before an eruption on 27 May. This quiescence preceding the eruptions is a common feature for the 2010 eruptions, in contrast with the 22 August eruption, where a seismic swarm continued since 3 days before the eruption.

Keywords: Kirishima Volcano Group, Volcanic Earthquake, eruption

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SVC050-10

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## Crustal deformation of Kirishima Volcano before eruptions in January 2011

Shigeru Nakao<sup>1\*</sup>, Yuichi Morita<sup>2</sup>, Kazuhiko Goto<sup>1</sup>, Hiroshi Yakiwara<sup>1</sup>, Shuichiro Hirano<sup>1</sup>, Hideki Ueda<sup>3</sup>, Tomofumi Kozono<sup>3</sup>, Jun Oikawa<sup>2</sup>

<sup>1</sup>GSSE, Kagoshima Univ, <sup>2</sup>ERI, Univ. of Tokyo, <sup>3</sup>NIED

Shimoedake in Kirishima Volcano began eruption activity on 26 January 2011. On 27 January blast eruption occurred after 52 years. Activity of Shinmoedake is kept high.

In 2007 three continuous GPS (CGPS) observation started around Kirishima Volcano and an additional CGPS started in October 2010. Joint GPS analysis with GEONET site is carried out and crustal deformation with volcanic activity was able to observe. We discuss source of volcanic activity.

Three CGPS, which is KVO, KRSP and YMNK started in March in 2007 and KKCD occupied in October 2010. KRMV and KRHV of NIED started CGPS observation in April, 2010. Bernese GPS Software Ver. 5.0 is used for GPS data analysis for our CGPS and GEONET sites. IGS precise and rapid ephemeris and earth rotation parameters are used, and troposphere delay parameters and gradient estimate every one hour and 24 hours, respectively. IGS2005 coordinate system is used.

Crustal deformation, 1 to 15 mm, in the period from October 7, 2010 to January 25, 2011 is detected. Source of this deformation is estimated about 4 km WNW from Karakunidake, whose depth and volume change are 9.7 km and 6.8 million cubic meter. Crustal deformation, 1 to 14 mm, in the period from January 25, to January 31, 2011 is detected, whose source is estimated also about 3- km WNW from karakunidake. Its depth and volume change are 6.9 km and 10 milion cubic meter.

Keywords: Kirishima Volcano, GPS, Crustal deformation

SVC050-11

Room:302

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## Crustal velocity structure beneath Mt. Asama using ambient noise tomography

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Mt. Asama is an active volcano, experiencing minor and moderate eruptions in 2004, 2008 and 2009. Probing crustal structure is expected to provide additional insights into the dynamics of magma transport and resulting eruptions of Mt. Asama. In this study we estimated the crustal seismic velocity structure beneath Mt. Asama from surface wave tomography using Rayleigh wave extracted from ambient seismic noises.

We employed the seismic wave interferometry to extract the seismic wave propagation between two seismic stations by taking a cross correlation of random wavefields, such as the ambient seismic noise or the seismic coda wave, recorded at two stations. The cross correlations of random wavefield recorded at two receivers can be represented as if the source is at one receiver and the recorder is at the other. This technique is suitable for exploring local structure since the extracted wave is sensitive to the internal structure between two stations.

We inferred the crustal phase velocity structure from surface wave tomography using the vertical component of the ambient seismic noise recorded by a dense seismic array between July 2005 and June 2006. We first extracted a Rayleigh wave by taking cross correlations. We divided the analysis area into three regions, for each of which measured the reference dispersion curve. Next, we measured the Rayleigh-wave phase-velocity anomaly against the reference for each path in various frequency bands and convert it into travel time anomaly. We finally obtained tomographic images of phase velocity structure by inverting the travel time anomalies. The velocity structure we thus obtained for 0.1-0.2 Hz shows that the low velocity zone is located beneath the west part of Mt. Asama at the depth of 5-10 km. Combining our results with the tilt motions observed after the eruption of Mt. Asama in February 2nd, 2009, suggests that the low velocity zone to the west part of Mt. Asama marks the magma chamber of the volcano.

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Room:302

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## Development of the near real-time analyzing system for GPS observation data of the volcano monitoring network in NIED

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<sup>1</sup>NIED

We develop the near real-time automated analyzing system of GPS observation data to obtain every three-hourly updated site coordinates of volcano observation network introducing in NIED. In the present GPS analyzing system of volcano observation network in NIED, GPS site coordinates are estimated once per day using 24-hourly data. In the system developed in this study, GPS observation data in the network sites are analyzed near real-time with the nearby GEONET fiducial sites every three-hour using 24 hourly, 12 hourly, 8 hourly data and so on.

In the present analyzing system, GPS observation raw data of the volcano observation network are telemetered to NIED in Tsukuba one per hour, transformed to RINEX format file once per day, and the site coordinates are estimated automatically every day. In the system in this study, at first we develop the automated RINEX transformation program from GPS observation raw data every three-hour. Next we develop the program to estimate the best-fitting site coordinates of GEONET fiducial sites near volcano observation network, analyzing GEONET sites with around 20 IGS fiducial sites in and around Eastern Asia once per day to estimate daily GEONET site coordinates, then estimating updated best-fitting GEONET site coordinates applying recent 30 days daily coordinates solutions. In the last, GPS data of the volcano observation network sites are analyzed with the GEONET fiducial sites data automatically and estimated the latest site coordinates applying 24 hourly data or the data less than 24 hour (for instance, 12 hourly, 8 hourly, and 6 hourly data). For the RINEX converting program we adopt teqc program, for the GPS analyzing software we adopt GAMIT program, and we develop the programs to control those software adopting perl language. For from GSI data server GEONET data are available every three-hour with about 70 minutes delay, in this system we download RINEX files of the GEONET sites automatically just after the release of GEONET data, then begin to analyze GPS data, and obtain the latest site coordinates solutions around 90 minutes delay.

In this paper we also present the stability of site coordinates solutions obtained in the system automatically applying short (less than 24 hour) observation data.

Keywords: near real-time analysis, GPS observation, volcano monitoring network

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## Towards mid-term eruption prediction of Izu-Oshima volcano (4): deep LF earthquakes, magma accumulation, CO<sub>2</sub> degassing

Hidefumi Watanabe<sup>1\*</sup>

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In order to make successful mid-term or long-term eruption predictions, we need to detect particular precursor processes operating in magma-plumbing system. Since 1989, we have detected the secular re-inflation of the volcano and further revealed the repeated deflation-inflation cycles, resulting a net inflation of the volcano. The rate of secular inflation has decreased exponentially until 2006, and since then kept a constant speed. The amplitude of deflation-inflation cycles has also increased. The JMA catalog of hypocenters indicates that the activity of deep low-frequency (LF) earthquakes occurring at depth ranges of 30-40 km beneath Izu-Oshima volcano has increased since 2007, and that the elevation of LF earthquakes activity has preceded the volcano inflation. We naturally suppose that the volcano inflation is caused by the supply of magma from depths. What is the origin of the deflation? There are two possible processes causing the deflation, magma drain back and the contraction of magma due to degassing. In order to discriminate the deflation mechanisms, we need to combine the magma accumulation and degassing processes. To monitor the degassing of basaltic magma accumulating beneath the volcano, CO<sub>2</sub> is most helpful because CO<sub>2</sub> separates from melt at the earliest stage of accumulation. In September 2005, we started continuous monitoring of soil CO<sub>2</sub> concentration at the eastern part of the summit of Izu-Oshima volcano. We observed the correlated increase of soil CO<sub>2</sub> concentration during the periods of not only accelerated inflation but also deflation of the volcano, suggesting that the degassing of accumulated magma might cause the deflation. By integrating the observation data, we suppose that the rate of magma supply from the upper mantle has increased since 2007 causing an increase of CO<sub>2</sub> over-saturated region at the upper part of magma reservoir beneath the volcano.

Keywords: eruption prediction, precursors to eruption, Izu-Oshima volcano, magma accumulation, CO<sub>2</sub>

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SVC050-14

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## Ground deformation measurements in Izu-Oshima volcano (2)

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In Izu-Oshima volcano, inflation continues over 20 years since the end of the last eruption in 1986-87, suggesting magma accumulation for future eruptions. Recent continuous GPS observations revealed repetition of shorter term of deflation ? inflation events of the volcano. Meteorological Research Institute has been reinforcing the ground deformation observation such as GPS and APS. On February of 2009, dense GPS network was installed in the caldera area to enhance spatial resolution of ground deformation and source parameter estimations.

