SVC45-01 Room:304 Time:May 27 16:15-16:30

# New measures of tremor signals associated with eruptions and lahars

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Tremor signals are observed at volcanoes during heightened eruption activities and debris flows or lahars. Quantifying these signals is important in understanding dynamic processes associated with eruptions and lahars as well as monitoring these activities. The reduced displacement (RD) has been traditionally used as a measure of tremor. However, there are two main problems in the reduced displacement to quantify the size of tremor: (1) the frequency is not defined in estimating RD, and (2) the duration of tremor is not considered. In this study, we propose new measures of tremor signals using high-frequency seismic amplitudes. We use the amplitude source location (ASL) method utilizing high-frequency amplitudes under the assumption of isotropic S-wave radiation for tremor signals. We first estimate the source amplitude (SA) using vertical envelope amplitudes band-passed between 5 and 10 Hz and averaged over a 10-s window that includes maximum amplitudes. We then multiply the correction factor for the geometrical spreading and medium attenuation to the observed vertical waveform, and integrate in time its envelope amplitude with a passband of 5-10 Hz. We estimate the offset value of the integrated envelope amplitude during tremor, which we call the total source amplitude (TSA). SA and TSA may be related to the maximum mass flow rate and total mass volume involved during tremor, respectively. We estimated SA and TSA for tremor signals observed at Tungurahua and Cotopaxi volcanoes, Ecuador. We found that TSA linearly increases with increasing SA for lahar tremor signals, whereas TSA exponentially increases with increasing SA for eruption tremor signals. SA and TSA may be used as universal quantitative measures of tremor signals observed at different volcanoes.

SVC45-02 Room:304 Time:May 27 16:30-16:45

# Seismic signal variation during the transitional phase from repetitive explosion to effusive eruption at Stromboli

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Stromboli volcano, which is famous for Strombolian basaltic explosions, has changed the eruption style from repetitive explosion to effusive eruption in early August 2014. Our research group began temporary seismic and tilt observations at Stromboli volcano in late May and successfully obtained the continuous data throughout the transitional phase of volcanic activity. In this study, we investigate temporal changes in RMS amplitude and in polarization of seismic waves during 4 months of observation as preliminary analyses to understand the transition phases of the volcanic activity. Changes in intensity of volcanic activity will be reflected in RMS amplitude. Polarization of seismic signals will bring us information about source location and excitation mechanism.

Here we calculated RMS amplitudes of velocity seismogram in 8 frequency bands between 0.02 Hz and 5.12 Hz. The broadband seismic data at Stromboli mainly consist of two kinds of signals: very-long-period pulse (VLP pulse) and short-period volcanic tremor (SP tremor). The signals of higher frequencies over 1 Hz correspond to SP tremor. RMS amplitude of SP tremor gradually increased from early June to the evening of August 6, and then it suddenly decreased within two days. The rapid change in RMS amplitude of SP tremor is quite consistent with the beginning of lateral effusive eruption. Therefore, SP tremor amplitude may represent the change in altitude of magma head in the conduit and intensity of gas emission at a shallow depth. On the other hand, VLP pulse has a dominant period at around 10 s as reported in the previous studies (e.g., Chouet et al., 2003). Amplitude change in the lower frequency bands below 0.16 Hz mainly correspond to VLP activity. Contrary to SP tremor, long-term gradual increase in RMS amplitude towards August 6 was not clearly recognized. Instead, VLP activity in June seemed slightly higher than that in July. However, from the end of July, RMS amplitude of low frequency signals rapidly increased until August 6. VLP pulse observed at Stromboli is a kind of explosion earthquake that coincides with the vigorous gas ejection from the active vent. Change in seismic amplitude in low frequency signals may reflect the size of gas slug ruptured at the top of magma column.

Next, we made a list of occurrence time of Strombolian explosions from band-passed seismic data and estimated polarization azimuth and inclination of each VLP pulse. More than 45,000 explosions were identified during about 4 months of observation. Before the effusive eruption on August 6, two azimuthal peaks at around N37W and N32W were recognized. When we visited the volcano for the installation work in middle May, NE and SW crater have been repeating vigorous gas ejection. Therefore, these two azimuthal peaks may reflect the difference of location of explosion. After the beginning of the effusive eruption, it converged at around N32W. Inclination also increased coincident with the change in azimuthal direction, which strongly suggests the subsidence of VLP source. Giudicepietro et al. (2009) performed similar polarization analysis for the 2007 effusive eruption and found the temporal change in polarization of seismic waves after the beginning of effusive eruption in February 2007. Quantitative comparison between our data with their result will be a future study.

From this study, we confirmed the gradual increase in intensity of magmatic activity toward the beginning of effusive eruption in early August. However, there was no distinctive change in the polarization of VLP pulses before the transition from repetitive explosion to effusive eruption. This means that the location of magma in the conduit before the transition was almost stationary. The rapid increase in amplitude of low frequency signals a few days before the effusive eruption suggests the significant changes in the size of gas slug, magma pressure etc. towards the transition.

Keywords: Stromboli volcano, transition process of volcanic eruption, Strombolian explosion, effusion eruption, very-long-period signal

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SVC45-03 Room:304 Time:May 27 16:45-17:00

# Small inflations prior to volcanic earthquakes at Azuma volcano, Japan

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Existence of volcanic fluid in the shallow crust beneath active volcanoes is considered to be closely related to the generation process of volcanic earthquakes such as the nucleation of shear faulting due to the reduction in effective normal stress on the faults and the creation of tensile faults. In addition, the movement of volcanic fluids sometimes causes earthquake swarms and migration of hypocenters. Therefore, the observation and understandings of fluid-related phenomena associated with volcanic earthquakes would be important for understanding of volcanic phenomena. In this presentation, as an example of such interaction between volcanic earthquakes and volcanic fluids, I will report the detection of small inflation phase prior to the occurrence of volcanic earthquakes observed at Azuma volcano, Japan.

Azuma volcano is one of the quaternary volcanoes located at the volcanic front of the Northeast Japan arc, and it consists of overlapping stratovolcanoes of shield volcanoes, lava domes, and pyroclastic cones. Historical eruptions of Azuma volcano were mostly small phreatic eruptions at Issaikyo and O-ana crater at the northern end of the Higashi-Azuma volcanic complex. Just beneath the O-ana crater, occurrence of various types of volcanic earthquakes including volcanic, tremor, low-frequency earthquakes, monotonic/harmonic earthquakes, and Tornillos as well as the volcano-tectonic earthquakes have been reported, and these facts suggest the existence of hydrothermal system and fracture system beneath the volcano. Since 2014, the activity of Azuma volcano become rather high, and subtle ground deformation and increase in seismicity are observed. In addition, there is an earthquake swarm in the middle of January 2015.

To understand the nature of this earthquake swarm, we carefully analyze the seismic and geodetic (tilt) records observed at nearby stations, and detect the existence of small inflation phase just prior to the occurrence of volcanic earthquakes. The inflation phase starts about five seconds before the occurrence of earthquakes, and observed displacement and tilt vectors roughly point to the epicenteral area. The depth of the inflation source determined by fitting of displacement and tilt waveforms is around 2 km, and thus the location of inflation source is just below the source of thermal demagnetization/magnetization detected by the repeating magnetic field survey in this area. These results provide a direct evidence of the interaction between volcanic earthquakes and volcanic fluids, and further study may reveal the generation and triggering processes of shallow volcanic earthquakes.

Keywords: Volcanic earthquake, Volcanic fluids, Earthquake nucleation

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SVC45-04 Room:304 Time:May 28 09:00-09:15

# Eruptive activities of Aso Volcano, 2014-1015

OHKURA, Takahiro[1*] ; UTSUGI, Mitsuru[1] ; YOKOO, Akihiko[1] ; YOSHIKAWA, Shin[1] ; INOUE, Hiroyuki[1] ; KAGIYAMA, Tsuneomi[1]

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Aso Volcano is located in the central part of the Beppu-Shimabara graben and consists of an elliptical caldera measuring 18 km (E-W) by 25 km (N-S), and of central cones with more than 10 volcanoes aligned in the E-W direction. Among central cones, Nakadake volcano is the only active one. The Nakadake is composed of seven craters, which are aligned in a N-S direction. Only the northernmost crater (1st crater) has been active during the past 80 years, and its recent activities are characterized by ash and strombolian eruptions and phreatic or phreatomagmatic explosions. The last strombolian eruptions ended in the middle of the 1990s and after that, surface activities have been restricted to the fumarolic gas and ash emission from the northernmost crater of the volcano accompanying activity of long period tremors (LPT).