Deflation and inflation events occurred in 2009-2010. GPS and APS baseline lengths whole the island started to shorten around October of 2009 and continued until April of 2010. Then, baseline lengths reversed to extend and the number of earthquakes increased. Horizontal strain distributions derived from GPS baseline length results suggest deformation sources of both deflation and inflation events locate beneath the northern part of the caldera. If the Yamakawa-Mogi source located at 5 km-depth is applied, 2.4 million cubic-meters of volume decrease and 4.2 million cubic-meters of volume increase are estimated for the deflation and inflation events, respectively. However, calculated horizontal displacements at the northern and southern coastal areas do not fit well to the observed ones. This may indicates existence of another deeper deformation source.

Keywords: Izu-Oshima volcano, ground deformation, GPS

SVC050-15

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Time:May 23 12:15-12:30

## Magma intrusion model on the 2006 Mayon Volcano eruption based on GPS measurements

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### Mayon Volcano

Mayon volcano is located in the southern Luzon Island in Philippine. The volcano is an eruption history since 1616, and ranging from strombolian to basaltic plinian including lava flows. After the 2001 eruptions of central vent eruption, pyroclastic eruptions and lava flows, the volcanic activities was quiet until July 13, 2006. The 2006 eruption is characterized by lava flow of  $3.8 \times 10^7$  m<sup>3</sup> and no explosion. We discuss the magma intrusion process of the 2006 eruption based on ground deformation by GPS measurements and seismic records.

### Ground deformation detected by continuous GPS measurements

PHIVOLCS (Philippine Institute of Volcanology and Seismology) established eight continuous GPS network consisting 8 stations in 20 x 40 km radius around the Mayon volcano in 2004. The measurements are maintained by hand pick until now. The baseline lengths between the 8 GPS stations show the contraction of 1 cm in 2004 and the extension of 1 cm in middle of 2005. In 2006, the rapid contractions of 1-3 cm of the line lengths are detected until end of the year.

### Estimated pressure sources beneath the summit

We discuss the spherical pressure source model by Mogi solution and divide three periods of Jan.2004 - Dec.2004 (period 1), June 2005 ? Dec.2005 (period 2) and Jan.2006 ? Dec.2006 (period 3).

In the period 1, because of shortening line lengths, one deflation sources is estimated at the depth of 6.5 km beneath a little bit to the north from the summit, and another inflation source is calculated at the depth of 5.0 km. It means the migration of magma from the 6.5 km depth to 5.0 km depth. In the period 2, line length shortenings are turn to extension, an inflation pressure source is estimated at the depth of 7.5 km. In the period of 3, line length changing are come back to contractions and they are very rapid in few months since July 13. One deep deflation source of  $-1.8 \times 10^7$  m<sup>3</sup> is estimated at the 11.5 km depth.

### 2006 eruption

Since the 1999-2001 eruption, Mayon volcano was very silent and there are few small phreatomagmatic eruptions only. On July 13, the 2006 Mayon volcano eruption was started as the lava dome forming and lava flow at the summit.

It is estimated the magma migration at the depth from 6.5 km to 5.0 km. Moreover long-term volcanic tremors over few ten minutes are observed since June 2004 to February 2005. Long-term volcanic tremors are caused by magma migration to the shallow depth.

In the period 2, magma are intruded to the magma chamber at the 7.5 km depth, and there is no volcanic activity on the ground surface.

In the period 3, line lengths changing on the most baselines are to the contraction in 2006, and long-term volcanic tremors are observed again in March. On July 13, lava dome is observed at the summit crater and lava flows are recognized as the shaking by lava falling. Lava flows arrives 5 km from the summit in the southeast flank and continued until September 2006. The volume of lava flows is estimated  $3.8 \times 10^7$  m<sup>3</sup> (PHIVOLCS) and it just half volume of the estimated deflation source in the 11.5 km depth.

The research is depend on the collaboration between Philippines and Japan under the JIST=JICA projects. We have a plan to extend the monitoring system at the Mayon volcano in 2011.

Keywords: Mayon Volcano, Magma intrusion model, GPS measurements, volcanic activity, 2006 Mayon volcano eruption

SVC050-16

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## Steady deformation pattern and the magma storage system of Kilauea volcano

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### 1. Introduction

At Kilauea volcano, Hawaii, it has been known from GPS and other data sets that, at least after 1983, the summit and rift zones are subsiding and that the southern flank is displacing at up to  $\sim 8$ cm/year. This deformation pattern is usually explained by a superposition of the effects of opening of a vertical rift reservoir and slip of a subhorizontal decollement located at  $\sim 9$ km depth connected to the base of the rift reservoir (Owen et al., 2000). In the summit area, signals of subsidence and tilt change toward the summit have been observed, which has been interpreted by the activities of magma reservoirs located at depths of 3.5km and 0.5km (Cervelli and Miklius, 2003, USGS prof. paper).

The rift zones are bent especially at the summit where the east and southwest rift zones meet. Therefore, if the rift reservoir opens, strain is expected to accumulate around the bending points. Such effects of realistic rift reservoir geometry has not been fully studied by previous works. This study investigates such effects by assuming realistic structures of the rift reservoir and subhorizontal decollement and modeling the surface deformation pattern using the 3D mixed boundary element method (Cayol and Cornet, 1997).

### 2. Model setting

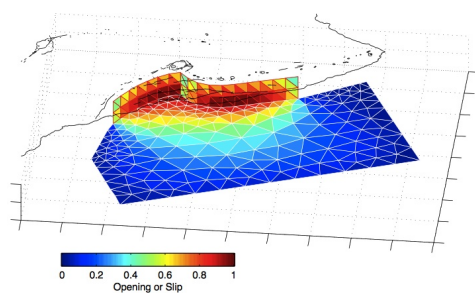
The rift reservoir and decollement are modeled by dislocations. The rift reservoir is vertical and has its upper and lower limits at 3km beneath the surface and 8km below sea level (9km beneath the summit), respectively. The horizontal location of the rift reservoir is assumed to coincide with the micro-seismicity which is considered to well characterize the tip of the reservoir. Furthermore, the subhorizontal decollement is assumed to be connected to the rift reservoir. Displacements on the ground surface are solved under boundary conditions of 1) uniform overpressure on the rift reservoir surface, 2) null shear stress change and normal displacements on the surface of the decollement. Under such conditions, the rift reservoir opens and the decollement slips in response to the overpressure of the rift reservoir.

### 3. Results

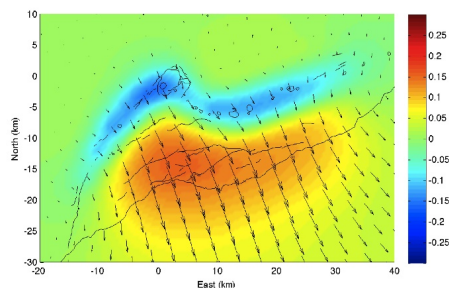
As shown in the figure, the considered model well explains 1) the subsidence of the rift zones, 2) the localized subsidence at the summit, and 3) the seaward displacements and uplift of the southern flank. Especially, the localized subsidence at the summit questions the presence of a summit reservoir at  $\sim 3.5$ km depth. The deformation pattern after 2007 has changed; the same pattern on the southern flank but a higher subsidence rate along the rift zone. The obtained results indicate that this kind of pattern can not be explained unless developed shallow reservoirs are considered beneath the rift zones.

### Acknowledgements

I thank the Hawaiian Volcano Observatory for providing GPS data and Dan Sinnett of Stanford University for data preparation.



(a) Opening distribution on the rift reservoir surface and slip distribution of the decollement. These displacements are created by over-pressurizing the rift reservoir.



(b) Surface displacements. Color shows the vertical and arrows show horizontal displacements, respectively.



Keywords: Kilauea volcano, Magma storage system, Crustal deformation, GPS, Boundary Element Method

# Japan Geoscience Union Meeting 2011

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SVC050-17

Room:302

Time:May 23 14:15-14:30

## Electromagnetic volcano-monitoring of Taal volcano, Philippines, under the SATREPS project

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We launched a five year (2010-2014) project to develop earthquake and volcano monitoring capability for effective disaster mitigation in the Philippines under the SATREPS (Science and Technology Research Partnership for Sustainable Development) program. Although the major objective of the program is to enhance the seismological and deformation monitoring of earthquakes and volcanoes in the Philippines with the aid of broadband seismometers and GPS network, our group are in charge of electromagnetic monitoring of volcanoes. We selected Taal volcano as our target area, which had frequently erupted and killed local people on Volcano Island (the central cone) for the past centuries. In November, 2010, we installed an integrated real time EM observation system with one magneto-telluric station and three highly-sensitive Overhauser proton magnetometers to watch the hydrothermal and magmatic system in the shallower part of the volcano. The data quality is extremely high thanks to no commercial electricity on the island. Furthermore, to clarify the 3-D resistivity structure of the volcano, we have a plan to make a magneto-telluric survey in FY2010-2012. The results will be included in our presentation. Other experimental studies are also planned such as magnetic susceptibility and Curie temperature measurements of the rock samples.

Keywords: Taal volcano, Electromagnetics

SVC050-18

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## Preliminary report on geological survey in and around Lake Nyos, northwestern Cameroon

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Lake Nyos, which is a maar volcano in northwestern Cameroon, exploded in August 1986, releasing a large amount of CO<sub>2</sub> that killed ca. 1800 people and over 3000 cattle. Since steady input of gas to the lake after the disaster implied recurrence of a similar event in the future, artificial degassing of the lake started in 2001 as an international project. However, a large amount of CO<sub>2</sub> still remains in the lake.

Recently a new project launched with a title "Magmatic Fluid Supply into Lakes Nyos and Monoun, and Mitigation of Natural Disasters through Capacity Building in Cameroon" under the Science and Technology Research Partnership for Sustainable Development (SATREPS, co-sponsored by JICA and JST). We performed preliminary fieldwork at Lake Nyos in January 2011 to clarify an eruptive history of the Nyos maar volcano. We found that pyroclastic deposits derived from the eruption of the volcano directly overlie the Pan-African quartz monzonite basement. The deposits can be divided into three units: pyroclastic-flow deposits, scoria-fall deposits and pyroclastic-surge deposits in an ascending order. Basal pyroclastic flow deposits are observed at the base of the eastern lakeshore wall and the downstream side of the dam. The deposits are poorly sorted and divided into the lower, fine grained unit and the upper clast-rich unit. Scoria-fall deposits overlying the basal pyroclastic flow deposits are recognized at the eastern to northeastern lakeshores. They are partially densely welded. Pyroclastic-surge deposits occur at the northern to eastern lakeshores. The surge deposits are well-stratified and thickest of all the pyroclastic deposits. The depositional sequence suggests that a series of eruptive events that formed Lake Nyos started with a pyroclastic flow eruption followed by a strombolian activity that produced scoria-fall deposits, and finally by explosive eruptions discharging multiple pyroclastic surges.

Keywords: volcanic lake, volcanic gas disaster, pyroclastic deposit, eruptive history

SVC050-19

Room:302

Time:May 23 14:45-15:00

## Instantaneous and localized temperature changes in atmosphere associated with the Icelandic eruption in April 2010 obser

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GPS radio occultation is a technique to observe phases of microwaves from GPS satellites near the horizon of the Earth with a receiver on board a low earth orbiter. Changes of the received phase are converted to the vertical profile of the atmospheric refractive index, which are further converted into quantities such as temperature and water vapor pressure of neutral atmosphere and electron density of ionosphere. With this technique, one can observe global atmosphere with high vertical resolution and accuracy comparable to radiosonde observations. FORMAT-3/COSMIC, launched in April 2006, is composed of six low earth orbiters, and is capable of obtaining up to 2500 profiles per day. As a brand-new application of the GPS radio occultation, Wang et al. (2009) analyzed temperature profiles obtained by COSMIC, and reported that temporary cooling occurred locally in the lower stratosphere above the volcanic fumes of the Chaiten volcano, South America, shortly after its eruption in May 2008. Temperature was found to have increased/decreased beneath/above the height of 12 km. SO<sub>2</sub>, a major constituent of volcanic gas, often reacts with atmosphere and forms sulfuric acid aerosols. By staying for a long time in the lower stratosphere, they bring about climatic impacts by blocking sunlight and performing as a greenhouse gas (McCormick et al., 1995). Water vapor is also included in volcanic gas and is another greenhouse gas that warms/cool troposphere/stratosphere. However, we still do not understand the mechanism responsible for the instantaneous atmospheric changes after the eruption as reported in Wang et al. (2009). Eruption of the Eyjafjallajokull, Iceland, started 14 April, 2010, and its volcanic ash and fumes reached maximum height of 11 km. They were carried to the European mainland causing disruptions in civil aviation. In this study, we use the temperature profile obtained with COSMIC, and try to detect localized changes in atmosphere after this eruption. We will then compare the results with the Chaiten volcano case. We first compiled the daily temperature profiles by COSMIC and calculated day-to-day average temperatures at a certain altitude. We then subtracted the reference temperature distribution forecasted from the atmosphere at 0 UT on the previous day by the NCEP GFS (Global Forecast System). We found that significant cooling above the volcano around the tropopause (height ~10 km) started on the next day of the eruption. This is similar to the Chaiten volcano case, but we could not find warming in troposphere as reported by Wang et al. (2009). Altitude of maximum cooling was ~14 km in the Chaiten volcano, but it was ~10.5 km in the present case. This possibly reflects the difference in the heights that the volcanic fumes of the two eruptions reached (Chaiten: ~20 km, Iceland: ~11 km). In addition to that, we found significant warming at the height of ~13 km to the east of the volcano where cooling was observed on the next day of the eruption. Such warming in the stratosphere was not observed in the Chaiten volcano case, and we do not know if it has a causal relationship with the eruption. Atmospheric cooling above the volcanic fumes might be due to the blocking of the long wave radiation from the lower atmosphere by the fumes, but definitive answer cannot be given until we get more examples. In the future, we would like to re-evaluate the reliability of the reference temperature and analyze other volcanic eruptions to get more examples.

Keywords: GPS, Radio occultation, Volcanic eruption, Iceland

SVC050-20

Room:302

Time:May 23 15:00-15:15

## Time-series analysis of volcanic ash from vulcanian eruptions at Showa-crater of Sakurajima volcano, Japan

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We study a temporal variation of texture of volcanic ash emitted by vulcanian eruptions at Showa-crater of Sakurajima volcano. We collected 34 ash samples during 14th-17th, January 2010. The collected ashes were examined from view point of variation of ash texture 1) through single eruption and 2) before and after big eruption emitting pumice clast. Ashes were classified on the basis of particle morphology and component. The classification of volcanic ash was performed on stereoscopic microscope. Volcanic ash is divided into 15 types of particle, K (black ash ash), B (brown color ash), W (white to colorless ash), Pumiceous particle (ash with extremely high vesicularity), N (ash with non-smooth surface), A (altered), Pl (plagioclase), Cpx (clinopyroxene) and Opx (orthopyroxene). Moreover, K is subdivided into three types of particle, K-B (shows blocky morphology), K-F (shows fluidal surface) and K-V (shows vesicular morphology). Also B is subdivided into B-B, B-F and B-V as well as K particle. W type ash is subdivided into W-B-T (shows blocky morphology with transparency), W-B-NT (shows blocky morphology with non-transparency) and W-V (shows vesicular morphology). The examination on polarized microscope indicates that groundmass crystallinities of B, W-B-T, W-V and pumiceous particles are lower than that of K and W-B-NT particles. The classification and time-series analysis of the ash reveals that 1) the number fraction of ash with low crystallinity (B, W-B-T, W-V and pumice) and 2) vesicular morphology (K-V, B-V, W-V and pumiceous particle) in later phase is larger than that in initial phase in single eruption, and 3) the number fraction of ash with low crystallinity increases approximately 1 day before big eruption (emitting pumice clast) and decreases after the eruption. These results imply temporal variation of volcanic ash texture is possible to be an indicator of progress of eruptive activity.

Keywords: Volcanic ash, Texture, Time-series, Progress of eruptive activity

SVC050-21

Room:302

Time:May 23 15:15-15:30

## Repetition of inflation of Sakurajima volcano

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<sup>1</sup>DPRI, Kyoto Univ., <sup>2</sup>TITEC

Explosive activity at Minamidake summit crater of Sakurajima Volcano, Japan began in 1955 and the eruptivity continued for 54 years counting 7900 Vulcanian eruptions. The activity of Minamidake gradually transited to eruptions at Showa crater at eastern flank of the volcano from 2006. The eruptive activity increased step-by-step and 1033 explosive eruptions were counted in 2010. The main magma reservoir of the Sakurajima volcano is located at a depth of 10 km near the centre of Aira caldera, northern part of the Sakurajima and it is estimated that magma of 140 million m<sup>3</sup> have been stored in the reservoir since 1993 from extensional baseline observed by GPS. Explosive activity at Showa crater remarkably jumped up in October 2009. The eruptive activity from October 2009 is divided into 2 periods; inflation of volcano (October 2009 ? May 2010) and deflation (June ? November 2010). In inflation stage, a lot explosive eruptions occurred (907 events). The inflation was accelerated due to inflation of Aira caldera and migration of magma toward northern part of Sakurajima during January-March 2010. Explosive eruptions also occurred in deflation stage; however discharge rate of volcanic ash was less than inflation stage. Intrusion rate of magma was calculated from tilt change and weight of volcanic ash ejected. In inflation stage, magma intruded into Sakurajima from Aira caldera (0.4 million m<sup>3</sup>/month) and excess magma was ejected by explosive eruption. In deflation stage, intrusion rate decreased (<0.1 million m<sup>3</sup>/month) and magma stored in inflation stage was consumed by eruptions. At the end of November 2010, the deflation turned to inflation again. The deflation was revealed by extension of the ground at Harutayama (northwest of the central cones) and tilt change of crater-side-up at north and northwest flank. Tilt vectors indicate that center of inflation is located at north flank of Sakurajima. Associated with inflation of the ground, concentration of CO<sub>2</sub> from hot spring increased in observation well at Kurokami (4 km east of Showa crater). The number of explosive eruption increased and 95 explosive eruptions were recorded in January 2011. This suggests that magma intruded into Sakurajima from northern part with minor inflation of northern part and magma smoothly moved to Showa crater, increasing explosiveity at the crater.