Aso Volcanological Laboratory (AVL) has conducted geophysical studies of Aso volcano since 1928, through seismic, geodetic, geomagnetic and geothermal methods.

After 21 year's dormancy, magmatic eruptions were resumed from the 1st crater in November, 2014. In this presentation, summaries of the observation results before and during the 2014-2015 eruptive activities will be introduced.

Keywords: Aso Volcano, Eruption in 2014

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SVC45-05 Room:304 Time:May 28 09:15-09:30

# Preliminary report on sequence and deposits of the 2014-2015 eruption of Nakadake crater, Aso Volcano, Japan

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Nakadake crater, Aso Volcano in central Kyushu, southwestern Japan, began a series of eruptions on November 25, 2014. The activity continues to the present (February 2015), and the ash-fall deposits are distributed mainly southeast of the crater. We focus on the November 25-29 and December 9-11, 2014 eruptive events and their deposits.

The November 25-29 ash-fall deposits extended about 30 km to the east of the source crater with two dispersal axes (E and S trending). The ash distribution is consistent with wind directions changing from southwest-northwest (~15:00 on November 25) to north (between 16:00 on November 25 and 17:00 on November 27). The deposits were 4-5 cm thick (ca. 40 $kg/m^2$) at the southwestern to southern rims. Although well-vesiculated scoriaceous clasts (<30 cm in diameter) were observe on the surface, most of the deposits were black to dark gray sand-sized ash. The total weight of the November 25-29 ash-fall deposits was estimated at about 150,000 tons.

The December 9-11 ash was distributed mainly southwest of the Nakadake crater although it was dispersed to the north and east. The measured dried weights were 2.7 $kg/m^2$ at the southwestern crater rim and 2 $kg/m^2$ at 1.2 km southwest of the vent. The total weight of December 9-11 ash was calculated at approximately 70,000 tons. The event produced mostly sand-sized ash, but also well-vesiculated scoriaceous bombs which could be traced about 4 km of the crater.

The November 25-29 and December 9-11 ash-fall deposits were composed mainly of black to brown vesiculated glass grains although they contained lithics and crystals. Black crystalized glass particles were dominant in the former ash, whereas the proportion of brown lustrous glass grains increased in the latter ash.

The eruptive activity of Nakadake after November 25, 2014 was characterized by continuous ash emission from a vent of 20-30 m across (141 vent) formed near the center of the active crater (Nakadake first crater) and contemporaneous strombolian eruptions producing scoriaceous bombs at the same vent. During the 1989-1990 activity, strombolian eruptions occurred a few months after the beginning of the activity. In contrast, strombolian eruptions were recognized immediately after the initiation of the series of the 2014-2015 eruptions.

Keywords: Aso Volcano, Nakadake, ash eruption, strombolian eruption, eruption deposits

SVC45-06 Room:304 Time:May 28 09:30-09:45

# Temporal color variations of volcanic ashes from Aso Nakadake 2014-2015

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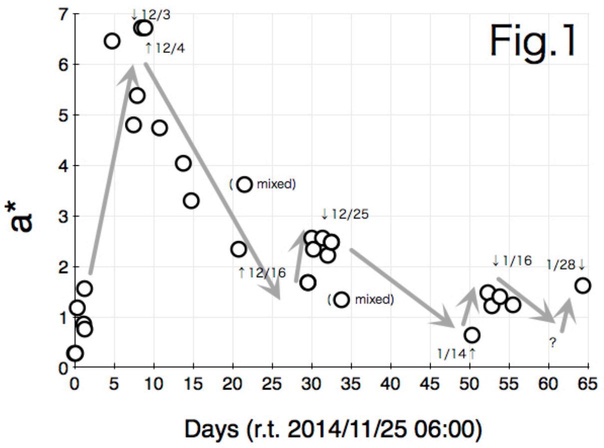
Current eruptive activity of a crater of Nakadake in Aso volcano, since 25th November 2014, provides frequent sampling of fresh magma. In order to understand the time variation of dehydration and oxidation process of magma during ash eruption, we focused on the color of the volcanic ash. We separated a finer (silt size or less in diameter) composition in the volcanic ash by elutriation and measured the color using a color-meter (Minolta SPAD-503). In addition, we measured the colors of a coarser component (0.25-0.5mm in diameter by sieving) in the volcanic ash after grinding for about 30 minutes in an agate mortar. The measured color data will be reported in the L∗a∗b∗color space defined by the CIE (1976). Systematic temporal change was observed over time in the a∗value (redness) for a finer component of volcanic ash samples. The a∗value of the volcanic ash samples showed a clear temporal variation; the redness increased significantly at the beginning of the observation period. Thereafter the redness appears to be reduced while oscillating. Specifically, a∗value is significantly increased from 0.3 to 6.7 through 4th December from 25th November, 2014, significantly decreased from 6.7 to 1.7 through 24th December, a slight increase from 1.7 to 2.5 over 27th December, minimum at 0.6 to 14th January, 2015, a slight increase from 0.6 to 1.5 over 16th January, gradually decline from 1.5 to 1.2 through 19th January, and in 28th January there was a slight increase from 1.2 to 1.6. In contrast the observation in coarse component of volcanic ash that a∗value of fine components have increased significantly over 4th December from 25th November, a∗value of the coarse-grained components have decreased from 0.94 (29th November) to 0.44 (3th December). The observed color change is by oxidation of iron in volcanic ash with atmospheric oxygen (Miyagi and Tomiya, 2002, J.Volc.Soc.Jpn.) and/or with oxidation due to hydrogen degassing (Miyagi et al., 1999; Geochem J.). Since a volcanic plume entraps a large amount of air, the plume temperature drops rapidly below 300 degree-C. As a result, time for iron oxidation in the plume temperature is only limited. Therefore, oxidation of volcanic ash particles occurs selectively for fines component that has a large specific surface area. On the other hand, the oxidation by dehydrogenation can happen in the volcanic conduit where atmospheric oxygen does not flow into. Therefore, color of the fine volcanic ash particles probably record the temperature of the plume. And the color of the coarse-grained volcanic ash particles may reflect the oxidation state of the magma in a volcanic conduit before eruption (Miyagi et al., 2010, Volcano). To the early December from the end of November, the color of fine grain volcanic ash changed to oxidative, and the color of coarse grain changed to a reductive. These observations can be interpreted as reflecting an increase in reductive magma supply and an increase in plume temperature. Since mid-December, volcanic ash contain relatively large amounts (>40%) of magmatic particles such as pale brown glass. Volcanic cloud is expected to be high temperature. However, the a∗value of fine grained ash keeps a low value. We guess that the actual plume temperature is lower than expected, or there exist mechanisms to inhibit the oxidation of the ash particles. We would like to thank the Japan Meteorological Agency (JMA) and to the Aso volcano observatory Kyoto university for their help in sampling.

Keywords: Aso, Nakadake, volcanic ash, color, oxidation, temperature



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SVC45-07 Room:304 Time:May 28 09:45-10:00

# Petrographic description of volcanic products from Aso Nakadake, November 2014 and later

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Aso Nakadake volcano made a magmatic eruption on November 25, 2014.

The earliest stage of activity characteristically includes Strombolian eruption. It discharged scoria and ash around the crater between the night of November 26 and the morning of November 27. The maximum scoria size was 30 cm. We will report petrographic description of scoria and volcanic ash sampled from the crater rim on November 27.