Keywords: Sakurajima, ground deformation, intrusion magma

SVC050-22

Room:302

Time:May 23 15:30-15:45

## Change of mode of eruptive activity and the magma plumbing system of Sakurajima Volcano since 20th century

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<sup>1</sup>Hokkaido University, <sup>2</sup>Kyoto University

Sakurajima volcano repeated large eruptions with dormant periods in 1471, 1779 and 1914, which were composed of plinian eruption and lava effusion. After 1914 eruption, medium scale of lava effusion occurred in 1946. Frequent vulcanian eruptions have repeated since 1955 until now. Thus, mode of eruptive activity of the volcano has changed since 20th century. We carried out petrological research of eruptive materials from major historic eruptions from 1471 to 1946. In addition, we newly investigate the recent eruptive materials from 1955 to 2009. These suggest that magma plumbing system of the volcano has also changed, and that new type of magma has frequently injected into the pre-existed system. We discuss the relationship between the mode of eruptive activity and magma system to evaluate the present state of the activity of Sakurajima Volcano.

The rocks of 1471 and 1779 eruptions are CPX-OPX dacite, in which normally and reversely zoned pyroxene and plagioclase phenocrysts coexist. In addition, compositional distribution of plagioclase phenocrysts is bi-modal. These suggest that these rocks are mixing products between dacitic and andesitic magmas. This is consistent with compositional variations of whole-rock chemistry for these rocks. On the other hand, the rocks of 1914 and 1946 eruption often contain olivine phenocrysts. Plagioclase and pyroxenes phenocrysts in these rocks show similar features to those of 1471 and 1779 eruptions, suggesting that these rocks are also mixing products of two end-member magmas, dacitic and andesitic ones. However, olivine phenocrysts are much magnesian compared with pyroxenes phenocrysts, indicating that these olivine phenocrysts are derived another magma, basaltic one. Thus, the basaltic magma injected into the mixed magma between dacitic and andesitic ones. Mixing among three magmas has been recognized since 20th century. We estimate the timing of mixing on the basis of compositional variations of rim of phenocrysts and compositional zonation of pyroxene phenocrysts. It seems that mixing between dacitic andesitic magma had occurred more than 10 years before eruption, and that the basaltic magma had injected several tens days before eruption. According to geophysical observation, voluminous magma has accumulated beneath the Aira caldera, and part of the magma has moved beneath Sakurajima volcano to occur eruption. Our petrological analysis suggests that monitored voluminous magma would be dacitic magma, in which andesitic magma has repeatedly injected beneath Aira caldera. Before 20th century, the mixed magma had moved toward the volcano to accumulate for large plinian eruptions. In contrast, injection of basaltic magma has repeated occurred to mix with accumulating mixed magma since 20th century. This injection would occur beneath the Sakurajima volcano, because timing of the injection must not be long before eruption.

The rocks from frequent vulcanian eruption since 1955 also contain minor amount of olivine phenocrysts, suggesting the injection of basaltic magma has continued after 1946 eruption. In 1974-78 and 1987 periods, relatively larger scale of vulcanian eruptions had occurred. The rocks from these periods contain considerable amount of olivine phenocrysts, indicating mixing ratio of the basaltic magma was relatively larger than that of other periods. Thus, the effect of the injection correlates with scale of the vulcanian eruptions. During 20th century, frequent eruptions had been triggered by the injection of the basaltic magma. In addition, large scale of the injection would cause larger eruption. Temporal change of mode of eruptive activity of Sakurajima Volcano must be related with frequent injection of basaltic magma. In order to predict future eruptive activity, detecting of movement of the basaltic magma should be important.

Keywords: Sakurajima Volcano, magma plumbing system, magma mixing, eruption prediction, mode of eruptive activity

SVC050-23

Room:302

Time:May 23 15:45-16:00

## Temporal variations of the petrological features of the juveniles from Showa crater since 2006, Sakurajima volcano

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On June 2006, Sakurajima volcano, Japan, has resumed its eruptive activity at Minamidake after ca. 6 years' quiescence. Most of the explosions have occurred at Showa crater. The eruptive activity from Showa crater is divided into the following four episodes: Episode-1, from June 2006 to August 2009, low explosive activity with slow inflation; Episode-2, from September 2009 to March 2010, high explosive activity with inflation; Episode-3, from April 2010 to May 2010, lower-explosive activity without inflation; and Episode-4, from June 2010 to September 2010, high explosive activity with deflation. The eruptive products are mainly composed of volcanic ash, and sometimes lapilli. Focusing on the petrographical features, the volcanic ashes are distinguishable into four types, agreeing with the eruptive episodes as follows. Episode-1: the absence of fresh glass particles; Episode-2: the existence of many fresh glass particles increasing its ratio with time; Episode-3: the existence of a small amount of fresh glass particles in addition to strongly-altered lithics; and Episode-4: the existence of fresh glass particles almost without strongly-altered lithics. Petrographical features of the lapilli are similar to those of the fresh glass particles. On whole-rock chemistry, the lapilli are consistent with the compositional trends of the juveniles from Minamidake crater since 1955, showing the most mafic compositions ( $\text{SiO}_2=58.5$  wt.%). The glass compositions of the lapilli and fresh glass particles are dacite ( $\text{SiO}_2=67.2-72.7$  wt.%), and they have a systematic variation: the silica content decreases with time in Episode-2 and Episode-3, and again increases in Episode-4. Such temporal variation corresponds to the geophysical change: from inflation to deflation. This agreement suggests that the recharge of mafic magma into magma chamber affects the compositions of volcanic glass. The comparison between the temporal change of the petrological features of juveniles and the geophysical dataset can contribute to understand the detailed magma migration beneath the volcano.

Keywords: Sakurajima volcano, Showa crater, temporal variation, volcanic ash, juvenile materials



SVC050-24

Room:302

Time:May 23 16:00-16:15

## The second seismic survey round in Sakurajima Volcano

Tomoki Tsutsui<sup>1\*</sup>, Masato Iguchi<sup>2</sup>, Takeshi Tameguri<sup>2</sup>, Koichiro Saito<sup>3</sup>, Research Group of the Seismic Survey Round 2010 in Sakurajima<sup>2</sup>

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The second seismic survey round in Sakurajima Volcano and the variation of reproduced seismograms are presented. The seismic survey rounds have been done in the northeastern part of Sakurajima Volcano since November 2008 in order to detect movement of underground magma. The pilot survey had been done on November 2008 and the first survey was carried out on December 2009.

The survey includes 14 shot points, 248 temporary stations and 39 participants. The geometry of the network was the same as that of 2009's survey. The shot points and almost all stations were well reconstructed. Charge size are 20kg and the charge was detonated in a single hole in all 14 shot points, which were the same condition as that of the previous year. Each station included a vertical motion sensor (4.5Hz) and the compact digital recorder LS8200SD. The observation was successfully finished at 245 stations except for failed three stations. Peak amplitude ratio ranges 0.83 to 1.52 with reference to 2009's seismograms. Variation in the seismograms will be reported with comparison to those of preceding years along the same lines, and with referring to volcanic activity in Sakurajima.

Member of Research Group of the Seismic Survey Round 2010 in Sakurajima: Tomoki Tsutsui, Takeshi Tameguri, Masato Iguchi, Jun Oikawa, Hiromitsu Oshima, Tokumitsu Maekawa, Hiroshi Aoyama, Sadato Ueki, Satoshi Hirahara, Kenji Nogami, Takao Ohminato, Mie Ichihara, Hiroshi Tsuji, Shinichiro Horikawa, Takashi Okuda, Hiroshi Shimizu, Takeshi Matsushima, Takahiro Ohkura, Shin Yoshikawa, Tadaomi Sonoda, Hiroki Miyamachi, Hiroshi Yakiwara, Shuichiro Hirano, Koichiro Saito, Koichi Suemine, Susumu Goto, Takamitsu Ikegame, Koji Kato, Shinichi Matsusue, Taisuke Kohno, Shingo Utsunomiya, Hirohito Goto, Ryuichi Watanabe, Yuki Maehara, Izumi Satoh, Ryudo Oyabu, Hidehiko Shimizu, Yusuke Yamashita

Keywords: Sakurajima Volcano, Volcano structure, Active volcano, Seismic survey, Underground movement detection

SVC050-P01

Room:Convention Hall

Time:May 23 16:15-18:45

## The development of infra-free and portable muon counting system for muon radiography

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We will report the development of portable and infra-free muon counting system with silicon photon-counting device, which will achieve more frequent observations for muon radiography. We are hoping for discussing what kind of geological information can be retrieved with the new muon detector.