The 5-cm scoria observed under microscope was vesicular with rounded vesicles attaching each other. Phenocrysts and microphenocrysts of olivine, clingyroxene, and plagioclase were found between bubbles. Rare orthopyroxene phenocrysts with reaction rim of clinopyroxene, and a few opaque minerals of phenocryst to microphenocrsyt size were also found. Groudmass is mostly occupied by pale brown glass and shows hyalopilitic texture. Bulk composition corresponds to low-MgO basaltic andesite.

Scoria found northwest of Nakadake crater representing 1989 eruption was analyzed for comparison. It is also vesicular, however, vesicles do not attach each other. Phenocryst and microphenocryst include olivine, clinopyroxene, and plagioclase, with a few orthopyroxene with reaction rim of clinopyroxene and opaque minerals. Plagioclase crystals with honey comb structure are found. Groundmass show intersertal texture, and include microlites and dark brown glass. This scoria is low-MgO basalt.

Volcanic ash sampled near Nakadake crater rim on November 27 contain crystals of olivine, clinopyroxene, and plagioclase. Observed samples do not include orthopyroxene. Some plagioclase crystals show honey-comb structure. Crystals with groundmass or lithic volcanic rock fragments are often found. Few are vescicular. Pale brown glass observed among groundmass of scoria samples from current eruption are few, whereas dark brown glass and microlites are abundant. Altered volcanic rock fragments and crystals are also observed as well as fresh ones.

Miyoshi et al., (2005) classified post-caldera Aso volcanic rocks into seven groups based on chemistry and petrography. The scoria samples we described this time belong to group VII (Orthopyroxene olivine clinopyroxene basalt to basaltic andesite), the most magic group. It includes volcanic rocks from Nakadake, Takadake, Ojodake, Kijimadake, and Komezuka, and is associated with orthopyroxene with clinopyroxene reaction rim and plagioclase with honey-comb structure. The samples we observed in this study include rare existence of orthopyroxene with reaction rim, however, do not include plagioclase with honey-comb structure. Such plagioclase was only found among volcanic ash samples. Petrological characters of volcanic products from Aso volcano are probably explained by the interaction between shallow silicic magma reservoir system and deep-seated mafic magma supply.

Keywords: Aso volcano, Nakadake, eruption, petrographic description, chemical composition

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SVC45-08 Room:304 Time:May 28 10:00-10:15

# Variation of volcanic gas composition during transition from crater lake activity to eruption at Aso volcano, Japan

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Aso volcano started eruption at the end of November 2014 from the summit crater after dry up of the hot acid crater lake. We report variation of volcanic gas composition during the transition from a stable crater lake, dry up then to eruption. The lake water volume decrease started in early 2013 and almost dried up at the end of 2013. High temperature gas emission from the center of the crater was observed in early 2014. Continuous ash emission with small scale strombolian eruptions started in November 2014 at the center of the crater. During the quiescent period, acid gases are discharged from the surface of the hot acid crater lake (crater lake gas) and high-temperature fumaroles at the southern rim of the crater (south fumarole). The crater lake gas composition is similar to a typical high-temperature gases with high SO2 and H2 contents, suggesting that high-temperature gases continuously supplied to the crater lake. The crater lake gas and the south fumarolic gas have contrasting composition with low and high CO2/SO2 ratio, respectively and the contrasting compositions were interpreted as a results of gas-liquid separation in a hydrothermal system. The contrasting CO2/SO2 ratios, however, did not change by the transition from the stable crater lake to dry then to the eruption, implying that the contrasting compositions are not the results of the hydrothermal differentiation but imply the existence of two different magmatic gases, likely separated from a magma at different conditions. The stable gas compositions indicate that the degassing conditions remains similar during the activity transition.

Keywords: Volcanic gas, Crater lake, eruption, Aso volcano

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SVC45-09 Room:304 Time:May 28 10:15-10:30

# Step-wise temporal change in the frequency-amplitude distribution of volcanic long period tremors at Aso volcano

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Introduction

Aso volcano located in Kyushu Island is one of the most active volcanoes in Japan. At the volcano, different seismic phenomena related to the volcanic activity have been observed, including characteristic long period tremors (LPTs) with a period of 15 sec. The origin of LPTs is found to be the tensile crack almost parallel to the chain of the craters. In this study, we monitored LPTs from Aso volcano for around three years of 2011-2014 and found that the activity has changed with time before and after a Strombolian eruption on November in 2014, .

The monitoring of LPTs

We detected and located the LPTs by means of waveform correlations. Seven stations in Kyushu Island have been chosen from F-net broadband seismograph network operated by NIED for the period starting from October 5, 2011 to December 28, 2014. First, we picked up candidates of LPT signal by amplitude threshold at vertical-component band-pass filtered (10-20s) velocity seismogram at the Tomochi (N.TMCF) station, where is located nearby the volcano and provides high-quality data. Next, the delay times between 13 pairs of stations were measured by taking waveform cross correlation. All candidates were located by the grid search by assuming the propagation velocity of 3.5 km/s, which is typical to the Rayleigh wave. Finally, if the source of the candidate is located near the crater, we adopted it as a volcanic LPT.

We found that the LPT activity was separated into several stages particularly before and after the eruption in 2014. From October 2011 to August 2014, the LPT activity had been generally infrequent, except for small bursts with short-term period. After the late August 2014, LPTs began to occur more actively and frequently. The amplitude level also was getting higher with repeating stages composed of a temporary tremor stop and a sudden increase of tremor amplitude. This high amplitude level of LPTs abruptly dropped around 3 hours before the Strombolian eruption on November 25. Just after the eruption, LPTs with a large amplitude occurred frequently again. However, the amplitude level decreased distinctively within 5 or 6 days after the eruption. In total, we detected 65,942 LPTs, while 98.2% of them were occurred within 123 days around the eruption.

Changes in frequency-amplitude distribution

We investigated the frequency-amplitude distribution and its temporal changes. Based on the amplitude level and the Stromboli eruption on November 25, the LPT activity from the late August to the end of December 2014 was divided into five stages and the frequency-amplitude distributions was estimated. The result shows the following sequent transits of the LPTs activity. (1) In the first three stages before the eruption, the distributions were well fitted to the exponential-type distribution. However, the characteristic amplitudes of the distribution increased at stages with increasing time towards the eruption. (2) Just after the eruption, the distribution at the 4th stage obeys preferably to the power law rather than the exponential, which implies the characteristic amplitude had been lost within this stage. (3) In the last stage, the distribution again obeys the exponential law as similar to before the eruption.

Previous studies suggested that the frequency-amplitude distribution at volcanoes is well explained by the exponential distribution rather than the power-law, which implies that the characteristic amplitudes are related to the sizes of the tremor sources at volcanoes. Our results show that the characteristic scale of LPTs at Aso volcano has changed in stages and the scale had been lost in association with the Stromboli-type eruption. It implies the possibility of forecasting eruptions by investigating a transition of the frequency-amplitude of LPTs, which is considered related to the change of the generating system, such as the crack and the hydrothermal system between magma and groundwater.

Keywords: Frequency-amplitude distribution, Volcanic tremor, Long period tremor, Strombolian eruption

SVC45-10 Room:304 Time:May 28 11:00-11:15

# Eruption sequence of Ontake-san (Ontake Volcano) 2014 eruption, based on the images and the field survey.

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Over 60 casualties including missing people were recorded in a phreatic eruption at Mount Ontake (3, 067 m) on 27 September 2014, 11:52. We clarified the eruption sequence of the 2014 eruption, based on the recording images (photographs and videos from climbers), the interviews with Workers in the mountain huts, and the field survey of the summit area. The onset of eruption was sudden without any clear surface precursory phenomena such as ground rumbling and strong smell of sulfur. The eruption started with pyroclastic surges descending about 2.5 km from the craters to SW and moving horizontally about 1 km to N and W beyond summit ridges. That time, rock fragments up to 50 cm showered densely on the summit area: 20-30 cm-across fell about 1.3 km away from the craters. In the summit area, the first 30 minutes of the eruption there was a violent falling rock fragments. Then, the number of falling rock fragments become gradually less. At that time, the plume rose up to maximum high (7 km above the summit); mud rain has been falling from the plume. In about 16:00 after, Lahar generated by the hot water overflowing from the crater, flowed down the Jigoku-dani.

Keywords: Ontakesan, Ontake Volcano, eruption sequence, recording images, interviews

SVC45-11 Room:304 Time:May 28 11:15-11:30

# Numerical Study of Clast Transport of 2014 Ontake Eruption, Japan

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We present an estimate of the ejection conditions and energy of clasts at the deposition points during the 2014 phreatic eruption of Ontake volcano, Japan. When Ontake volcano erupted around noon on September 27, a fine day of the high season of mountaineering, many people were up around the summit of the mountain. 57 people died and 6 people are still missing. 55 out of 57 people died from an injury of clast hitting. In our study, we searched ejection conditions and energy of clasts at the deposition point based on the distributions of clasts and numerical simulations. Multi-particle numerical model including particle-particle collision are used for simulating clast transport. We tried three types of transport conditions. First is a purely ballistic transport, second is a transport with plume, and third is a transport with blast. By considering results of simulations and video images of the eruption together, we found that the third condition is a reasonable estimate. We would like to discuss about the impact energy of clasts and a possible measure for its damage. This study contribute to the establish a standard to prepare for a damage by a clast release from the vent, for example, constructing shelters around vent or putting a restricted area when the seismicity increases.

Keywords: Numerical Model, Hazard mitigation, Volcanic clast, Ontake, Shelter

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SVC45-12 Room:304 Time:May 28 11:30-11:45

# Theoretical Analysis on the Conditions for Generating Pyroclastic Density Current during 2014 Eruption of Ontake Volcano

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I will present a preliminary result on the theoretical analysis on the condition that causes the collapse of an eruption column and generates pyroclastic density currents during the 2014 phreatic eruption of Ontake volcano, Japan by applying an integral model of buoyancy-generating turbulent plume. A video camera recorded the eruption column that was generated soon after the phreatic eruption of Ontake on September 27 has begun collapsed and flew down along the flank of the mountain as pyroclastic density currents. The behavior is significantly different from that of the eruption column spread high in the atmosphere as ash clouds during the 1979 phreatic eruption of Ontake. This implies that there are some differences in the source conditions at the vents among the two eruptions. Therefore, we discussed the physical conditions for the collapse of an eruption columns by applying a steady-state one-dimensional integral model of a turbulent plume that were modified to include the effect of the significant thermal expansion of entrained air to increase the buoyancy flux in an eruption column for properly describing the characteristic feature of a volcanic eruption column. The theoretical analysis based on the integral model yields that an eruption column collapses when a value of a constant that is directly proportional to the radius of a volcanic vent and the third root of the initial density of a gas-particle mixture in an eruption column and inversely proportional to the two-thirds root of the ejection speed of a gas-particle mixture at a vent and the two-thirds root of the temperature difference between inside and outside of the eruption column at the vent height is large. This implies that the pyroclastic density currents occurs during the 2014 eruption because the initial density of a gas-particle mixture in the eruption column is larger than that in 1979 eruption column because fields surveys indicate that there are no significant difference in the size of the vents and the temperature of the ejected materials among the 1979 and 2014 eruptions. The field surveys also indicate that the density of a gas-particle mixture of the 2014 eruption should have been significantly larger than that of the 1979 eruption because the former generated the largest eruption at the initial stage when the steam conduit under the ground was not yet completely established and the eruption involved a large amount of surrounding rocks.

Keywords: Ontake volcano, eruption column collapse, pyroclastic density current, integral model

SVC45-13 Room:304 Time:May 28 11:45-12:00

# Spatial temporal evolution of seismicity before and after the 2014 phreatic eruption of Mount Ontake

KATO, Aitaro[1*] ; TERAKAWA, Toshiko[1] ; YAMANAKA, Yoshiko[1] ; MAEDA, Yuta[1] ; HORIKAWA, Shinichiro[1] ; MATSUHIRO, Kenjiro[1] ; OKUDA, Takashi[1]

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On 27 September, 2014, Mount Ontake caused a phreatic explosion, spraying ash, gas and debris on the surrounding areas. The height of the ash column reached around 7000 m. Earthquake catalog constructed routinely shows that a micro-seismicity (Magnitude $<1.0$) beneath the summit sharply increased around two weeks before the eruption. However, the preparation stage of the phreatic eruption is not well constrained. In order to understand the physical process associated with the phreatic eruption, we relocated earthquakes including two low-frequency earthquakes beneath the summit using double differential travel times extracted from waveform cross-correlation method, and revealed a spatial and temporal evolution of seismicity applying the matched filter technique to continuous waveform data from 23 August to 30 September, 2014.

The relocated hypocenters aligned along a vertically dipping plane, oriented to NWN-SES. The size of the vertical plane was approximately 0.5 km length and 1 km width. The distribution of hypocenters well matched with alignments of volcanic vents identified by remote sensing images (GSI). Earthquakes before the eruption were tightly clustered and located at relatively deep depths. In contrast, earthquakes after the eruption occurred at depths shallower than the preceding seismicity by around 0.5 km. The vertical alignment of hypocenters implies an intrusion of vapor/gas into volcanic vents near the summit.

Using these relocated hypocenters as template events, we searched similar waveforms to the template events from continuous waveform data. The total number of the newly detected events was greater than 2600. The newly detected seismicity initiated from the end of August and gradually increased to the middle of September, 2014. Following this phase, the seismicity had a peak on the middle of September, and kept the relatively high rate, while slightly decaying. The number of low-frequency earthquakes increased, having a delay of about 5 days from the peak of regular earthquakes. About ten minutes prior to the eruption, the hypocenters migrated to shallower depths and expanded to both NWN and to SES directions, accompanying with typical volcanic tremors. The amplitudes of volcanic tremors increased at an accelerated rate before the eruption. These observations suggest that pressurized vapor/gas rapidly intruded into shallow conduits during final ten minutes, resulting in the 2014 phreatic eruption.

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SVC45-14 Room:304 Time:May 28 12:00-12:15

# Temporal changes in earthquake focal mechanism solutions following the 2014 eruption of the Mt. Ontake volcano

TERAKAWA, Toshiko[1*] ; KATO, Aitaro[1] ; YAMANAKA, Yoshiko[1] ; MAEDA, Yuta[1] ; HORIKAWA, Shinichiro[1] ; MATSUHIRO, Kenjiro[1] ; OKUDA, Takashi[1]

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On 27th September in 2014, the Mt. Ontake volcano caused phreatic eruption after an interval of 7 years. In order to understand physical processes associated with the phreatic eruption of the Mt. Ontake volcano, we investigated relationship between the tectonic field and focal mechanism solutions of VT microseismicity in the Ontake region.

We applied a method of stress inversion, termed the CMT data inversion method (Terakawa & Matsu'ura, 2008), to 550 focal mechanism solutions of seismic events ($M > 1$), and estimates the tectonic stress field in the Ontake region. The stress pattern was characterized by strike-slip faulting with the maximum principal stress axis in the direction of WNW-ESE. On the other hand, we estimated focal mechanism solutions of about 70 VT events below the craters during September 2014 to January 2015 using S/P amplitude ratios as well as polarities of P wave first motion (Hardebeck & Shearer, 2003). We found that events before the eruption were mainly normal faulting with east-west tension, while those after the eruption were reverse faulting with east-west or north-sourth compression. The hypocentral depths became $<1$ km shallower after the eruption, but the epicentral locations were almost the same.

To measure cocnsistency of focal mechanism solutions with the regional stress pattern, we evaluated misfit angles between actual slip vectors and theoretical slip vectors expected from the regional stress pattern in the Ontake region, based on the idea that seismic slip occurs in the direction of the resolved shear traction acting on a pre-exsiting fault (Wallace, 1951; Bott, 1959). The events of reverse faulting after the eruption were well controlled by the regional stress field. They may be related with some physical processes of crustal contraction follwong the emission of vocanic products like debris, volcanic ashes and steam. However, the events of normal faulting before the eruption were inconcictent with the regional stress pattern, although these events may be linked with inflation of dike. This suggests that the local stress field at depths of 2-3 km below the craters would have temporally changed controlled by inflation, or that the stress field would be heterogeneous originated by vocanic processes. In any case, events of normal faulting just below the Mt. Ontake may show one of the signs of an increase in volcanic activity.