Muon radiography is a non-destructive inspection based on high penetration power of cosmic ray muon. It has been applied to several volcanoes. For example, the observation at Mt.Showa-Shinzan (Tanaka.et.al,2007) found the density excess which implies the intrusive magma. In Satsuma-Iojima Island, the density deficit below the crater was detected which indicates the existence of high porosity region. In addition, three-dimensional tomography with dual observations was conducted in Mt.Asama(Tanaka.et.al,2010).

However, all of these observations were conducted where the infrastructure (e.g. electricity and road) was well-organized. If we can improve the flexibility in measurement location, more comprehensive search for various volcanoes becomes possible. For instance, we could place a detector near an active volcano and could detect the movement of magma in a vent. Three-dimensional tomography will be more easily achieved.

The present muon detector comprised of plastic scintillators and photomultiplier tubes (PMTs) requires commercial electricity or huge solar panels (at least 1 meter square). Therefore, the measurement locations have been limited. A more power-effective and light detector has to be developed. For these purposes, silicon photon-counter MPPC(Multi-Pixel Photon Counter) is a feasible device because it is small (< 1cm cube) and does not need high voltage compared with PMT (70V for MPPC and > 1kV for PMT). If we can build a detector with MPPC, the power consumption of front-end electronics becomes almost negligible. MPPC is also good at cost compared with PMT (50 USD for MPPC and 1000 USD for PMT per channel).

In this report, the inspection of MPPC's performance and the whole design of MPPC muon counting system will be explained. The authors are hoping for discussing the possible applications to volcanology.

Keywords: muon, radiography, density structure, MPPC

SVC050-P02

Room:Convention Hall

Time:May 23 16:15-18:45

## Development of a small unmanned aerial vehicle with GPS-guided automatic navigation for volcano observation

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An unmanned aerial vehicle (UAV) named "Sky-1 Stonefish" with GPS-guided automatic navigation system was developed as a tool that the researchers and the staff of the municipality who investigate volcanic field were able to operate easily and at low cost. Sky-1 Stonefish was developed from a radio-control (RC) UAV "Sky-1". RC Sky-1 had shown good performance at volcanic fields, but the actual control range is limited to ~400 m by human ability. To overcome this defect, GPS-guided autopilot system Ardupilot was added to Sky-1. Ardupilot is a low-cost autopilot system based on the Arduino open-source hardware platform. It uses 3 axis accelerometer and three gyro sensors for stabilization and GPS and Pitot tube for navigation. The strong points of Sky-1 Stonefish are as follows: "An electric ducted fan is employed to secure the safety", "Portable on one's back because of the new design of the airframe division", "The payload that reaches 300 g is reserved", and "Achievement of the high flight performance against the strong wind around 10 m/s", etc. RC Sky-1 was tested at Kusatsushirane volcano, Aso volcano, and Izu-Oshima, and Autopilot Sky-1 Stonefish was tested at Izu-Oshima and Kansai Mokei Airport (Uji, Kyoto). The design and performance of SKY-1 Stonefish will be presented.

The specification of Sky-1 Stone Fish is listed as follows;

Name: Osaka University Sky-1 Stonefish,

Maximum length: 90 cm,

Maximum width: 90 cm,

Airframe Material: Expanded polypropylene (EPP),

Weight: 500 g (with a battery),

Payload: 300 g maximum,

Battery: 11.1V Lithium-polymer battery,

Propulsion: Ducted fan with brushless motor,

Thrust: 500 gf, Control: 3 ch (motor, aileron, elevator) by GPS waypoint navigation,

Flying range: 3~4 km (with a standard battery)

Keywords: UAV, robot, GPS, volcano, airplane, arduino

SVC050-P03

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## Trial of measuring hydrogen isotopic ratios of water vapor in fumarolic gas collected in a gas bag

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### 1. Introduction

Isotopic ratio of water vapor in fumarolic gas reflects geothermal structures where magmatic water is mixed with meteoric water, and it is one of the indicators which represent the state of volcanic activity. We are evaluating the method to collect volcanic gas with gas bag in order to develop the gas-collecting method using mobile vehicles such as an Unmanned Aerial Vehicle. Because the amount of water collected in a gas bag is little, we applied "Zn shot method" (Coleman et al., 1982) to reduce the water into H<sub>2</sub>. However, the percentage of success of the reduction was low, so we reviewed the factor of our failure.

### 2. Fumarolic gas samples

We collected condensed water and gas samples from Kengamine fumarole in Mt. Mihara, Izu-Oshima. The samples are 100 mL water condensed from the fumarolic gas by iced-water, and gas collected in 10 L gas bag just above the fumarole (Bag 1, 2, 3), gas collected in 10 L gas bag about 10 m above the fumarole along slope (Bag 4, 5, 6). The 2 micro L of the condensed water measured with microcylinder was packed into a reduction glass tube with Zn shots using a glass-line. Water samples in gas bags were also extracted and packed into the reduction tube in the same way. The maximum amount of water in the gas bag was estimated to be 10 micro L.

### 3. Experimental method

The reduction tube containing Zn shots and water was set into a mantle heater whose temperature was set to 490 to 495 deg C to reduce the water. The reduction time was set to 30 minutes. After reduction, Zn metal re-condensed on inside the tube like mirror. We judged the end of the reduction by appearance of the mirror. Hydrogen isotopic ratio of samples was measured on a mass spectrometer of Sercon, Geo20-20.

### 4. Results

Three samples of the condensed water were succeeded in reduction, and their hydrogen isotopic ratio were  $\delta D_{SMOW} = -69$  permil. This value is consistent with the result of Ohba (2007). The reduction of the sample of Bag 2 had not finished for 30 minutes heating. The reduction of the samples of Bag 5 and 6 also had not finished for 30 minutes heating, therefore the duration of reduction was extended for another 30 minutes. The isotopic ratio of Bag 5 sample is  $\delta D_{SMOW} = -78$  permil and that of the Bag 6 is  $-141$  permil. There is wide difference between the isotopic values of 2 samples, though they had been collected in the same site.

### 5. Discussion

The results show that there were some problems in the processes of Zn shot method. The reduction processes have 3 steps, evaporation of Zn, diffusion of Zn vapor, and reduction of water. Every step can be hindered by excess water vapor pressure. We have estimated the influence of initial water content on the diffusion and reduction steps. The diffusion profile of Zn vapor was calculated for the two initial water contents; 2 micro L (proper amount), and 20 micro L (excess amount). We derived diffusion coefficients *D* of Zn from its mean free path for two cases. Using these *D* values, we calculated the profile of Zn vapor contents in the reduction tube by the finite difference method. The result shows there is little difference in the Zn content profiles between these two cases. Next, we estimated the equilibrium constant of the reduction at 500 degC, and calculated hydrogen partial pressure in equilibrium state for 2 and 20 micro L of water content. The result indicated that in both cases, hydrogen partial pressure nearly equals to total pressure. The results of our calculations suggest that, as far as Zn vapor is supplied from solid Zn, Zn vapor spread sufficiently within the tube, and all the water is reduced to be hydrogen. The remaining cause of failure in case of excess amount of initial water would be inhibition of Zn evaporation. When oxidation speed of Zn is faster than its evaporation speed, the surface of Zn liquid might be immediately covered with the film of ZnO.

Keywords: Zn shot method, water vapor, hydrogen isotope, fumarolic gas

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SVC050-P04

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## Tilt response of broadband seismometer

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<sup>1</sup>ERI

Recently, we often use broadband seismometers to measure long period motion near the volcano. We know clearly broadband seismometers have enough sensitivity to tilt change. We can calculate the trace under the equation of motion of the seismometer. The trace is given to convolve a tilt motion with a response function of tilt change. On the other hand, tilt motion is given to deconvolve a trace with that. In this study, to ascertain whether the trace of broadband seismometer on tilt change consists of previous calculated result.

To estimate tilt motion at the Kirishima volcano in the future, I used Trillium40, Trillium120 and CMG3T. I will express how to check below. First, I put seismometer on one side of 1m plate. Second, I move the other hand fluctuation. If the displacement is smaller than the length of the plate, I can approximate the tilt by displacement. I measure the displacement with a dial gauge and a laser. I gave a few micro radian.

I resulted that the trace of horizontal component consists of the result calculated from the equation of motion. And vertical component is smaller than that. The application of this result to real observed data is the future work.