Keywords: volcano, eruption, VT earthquakes, focal mechanism, stress field

SVC45-15 Room:304 Time:May 28 12:15-12:30

# Preparatory process for the 2014 eruption in Ontake Volcano estimated from precise leveling (2006-2014)

MURASE, Masayuki[1*] ; KIMATA, Fumiaki[2] ; MIYAJIMA, Rikio[2] ; MORI, Hitoshi, Y.[3] ; YAMANAKA, Yoshiko[4] ; HORIKAWA, Shinichiro[4] ; MATSUHIRO, Kenjiro[4] ; OHKURA, Takahiro[5] ; YOSHIKAWA, Shin[5] ; INOUE, Hiroyuki[5] ; MISHIMA, Taketoshi[5] ; SONODA, Tadaomi[6] ; MATSUSHIMA, Takeshi[7] ; UCHIDA, Kazunari[7]

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A preparatory process for the 2014 eruption in Ontake Volcano was estimated from vertical deformations detected by precise leveling. We installed leveling routes in the east part of Ontake volcano and conducted the precise leveling survey since 1999 (Kimata et al., 2004).

Here we focused on the vertical deformations during 2006-2014 to discuss the preparatory process for the 2014 eruption. Before 2006, slight uplift was detected just above the region of the most active earthquake cluster. The uplift, however, was detected around summit area after 2006. Despite the occurrence of eruption in 2007, slight uplift was continued to the 2009. The total value of the uplift during 2006 -2009 was about 1cm. The leveling survey was conducted with small part of the leveling routes in 2013. Although the result from the leveling survey with small distance is strongly affected by reference point, the result suggests that the slight uplift might be continued to the 2013. In the survey after 2014 eruption, the subsidence with about 1 cm was detected.

Based on the leveling results, possible preparatory process for the 2014 eruption in Ontake Volcano was as follows. The magma intruded to the shallow part of Ontake volcano in 2006 and small eruption occurred in 2007. The magma supply, however, was continued slightly after 2007 eruption and then 2014 eruption occurred. After 2014 eruption, magma with shallow part was deflated.

Keywords: Ontake volcano, precise leveling

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SVC45-16 Room:304 Time:May 28 14:15-14:30

# Development and evaluation of UAV hanging type sampling device for pyroclastic materials

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Observation method of active volcano is limited depending on the access restricted area for human safety. Therefore, technologies of unmanned volcanic explorations have been required and tele-operated mobile ground robots have been developed in Japan and Italy until now. As a result, it is becoming possible to get data of the inside of the restricted area, for example digital images from cameras and numerical values from sensors. However, there is no practical sample-return method for obtaining pyroclastic materials from such restricted areas. Therefore, in this research, I aim to realize an unmanned sample-return system, and I develop and evaluate a sampling device for obtaining pyroclastic materials that is most important in this system.

The sample-return system consists of 3 parts: (1) a multi-copter, (2) a sampling device, and (3) a tether. The multi-copter that hangs the sampling device with the tether flies from the out of the restricted area. The automatic flight setting is based on the GPS data. On the target area, the multi-copter comes close to the ground and releases tether to touch down the device to the ground, and keeps the altitude for sampling. During the hovering, the device conducts sampling. After sampling the multi-copter rises up, and comes back to the departure point.

The roller system is adopted for sampling device. Its size has a length of 180mm, a width of 190mm, a height of 130mm and its weight is 840g. It gathers pyroclastic materials by the following procedure: (1) the pair of rollers that rotate mutually and reversely shaves off pyroclastic materials on the weak ground, (2) the rollers catch up the pyroclastic materials and (3) they are captured into the buckets. The parallel link plays a role that changes the distance between two rollers to obtain various sizes of samples. The maximum particle size of pyroclastic materials that the device can obtain is 25mm (The maximum particle size of pyroclastic materials that the device can put between rollers is 65mm).

Sample size distribution was measured to evaluate the performance of this sampling device. Simulated standard sample in this work is ”Fuji sand”. Fuji sand having particle size of 4mm or less, Fuji sand having particle size of 4mm or more and mixtures of them were used as simulated field. The result of these experiments shows that the developed device can obtain samples that are approximately 100 g in weight and approximately 15 mm in depth. Furthermore, when the particle size of the weak ground is even-grained, the device obtains the same particle size distribution as the ground. However, when the particle size of the weak ground is uneven-grained, the device obtains samples containing a high proportion of large particle size.

Field test was held after evaluations by simulated standard sample in laboratory. The target fields were Mt. Asama, Sakurajima, and Izu Oshima. In these field tests, the sample-return system worked properly to obtain samples and succeeded in performing an autonomous sample-return motion based on GPS navigation of multi-copter’s flight system.

Keywords: sampling, sample-return, pyroclastic materials, UAV

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SVC45-17 Room:304 Time:May 28 14:30-14:45

# Development of volcano observation technology by cosmic ray muon radiography with nuclear emulsion

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Muon radiography is the non-destructive testing technique of large-scale constructions with cosmic ray muon. Cosmic ray muon has high penetrating power and it always comes from the whole sky. In the same way of taking a X-ray photograph, we can obtain integrated density of constructions. We had ever applied this technique to nuclear reactors, volcanos and so on, tested the principle.

At now, in order to more widely deployed this technology, we are developing it from both sides of the data-processing system and the detector. Our detector, nuclear emulsion (Fig), is high resolution three dimensional track detector. This detector has mrad angular resolution. In Nagoya University, we launched emulsion manufacturing equipment at 2010. It has become possible to flexible development of our detector. An important factor is the temperature characteristic to withstand the outdoor observation as a detector to be used in the muon radiography. In addition, the features which requires no power supply and can observe in a large area suitable for muon radiography. In this talk, I talk about basic characteristics (especially sensitivity and thermal properties) of nuclear emulsion and detector structure.

Keywords: Volcano, Muon radiography, Nuclear emulsion

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SVC45-18 Room:304 Time:May 28 14:45-15:00

# Very Long Range Muography for Monitoring a Volcano Eruption

KUSAGAYA, Taro[1*] ; TANAKA, Hiroyuki[1]

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A radiographic imaging technique with cosmic ray muons (muography) offers us a tool to remotely observe a hazardous erupting volcano. Practical muographic observations of a volcano from a distance are, however, difficult and thus, various observations have been carried out in the vicinity (<1.5 km) of the volcano peaks in order to suppress a background noise and enhance an image. Here, we created a muographic image right below a caldera floor of an erupting Shinmoe-dake volcano, Japan by locating our muography telescope at a distance of 5 km from the peak. Shinmoe-dake volcano started to erupt on January 19, 2011, and within less than one month, the ejected lava almost completely filled the caldera, and completely changed the topography of its caldera floor. The resultant image showed a low-density region underneath the western part of the newly created caldera floor, indicating the existence of a void there. We anticipate that our novel muography will be a practical tool to monitor and predict an eruption sequence in the near future.

Keywords: cosmic ray, muon, muography, volcano, eruption, remote

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SVC45-19 Room:304 Time:May 28 15:00-15:15

# A discussion on the synthetic reflection seismogram derived from the sonic log obtained at the academic drilling hole in

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A synthetic reflection seismogram derived from well-logging at the drill hole in 2000's craters of Usu volcano is presented. The purpose is understanding shallow structure which controls volcanic phenomena at the surface through correlating with the seismic section. Such direct correlation has not done in the vicinity of active crater.

An academic drilling project in 2000's crater of Usu volcano has run since 2009 to 2013, as a part of Observation and Research Program for Prediction of Earthquakes and Volcanic Eruptions. The drilling point is located at the maximum upheaval point in the swelling area associating 2000's activity. The seismic reflection profiling is executed through the drilling point in order to detect structural evolution associating decaying volcanic activity. The drilling point is located at 350m from the north end of the seismic profile.

Core samples and logging data were fully obtained down to 500m depth from 90m below the surface. P-wave and S-wave velocity was measured at each 1m with susupention type sonde in the hole. Typical specimens were choosed from the core samples and their seismic velocity and density were measured in the laboratory under natural, wet and dry states.

Density is necessary to derive synthetic seismogram from logging data. However the logging data does not include direct measurement of density. Then, empirical formulas were derived from laboratory measurement of the specimens and used to estimate density from velocity at depths.

Although the target zone was beneath the water table, the formula for the natural condition is used to derive the density for the actual calculation. In the density derivation, typical velocities at the depth are obtained through the median filtering with 10 point length. Surface velocity down to top of loggong data is interpolated linearly from the result of seismic profiling in the vicinity.

Synthetic reflection coefficient was calculated for each 1ms over 0.288s from 0.134 to 0.422s, whose input was the logging velocities and derived densities. Bandpass filetered seismogram were compared with the seismic profile, whose passband is 12-48Hz with refer to predominant frequency about 24Hz in 0.1 to 0.2s of the seismic profile. Four clear reflection events at 0.161, 0.209, 0.279, 0.307s are found in the filtered synthetic seismogram.

Although clear event at 0.27s is observed in the profile, the latest event at the same time in the synthetic is not clear. Lateral variation in little bit later reflection horizon is observed at 0.307s in the profile. The event at 0.209s in the synthetic is correlated clearly in the profile. The event at 0.16s in the synthetic looks clearer than that in the profile.

Because descrepancy in the appearance may be caused by choise of the empirical formula for the density derivation, Other formulas were tested in the obtained synthetics. There was no clear amplitude difference in the obtained synthetics except for that of 0.279s . It is concluded that the empirical formular is acceptable and synthetic is fair approximation of the zero-offset seismogram at the site.

Keywords: Usu Volcano, Academic drilling, Well-logging, Synthetic seismogram, Active crater

SVC45-20 Room:304 Time:May 28 15:15-15:30

# Crust and Upper mantle structure revealed by simulated annealing inversion of receiver functions

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Mt. Fuji has ejected a huge amount of basaltic products during the last 100,000 years. Even though the region around Mt. Fuji is tectonically active, the seismicity below Mt. Fuji is low, resulting in little knowledge about the seismic structure there. To gain more insight into the magma-plumbing system, we obtain the seismic structure beneath Mt. Fuji by the receiver function (RF) technique. Cross sections of RF amplitudes reveal two distinct velocity boundaries around Mt. Fuji, at depths of 40?50 km and 20?30 km, which we interpret to be the boundary between the crust-mantle transition layer (CMTL) and the uppermost mantle of the Izu-Bonin arc (IBA) and the velocity discontinuity just below the region where low- frequency earthquakes (LFEs) of Mt. Fuji have occurred, respectively. The velocity boundary at about 50-km depth shows a clear gap just beneath Mt. Fuji. We suggest that this gap represents a weaker velocity contrast zone through which the magma of Mt. Fuji ascends from the Pacific (PAC) plate. We investigate the velocity structure around Mt. Fuji by simulated annealing inversion of receiver functions. Velocity structure are constrained by combining receiver functions and dispersion curves. Each dispersion curve is calculated using the velocity structure obtained from an ambient noise surface wave tomography by Nishida et al. (2008). Preliminary calculation reveals that a low-velocity region around 20 km depth explains all the characteristics of RFs near Mt. Fuji, leading us to interpret the high velocity boundary just below the LFE region as the lower boundary of Mt. Fuji's magma chamber.

Keywords: receiver function analysis, seismic structure below volcanoes, Mt. Fuji

SVC45-21 Room:304 Time:May 28 15:30-15:45

# Crustal deformation around Azumayama Volcano

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Azumaya Volcano is an active volcano located in northeastern Japan and have erupted at and around the Oana crater within recorded history, and currently a large fumarolic area extends across its southern and eastern flanks (Japan Meteorological Agency, 2013). Recent seismicity between 2001 and 2009 are characterized as repeating active and quiet periods with intervals of around 2 to 3 years, while it shows steady activity after 2010 (Japan Meteorological Agency, 2014a). Seismic activity looks slightly declined after 2013, however, it gradually increased since October 2014. A volcanic tremor with a duration of about 35 minutes occurred on December 12, 2014, and the monthly number of volcanic earthquakes in December 2014 counted 576, which is the largest since November 1998 (Japan Meteorological Agency, 2014b).

Japan Meteorological Agency (JMA) deploys 6 continuous GPS sites around the volcano. The data are processed using the precise point positioning strategy (Zumberge et al., 1997) of GIPSY-OASIS II ver. 6.2 with IGS08 precise ephemerides and GMF mapping functions (GMF, Boehm et al., 2006). Since the wide area of northeastern Japan still suffers the long lasting postseismic deformation following the 2011 Tohoku-oki earthquake (M9.0), we try to extract volcanic deformation related to the unrest of the volcano by fitting an approximation function of time consisting of linear, logarithmic, annual, and semi-annual terms. The coefficients of each term are estimated by the least-squares method for the period between April, 2011 and September, 2014.

Resulting displacements around the volcano for the period between October to December, 2014 show radial expansion and slight uplifting, which can be roughly modeled with an point pressure source at a depth of 3.4 km just beneath the summit of Issaikyozan.

Acknowledgement
Authors are grateful to the Japan Meteorological Agency and the Geospatial Information Authority of Japan for providing GNSS data used in this paper.

Reference

Boehm et al. (2006), GRL, 33, L07304, doi:10.1029/2005GL025546.
Japan Meteorological Agency (2013), http://www.data.jma.go.jp/svd/vois/data/tokyo/STOCK/souran_eng/menu.htm
Japan Meteorological Agency (2014a), http://www.data.jma.go.jp/svd/vois/data/tokyo/STOCK/kaisetsu/CCPVE/shiryo/130/130_no06.pdf

Keywords: volcanic activity, crustal deformation, GNSS

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SVC45-22 Room:304 Time:May 28 15:45-16:00

# Volcanic deformations around Mt. Meakan detected by GPS observations after the 2008 eruption

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Mt. Meakan sits the eastern Hokkaido, Japan. The newest magmatic eruption occurred about 1000 years ago. After that eruption, phreatic eruptions happened sporadically. Recently, small phreatic eruptions occurred in 2006 and 2008. From the GPS data observed by JMA and Geological reseach department of Hokkaido, they didn't find the volcanic deformation near the central crater. In this study, we used the GPS data to discuss the process of magma movement beneath Mt. Meakan.

The GPS observations around Mt. Meakan were started in 2006, there are 8 stations. The 2 of them are continuous stations. Each observation period was a few days to several weeks. These data are analysed with the continuous GPS data of JMA and GSI. For data analysis, we use the program "RTKPOST". The GEONET station RKB(020873) is chosen for the reference station. RKB station is far enough from the volcano to be unaffectedby the volcanic deformation of Mt. Meakan. Using the data at four GEONET stations surrounding our network, we removed the tectonic movements and the coseismic deformations. The results show the expansive movement after 2008 eruption around Mt. Meakan. Similar expansive deformation were confirmed from continuous data at GEONET station, AKN2. The deformation started on October 2008, and continued to June 2009 at AKN2. The deformation at AKN2 came up to about 2cm. We tried to estimate the pressure source of this deformation with an inversion method. We used the models of a point pressure source (Mogi, 1958) and an open crack source (Okada, 1985). The best fit model is a point pressure source located in about 4km to the south-east and 6km in depth, and its volume change is $5*10^6 m^3$. This model corresponds with the data of InSAR. In our presentation, we discuss these results in detail.

Acknowledgements: We want to thank Mr. Okuyama. His support were invaluable. We wish to thank JMA to give the GPS data. We used the GNSS data observed by GSI. We also used the program RTKPOST developed by Mr. Takasu, the MATLAB program okada85.m constructed by Mr. Franois Beauducel, invmogi_sa.m by Mr. Nico Fournier. We would like to express my gratitude to them.