SVC050-P05

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## MaGCAP-V (4) -Upgrade for gravity data and spheroidal model

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<sup>1</sup>Meteorological Research Institute, <sup>2</sup>Volcanology section, JMA, <sup>3</sup>MEXT, <sup>4</sup>VisCore Corp.

We developed the software MaGCAP-V (Magnetic and Geodetic data Computer Analysis Program for Volcano) to evaluate the magmatic activity from ground deformation data and geomagnetic changes observed at volcano. MaGCAP-V can handle both geodetic and geomagnetic data, and can do modeling the source of change through trial and error or inversion method by using GUI on Windows PC (Churei *et al.*, 2002; Fukui *et al.*, 2005).

MaGCAP-V Version 1.1 (released in 2005) handles the following data, 1) GPS (X, Y, Z, latitude, longitude, and ellipsoid high), 2) displacement (also leveling data), 3) tilt, 4) magnetic total intensity, 5) atmospheric pressure, temperature, humidity, precipitation, and 6) hypocenter. DEM data (GSI DEM or user's DEM) are used for the modeling and drawing the topography. And also users can use the vector data to display the lakeshore and fault, etc.

It is possible that plot data in any combination of observation items as time series graph and as map graph. Map graph plots marks and vectors on observation points, or draws as color map created from interpolated grid data. GPS and displacement data in map graph create from a difference between two-period or displacement speed calculated from data within the designated period. The effect of the regional stress field can be removed from GPS and displacement data.

The following models are used, 1) Mogi model, dislocation model, and composite source for ground deformation, 2) thermal demagnetization model for sphere, column, conical, box, and composite source, 3) piezo magnetism which makes the multiple Mogi models. In order to reduce the effect of topography, we use a simple model such as the modified Mogi model (Fukui *et al.*, 2003). And modelings of volcano deformation by using a FEM simulation database (Fukui *et al.*, 2006) are used to remove the effect of topography, heterogeneity structure and the shape of source.

MaGCAP-V was upgraded for the application to electro-optical distance measurement (EDM) data, interferometric SAR (InSAR) data and analysis of dynamic process in 2009, and was upgraded for gravimetric data and spheroidal model (Sakai *et al.*, 2008), and improved performance through programming for multi-threading CPU and double buffer in 2010.

### Acknowledgements

The preliminary version of this software was developed under the special coordination funds for the promoting science and technology 'Unzen volcano: International cooperative research with scientific drilling for understanding eruption mechanisms and magmatic activity (1999-2001)'. We are grateful to Mr. Koji Nakamura for information on SEIS-GPS and PAT-ME, and to Mr. Hiroto Naito on PAT-ME, and to Dr. Masatomo Furuya for gravity model.

Keywords: software, volcano monitoring, gravity, GPS, InSAR, EDM

SVC050-P06

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## Stratigraphy of the 1883 Krakatau Mega Eruption and Tsunami in the Coastal Area of Java and Sumatra, Indonesia

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<sup>1</sup>Hokkaido University, <sup>2</sup>Indonesian Institute of Sciences (LIPI)

The 1883 mega eruption destroyed large part of Krakatau and formed a 7 km diameter caldera. During the paroxysmal stage, a series of eruption and tsunami occurred and destroyed more than 250 coastal villages along the Sunda Strait. This tsunamigenic volcanic activity left a unique stratigraphy along the coastal zone of Sunda Strait. This stratigraphy was formed by successive deposition of tephra and tsunami deposit, and also erosion by tsunamis. These near-field volcano-related tsunami deposits are different from usual sandy tsunami deposit caused by subduction-type earthquakes. The tsunami layers sometimes contain pumice and/or ash that have been carried up inland together with beach sand from their original position by the tsunami run up. In this study, we conducted field work at two sites in the coastal area of Java (Anyer, located 45 km east of Krakatau volcano and Carita, located 40 southeast of Krakatau volcano) and two other sites in the coastal area of Sumatra (Tarahan, located around 50 km north of Krakatau volcano and Limus, located around 70 km northwest of Krakatau). This geological work is important to reveal transport and depositional processes of the tsunami deposits. Beside careful examination of sedimentology characteristics, we used historical record account in conjunction with the stratigraphy characteristics. At each site, the stratigraphic profile is different, but all composed of sand layers intercalated by ash and pumice layers. The ash layers contain shell fragments with no lithic in Tarahan, and they contain shell fragments and foraminifera with minor lithic and heavy mineral in Anyer. We interpreted this layers had been deposited by the tsunami. The shape of the pumice is also a key feature for this recognition. The shape of pumice fragments in Limus is more angular than that of other locations. This pumice layer does not contain any shell fragments nor foraminifera. We interpreted this layer as the primary tephra fallout deposit. This conclusion is also supported by historical record in which the pumice fall was apparently directed to the west. As the depositional processes of the deposits obtained, thus the chronology of eruption and tsunami during the paroxysmal stage of the 1883 Krakatau eruption can be described.

Keywords: Krakatau, eruption, tsunami deposit, stratigraphy, historical record, 1883

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## The volcano monitoring system installed in 47 active volcanoes

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JMA installed the observation system, including seismometers, GPSs, infrasonic sensor in 47 active volcanoes. We will report the overall information about the installation and the observed data.



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## Migration of tremor locations associated with the 2008 eruption activity at Meakandake volcano

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<sup>1</sup>Japan Meteorological Agency

We estimated locations of three tremor sequences occurred during the 2008 activity at Meakandake volcano, using the observed RMS amplitude at each station. While the tremor on Sep. 29(tremor A) were located about 1.5km far from the erupted crater, the continuous tremor on Nov. 18(tremor C) were located close to the erupted crater. The tremor on Nov. 16(tremor B) were divided into three phases by the temporal variations of amplitude. The first and second phases were located at similar points to that of tremor A, while the location of the later third parts was similar to that of tremor C. Locations are migrated systematically from far to close the erupted crater. In addition, locations of tremor B were changed in time, which implies the migration of volcanic fluid, as suggested by other geophysical observations. These two migration phenomena may be important for monitoring of volcanic activities as well as studies on the mechanism of volcanic eruption.

SVC050-P09

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## Resistivity structure around the Kutcharo caldera

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Kutcharo caldera hoards potentials of disaster eruptions. From disaster prevention point of view, it is surely important to comprehend the mechanisms of eruptions of this volcano. This volcano belongs to Akan-Shiretoko volcanic line, the western end of Kurile volcanic line, which shows offset collocation. The offset is also clear around Kutcharo caldera, from topography and the gravity anomaly map. From this standpoint, the Kutcharo caldera locates on the offset point of the volcanic line. Several geophysical approaches for this area exist, however the precise structural model had never been proposed around this region. For instance, Satoh et al. (2001) installed three observation lines of MT survey over the Eastern Hokkaido region, while Nakanishi et al. (2009) executed seismic exploration over this area. Still, there are no arguments for the magma provision.

We executed MT survey around the Kutcharo region, during 2009 to 2010, and examined 2-D inversion analyses (Ogawa and Uchida, 1996), for five profiles. The observed data shows acceptably good quality. The strike angle of this region is assumed to the direction of the volcanic line. So the observation point is allocated for direction across the volcanic line. The principal axes of impedance phase tensor, for the southern part of the region, align across the volcanic line as expected. But it mostly deviates in the northern part. Therefore, we chose the TM mode analyses. The strike direction is decided by the rose histogram of the principal axis of impedance phase tensor.

The consequent resistivity structure shows aspects as follows. For all profiles, surface layer shows high resistivity, due to tephra. Then, the Tertiary stratum shows low resistivity. Then again, middle crust shows high resistivity. And the extraordinary low resistivity body penetrates the high resistivity crust. The resistive body rises to the Atosanupuri volcano. The top of this body rises to 6 km under the Atosanupuri volcano. The depth coincides to the source depth of the diastrophism, which reported from InSAR analyses during 1994 to 1995, accompanied an earthquake swarm.

Nakanishi et al., 2009. *Tectonophysics*, 472, 105-123.

Ogawa, Y. and Uchida, T., 1996. *Geophys. J. Int.*, 126, 69-76.

Satoh et al., 2001. *EPS*, 53, 829-842.

Keywords: MT survey, resistivity structure, caldera

SVC050-P10

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## Geomagnetic changes over Usu Volcano detected from aeromagnetic repeat surveys

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### 1. Introduction

We conducted an aeromagnetic survey over Usu Volcano in September 2010. The survey was planned to compare the previous one in June 2000 by GSJ, AIST (Okuma et al., 2001), with detection of temporal changes during this decade as its main objective. In this paper we summarize the 2010 survey and discuss the magnetic changes for the ten years by comparing with the recent measurements on the ground.