Keywords: volcanic deformation, GPS, Mt. Meakan

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SVC45-23 Room:304 Time:May 28 16:15-16:30

# Reexamination of concentration of hot spring gas from Kurokami well at eastern flank of Sakurajima

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Concentrations of $CO_2$ and $H_2$ gas from the well at Kurokami, 4.0 km east of the Showa crater, where vulcanian eruptions have frequently repeated, have been monitored by sampling for 5 minutes every day. Concentrations of the gases are measured by devices and are calibrated every 3 months.

Concentrations of $CO_2$ and $H_2$ suddenly increased in March or April, 2009 and reached peaks in July, and then were followed by increase in eruptivity from October 2009. Increase in the concentrations were precursory phenomena to increase in vulcanian eruptivity.

The concentrations decreased from July 2009, but they showed different manners of decaying. Concentration of $CO_2$ normally decreased in summer and increased in winter, however it did not decrease in the summer in 2013. In summer, especially in June, the peak of rainy season, precipitation increased. Temperature of the hot spring decreased while a large amount of precipitation. This implies rain water diluted hot spring including a large amount of $CO_2$, as the result, observed gas concentration decreased in summer. In the summer in 2013, only a small amount of precipitation was recorded. Concentration of $CO_2$ has been influenced by precipitation. Concentration in winter while lower influence by rain, gradually decreased from 2010 to 2015.

Concentration of $H_2$ gradually decreased from July 2009 and the decay shows exponential pattern. Residual of measured concentration from the exponentially decaying curve is well correlated with atmospheric pressure; increase in residual in summer and decrease in winter. Concentration of $H_2$ decreased exponentially affected by atmospheric pressure.

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SVC45-24 Room:304 Time:May 28 16:30-16:45

# Temporal volume change of deformation sources of Sakurajima volcano during activity at Showa crater

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During active period of vulcanian eruption at summit crater of Minami-dake (1974 — 1992), ground subsidence was detected by precise leveling, and 2 deflation sources were estimated at a depth of 10 km beneath Aira caldera and at a depth of 3 km beneath Minami-dake [Eto, 1989, DPRI annual]. Eruptive activities at Showa crater started in June 2006. After 2009, ground inflation was detected with increase in eruptive activity during the periods of October 2009 — May 2010 (2009 event), October 2011 — March 2012 (2011 event) and January — June 2013 (2013 event). Ground deflation also detected after 2009 and 2013 events (May — September 2010; July — October 2013), and before 2011 and 2013 events (March — September 2011; July — December 2012).

We performed combination analysis of GNSS, tilt and strain data for 2011 event assuming 3-pressure-source model. 2 inflation sources are located beneath Aira caldera at a depth of 9.6 km depth (A-source) and beneath Kita-dake at a depth of 3.3 km (K-source), and a deflation source is located beneath Minami-dake at a depth of 0.7 km (M-source) [Hotta et al., 2014 AGU Fall Meeting].

In this study, we estimate temporal volume change of each source after 2009 on the assumption that sources do not change their position at A-, K- and M-sources of 2011 event. A- and K-sources repeat inflation and deflation on a 1- to 1.5-year cycle. However, start of the change of K-source is simultaneous or several months earlier than that of A-source. Overall trend of volume change of A-source is inflation. On the other hand, K-source shows no significant inflation or deflation trend. M-source inflates several months before 2009 and 2011 events and deflates during these events, which is considered to be magma migration and ejection, respectively. M-source is continuing deflation after 2011 event. Assuming DRE of 2500 kg/m$^3$ for magma, we convert amount of ejected magma from weight of ejected ash and then estimate volume of migrated magma between sources. Magma injection progressed in inflation events, but stopped during other periods. It is considered that magma injected intermittently toward A-source. Amount of magma ejection increased in 2009, 2011 and 2013 events, but is less than that of magma injection from A- to K-source. On the other hand, it is in reverse for deflation periods.

Keywords: Sakurajima volcano, GNSS, tiltmeter, strainmeter, Mogi model, temporal change

SVC45-25 Room:304 Time:May 28 16:45-17:00

# Sampling volcanic plume using aircraft for remote determinations on the temperature of fumaroles: Sakurajima volcano

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Molecular hydrogen ($H_2$) in fumarolic gases shows the hydrogen isotope exchange equilibrium with coexisting $H_2O$ at a temperature more than 400 ℃. Recently, we developed a new remote temperature sensing using the characteristics of D/$^1$H ratio of $H_2$ (HIReTS). In this method, the D/$^1$H ratio of fumarolic $H_2$ is obtained remotely from the observation of volcanic plume, and the outlet temperature of the fumaroles is estimated from the D/$^1$H ratio, assuming that the hydrogen isotope exchange equilibrium is quenched within volcanic plume during the process of admixture between fumarolic gases and air. In the previous studies applying HIReTS in active volcanoes, such as Aso and Satsuma-Iwo volcano in Japan, the volcanic plumes were taken at the rim of each volcanic crater, at the distance of a few hundred meters from fumaroles. Direct access to such volcanic crater rims, however, is neither practical nor safe in many highly active volcanoes. In general, volcanic plumes spread laterally at the height close to the summit of each volcano where the plumes are ejected. As a result, we must utilize some flying devices, such as aerial vehicles, balloons, or kites, to take the samples of volcanic plume in safety area distant from fumaroles, for the aim of applying HIReTS to highly active volcanoes.

In this study, we used an aerial vehicle to take samples of volcanic plume ejected from highly active Sakurajima volcano in Japan, to determine the outlet temperature of fumaroles remotely by using HIReTS, at the distant of more than 3 km from the fumaroles. Sakurajima volcano has continued its explosive activity at the summit crater since 1955 so that nobody dared to determine the outlet temperature of fumaroles directly.

The average $H_2$ concentration of the plume samples taken during two flights on Sep. 2014 was 0.76 ppm (from 0.60 to 1.29 ppm), while that taken apparently outside the volcanic plume was 0.60 ppm. Besides, the reciprocal of the $H_2$ concentration in the plume samples showed a good linear relationship with the D/$^1$H ratio ratio. By extrapolating the linear relationship to exclude the contribution of the tropospheric $H_2$, we estimated that the $\delta$D value of the fumarolic $H_2$ to be -134.6±6.5 ‰ (vs. VSMOW) and the outlet temperature to be 1050±80 ℃, assuming global average $\delta$D value of magmatic $H_2O$ to the fumarolic $H_2O$. The estimated temperature was close to the melting point of lava in the volcano, implying that magma have been close to the surface in the volcano, at least during the observation.

Keywords: fumarolic gases, volcanic plume, molecular hydrogen, stable isotopes, remote temperature sensing, Sakurajima volcano

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SVC45-26 Room:304 Time:May 28 17:00-17:15

# Repetitive sulfur dioxide flux measurements of Kuchinoerabujima volcano, Japan

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Kuchinoerabujima is a remote volcanic island located about 15 km NWW of Yakushima island, Japan. The volcano erupted from Shindake crater on Aug. 3, 2014, after dormancy of 34 years. Sulfur dioxide flux which was about 60 ton/day two month before the eruption had increased to several hundred ton/day after the eruption (JMA, Aug. 2014). The flux continued to increase and emitted 500 and 700 ton/day in Oct. and Nov. 2014, respectively (JMA, Nov. 2014).We started repetitive sulfur dioxide measurement at Kuchinoerabujima volcano in response to the ongoing rise of the flux.

In this study, we deployed a UV spectrometer system which has been automated for the most of measuring procedures, and carried out measurements onboard a regular liner between Yakushima and Kuchinoerabujima islands. The liner, Ferry Taiyo makes one round trip a day between the islands and navigate off the south coast of Kuchinoerabujima island. Due to predominant northerly wind from autumn to spring, we can expect repetitive sulfur dioxide traverse measurement on board the liner at least for the season above.

The measurements started in the end of Nov. 2014. Although, there have been some missing observations due to unfavorable wind direction, bad weather, liner cancellation and data transferring troubles, we made 26 days of flux measurements out of about 70 days by the beginning of Feb. 2015. The flux kept about 700 ton/day until the end of Nov. 2014, but it went over 1000 ton/day soon after the beginning of Dec. 2014 and has been in the high flux range of 1000 to 2500 ton/day for the most of the measurements at least until the first week of Feb. 2015. This flux range is comparable to that of Sakurajima volcano and of Aso volcano in active period, and implies significant magma degassing beneath Kuchinoerabujima volcano. In our presentation, we will show instrumentations and monitoring methods, and discuss the flux variations of Kuchinoerabujima volcano.

Keywords: Kuchinoerabu Volcano, sulfur dioxide, flux

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# The variation in the chemical and isotopic composition of fumarolic gases at Kusatsu-Shirane volcano and the implication

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Introduction

At Mt Kusatsu-Shirane the number of volcanic earthquakes have increased since Mar 2014. The inflation of volcanic body occurred simultaneously (HP of Japan Meteorological Agency). In Mar 1976, a steam explosion happened at Mizugama crater at Mt Kusatsu-Shirane. Ossaka et al (1980) detected an increased SO2/H2S ratio in the fumarolic gas composition of Kitagawa geothermal area 8 months prior to the eruption. In 1982 and 1983, steam explosions happed within Yugama crater bringing a significant change in the chemical composition of the lake water in Yugama crater (Ohba et al 2008). Steam explosion is the break of a hydrothermal reservoir. The volatiles in the reservoir is supplied to fumarolic gas and crater lake. For the understanding and prediction of steam explosion, the observation of fumarolic gas and the lake water is important. In this study, fumarolic gases were sampled after the unrest on Mar 2014. An ongoing process at the depth of Mt Kusatsu-Shirane is discussed.

Sampling and analysis of fumarolic gas

Fumarolic gases were sampled in July 2014 at two points (K1 and K2) in the Kitagawa geothermal area 500m north of Yugama crater, at one point (M1) in the Manza geothermal area 2.4km northwest of Yugama crater, and at one point (S1) in the Sesshou geothermal area 3km southeast of Yugama crater.

The fumarolic gases were sampled and analyzed along the method by Ozawa (1968). The fumarolic gas was cooled by use of a double glass tube to obtain condensed water for the determination of isotopic ratios by use of an IR laser cavity ring down analyzer (Picarro).

Result

The fumarole K1 discharged gas with the presser highest in the Kitagawa geothermal area. The feature of discharge was common to the K1 in 1999. The outlet temperature of K1 was 92.4C slightly lower than the temperature 104C in 1999. The outlet temperature of K2, M1 and S1 was 94.1, 96.2 and 94.5C, respectively, close to the boiling temperature of water at the local altitude. The SO2/H2S molar ratio of K1, K2, M1 and S1 was low as 0.013, 0.013, 0.019 and 0.011, respectively. Eight months prior to the Mizugawa eruption in 1976, Ossaka et al (1980) detected the SO2/H2S ratio as high as 0.29 in fumaroles in the Kitagawa geothermal area. The current CO2/H2O ratios of K1 and K2 were 0.044 and 0.042, respectively. The value of K1 is about 8 time larger than 0.0052, which is the ratio of K1 in 1999. Ossaka et al (1980) detected similar large ratio, 0.059 8 months prior to the Mizugama eruption in 1976. The H2/H2O molar ratios of K1 and K2 was 2.7E-7 and 2.6E-7. In 1999, the ratio of K1 was 2.6E-7, almost same as in the current value. The isotopic ratio of H2O in fumarolic gases was similar to the ratios in 1999 and 2000.

Discussions

The high CO2/H2O ratio found in K1 and K2 might be explained two ways. If the condensation of water vapor happened in the channel of volcanic gas, CO2 will be enriched relative to H2O resulting in the increase in the CO2/H2O ratio. However such a condensation is possible at the fumaroles with a low discharging pressure. The strong discharging pressure of K1 in Jul 2014 is inconsistent to the condensation for the explanation. Another straightforward explanation for the high CO2/H2O ratio is the enrichment of CO2 at the magmatic gas source. Beneath the Yugama crater a depleted solidifying magma is expected, based on the chemistry of lake water (Ohba et al 2008). Such a magma cannot emit CO2, suggesting another new CO2 enriched magma is now degassing. The low SO2/H2S and H2/H2O ratios of K1 and K2 suggest the temperature of hydrothermal reservoir beneath the Kitagawa geothermal area is not increased recently. The ongoing process at Mt Kusatsu-Shirane is limited in the deep region. A steam explosion at Mt Kusatsu-Shirane is not likely.

Keywords: Kusatsu-Shirane volcano, Hydrothermal system, Volcanic gas, Steam explosion, Magma, CO2/H2O

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# Geomagnetic field variations associated with enhanced volcanic activity at Kusatsu-Shirane volcano

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During the 2014 activity of Kusatsu-Shirane volcano, changes in the geomagnetic total intensity were observed by four proton precession magnetometers installed in the summit area. As a result of a careful treatment of the data, we found that those changes had occurred only for about three weeks in May, 2014. Using a simple differencing method from the data at Yatsugatake Magnetic Observatory of the University of Tokyo, we estimated that the amount of geomagnetic variations during that period was 1.1 nT at the maximum. The distribution of the estimated variations showed a spatial pattern suggesting demagnetization occurred at some depths beneath around the Yugama-Mizugama craters. The estimated changes in the geomagnetic total intensity were modeled by a magnetic dipole source under the assumption that the horizontal source location lies around the Mizugama crater. As a result, we found that a demagnetization source located at depths between 1000 and 1300 m below Mizugama crater satisfies the condition of the estimated changes in the geomagnetic total intensity. From several evidences of the enhanced volcanic activity such as a sudden increase of fumarolic temperature, and inflation of the ground, we infer that a sudden intrusion of the high-temperature volcanic fluids caused demagnetization of rocks beneath the Mizugama crater.

Keywords: Kusatsu-Shirane volcano, volcanic activity, geomagnetic field observation, thermal demagnetization, hydrothermal system

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# Ground deformation caused by an accumulation of hydrothermal water beneath hot crater lake at Kusatsu-Shirane volcano

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Kusatsu-Shirane volcano is one of the most active volcanoes in Japan in terms of persistent heat-release of approximately 150 MW. Mt. Shirane which is one of the pyroclastic cone contains a hot crater lake, locally referred to as Yugama, showing interesting variations of water temperature and chemical concentrations. These thermal activities are caused by subsurface circulations of hydrothermal water; however, a detailed understanding of the hydrothermal system including localities of heat source and ascent routes has not yet been clearly established.

At Shirane pyroclastic cone, three continuous bore-hole type tilt meters and seismometers are installed by Volcanic Fluid Research Center, Tokyo Institute of Technology. In addition them three seismic stations are deployed on the ground surface. All of stations are located within 1 km form the center of Yugama crater lake.

Intense earthquake swarms have been detected at shallow depth around Shirane pyroclastic cone since March 2014, accompanied by a ground deformation, changes in geomagnetic field and chemical concentration of volcanic gas. Records of tilt meters include fluctuations caused by earth tidal effect, atmospheric pressure and co-seismic variation as well as seasonal long-term changes. To estimate these non-volcanic variations in tilt meters, we apply a code of BAYTAP-G (Tamura et al., 1991) to past records of tilt observed during calm period. As a result, our tilt meters reveal that a single inflation source is formed at shallow depth of Yugama crater lake. Applying the Mogi model we find the inflation source at a depth of only 500 meters from the bottom of Yugama crater lake. A total volume change of the inflation source during the period from March 2014 to January 2015 is estimated to be 84,000 cubic meters.

3D magnetotelluric surveys revealed that bell-shaped low-resistivity region underlays beneath Yugama crater lake (Ogawa et al., personal comm.). Chemical analyses of samples obtained from bore-holes suggest the low resistive layer is composed by highly altered materials such as clay which acts as an impermeable layer. The pressure source obtained in this study is located just beneath the low resistivity layer. We consider that accumulation of hydrothermal water is controlled by such subsurface structure.

Keywords: Kusatsu-Shirane volcano, ground deformation, tilt meter, hydrothermal system, cap rock