### 2. Summary of the 2010 aeromagnetic survey

The survey flight was designed to optimize the conditions required for the generalized mis-tie control method (Nakatsuka and Okuma, 2006). Magnetic field and sensor position were measured at 10 Hz and stored in the instruments in a bird which was suspended from a helicopter. Flight was done with a constant (about 150 m) spacing to topography. The 2010 survey successfully retrieved the magnetic total field over the recent eruptive areas in 2000 (NW foot), 1977-82 (summit crater), and 1943-45 (Showa-Shinzan).

### 3. Detection of temporal changes validated with the aid of ground surveys

After the data processing with the mis-tie control method, we successfully retrieved some distinct magnetic changes over the three areas mentioned above, in which amplitude of the anomalous changes overwhelms the detection error level. Another related paper (Nakatsuka et al., 2011; this JpGU meeting) discusses in detail on the data processing and a factorial analysis of possible contributing elements on the estimation errors.

Preceding the flight, Hokkaido University has repeated magnetic surveys on the ground since 2003 for NW foot and since 2008 for the summit crater and Showa-Shinzan. As was already reported by Hashimoto et al. (2010; JpGU meeting), these three areas show clear magnetizing trends which is plausibly due to cooling. We here extrapolated the linearly-fitted rates of change for ten years and projected the estimated magnetic changes onto a smoothed plane 200 m over the topography, which ensured a general agreement with the aeromagnetic result. Our result may be the second case succeeding the one at Kujū Volcano (Utsugi, 2010), in which magnetic time changes with grounded validation are detected from repeat aeromagnetic surveys. Availability and usefulness of this method now became more pronounced.

### 4. Discussion on the magma cooling beneath the summit crater

We here describe some features of the magnetic changes in the summit crater where the 1977-82 eruption took place.

(1) A distinct magnetic increase was recognized around Gin'numa crater. It agreed well with the estimation from the ground measurements from 2008 through 2010. This subsequently suggests that the recent magnetizing trend is not a temporary one but a steadier process at least for these ten years.

(2) Cooling of the intruded magma in the 1977-82 eruption might be a candidate for the source. However, no remarkable magnetic change was detected over Usu-Shinzan itself, under which the intruded magma is thought to remain (e.g. Matsushima et al., 2001).

(3) A remarkable decrease was found over the NW somma (Kita-Byobu-Iwa). It might be the counterpart of the increase which is mentioned in (1). This implies the possibility that a substantial part of the intruded magma under Usu-Shinzan still keeps a high temperature and thus is not yet able to be magnetized.

(4) Some magnetic changes with relatively small amplitude are recognized around Oo-Usu lava dome, which also suggest cooling magnetization. The significance, however, should be carefully investigated as we have no ground data on that area.

**Acknowledgments:** This study was supported by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan, under its Observation and Research Program for Prediction of Earthquakes and Volcanic Eruptions.

**Keywords:** Geomagnetic field, Usu Volcano, Aeromagnetic survey, temporal variations, helicopter, magma cooling

SVC050-P11

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## Relationship between mode of eruption and plagioclase in the basaltic eruption products of Fuji volcano

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<sup>1</sup>Shizuoka Univ, <sup>2</sup>Earth Plan Sci, Kobe Univ

In this work, we analyzed some of the textural features of basaltic eruption products of Fuji volcano to identify the key processes determining the mode of eruptions. Fuji volcano mostly consists of mildly evolved basalt, although its mode of eruption varies from explosive sub-Plinian type to effusive lava flow emplacement. Previous studies suggested that degassing of magmas during ascent mainly determines the mode of eruptions. Jaupart and Allegre(1991) suggested that variation of initial ascent rate of magmas eventually bifurcates the ascent rate by vesiculation and degassing at shallow depth, whereas Woods and Koyaguchi(1994) presented a model that accounts for the two numerical solutions for explosive and effusive eruptions caused by the variation of mass eruption rate. Degassing of water from magmas raises the liquidus temperature of the magma, thus causing degassing-induced crystallization. Because Ca/(Ca+Na) ratio of plagioclase is strongly affected by water content of magmas, we examined the zoning profiles of plagioclase in the basaltic ejecta of Fuji volcano to find water content of magmas where plagioclase crystallized. We examined the effusive samples of the Aokigahara, Kennomarubi, Takamarubi, Hinokimarubi, Kansuyama lava flows and explosive Hoei, Yufune-2, Zunazawa, S-18, S-12, and explosive to effusive eruption products of Omuroyama parasitic cone. The core composition of plagioclase in explosive eruption products generally have high Ca/(Ca+Na) ratio (0.80-0.92), whereas those in effusive eruption products tends to have lower Ca/(Ca+Na) ratio of 0.6-0.75 in Aokigahara and Kenmarubi lava flows, and of 0.75-0.88 in Takamarubi and Hinokimarubi lava flows. Previous experimental studies suggest that equilibrium liquidus plagioclase have high Ca/(Ca+Na) ratio at high water contents, and the core composition of plagioclase suggests that effusive magmas tends to have lower water contents just before the eruption compared with the explosive magmas. It is suggested that magma chamber of Fuji volcano is located at ca. 15km depth, and magma is halted at some depth (1-5km) before eruption where some degassing may induce crystallization of phenocrysts, and successive intrusion/mixing of magmas may eventually cause the final outbreak of vent to form either explosive or effusive eruptions depending on the water contents of magma, mostly determined by the depth of the magma pocket.

Keywords: Fuji volcano, mode of eruption, plagioclase composition, water content of magmas, degassing of magmas

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## Subsurface airflow detection at Miyakejima and Piton de la Fournaise volcanoes from micrometeorological and thermal data

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Subsurface airflow in the unsaturated zone of the soil has been extensively investigated in a variety of engineering disciplines such as mining, nuclear waste or agriculture science. In volcanology, the recent discovery of subsurface airflow close to the terminal cone of Piton de La Fournaise volcano (La Reunion Island, France) provides for the first time insights into the convective behavior of air within the unsaturated layer [1]. The characteristics of the aerothermal system, its occurrence in other volcanoes, its ability to transport heat during quiescent periods and the perturbation of this system before eruptions are the key questions we want to address following this discovery.

In this study, we present observations of subsurface convective airflow within surface-exposed fractures located at the summit of Miyakejima and Piton de la Fournaise volcanoes from micrometeorological and thermal data. At Miyakejima, air exhausts from several fractures with a vertical velocity of tens of cm/s. A difference of temperature of 10-15 degrees Celsius between the fractures and the atmosphere has been measured, while the fractures never cool during the diurnal cycle. In the case of Piton de la Fournaise volcano, several air exits as well entrances have been observed at the summit, suggesting that the aerothermal system may affect the whole volcano. The velocities and temperatures are close to the ones recorded at Miyakejima. Finally, thermal profiles realized across the fractures allow us to define the convective patterns. This study is the first concerning the occurrence of an aerothermal system within another volcano than Piton de la Fournaise. It constitutes a preliminary step to further investigations dedicated to the understanding of the perturbation of such systems before eruptions.

[1] Antoine R., Baratoux D., Rabinowicz M., Fontaine F.J., Bachelery P., Staudacher T., Saracco G., Finizola A., Thermal infrared images analysis of a quiescent cone on Piton de La Fournaise volcano: Evidence for convective air flow within an unconsolidated soil, *Journal of Volcanology and Geothermal Research*, Volume 183, Issues 3-4, 2009, Pages 228-244

Keywords: Volcano, Subsurface Airflow, Convection, Porous Medium, Micrometeorology, Thermal data

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## Shallow ultra-micro earthquakes beneath a long dormant Moedake Lava Dome at Kuchinoshima Volcano

Rika Ogawa<sup>1</sup>, Hiroshi Yakiwara<sup>2\*</sup>, Kengo Iwamoto<sup>1</sup>, Miyo Fukui<sup>1</sup>, Syuichiro Hirano<sup>2</sup>, Shigeru Nakao<sup>2</sup>, Kazuhiko Goto<sup>2</sup>

<sup>1</sup>Faculty of Science, Kagoshima Univ., <sup>2</sup>GSSE, Kagoshima Univ.

Kuchinoshima Volcano, an active volcano which is composed of several lava domes, is located in northern part of Tokara Islands. Moedake Lava Dome, the newest lava dome among ones within the volcano, was formed at 12 or 13 century (Geshi and Nakano, 2007). They also have estimated the occurrence of some phreatic eruptions and no magmatic eruption after the dome formation. We have seen very weak fumarole activity at craters on the dome for long time. Iguchi et al (2003) estimated the rate of thermal discharge from the lava dome to be 0.1MW. On the other hand, the activities of micro earthquakes in other geothermal fields concerning hot water and/or fumaroles have been studied. We, therefore, have performed the seismic observation in and around Moedake Lava Dome to clarify whether micro earthquakes occur or not inside the lava dome. As the result, we detected that the ultra-micro earthquakes occurred beneath the long dormant lava dome throughout the observation period. Most of these earthquakes are high frequency type that P and S phases are identified on the seismographs. Additionally, the high frequency events followed by weak precursor, and nearly monochromatic events were also observed. In the present study, we mainly focus on the hypocenter distribution of the high-frequency earthquakes in the 90 days from September 17, 2010 through December 15, 2010.

We have installed four seismic stations in and around the lava dome to obtain the continuous seismic data. The triggered data files were made from the continuous data to be used for the analysis. We picked up arrival times of P and S waves and maximum amplitudes at each station on a computer display. Because seismic velocity structures in and around the lava dome had been unknown, we examined 18963 seismic velocity models to search feasible velocity structure. We also performed hypocenter determination with the suitable seismic velocity structure. The estimated extents of the P and S wave velocities are 2.7-2.8 km/s and 1.5-1.6km/s, respectively. The calculations of 106 hypocenters throughout the observation period converged with the velocity model.

The most epicenters of the high-frequency earthquakes locate the limited area of about 150 meters radius, which is very close to the largest summit crater. The depths of the earthquakes were 0.0-0.6km below sea level. We estimated the depth of the largest crater on the lava dome to be about 250m by a simple measurement. The altitude of the upper limit of the hypocenters is about 150m deeper than the estimated crater bottom. The Magnitudes of these events were -0.7 and below. We concluded that ultra-micro earthquakes occur quasi-steadily in the quite limited area below the long dormant lava dome.

Keywords: Kuchinoshima Volcano, Moedake, Lava dome, micro earthquake

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## Crustal structure of Sakurajima Volcano and Aira Caldera from receiver function analysis

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Sakurajima volcano, located at the southern rim of the Aira caldera approximately 20 km in diameter, is well known to be one of the most active volcanoes in Japan. As a result of precise leveling surveys and GPS observation from 1995 to 2010, in the caldera, it was found that an inflation source is located at depths of about 10 km beneath the Aira caldera and the volume of the source increased by 0.1 km<sup>3</sup> in the period. Although this source is considered to be a magma chamber, the total volume of the chamber is unknown. Therefore, in order to determine the crustal structure of the Aira caldera and to estimate a total amount of magma accumulated beneath the caldera, we investigated seismic velocity structure of Sakurajima volcano and Aira caldera by a receiver function (RF) analysis.

A RF is calculated by deconvolving vertical component of a waveform of a teleseismic P-wave from its horizontal component. We used more than 3000 waveforms from 500 teleseismic events (epicentral distance: 30-90 deg, magnitude greater than 5.5) to estimate RFs, observed at Hi-net, J-array and seismic stations established by Sakurajima Volcanological Observatory, DPRI, Kyoto University. We extracted vertical and radial components of a teleseismic P-wave between 35 seconds before and 90 seconds after the onset, and vertical components of noise for 125 seconds before the onset. We cut off frequency content higher than 0.56 Hz with a Gaussian high-cut filter and applied an extended-time multitaper (Shibutani et al., 2008) to compute RFs.

Then, we constructed images with RFs migrated to the depth domain with a velocity model JMA2001 and projected on a cross section along WNW-ESE direction. Beneath the caldera, two phases with positive polarity were observed, corresponding to discontinuity with upward decreasing seismic velocity, at depths of 20km and 40km. This suggests the existence of a low velocity layer beneath the caldera like in the Aso caldera (Abe et al. 2010 JVGR).

In order to get the detailed seismic velocity structure beneath the Aira caldera, we used a genetic algorithm (GA) inversion for the obtained RFs. For the GA inversion, we stacked RFs for each station according to back-azimuth. As a result of inversion, a low velocity layer ( $V_S = 2.8$  km/s, 15-20 km in depth) was found in the north western part of the caldera. However, no low velocity layer could be found at the eastern rim of the caldera.

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## Magnetotelluric surveys in and around the Aira caldera (3)

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### 1. Introduction

In the present study, we conducted the electromagnetic investigation including the sea bottom in the area centered on the Kagoshima Bay (Aira caldera) in the north of Sakurajima, southern Kyushu, Japan. A magma reservoir of Sakurajima volcano is considered to exist at about 10km depth beneath the Aira caldera, which was inferred from the geodetic and the seismological observations over many years (Ishihara, 1990; Hidayati et al., 2007). It is presumed that accumulation of the magma to the reservoir is lasting because an upheaval of the ground around the Sakurajima has been observed since the first half of the 1990's. The objective of this study is to clarify the corresponding electrical resistivity structure to the assumed magma reservoir and to the supply routes to the Sakurajima volcano and to a submarine volcano called Wakamiko. Based on the results, we also aimed to verify the conventional image of the magma supply system inferred from the geodetic and seismic observations.

### 2. MT surveys

The surveys are planned for three years from 2009 to 2011 within a framework of Grants-in-Aid for Scientific Research (KAKENHI). We set three traverse lines in the direction of WNW-ESE crossing the Aira caldera and electrical resistivity structures are inferred from the magnetotelluric (MT) measurements on land and on the seafloor along the traverse lines. In fiscal year 2009, we carried out the MT survey at the 10 land sites and the 5 seafloor sites mainly along the middle of three traverse line. A similar survey was conducted along the northern traverse line in fiscal year 2010. The MT data at 30 sites in total were obtained for the last two years. In this presentation, we will report some results of a 2-dimensional inversion, in which the strike direction of the underground resistivity structure is assumed as the north-south against each traverse line.

Keywords: magma reservoir, Sakurajima volcano, resistivity structure, Aira caldera, OBEM



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## Change in the water-soluble components of the ash from Sakurajima in the sequence of its eruptive activity

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Sakurajima, located on the south edge of Aira caldera, is a stratovolcano and one of the most active volcanoes in the world. Recent eruptive phase has been sustained at the summit crater, Minamidake, since October 1955. In 1970s and 1980s, its activity was extremely heightened with numerous powerful explosions, and huge amounts of tephra were discharged from the summit crater.

Strombolian eruptions with swarm of BL-type earthquakes forerun vulcanian explosions with explosion earthquakes, and vulcanian explosions are often followed by continuous ash eruptions with tremor, which is the ordinary sequence of the eruptive activity of Sakurajima volcano (Kamo, 1978). Geophysical observation revealed that hypocenters of BH-type, BL-type and explosion earthquakes are concentrated inside a cylindrical chamber with a radius of 200m, at depths from 1 to 3 km beneath the crater. The cylindrical chamber was a magma conduit, which connected the summit crater and a shallow magma reservoir (Ishihara, 1990; Iguchi, 1994). BH-type earthquake swarm is associated with slow inflation of the summit without significant eruptive activity, whereas BL-type earthquakes swarms during rapid deflation of the summit with strombolian eruptions (Ishihara and Iguchi, 1989). Dominant frequencies of BH-type, BL-type and explosion earthquakes are different from each other although hypocenters of these earthquakes distribute inside the cylindrical chamber beneath the crater, which attributed to difference in source processes affected by the state of the magma conduit (Iguchi, 1994).

Volatile components such as water (H<sub>2</sub>O), fluorine (F), chlorine (Cl), sulfur (S) and carbon (C) are chemical substances dissolved in magma under high pressure. Ascent of magma causes exsolution of volatiles, mostly H<sub>2</sub>O, which provides the driving force for explosions. Further, release of volatiles highly changes viscosity and density of magma, and thus influences the violence of explosions. Examination of the behavior of volatiles can provide a better understanding of eruptive activity and degassing processes from magma. Pristine ash particles react with HF, HCl and SO<sub>2</sub> in eruption plumes, and certain proportions of HF, HCl and SO<sub>2</sub> in gas phase are fixed onto the surface of the particles in water-soluble forms. The HCl/SO<sub>2</sub> value of smoke is equal to the Cl/SO<sub>4</sub> values of the water leachate of ash (Ossaka and Ozawa, 1975; Nogami et al., 2008). Change in the mode of the eruptive activity at Sakurajima is drastic and release of volatiles from magma corresponding to its activity is examined by analysis of water-soluble Cl and SO<sub>4</sub> in volcanic ash.

The Cl/SO<sub>4</sub> values of the ash issued by strombolian eruptions with BL-type earthquake swarm are significantly higher than those of the ash ejected by vulcanian explosions and continuous ash emission. In the sequence of strombolian eruption to continuous ash emission, the Cl/SO<sub>4</sub> values of the ash decline steeply. And re-ascent of magma with BL-type earthquake swarm after continuous ash emission synchronized with return increase of the Cl/SO<sub>4</sub> values of the ash. These results demonstrate that magma intrusion to the shallow zone of the volcanic edifice is detectable through geochemical observation if the swarm of BL-type earthquake is not significant.